P. GREGUSS

IDENTIFICATION OF LIVING GYMNOSPERMS ON THE BASIS OF XYLOTOMY

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PREFACE

Great is the number of works published on the xylotomy of gymnosperms. They survey the earlier and the latest results, and treat of them in detail. Despite their great value and scientific significance, these books and papers are deficient in one respect: either they only deal with wood and its applicability as a commercially important raw material, or they are devoted to some single problem of detail, to some of the more important families or genera, and thus do not even attempt to provide a comprehensive guide to the identification of all living gymnosperms on the basis of xylotomy. Mostly they are without any good illustrations of the individual species, or if they do bring detailed photomicrographs and drawings, then the xylotomic descriptions in them are imperfect and incomplete. Yet, obviously, there is nothing that would more warrant success in the xylotomic identification of the genus or species of, say, a critical conifer than good photomicrographs and accurate drawings accompanied by detailed and exact diagnostical descriptions. Ready and reliable identification is undoubtedly of great practical importance, particularly at a time when archeology and palaeontology can no longer do without the latest results of the art of xylotomy, and when they are indispensable to a number of large industries such as the building, furniture, paper, cellulose and artificial silk industries, even the machine tool industry depending on them. With timber one of the most essential raw materials of the age, scientific research work on wood has become of paramount interest to national economy.

The writer's earlier work, entitled "*Identification of Central European Trees and Shrubs on the Basis of Xylotomy*", has received recognition in our branch of science. The present book is its continuation to embody the description of the xylotomic characteristics of the genera, and as far as possible of the species, of all the living gymnosperms and, in an appendix to the volume, of all the chlamydosperms. There is not one family or genus, respectively, among those of the known living coniferous plants of which at least one species would not be worked up in this book. Of some others, a quite considerable number of species is elaborated, e.g., 70 *Pinus* species, or about 80 per cent of all known to be living. (An independent work of the present author on the xylotomy of the *Pinus* was published in 1950).

In compiling this large-scale comprehensive work the first step was to obtain adequate material of a specification carefully determined in advance. Laborious efforts having secured it, the next task was to prepare microscopic sections, photographs, accurate drawings, detailed descriptions and to develop synoptic keys easy to handle and readily affording quick identifications of reasonable reliability.

The specimens were collected from the most different parts of the world. Requests for them met with ready compliance in all quarters. The writer wishes to record his thanks to all who most kindly facilitated his bringing together a collection rich enough for the purposes of the present work. For specimens furnished he is under particular obligation to Mr. J. W. ADAMS, Curator of the Morris Herbarium, University of Pennsylvania, Philadelphia, Pennsylvania; Mr. I. BÁNÓ, Scientific worker of the Forest Research Institute in Kámon, Szombathely, Hungary; Professor P. A. BARANOV, Assistant Director of the Chief Botanical Garden of the Academy of Sciences, Moscow, U.S.S.R.; Dr. Jutta BERGEMANN, Bundesanstalt für Forst- und Holzwirtschaft, Reinbeck, Bez. Hamburg, Western Germany; Mr. John T. BLACK, Cultural Officer of the Foreign Service of the U.S.A., American Legation, Budapest, Hungary; BOTANICAL GARDENS, KAUNAS, U.S.S.R.; BOTANICAL GARDENS, NEW YORK, U.S.A.; BOTANY SCHOOL, CAMBRIDGE, England; BOYCE THOMPSON ARBORETUM, Yonkers, New York, U.S.A.; Mr. H. CALLENS, Director of the Jardin "Gillet", Kisantu, Belg. Congo; Professor C. L. CHANG, Forest Chemistry Laboratory, Nanking, China; CHIEF FOREST PRODUCTS OFFICER, Forest Products Institute, Pretoria-

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partment of Agriculture and Natural Resources, Manila, Republic of the Philippines ; Mr. M. de VILMORIN, Director of the Arboretum des Barres, Nogent sur Vernisson, France ; Messrs. WEBNER (PTY.) LTD., Cape Town, South Africa, Mr. Alexander WOLSKY, Delhi, India. B. CHOLNOKY, Pretoria Universiteit, E. T. H. Laboratorium f. Holzforschung, Zürich, (H. H. BOSSHARD) Editor of Tropical Woods, New-Haven (W. STERN; Academica Sinica, Peking (DR. YU)

Wherever possible, use has been made of the results reported in the literature. Particular benefit has been derived from the following works : W. Gothan : Zur Anatomie lebender und fossiler Gymnospermenhölzer (1905) ; R. Kräusel : Die fossilen Gymnospermenhölzer (1949) ; I. Phillips : Identification of Softwoods (1948) ; E. C. Jeffrey : The Anatomy of Woody Plants (1917) ; K. Mägdefrau : Paläobiologie der Pflanzen (1953) ; W. Zimmermann : Phylogenie der Pflanzen (1949) ; Br. Huber : Mikroskopische Untersuchung von Hölzern (1952) ; W. Müller-Stoll : Mikroskopie des zersetzten und fossilisierten Holzes (1951) ; F. Hollendonner : Vergleichende Anatomie der Nadelhölzer (1913).

Not infrequently it was found difficult to decide on the use of botanical names. With a view to achieving uniformity in nomenclature, the names accepted are with a very few exceptions those adopted in A. Rehder's Bibliography of Cultivated Trees and Shrubs (1949) and Dalimore-Jackson's A Handbook of Coniferae (1948.)

All the drawings and photographs have been made and the descriptions drawn up, directly from the material itself.* To a certain extent, this independent originality was felt to be a drawback, for in a degree it precluded consideration of and comparison with the findings of other research workers. This is a deficiency of the present work, but one for which, in part at leart, des fart is respomible has the writer was unable to secure material for comparative purpotes from the same habitat and, what is more important, of the same age. Thus it was not always possible to decide, for instance, whether a certain histological feature, in most cases some peculiar arrangement of wood elements, to be found in a particular specimen, a piece of branch or stem, was a specific constant, or whether it was due in part to the modifying action of external conditions. (The capital letters *Y* and *M*, respectively, set at the end of each item in the keys, and at the termination of the preliminary remarks to the detailed description of the individual species, indicate whether samples of *young* or *mature* wood have been examined by the writer). In spite of these deficiencies, it is hoped that on the whole this book will help readers to find their way in the xylotomy of the extinct and living *Gymnospermae* and *Chlamydospermae*, and to identify critical woods on the basis of xylotomy.

On the completion of this work, the writer deems it his pleasant duty to offer thanks to Mr. Imre Horváth, a former student of his and university demonstrator, for having prepared a part of the sections and elaborated the genus *Picea ;* to Mr. István Varga, another of his students, now secondary-school teacher, for having assisted in working up the genus *Pinus ;* to Mr. Pál Simoncsics, the writer's assistant at the university, and to Mr. Béla Nemessányi, for their valuable help in preparing sections and copies of photomicrographs ; to Messrs. György Bodrogközy, József Matuszka and János Maácz, assistant professors of the university, for help given in the technical completion of the manuscript, in the making of some drawings and in the compilation of tables. Thanks are due to Dr. Margit Szabados, assistant professor of the university, and to Miss Lenke Gosztonyi, who under the guidance of the writer prepared the drawings of the individual species and helped to compile some of the tables ; to Mrs. Alajos Kalmár, administrative worker of the institute, who undertook the typing of the text and assisted in the execution of minor technical details.

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*The Numbers in brackets at the end of each item in the keys, and at the termination of the preliminary remarks to the detailed description of the individual sqecies, refer to those works of earlier authors, enumerated in the bibliography, in which that particular wood has already been described from a xylotomical point of view.

the subject matter for this work progressed for ten years.

The writer is fully aware that this work, whatever its merits may or may not be, owes its perhaps not untimely completion to the collective efforts of these collaborators as well as to assistance by word and deed from other friends and acquaintances, to whom he likewise acknowledges his indebtedness.

In conclusion, the author expresses his sincere gratitude to the *Hungarian Academy of Sciences* for the financial support, which enabled him to compile and write this comprehensive and expensive work, and has made its publication possible. This book has been prepared in the Botanical Institute of the University of Szeged in the years of 1946—1954.

Szeged, December 31., 1954.

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INTRODUCTION

Modern taxonomy divides the gymnosperms *(Gymnospermae)* into six classes (orders), namely :

I. *Pteridospermae* (Cycadofilices)
II. *Cycadinae* (Cycadales)
III. *Bennettitinae* (Bennettitales)
IV. *Cordaitinae* (Cordaitales)
V. *Ginkgoinae* (Ginkgoales)
VI. *Coniferae*

Of these, *Pteridospermae*, *Bennettitinae* and *Cordaitinae* are extinct, *Cycadinae* and *Ginkgoinae* have a few living species, while not fewer than about 550 living members are known of *Coniferae*. Phylogenetically intermediate between the gymnosperms and the angiosperms are the *Chlamydospermae* or *Gnetales* with three families : *Ephedraceae* including about 40, *Gnetaceae* about 35, and *Welwitschiaceae* a single living species. Wood anatomy furnishing manifold evidence of phylogenetic relationship existing between the *Gymnospermae* and the *Chlamydospermae*, these, too, require to be included into this work on comparative xylotomy, however briefly and if only for the sake of completeness.

Many relationships particularly interesting from the point of view of phylogeny have already been detected with the aid of comparative xylotomy. For this reason, although the primary aim of the present work is the anatomical identification of the *Coniferae*, it is not intended to neglect those histological characteristics of the other extinct and living gymnospermous and still existing chlamydospermous plants that will enable us to identify on a xylotomic basis not only recent but also fossil representatives of these phylogenetically extremely interesting types. Accordingly, over and above containing the xylotomic identifications of the living species of the *Gymnospermae* and *Chlamydospermae*, this work intends to show how the results flowing from them should be built into the framework of phylogenesis. The overwhelming majority of the studies undertaken refers of course to the living *Coniferae*, of which about 350 species are worked up in this book.

As to methodology, by way of introduction this book briefly acquaints the reader with the rudiments of a working knowledge of xylotomic identification, and of the indispensable technical procedures. Photomicrography, maceration, drawing, etc. are mentioned but fleetingly in view of the many valuable and very useful reference works and papers on these subjects. This is followed by a brief glossary of the technical terms used in the identification of woods. The book then proceeds to describe the manner in which by virtue of their anatomical characteristics wood sections and cuttings are classed into families as a preliminary to their final identification on the authority of generic and specific characters.

With a view to ensuring a higher rate of reliability in the identifications to be undertaken with the aid of this work, there are four different microphotographs and a plate of drawings submitted for each individual species. Identification work is believed to be further facilitated by a number of annexed tables permitting an easy survey of the xylotomical features of the individual species within the families.

GENERAL PART

PRELIMINARIES TO THE XYLOTOMIC EXAMINATION OF THE LIVING GYMNOSPERMS (ANATOMICAL TECHNIQUE)

a. SECTIONING OF MATERIAL

In identifications of gymnospermous woods on the basis of their xylotomy it is well to take account of a number of other than histological features. Generic or specific differences frequently manifest themselves on macroscopic inspection, e.g., in *specific gravity*, *colour*, *odour*, *taste*, *touch*, etc. However, the final exact identification of a critical piece of wood will always depend on microscopic examination. For this the sample to be identified has to be adequately prepared. The simplest procedure of course is to prepare appropriate *cross*, *tangential* and *radial* sections from freshly cut stems or branches. But seldom is such material received. Samples submitted for identification are usually in a dry condition, in which they are not suitable for being studied. For cutting sections they must first be softened by means of an adequate procedure. The direct way of softening a sample is to boil it for from one or two hours to two or three days, or to let it soak in water for two or three weeks. KISSER's boiler greatly facilitates the process. It makes it possible to reduce the dry material with a guided hot steam jet to the required grade of softness. In the absence of such an apparatus it is advisable to do the boiling or soaking in a 2 to 4% solution of caustic potash. Useful information on this point is contained in HUBER's Mikroskpoische Untersuchung von Hölzern (Mikrosk. i. d. Techn. V/1.) and KISSER's Die botanisch-mikrotechnischen Schneidemethoden (Abderhaldens Handbuch d. biol. Arbeitsmethoden. XI/4. 1939. 391—738).

Reichert sliding microtome and the *Sartorius* microtome, respectively, was used by the writer in cutting sections in the three main planes, i. e., in preparing cross, tangential, and radial sections from the properly pretreated material. In thickness they varied between 10 and 20 μ. The selected ones were immediately put in 3 to 4 cu. cm. of "Eau de Javelle" and heated to boiling over a small flame. They were then allowed to stand in the solution for an additional 8 to 10 minutes to ensure a degree of bleaching as high, and an extraction of the cellular contents as complete as possible. Occasionally, their contents make possibly occurring longitudinal parenchyma cells more readily observable in untreated sections. Excessive Javelle-treatment is not adviseble, because it makes the sections too soft. The next step was to transfer the sections from the alkaline solution into an acid medium (1—2% acetic acid) for neutralisation. From the acid bath they were removed into distilled water to be thoroughly washed in case they were to be stained. It is advisable to do the removal with the help of a brush because owing to the boiling and soaking the cuttings are liable to become weak in structure. Thereafter a part of the sections was stained either with malachite green or with fuchsin and picric acid. When applying basic fuchsin and picric-acid staining the sections were first thoroughly soaked in water, then put into a 2% aqueous solution of fuchsin for 20 minutes, thereafter washed, allowed to stand for 5 minutes in concentrated alcoholic picric acid (the solution having previously been diluted to the half), and finally washed in alcohol until they no longer released any dye. The reason for this procedure was that picric acid is known to blotch the staining of the sections. In the majority of the cases, the sections were subjected to carbonization instead of staining.

b. CARBONIZATION PROCESS

From the writer's experience it would appear that carbonized sections are superior to stained ones for they are not only quick and easy to prepare but bring out contrasts in structure to better advantage.

Carbonization is carried out as follows: the same as in preparing for staining, the thin sections are first freed of their protoplasmic contents, in the manner described above, in order to prevent the latter from getting burnt into the cell walls impairing thereby microscopic examination and photographic reproduction. Thereafter the sections are subjected to dehydration by being immersed first into a 50%, then a 75% solution of alcohol and, finally, run up into absolute alcohol. Complete dehydration is indispensable because sections containing the least amount of water will crack and burn on the slides during the carbonization process.

Dehydration effected, the sections are placed by means of a fine brush or a spatula between two carefully cleaned microscopic slides or glass (photographic) plates held together at both ends by film clips. Thin slides or glass plates should be used because thick ones are apt to crack when heated or cooled suddenly. The sections are then carbonized, under constant agitation, over a feeble Bunsen flame until they turn sandy-coloured, but in this the subsequent browning effect of the hot slides must duly be taken into account. Provided they have been properly cleaned and dehydrated, their own weight will cause the sections to slip readily from the clean slides free of fat. Should they fail to come off by themselves, a very thin razor blade will suffice to remove them from the slides.

Following carbonization, the sections are immediately immersed in xylol, allowed to stand for from 5 to 10 minutes, and then mounted in Canada balsam. Thin tangential and radial section require to be carbonized to a slightly darker colour than cross sections to contrast all the details of structure.

c. PHOTOMICROGRAPHIC REPRODUCTION

Employing the above-described procedure, sections were cut in three planes (cross, tangential, and radial) of each and every species dealt with in this work, and four photomicrographs were made of each of these sets containing three sections. The simplest picture of the inner structure of a wood is most conveniently observed in the cross section. This is the section that affords a good view of the width and delimitation of growth rings, of the pattern and arrangement of tracheids and parenchyma cells, of ray structures, a. s. o. These structural features are brought out to best advantage under moderate magnification. Accordingly, of the cross sections photographs were taken at very moderate (30 ×) magnification, and for the study of the finer structure, at moderate (100 ×) magnification. The tangential sections of a part of the material were also megnified 100 ×, but the rest of them and all the radial sections were enlarged 300 ×. By enlargement to this extent the finer details are made apparent and structural differences are more readily discernible. Uniformly, these three magnifications were used throughout the material so as to allow conclusions to be drawn from the comparative study of the individual species. Most of the pictures were taken with a "*Promar*" photographic apparatus of the system *Leitz*. In a very few instances, perhaps 10 to 15 in all, when photographing tangential and radial sections, it was not possible to get hold in a single picture of all the anatomical details characteristic of the particular wood; in these cases two parts of the identical section were photographed separately and their pictures fitted together subsequently. The very few pictures adapted in this manner are marked with an asterisk.

d. MACERATION

Histological examination of the individual species was not confined to the spatial arrangement of the tissue elements; in some cases it was extended to the finer structure of the elements building up the wood. For this purpose, the wood was reduced to its components, following *Schulze*'s procedure. (For a detailed description of it cf. Vol. I. of that author's work.)

e. REPRESENTATION BY DRAWINGS

Photomicrographic reproductions do not always reveal the finer morphological features of the various tissue elements. To make up for this deficiency, representation by drawings has been resorted to. Drawings were prepared at a scale

of 1 : 300, exceptionally at 1 : 400, in the first place of the radial structure of rays, the structure of rays and tracheids, their pitting, and of the radial structure of tracheids in every type of wood dealt with in the present work. Their approximately identical scale facilitates comparing them. The actual scale applied is marked on each plate, and is easy to control. Photomicrographs and drawings are supplementary one to the other, and are explained in detail in the descriptions of the woods by species. The four photomicrographs, the drawings, and the detailed descriptions of the individual species together afford a reliable basis for, and greatly facilitate, the identification of the sample.

FUNDAMENTALS FOR IDENTIFYING WOODS ON THE BASIS OF THEIR XYLOTOMY

Successful identification of a coniferous wood on the basis of its xylotomy requires knowledge of its structural features, its elements, their spatial arrangement, a number of fundamental conceptions, etc. In addition, it must be kept in mind that each species is best characterized by the spatial arrangement of its elements. This invariably results in a peculiar pattern, visible to some extent to the unaided eye and repeating itself identically in the wood of practically all the species of the *Coniferae*. However, subjected to microscopic inspection, the inner structure, i. e. the shape and arrangement of the elements, reveal in the majority of the cases quite peculiar finer patterns characterizing the species.

Reference is made to Plate 1. This is a schematic drawing intended to assist the reader in understanding the technical terms used in this book, and to help visualizing the spatial arrangement of the individual wood elements. It has been designed by the writer, basing himself on the microscopic features of *Picea excelsa*, and was drawn, under his guidance, by MISS LENKE GOSZTONYI. It clearly shows the three main planes, in which wood is customarily examined. The section cut in the longitudinal plane dividing the cylinder is called the *radial section ;* in the text this is always denoted with the letter *R*. The section cut in the plane parallel with the long axis, and which is a chord of the curved surface of the tree, is the *tangential section*, and is referred to by the letter *T* in the descriptions of woods by species. Finally, the section cut in the plane transverse to the long axis, is the *cross* or *transverse section*. In the text and on the photographs this section is always denoted with the letter *C*. The numerals 1 to 4 in the text and on the photographs refer to the following : 1 denotes cross sections enlarged 30 × or 100 × ; 2 always denotes tangential sections enlarged 100 × ; 3 invariably indicates radial sections magnified 300 × ; and 4 tangential sections magnified 100 × or 300 ×. In the drawings, the various letters serve to obtain a clear conception of the positions of the tissue elements to be found commonly in the wood.

In the drawing on Plate 1, the thin-walled tissue elements in the axis of the young tree constitute the *pith* (No. 9). Sporadically, this is interrupted by transversely aligned thick-walled *sclerenchyma cells* (No. 10). The annular layer bounded by concentric cylinder jackets in the wood is called *growth ring* or *annual ring*, within which we distinguish *spring-* or *earlywood* (No. 7) and *summer-* or *latewood* (No. 8). Between two growth rings lies the *growth ring boundary*. The rows of cells passing radially across the growth rings are known as *xylary rays*, or *wood rays*, or simply *rays* (No. 12). The cells on the upper or the lower margins of a ray, differing from those in the body, are called *marginal cells* (or in *Picea* they are designated as *marginal tracheids)* (No. 14). Likewise in the rays there are the *horizontal resin ducts* (No. 6), while the *vertical resin ducts* (No. 5) extend parallel with the axis. The so-called *epithelial cells* (No. 15), which line the resin ducts, are thick-walled in *Picea*. The layer which covers the outer surface of the wood like a cylinder jacket is the *cambium* (No. 4). This underlies the *phloem* or *bast* (No. 3), which is bounded on the outside by the *periderm* (No. 2). The outermost continuous layer taking the place of the *epidermis* is the *paracortex* (No. 1). The portions inside the *phloem* and *cortex*, respectively, constitute what in the narrower sense of the word is called the *wood* or *xylem. It should be noted from the outset that the present work is solely concerned with these portions of gymnospermous woods, i. e., with the histological structure of wood or xylem*, leaving the phloem entirely out of consideration. Regarding

the latter, the reader is referred to *Hohlheide*'s excellent book entitled "Anatomie mitteleuropäischer Gehölzrinden".

In *cross sections*, the more or less tiny pores visible sometimes to the unaided eye or through the lens are really the transverse sections of the longitudinal *tracheids* or other elements in the xylem.

In *radial sections*, the cellular bands of varying width, at right angles to the axis and visible sometimes to the unaided eye, are but the lateral surfaces of the *rays*.

In the *tangential sections*, the longitudinal cells

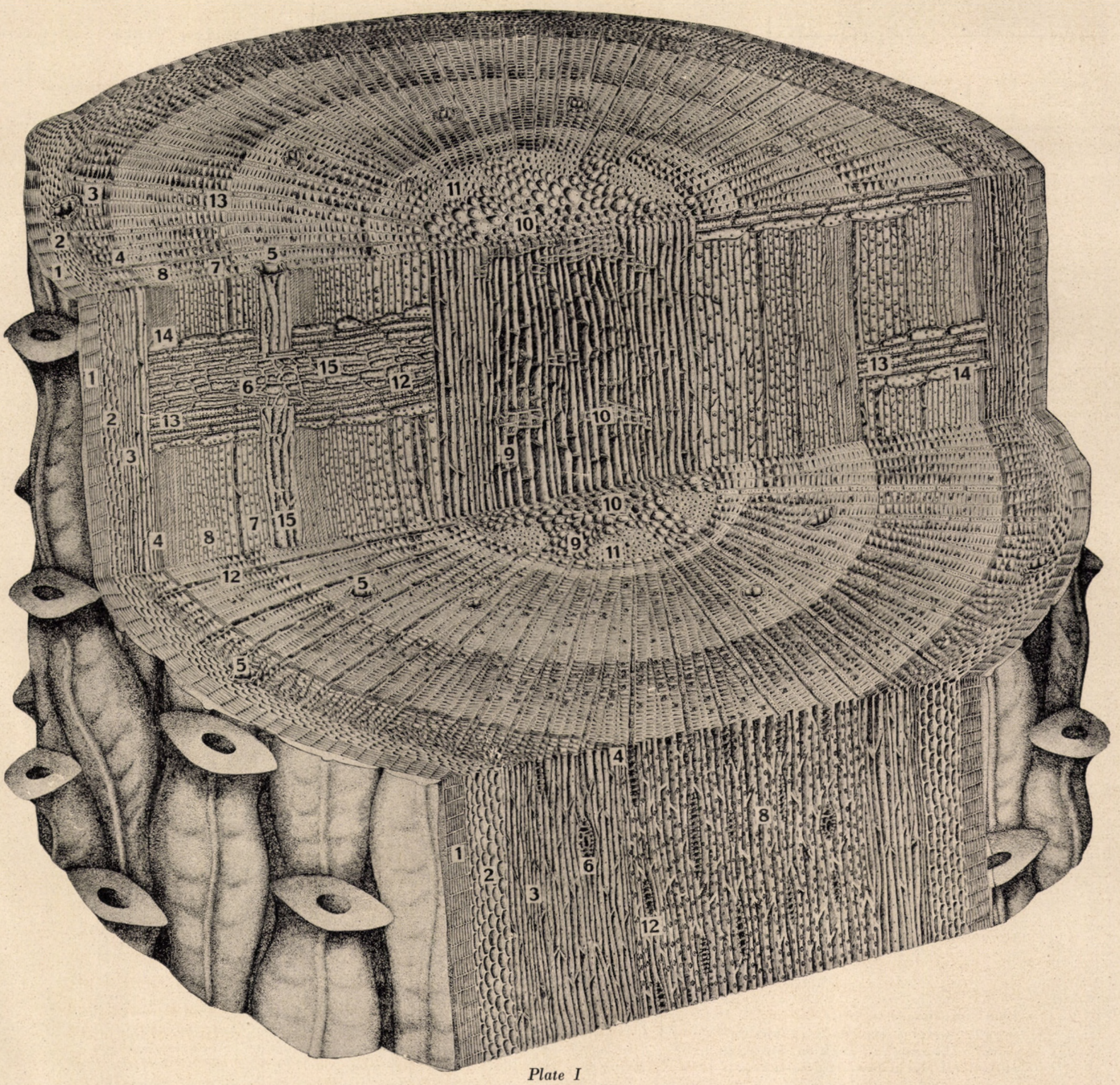


Plate I

Schematic drawing showing the wood of a 3-year old spruce twig in three planes of section. 1. Epidermis. 2. Periderm. 3. Phloem. 4. Cambium. 5. Vertical resin duct. 6. Horizontal resin duct. 7. Earlywood. 8. Latewood. 9. Pith. 10. Pith sclerenchyma. 11. Primary wood. 12. Medullary ray (seen in tangential view). 13. Thick-walled ray cells. 14 Marginal cells, transverse tracheids. 15. Thick-walled epithelial cells.

are really the tracheids in the wood, while the shorter but as a rule much sturdier cell rows represent the cross sections of *rays* (No. 12) and *resin ducts*, respectively.

But in addition to finding one's bearings by gross inspection microscopic examination of the wood is invariably required, and also a good knowledge of the essential fundamental concepts derived from the latter. The most important technical terms employed in descriptive softwood anatomy are given under the next caption, arranged alphabetically.

GLOSSARY OF TERMS USED IN IDENTIFYING WOODS

Alternate *(araucaroid)* pitting: bordered pits extending in oblique rows across the cell wall and polygonal due to crowding *(Araucaria, Agathis.* Plate IV, Figs. 32—34).

Annual ring: see growth ring.

Araucaroid pitting: see alternate pitting.

Autumn wood: see latewood.

Bark: the tissues of the stem and root outside of the cambium and consisting of *inner* living and *outer* dead bark (Plate I, Fig. 3).

Blind pit: a pit with its aperture leading into an intercellular space between two cells.

Bordered pit: a pit in which at certain points thickening of the secondary wall gives rise to semi-lentiform recesses with circular, rod-shaped, elliptic, or slitlike *apertures* in the middle. In surface view, bordered pits are round, ovoid, or angular (Plate IV, Figs. 32—33) (Text Fig. 2).

Bordered pit pair: two complementary bordered pits directly opposite each other on the walls of contiguous cells. In shape, the pair is suggestive of a biconvex lense. The equal-sized spaces in the two pits are separated by the pit membrane and the torus, respectively (Text. Fig. 2).

Callitroid thickening: the well-developed thickening bands surrounding the bordered pits of the tracheids in some *Callitris* species *(Callitris glauca.* Plate IV, Fig. 35).

Cambium: layer of meristematic tissue between the xylem and phloem (Plate I, No. 4).

Circoporoid pit: see dacrydioid pit.

Coefficient of rays: the ratio in the rays of rows of parenchyma cells to rows of horizontal tracheids. It is obtained by the formula

$$\text{coefficient of rays} = \frac{\text{number of rows of parenchyma cell}}{\text{number of rows of horizontal tracheid}}$$

Compound resin duct: see resin duct.

Compression wood: see redwood.

Crassulae: thicker portion of the intercellular layer above and below primary pit fields; formerly called *Bars of Sanio* or *Rims of Sanio* (Plate VII, Fig. 80).

Cross field *(also known as ray crossing)*: the area bordered by the horizontal walls of a ray cell and the vertical walls of a tracheid or wood parenchyma cell in back of it. Cross-field structure is very frequently of diagnostic significance (Plate VI, Figs. 60—74).

Crytals: occasional inclusions of calcium oxalate in the parenchymatous elements or tracheids (ray tracheids) of the wood. Their presence is sometimes of diagnostic value (Plate VII, Figs. 75, 76 and 77).

Cupressoid pits: pits in the cross field with their apertures invariably oblique or vertical in position; they themselves are oblique ellipses and the apertures lie in the direction of the latter's conjugate axis (Plate VI, Figs. 65—70).

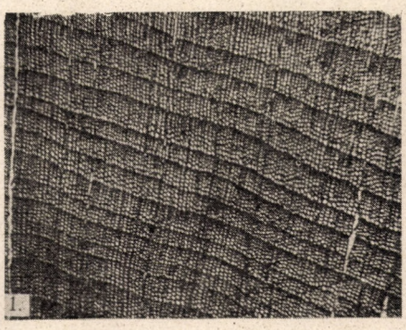
Dacrydioid pit *(also called circoporoid pit)*: a circular pit partly or entirely filling a cross field. Occasionally there are two in one cross field.

Diffuse parenchyma: parenchyma cells scattered among the fibrous elements, as seen in cross section (Plate II, Fig. 4).

Earlywood or springwood: the differently wide inner portions of growth rings

Plate II

Coniferous woods in cross section. 1. Extremely narrow growth rings *(Microcachrys tetragona* 30×). 2. Wide growth rings with latewood conspicuous *(Pinus rigida* 30×). 3. Indistinct growth rings *(Callitris glauca* 100×) 4. Wood parenchyma scattered in latewood *(Taxodium mucronatum* 100×). 5. Barrel-shaped ray cells *(Abies veitchii* 100×). 6. Terminal wood parenchyma *(Widdringtonia dracomontana* 100×). 7. *Pinus*-type resin duct *(Pinus ponderosa var. Jeffreyi* 100×). 8. *Larix*-type resin duct *(Larix europaea* 100×). 9. *Picea*-type resin duct *(Picea jezoensis* 100×) 10. Resin cyst *(Abies arizonica* 100×). 11. Cell proliferation on outer edge of growth ring *(Picea koreana* 100×). 12. Uniformly thick cell walls in both late- and early-wood *(Pinus montezumae* 100×). 13. Smooth horizontal and nodular tangential walls in ray cells *(Sequoia sempervirens* 300×). 14. Horizontal and tangential ray-cell walls pitted (Cedrus atlantica 300×). 15. False growth rings and resin cyst *(Abies veitchii* 100×).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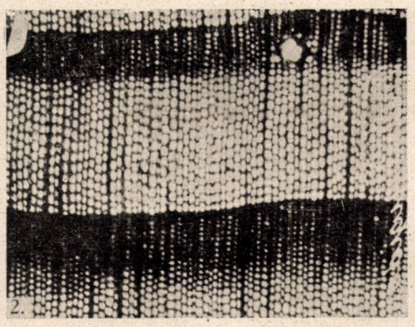
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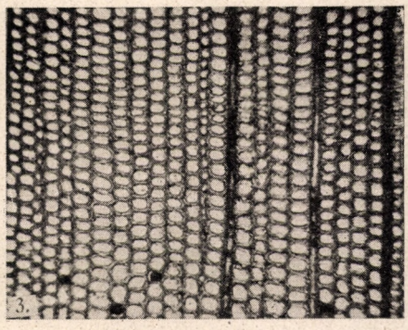
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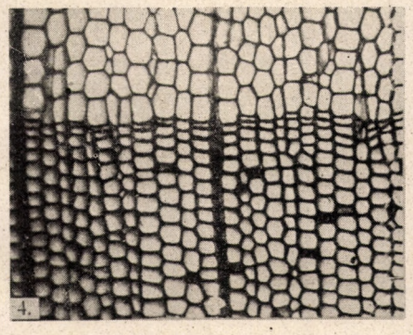
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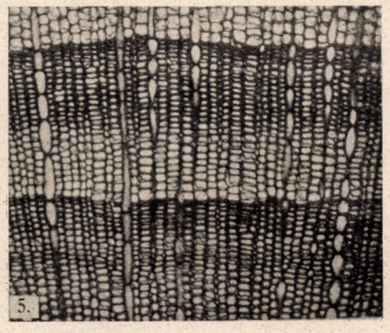
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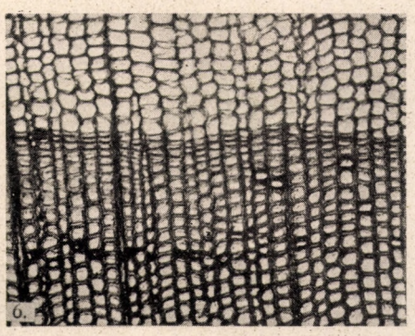
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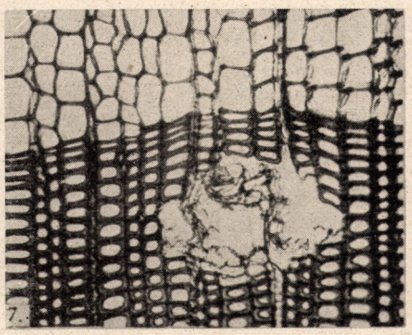
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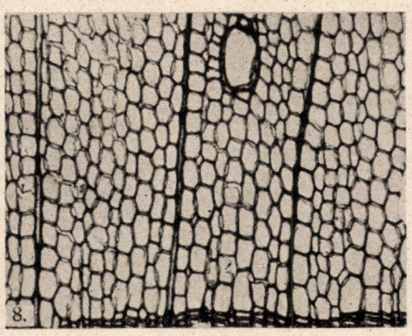
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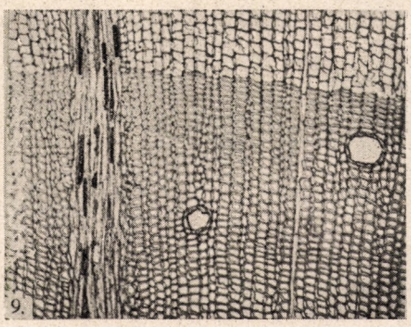
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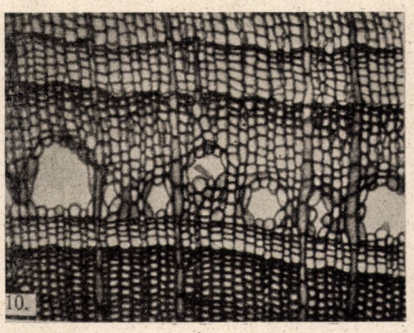
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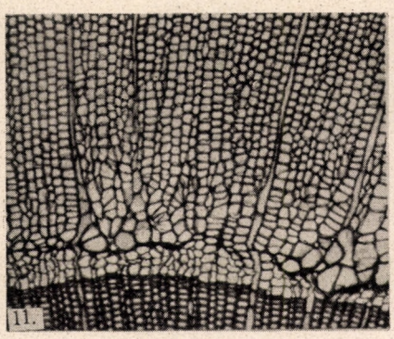
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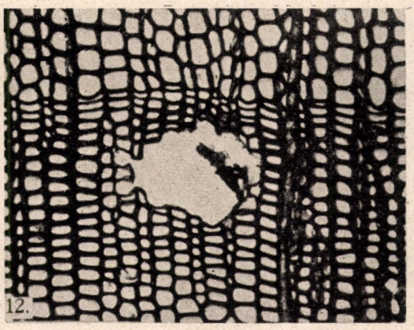
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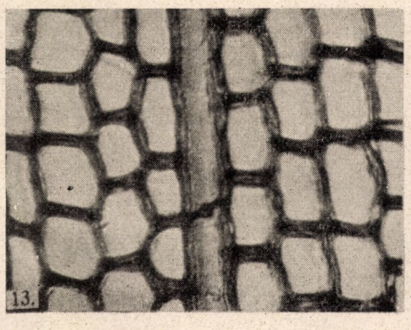
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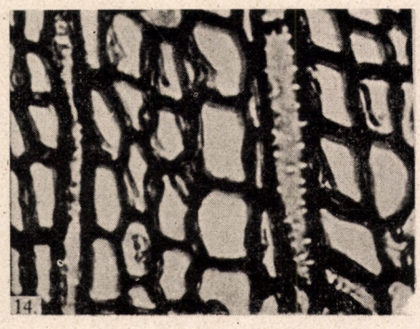
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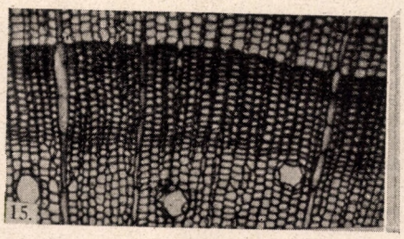
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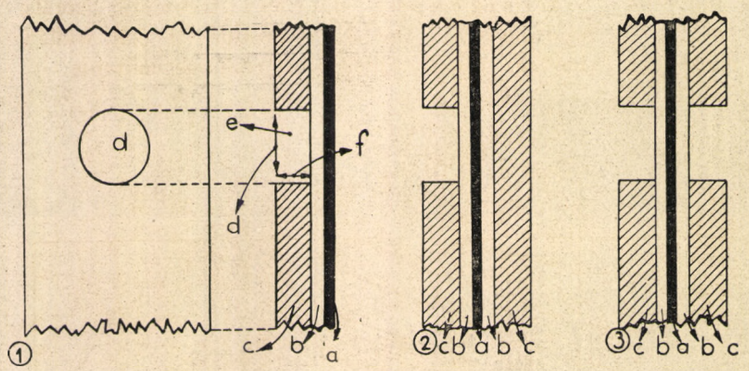
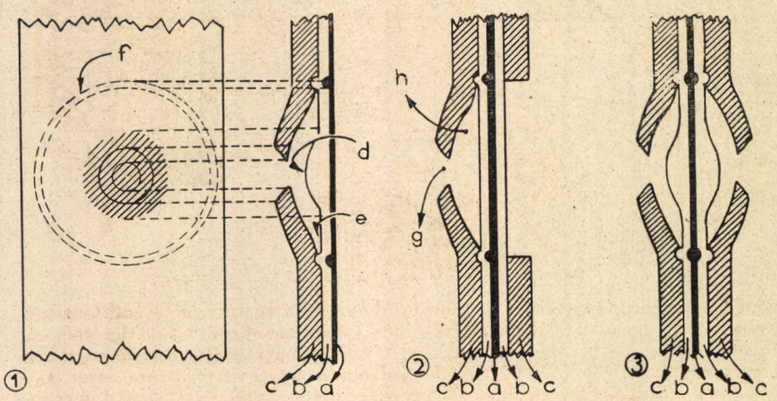
containing the elements formed at the beginning of the growing season. Radially, in some *Conifers* the earlywood tracheids measure 5 to 6 times as much as the outermost latewood tracheids;



Text fig. 1. Diagrams showing the origin and structure of a simple pit. In 1: a = middle lamella (fat line); b = primary wall; c = secondary wall; d = simple pit in surface view and aperture in lateral view, respectively; e = pit canal; f = depth of pit. 2: Unilateral simple pits are structural features of the secondary wall alone, the primary wall is not involved. 3: Simple pit pair with the primary wall and the middle lamella in between. (After *Boureau)*



Text fig. 2. 1: Structure of a bordered pit. 2: Compound pit pair. 3: Bordered pit pair. Bordered-pit structure in surface view: f = pit annulus; e = closing membrane; d = torus; g = bordered-pit aperture; the inner aperture opens into the cell lumen, the outer aperture into the chamber; h = pit chamber. In all three diagrams: a = middle lamella; b = primary wall; c = secondary wall. (After *Boureau)*

the growth ring delimitations are then always distinct (Plate II, Figs. 2 and 7).

Ephedroid perforation: a perforation plate between two vessel segments with small groups of bordered pit like hexagonal or circular openings in it (Plate VII, Fig. 83).

Epithelial cells: the thick- or thin-walled, apparently unlignified, parenchymatous cells mostly devoid of pits, which line the resin ducts (Plate I, Figs. 5—6, and Plate III, Figs. 16—19).

Fall wood: same as latewood.

False growth rings: they arise in consequence of disturbances during the growing season, e. g. insect infestation. Whenever they appear, these false rings, always narrower than the true ones, are wholly included within the normal ones (Plate II, Fig. 10).

Growth rings: concentric layers representing seasonal increment. They vary in width depending upon external factors and the age of the tree. For identification purposes width is not an absolutely reliable property (Plate II, Figs. 1, 2, 5).

Growth ring delimitation is made up of the contrast between the final rows of latewood cells and the succeeding rows of earlywood cells in transverse section. When the narrow-lumened and thick-walled elements in the latewood are followed by wide-lumened and thin-walled earlywood elements the delimitation is called distinct (Plate II, Figs. 2, 5).

Growth-ring field: the portion of a single growth ring bounded by two adjacent rays; its width varies with the closeness of the spacing between them and is sometimes a useable diagnostic feature.

Half-bordered pit: a bordered and a simple pit communicating with each other in the walls of two adjoining cells. In surface view they generally appear as two concentric circles within the pit border (Text Fig. 2).

Heartwood: the inner core of the woody stem differing from the outer sapwood by its darker colour and its density. In conifers, this difference is rarely to be seen, yet in some species it is marked *(Larix, Metasequoia)*.

Height of rays: a term of convenience used in expressing the number of superposed cell rows in a ray. It greatly varies, as a rule, within the same specimen, yet in some instances it may be a feature of importance in identification. As regards *ray cells*, their height and width and the

thickness of their walls, when measured in μ, may offer a further means of separating coniferous woods (Plate IV, Figs. 41—43).

Heterogeneous ray: a ray consisting of two kinds of elements, ray tracheids and cells of ray parenchyma (Plate IV, Fig. 39).

Homogeneous ray: a ray consisting of cells more or less uniform in size and shape, and similar in structure (Plate IV, Figs. 41—43).

Indentures: the two small pitlike hollows at the corners of ray cells where the horizontal and tangential walls meet. They are characteristic of certain genera of *Coniferae* and, accordingly, can be of particular value in identification. Absent for instance in *Araucariaceae* (Plate V, Fig. 49).

Inner pit aperture: the opening of the canal of a bordered pit into the lumen of the cell (Text Figs. 2—3).

Intercellular space: a cavity resulting from the interwall space in a group of cells not compactly arranged but more or less free from one another. In cross section it appears triangular or rectangular.

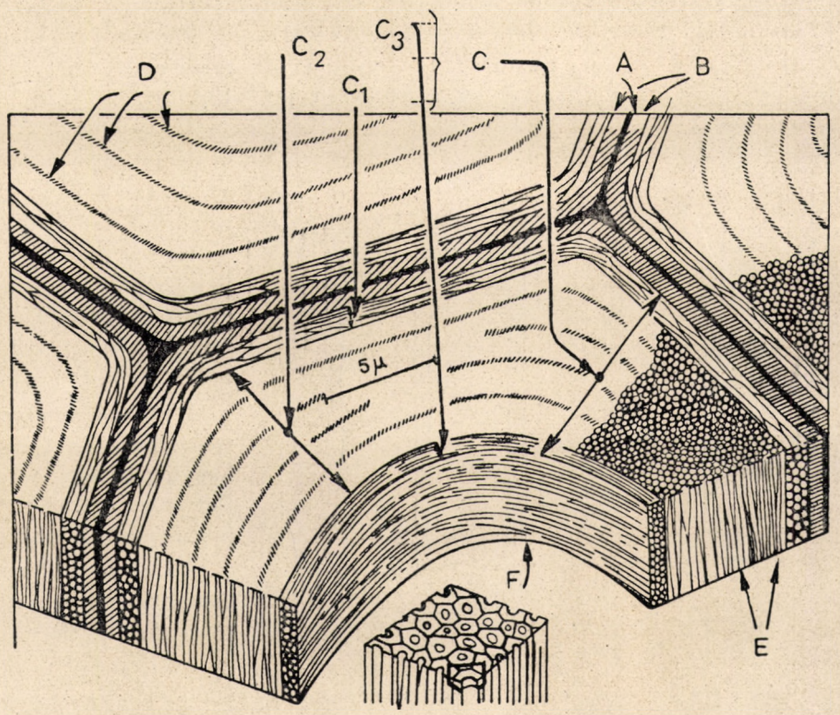
Latewood *(also called autumn, fall, or summer wood)*: the outer portion of a growth ring consisting of elements produced during the latter part of the growing season. It greatly varies in width in different species, and in individual trees of the same species, from just a few layers of cells (Plate II, Fig. 4) to the overwhelmingly larger part of the growth ring.

Longitudinal parenchyma: see wood parenchyma.

Longitudinal tracheids: longitudinal vascular elements with walls smooth or displaying bordered pits or, occasionally, spiral thickenings; they are as a rule prismatic or cylindrical in shape (Plate IV, Figs. 28—34).

Lumen: the cavity of a cell.

Lysigenous ducts: traumatic canals resulting from the disintegration of cell walls; they are usually filled with resinous contents.



Text fig. 3. The detached diagram at the bottom shows the structure of several longitudinal sclerenchyma; enclosed in a frame of fat lines is the place of contact of the walls of four cells. On the middle lamella, *A*, are layered the primary walls, *B*, and on these the secondary walls, *C*, which are of lamellate structure being divided into outer, C_1, median, C_2, and inner, C_3, layers. *D* = the layers of the secondary wall viewed in cross section; *E* = longitudinal structure of the secondary wall; *F* = tertiary layer. (After *Boureau)*

Marginal parenchyms *(also designated as terminal parenchyma)*: complete or interrupted, from narrow to broader strands of parenchymatous cells formed in the last period of the growing season on the outer margin of a growth ring. In coniferous wood, such strands may be in contact laterally, appearing in cross section as an independent tangential row of cells (Plate II, Fig. 6).

Marginal ray parenchyma cells: cells on the upper or lower margin of a ray, commonly different in structure from the inner ray cells, and therefore important in identification. (Fig. 4.)

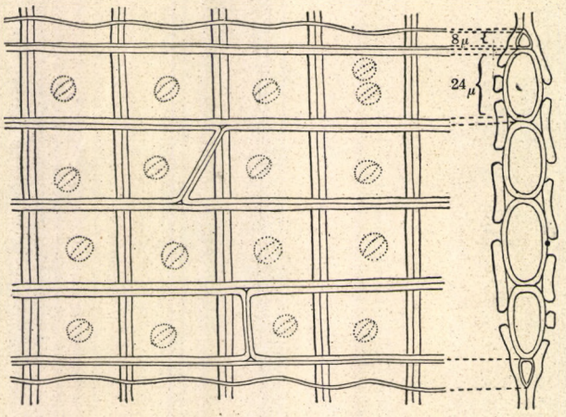
Middle lamella: the compound layer between the secondary walls of contiguous cells;

it consists of primary walls (a) on each side of an intercellular layer (b) of varying thickness (Text Figs. 1—2).

N o r m a l g r o w t h r i n g *(or true growth ring)*: a layer of secondary xylem formed in one growing season under normally favourable growth conditions (Plate II, Fig. 2).

O p p o s i t e p i t t i n g: bordered pits extending in transverse rows across the cell wall *(Taxodiaceae, Pinaceae.* Plate IV, Figs. 29—31).

O u t e r p i t a p e r t u r e: the opening of the canal into the chamber of a bordered pit (Text Figs. 1—2).



Text Fig. 4. (Original)

P a r e n c h y m a c e l l s: cells commonly with thin, simple-pitted, occasionally with quite smooth walls (Plate III, Fig. 20). We distinguish cells of *longitudinal or wood parenchyma* and *ray parenchyma.* The first extend in the wood parallel with the axis of the stem, the second at right angles to it. In cross section, longitudinal parenchyma cells are solitary, scattered, at times in tangential or nearly tangential rows, or forming clusters of varying size.

P e r f o r a t i o n: the opening or openings between two vessel segments (Plate VII, Figs. 83—85).

P i c e o i d p i t *(also referred to as piciform)*: tiny, mostly circular pits in the cross field with apertures commonly slitlike and extended; occurring principally in *Picea, Larix, Pseudotsuga* and *Cephalotaxus* (Plate VI, Figs. 60—61 and 63—64).

P i n o i d p i t s: a type of pit characteristic of the pines, occasionally with apertures as large as to render the border indiscernible (Plate VI, Fig. 62).

P i t: see s i m p l e p i t and b o r d e r e d p i t.

P i t a n n u l u s: outer thickened rim on the margin of the membrane of bordered pits (Text Fig. 2).

P i t a p e r t u r e: the opening or the mouth of the pit at the inner wall surface (Text Figs. 1—2).

P i t c a n a l: the passage from the cell lumen to the chamber of a bordered pit.

P i t c a v i t y: the entire space within a pit. In a simple pit it is a regular cylinder, in a bordered one it consists of several parts: the *pit chamber, pit canal, inner and outer pit apertures* (Text Figs. 1—2).

P i t c h a m b e r: in a bordered pit, the space between the pit membrane and the overhanging border, resembling a biconvex lens. The flat outer end of the pit chamber is closed by the pit membrane and the torus.

P i t m e m b r a n e: the membrane which closes the pit cavity externally and separates it from that in the complementary bordered pit.

P i t p a i r: two complementary pits in the walls of contiguous cells (Text Figs. 1—2).

P i t s t r u c t u r e X - f i g u r e d *(crossed)*: complementary pits of bordered pit pairs with their elongated oblique apertures crossed when viewed frontally.

P i t h: parenchymatous tissue constituting the innermost periaxial part of the woody stem; the loose primary tissue is as a rule 1 to 2 mm in diameter (Plate I).

P o d o c a r p o i d p i t: a bordered pit with an aperture almost as large as the bordered pit itself and mostly oblique or vertical in position (Plate VI, Fig. 69).

P o r e: a vessel presented in transverse section.

Plate III

Coniferous woods in tangential section. 16. *Pinus*-type resin duct *(Pinus thunbergii* 300×). 17. *Pseudotsuga*-type resin duct *(Pseudotsuga taxifolia* 300×). 18. *Picea*-type resin duct *(Picea likiangensis* 300×). 19. *Larix*-type resin duct *(Larix lariciana* 300×). 20. Smooth horizontal walls of wood parenchyma cell *(Taiwania glyptostroboides* 300×). 21. Nodular horizontal wall of wood parenchyma cell (*Glyptostrobus pensilis* 300 x). 22. Dentate horizontal wall (*Taxodium ascendens* 300 x). 23. Dentate horizontal wall *(Pseudotsuga taxifolia* 300×). 24. Barrel-shaped ray cells *(Actinostrobus acuminatus* 300×). 25a. Spiral striations in the tracheid walls *(Juniperus barbadensis* 300×). 25b. Spiral bars in tracheids *(Ginkgo biloba* 300×). 26. Simple spiral thickenings *(Taxus wallichiana* 300×). 27. Double spiral thickenings *(Torreya taxifolia* 300×).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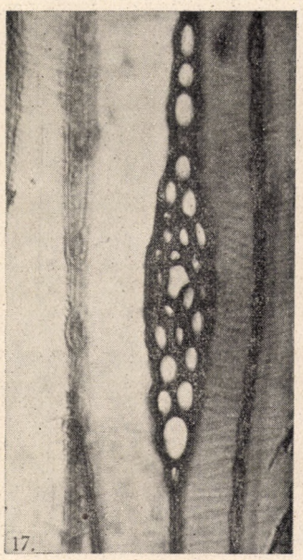
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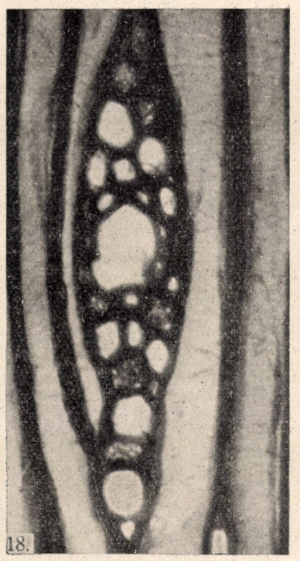
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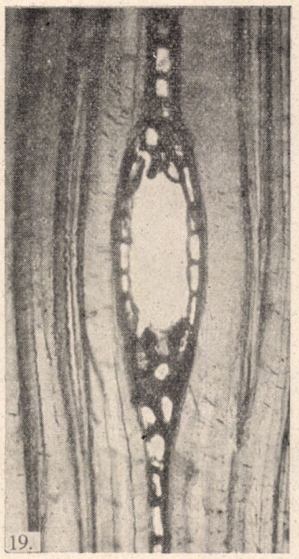
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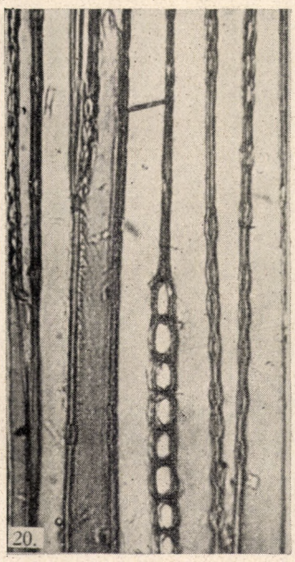
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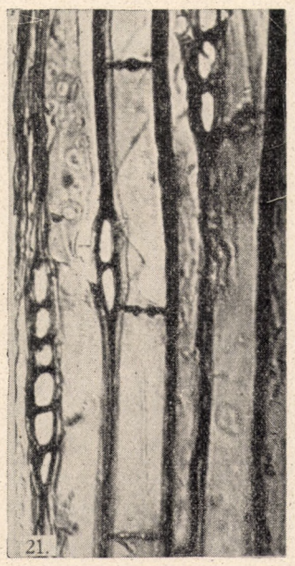
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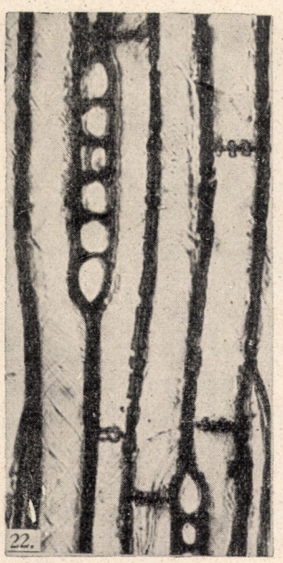
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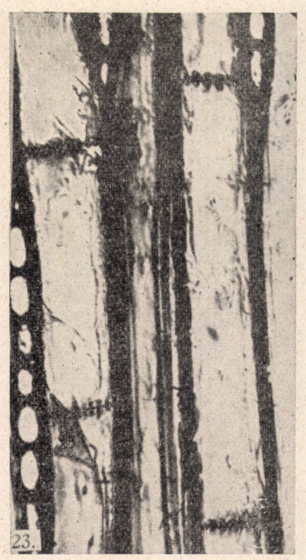
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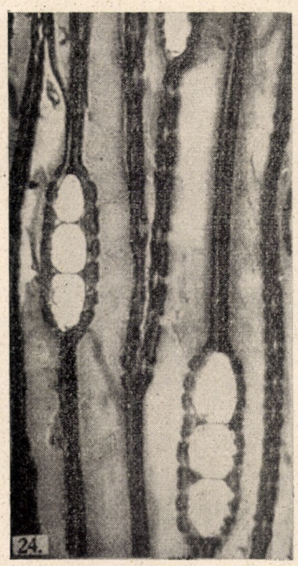
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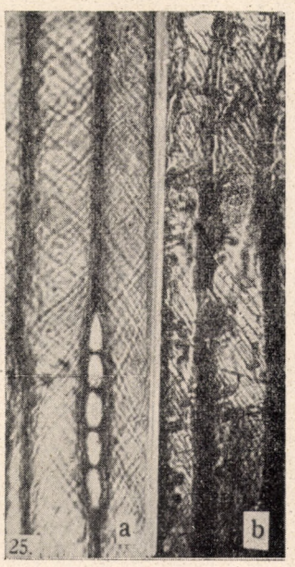

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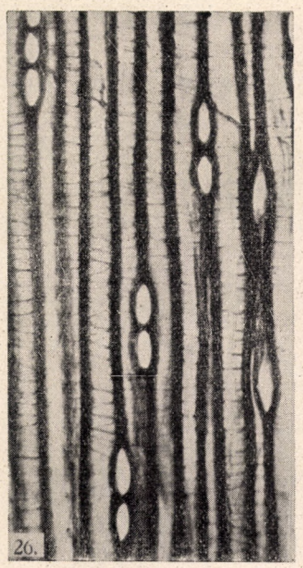
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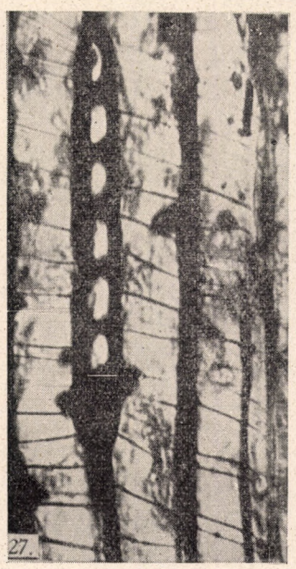
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Primary pit field: a thinner area of the intercellular layer and the primary wall in which one or more pits usually develop.

Primary wall: the wall of the meristematic cell modified during postcambial differentiation. It must not be confused with the thin, markedly anisotropic, first-formed part of the *secondary* wall (Text Figs. 1—2).

Radial parenchyma: see ray parenchyma.

Rays: strands of one or more layers of cells, commonly parenchyma cells, different in height, which extend radially across the grain (Plate I, No. 13). They serve as transverse avenues of food conduction. Size, shape, structure, and arrangement of ray cells although they may considerably differ in one and the same ray, are characteristics of certain species. Of marked significance are in this respect the lowest and topmost rows of cells, the so-called *marginal ray cells* or *transverse tracheids* (Plate I, No. 14). The ray cells in the early- or latewood near the growth ring delimitations and those within the higher rays may sometimes become longer, sometimes shorter.

Structural details of rays are shown in all three sections under Nos. 6 and 12—15 on Plate I. The cross and tangential sections show immediately whether the rays are uni- or biseriate.

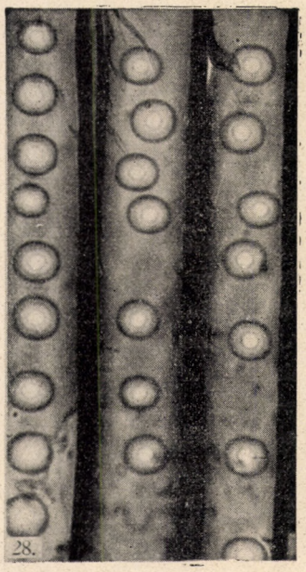
Ray structure may be most useful in the generic and specific identification of coniferous woods. The number of rays or ray cells per sq. mm. of tangential section may also be regarded as a criterion for differentiating, though not as a wholly reliable one. All the photographs of tangential sections in this book being 100fold magnifications of exactly 0,4 sq. mm. areas, multiplication by 2,5 of the number of rays or ray cells seen in them produces the corresponding number for one sq. mm. But one may go one step further and differentiate between narrow and wide rays, for instance those containing resin ducts, for the photographs show both distinctly.

Ray parenchyma *(also designated as transverse or radial parenchyma)*: parenchyma included in rays; the long axes of its cells are oriented radially; all cell walls are either smooth *(Araucaria, Tetraclinis*, Plate V, Fig. 53) or provided with one or more from small to larger pits *(Abies, Taxus, Pinus aristata.* Plate V, Fig. 55). Smooth cell walls or the type of pitting present in them are sometimes features of particular value in identification. All the walls of ray parenchyma cells are thin in certain families *(Araucariaceae)*, and thick in others; yet in others thick and thin cell walls occur alternately *(Pinus Balfouriana.* Plate V, Fig. 48). In the walls of some ray cells there is only primary pitting, with pits almost indiscernible like so many dots or points.

Ray tracheids *(also called transverse tracheids)*: cell rows perpendicular to the long axis of the woody stem, commonly present on the upper and lower margins of the ray *(marginal tracheids)*, but not infrequently occurring also in its body. If pits are present in the walls of ray tracheids, they are always bordered. If unpitted, the walls are smooth *(Pinus cembra, Tsuga canadensis.* Plate V, Fig. 44), or small teeth readily visible on radial section project from them into the lumen *(Pinus silvestris.* Plate V, Fig. 45). Sometimes there appear spiral thickenings in them *(Pseudotsuga*, some species of the genus *Picea.* Plate V, Fig. 47). Accordingly, we distinguish *smooth-walled, dentate* and *spirally thickened* ray tracheids. The morphological structure of ray tracheids is of diagnostic significance within the individual families, generic and specific differentiation being primarily based upon the nature of the walls. Transverse tracheids occur normally in *Pinaceae*, sporadically in the *Cupressaceae* and *Taxodiaceae*, and are never present in the other families.

Plate IV

Types of pit arrangement and ray structure. 28. Uniseriate and scattered bordered pits *(Larix laricina* 300×). 29. Paired pits *(Larix occidentalis* 300×. 30. Threeseriate opposite pitting *(Sequoia sempervirens* 300×). 31. Single pits and paired pits *(Podocarpus longifoliatus* 300×). 32. Araucaroid pitting *(Agathis mülleri* 300×). 33. Araucaroid pitting *(Agathis palmerstonii* 300×). 34. Araucaroid pitting *(Cycas revoluta* 300×). 35. Callitroid pitting *(Callitris glauca* 500×). 36. Scalariform pitting in tangential walls of ray cells *(Juniperus horizontalis* 300×). 37. Sievelike pitting in tangential walls of ray cells *(Cedrus deodara* 300×). 38. Resinous wood parenchyma cells; horizontal walls smooth *(Sequoia gigantea* 300×). 39. Alternating thin-walled ray cells and thick-walled transverse tracheids *(Pinus leiophylla* 300×). 40. Resin duct *(Pinus silvestris* 100×). 41. Low rays *(Actinostrobus acuminatus* 100×). 42. Uni- and biseriate rays *(Keteleeria davidiana* 100×). 43. Extremely tall rays *(Taxodium distichum* 100×).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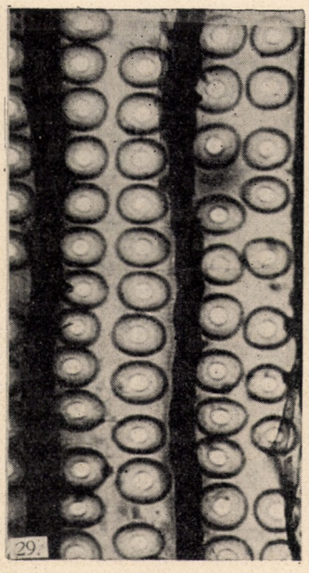
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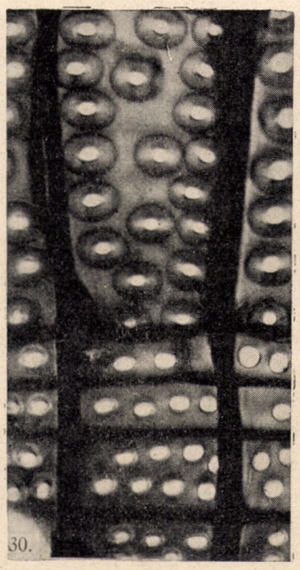
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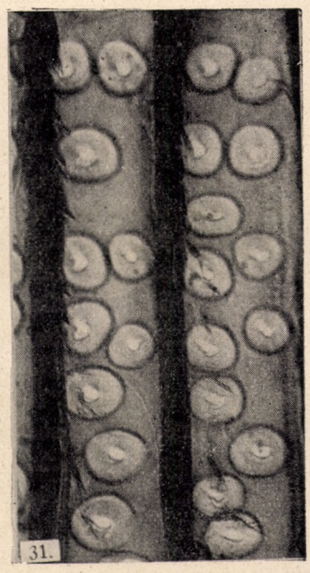
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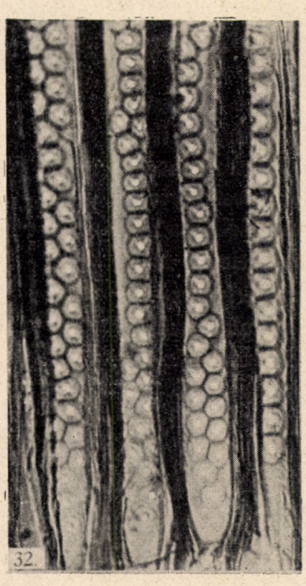
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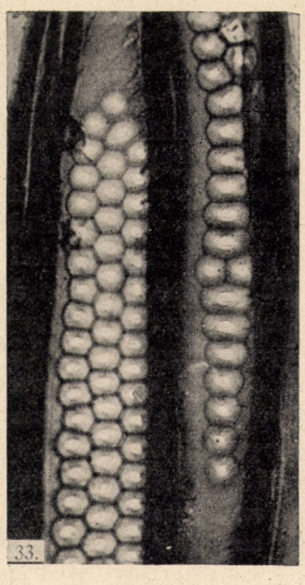
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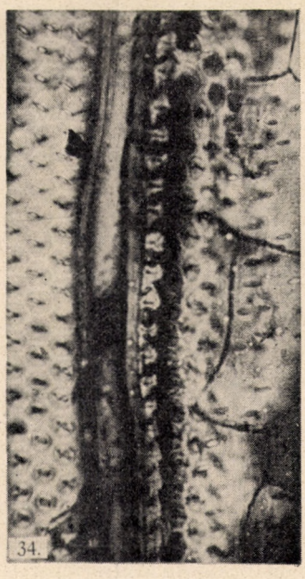
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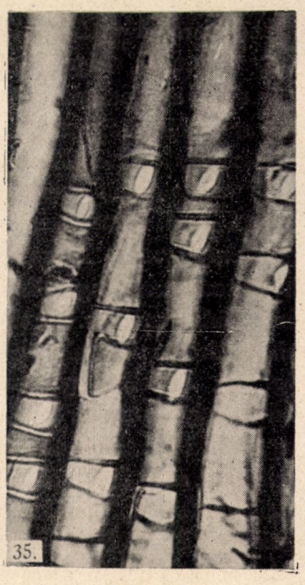
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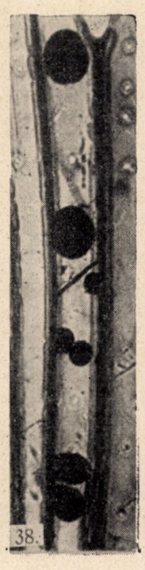
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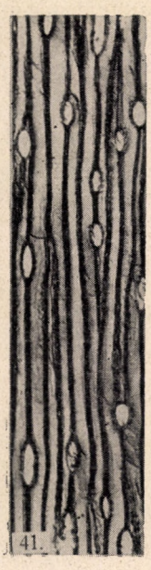
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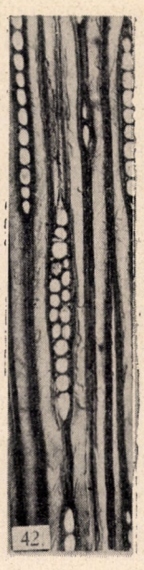
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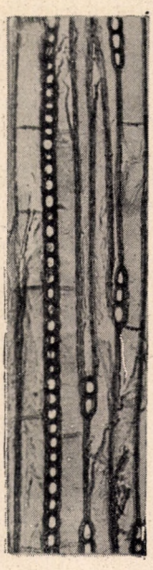

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Redwood: the latewood tracheids of some coniferous woods with pigment deposited in them resulting in a red colour.

Resin canal: see resin duct.

Resin-canal parenchyma: see resin-duct parenchyma.

Resin cysts: differ from resin ducts in that they do not conduct resin, only store it. They are like pockets and commonly of lysigenous origin. They have no epithelial cells, and their wood parenchyma cells are short and square, their walls thick and full of slitlike simple pits. Sometimes they are arranged in longitudinal parallel rows which at places disappear and then reappear again (Plate II, Fig. 10). Their diagnostical value is not great, but of some species they are characteristic.

Resin ducts *(also called resin canals or compound resin ducts)*: tubular cavities sheathed by resin-excreting cells. *Longitudinal resin ducts* extend parallel with the long axis of the woody stem (Plate II, Figs. 7—9, and 12). *Transverse resin ducts* are located in the central portion of the ray and following the latter's direction extend horizontally (Plate III, Figs. 16—19). Commonly there exists direct communication between longitudinal and transverse resin ducts, forming a *resin duct system*. There are two kinds of parenchymatous secreting cells, i. e. epithelial cells, in the tubular cavities. In the genus *Pinus* they are thin-walled, unpitted, and unlignified (Plate II, Fig. 7); in other genera they are thick-walled and mostly lignified. In *Larix*, *Picea* and *Pseudotsuga* the epithelial cells are first thin-walled and unpitted, and it is only later that their walls thicken, develop simple pits and mostly become lignified (Plate III, Figs. 17—19). Longitudinal resin ducts commonly extend in latewood (Plate II, Figs. 2 and 7), but sometimes appear in both earlywood and early latewood (Plate II, Fig. 8). Size of resin ducts is a feature that can sometimes be an aid in the separation of species *(Pinus Lambertiana)*.

Resin ducts due to wounds *(also known as traumatic resin ducts)*: a phenomenon frequently observed in coniferous woods; at or near the site of an injury proliferation of parenchymatous cells occurs; the arrangement of these cells is without any regularity.

Resin duct parenchyma: cells bounding resin ducts; their walls are thin or thick, smooth or pitted (Plate IV, Fig. 40).

Resinous tracheids: in longitudinal tracheids of certain *Araucariaceae* and *Podocarpaceae* transverse plates extend sometimes across the walls as if connecting them. In shape they resemble trabeculae, but are thinner *(Agathis australis, Cycas.* Plate V, Figs. 57—59).

Rexigenous ducts: ducts arising through the separation ofs ome tissue elements owing to growth.

Sapwood: the younger, i. e. outer, still living portion of the woody stem.

Scalloped torus: a torus with ragged margin, the border being cut into scallops. It is charateristic of cedars, and very rarely seen in some species of *Pinus* and *Larix*.

Schizogenous ducts: arise from the separation of cells along their primary walls, and from their cleavage, but leaving the cell content intact.

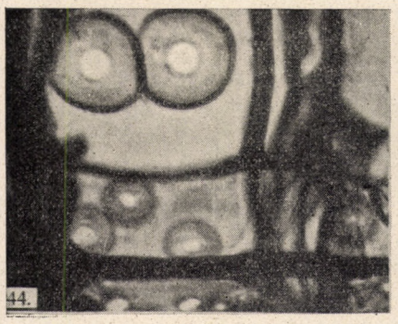
Secondary wall: the innermost layer of the cell wall; it varies markedly in thickness and in its physical and chemical properties; it is stratified, striated, and pitted (Text Figs. 1—2).

Simple pit: a pit in the cellular wall of the shape of a regular cylinder. In surface view it appears a round opening. If two simple pits are directly opposite each other and separated only by a primary wall, the term *simple pit pair* is used (Plate III, Fig. 22). Longitudinal parenchyma cells always communicate through simple pits with one another and with ray parenchyma cells. In the walls of parenchyma cells that communicate with tracheids the pits are simple, while those in the walls of tracheids are half-bordered *(unilaterally bordered pits)*.

Spiral thickeining: more or less delicate ridgelike thickenings in the form of a spiral on the inner face of the secondary wall arising

Plate V

Types of cross fields. 44. Smooth-walled transverse tracheid *(Tsuga canadensis* 600×). 45. Moderately dentate transverse tracheids, pinoid pitting *(Pinus silvestris* 600×). 46. Reticular thickenings in transverse tracheids, pinoid pitting *(Pinus rigida* 600×). 47. Transverse tracheids with spiral thickenings *(Picea smithiana* 600×). 48. Thin- and thick-walled ray parenchyma cells *(Pinus balfouriana* 600×). 49. Indenture *(Thuja standishii* 600×). 50. Smooth and thin tangential walls in ray cells *(Taiwania cryptomerioides* 600×). 51. Beadlike thickenings in tangential walls of ray cells *(Cupressus* 600×). 52. Dentate tangential walls of ray cells *(Pseudolarix* 600×). 53. Thin and smooth horizontal walls of ray cells *(Tetraclinis articulata* 600×). 54. Variably thickened horizontal walls *(Taxus chinensis* 600×). 55. Thickened and pitted horizontal walls *(Pinus aristata* 600×). 56. Strongly thickened ray parenchyma cells *(Agathis macrophylla* 600×). 57. Resin rings in tracheids *(Cycas* 600×). 58. Resin plates in tracheids *(Cycas* 600×). 59. Resin rings *(Cycas* 600×).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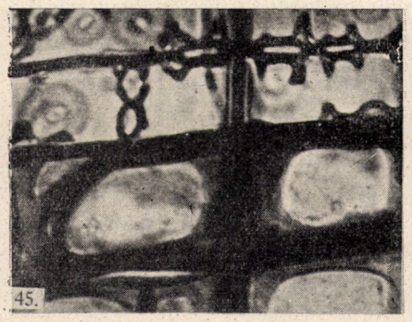
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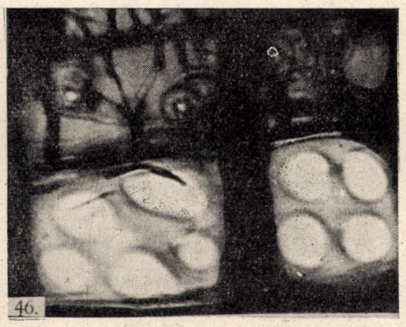
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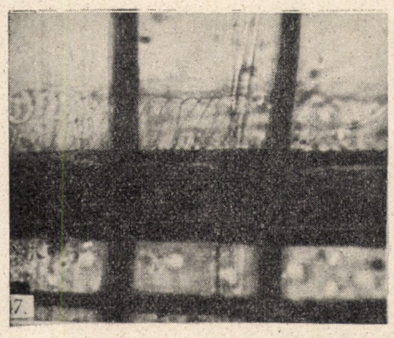
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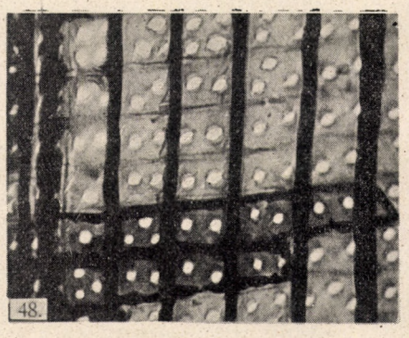
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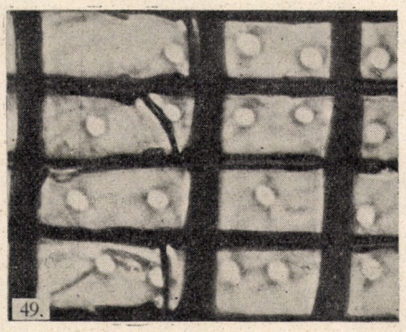
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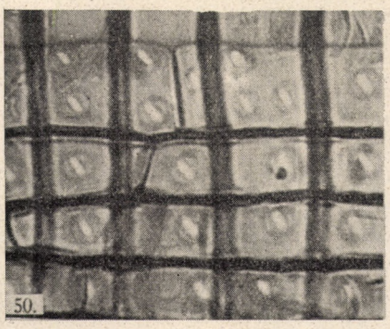
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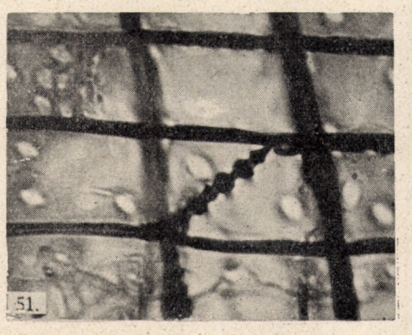
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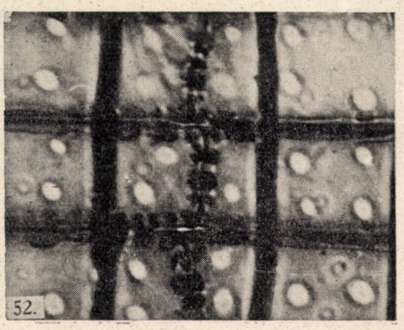
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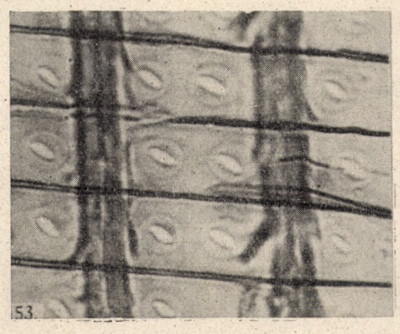
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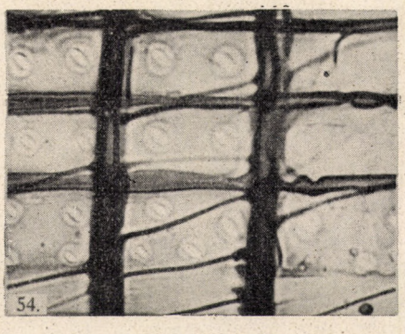
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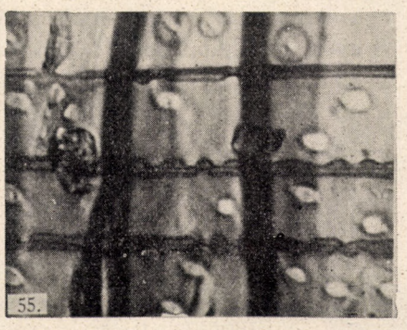
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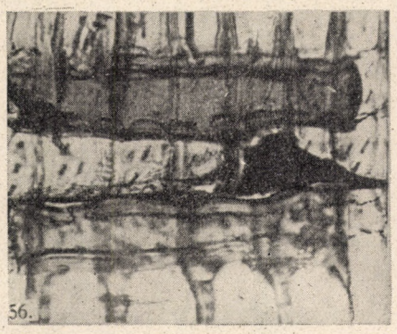
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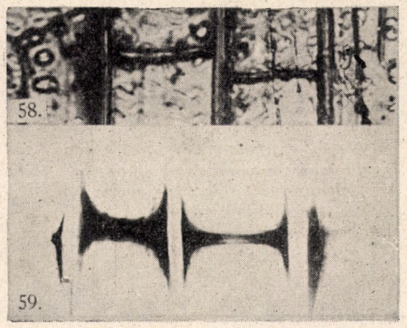
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from the tertiary layer. The angle assumed by the spirals varies considerably attaining not infrequently 45 degrees from the horizontal, and exceptionally almost the horizontal itself. The presence and structure of spiral thickenings often furnish a means of importance in generic and even specific separation *(Picea likiangensis)*. Not infrequently spiral thickening occurs together with bordered pitting. The number of spirals usually ranges from one *(Taxus.* Plate III, Fig. 26) to three *(Cephalotaxus, Torreya.* Plate III, Fig. 27).

Spring wood: see earlywood.

Striation: an oblique close-spaced striation is occasionally to be seen in the walls of tracheids, caused probably by the winding of the tree. This is therefore not a spiral thickening but a series of fissures (Plate III, Fig. 25).

Structure of rays: the structural picture of the ray viewed from the tangential side. It furnishes information concerning the height, width, homogeneous or heterogeneous character of rays, the shape and size of cells, possibly the type of pitting in their walls, and the position and character of the transverse resin ducts, etc. Exact knowledge of the structure of rays is essential in the identification of woods (Plate IV, Figs. 36—43).

Summer wood: see latewood.

Tangential wall: the tangential face of the elements constituting the wood, i. e. of the tracheids, longitudinal parenchyma cells, and ray cells (Plate IV, Figs. 36—43).

Taxodioid pit: approaches the cupressoid type but differs in that the long axis of the aperture is horizontal in position or but slightly oblique (Plate VI, Figs. 72—73).

Terminal parenchyma: see marginal parenchyma.

Torus: central thickened portion of the pit membrane of a bordered pit (Text Fig. 2).

Trabeculae: rodlike or spool-shaped parts of a cell wall which project radially across the lumen and extend from one tangential wall to the other (Plate VII, Fig. 79).

Tracheae: see vessels.

Tracheary elements: see vessels and also tracheids.

Tracheid: a very long unicellular wood element extending parallel with the long axis of the organ; imperforate; with bordered pits or spiral thickenings, or both; its functions are water conduction and mechanical support. Its walls may be thin or thick. The walls of tracheids in the latewood are commonly thicker.

Tracheids dentate: the walls of transverse tracheids are either smooth or tiny toothlike projections cen be seen on them in the radial section. These "teeth" are really the cross sections of plates penetrating into the lumen. Their shape, size, width, and reticular structure are features of diagnostic significance. In some species *(Picea, Larix)* these dentations are rather shallow and pointed or blunt, in some others *(Pinus s lvestris.* Plate V, Fig. 45) they reach the centre of the cell lumen, while yet in others they connect the opposite walls, forming what appears almost a network. Dentate tracheids are confined exclusively to the *Pinaceae* (Plate V, Fig. 46).

Transverse parenchyma: see ray parenchyma.

Transverse tracheids: see ray tracheids.

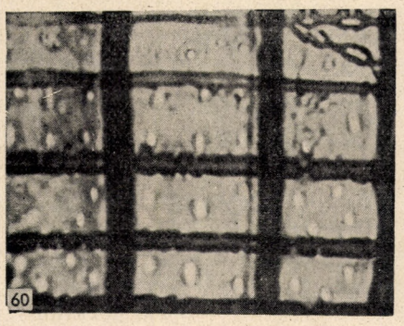
Unscalloped torus: when the margin of the membrane that separates the two cavities of a pit pair is unragged, this term is applied (Plate VII, Fig. 79).

Vascular bundles: conducting elements united to strandlike bundles. In the stems of young conifers they are arranged in rings parallel with the periphery. In coniferous wood they are collateral, the *xylem* being internal to the *phloem* with the *fascicular cambium* between the two.

Vessel *(also designated as trachea)*: a tubular structure formed by the fusion of cells which serves primarily the conduction of water and the transmission of inorganic solutes. There are no vessels in the xylem of gymnosperms, only rudimentary ones in the *Gnetales (Ephedra, Gnetum, Welwitschia)*, in which perforation is commonly simple or sievelike (Plate VII, Figs. 83—85).

Plate VI

Types of cross-field pitting (600×). 60. Piceoid (piciform) *(Picea mariana)*. 61. *Larix*-type *(Larix occidentalis)*. 62. Pinoid *(Pinus pallasiana)*. 63. Piceoid *(Picea likiangensis)*. 64. *Abies*-type *(Abies bracteata)*. 65. Cupressoid pitting in the cross field and beadlike thickenings in the tangential walls *(Juniperus ashei)*. 66. Smooth-walled ray cells *(Tetraclinis articulata)*. 67. Dacrydioid pitting *(Dacrydium)*. 68. Araucaroid *(Cycas revoluta)*. 69. Podocarpoid *(Podocarpus coriaceus)*. 70. Cupressoid *(Libocedrus austrocaledonica)*. 71. Cupressoid *(Taxus chinensis)*. 72. Taxodioid *(Taxodium distichum)*. 73. Taxodioid *(Athrotaxis)*. 74. Araucaroid *(Agathis australis)*.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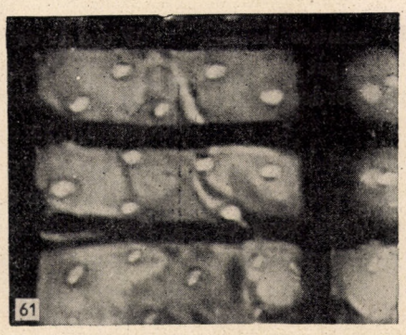
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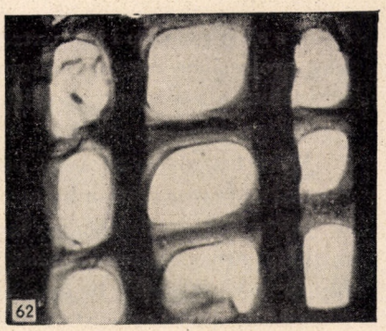
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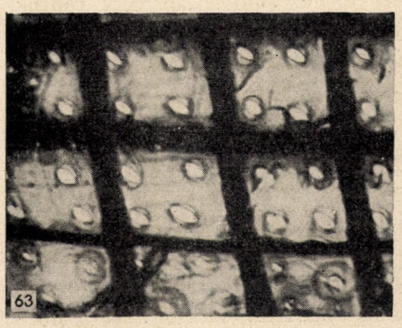
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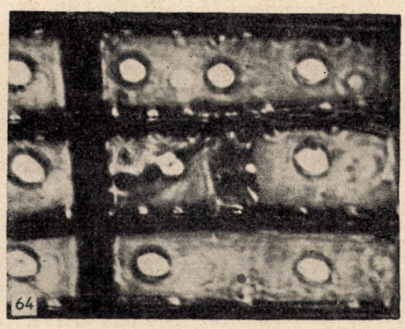
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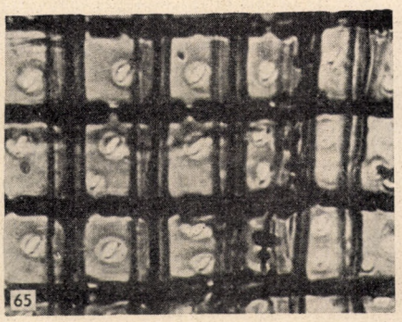
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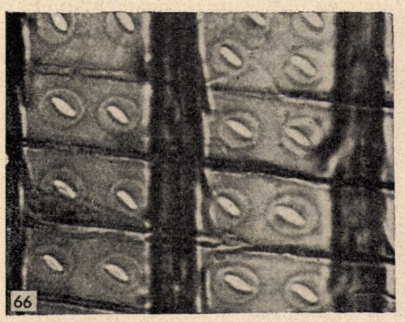
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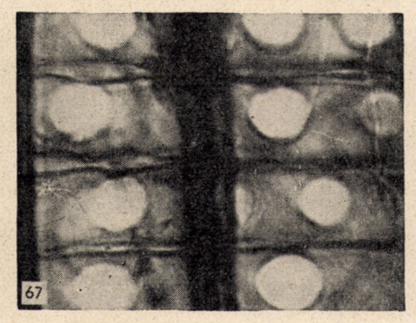
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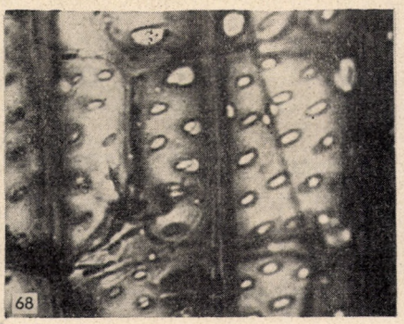
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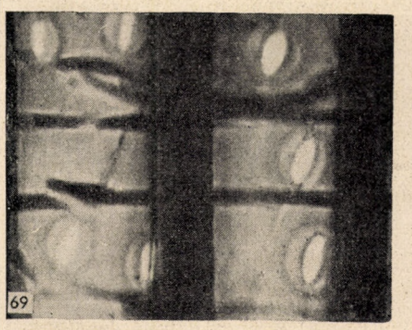
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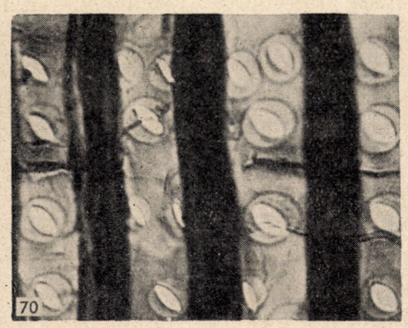
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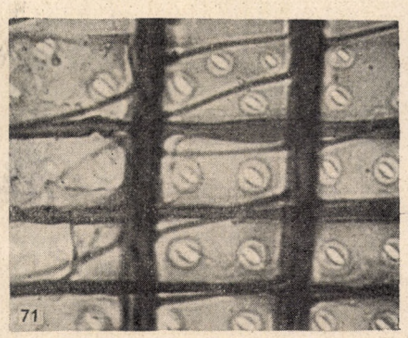
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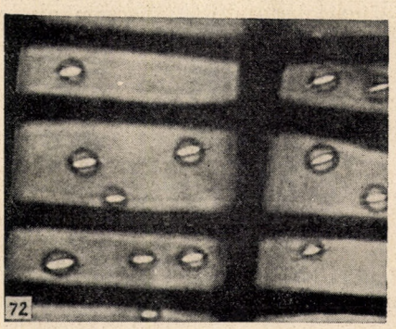
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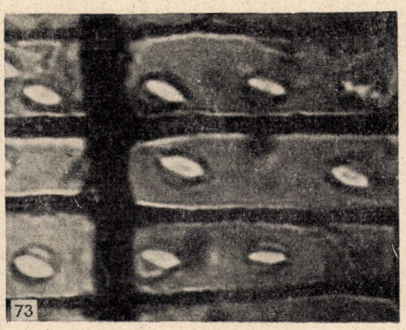
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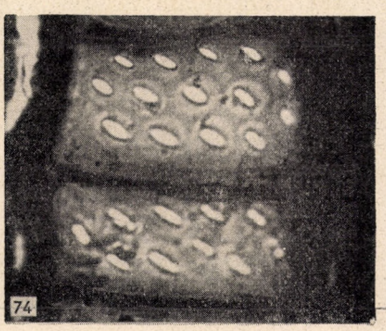
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Vestured pit: extremely minute bead-like projections on the margin of the pit border, or various other markings within the border (Plate VII, Figs. 81—82).

Width of ray: is best observed in tangential and cross section by establishing the number of juxtapositional cells in the ray. The rays of conifers are commonly uniseriate, exceptionally bi- or triseriate (Plate IV, Figs. 42—43). Those with resin ducts or cysts in them are up to 6—8 cells wide (Plate III, Figs. 16—19).

Wood or xylem: the principal strengthening and water-conducting tissue of stems and roots, characterized by the presence of tracheary elements (Plate I, Nos. 7—8).

Wood parenchyma or longitudinal parenchyma: series of vertically elongated thin-walled parenchyma cells, in cross section commonly scattered throughout the growth ring among the tracheids (Plate III, Figs. 3—4), sometimes arranged in more or less tangential rows (Plate II, Figs. 4, 6).

METHODS OF IDENTIFICATION

If a specimen of wood, more precisely a coniferous wood, perhaps lignitized or otherwise fossilized, is to be identified on the basis of its xylem, the first thing to know is its internal anatomical structure. For adequate comprehension of this structure very thin sections cut in the three main planes are necessary. A section cut in one plain only will never suffice to define an unknown sample precisely; at best, it will permit some conclusions as to the family or genus or, perhaps, species. With a little practicing, anybody can learn the art of preparing sections of wood and fossils. The methods employed in their preparation, the staining processes, photomicrography, representation by drawing, etc. have been briefly dealt with in the introductory part; besides, there are very useful textbooks available on these topics, first of all the standard works of Huber, Müller-Stoll, Kräusel, Kisser, etc.

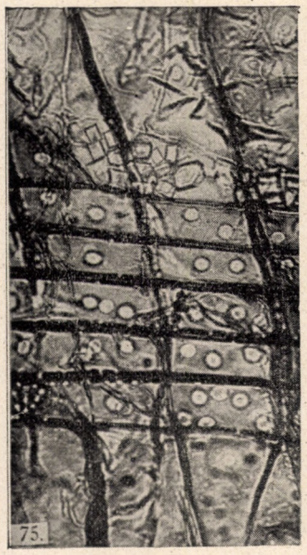
a) STUDY OF THE TRANSVERSE SURFACE OF SECTIONS

The identification of wood commonly begins with a study of the cross section. Cross sections showing roughly uniform cells arranged mostly in radial rows immediately permit the conclusion of some gymnospermous wood, in the first line some conifer. If along with smaller cavities there appear markedly large ones, one may at once think of some *Dicotyledones*, in quite exceptional cases of *Ephedra* or *Gnetum*.

The transverse surface particularly lends itself to the study of growth rings, the arrangement of elements within them, their principal features, width, delimitation, etc. Are the growth rings indistinct, rather blurred, one is to consider first of all tropical woods: *Araucariaceae*, *Podocarpaceae*, and some genera of the *Cupressaceae (Callitris*, *Callitropsis*, *Widdringtonia)*, since this type of structure points to growth under constantly uniform temperature and climatic conditions, respectively (Plate II, Fig. 3). On the other hand, growth ring delimitations distinctly visible to the unaided eye or at lens magnification (Plate II, Fig. 2) clearly indicate structural differences in the early- and latewood. These consist in that relative to the early-formed cells of the tracheids the late-formed cells are small and flattened (Plate II, Fig. 4), their walls are thick, and their lumina rather constricted (Plate II, Fig. 7). With the growing season advancing, the latewood composed of cells of this description either develops gradually with the walls of the tracheids, becoming stepwise thicker and thicker (Plate II, Figs. 2 and 7), or it forms abruptly at the end of the season giving rise, near the outer edge of the growth ring, to a conspicuous ring of thick-walled tracheids frequently well discernible to the naked eye (Plate II, Fig. 2). The thickening

Plate VII

Crystals, bordered-pit types, perforations. 75. Crystals of calcium oxalate in ray parenchyma cells *(Abies venusta* 300×). 76. Crystals of calcium oxalate in wood parenchyma cells *(Abies veitchii* 300×). 77. Druses in parenchyma cells *(Ginkgo* 300×). 78. Verrucose thickening in tertiary layer of tracheidal wall *(Actinostrobus pyramidalis* 600×). 79. Trabecula *(Pinus serotina* 600×). 80. Crassulae *(Larix laricina* 600×). 81. Vestured pits *(Abies concolor* 600×). 82. Vestured pit *(Agathis australis* 600×). 83. Ephedroid perforation *(Ephedra distachya* 500×). 84. Simple perforation *(Gnetum* 300×). 85. Simple perforation *(Welwitschia* 300×). 86. Spiculum cell *(Welwitschia* 300×).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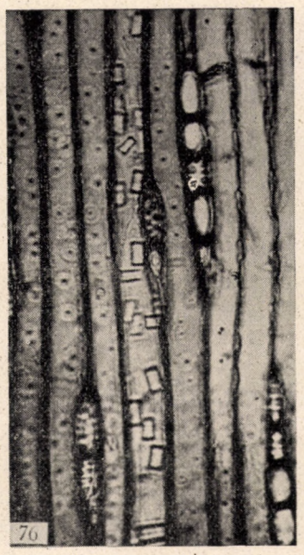
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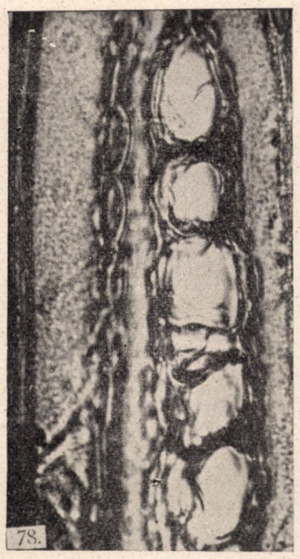
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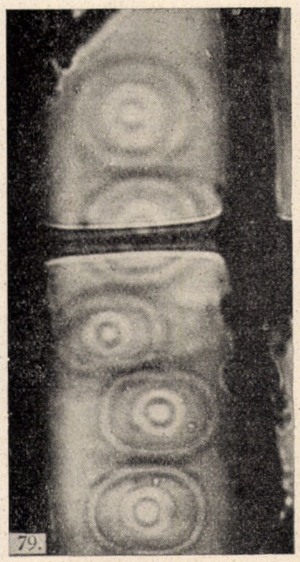
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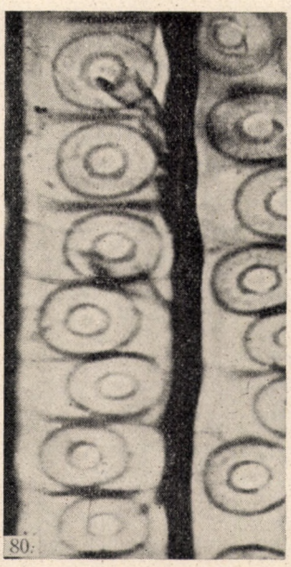
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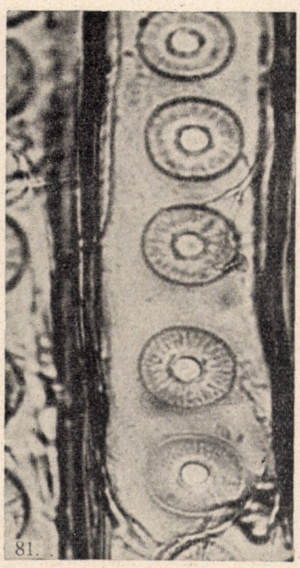
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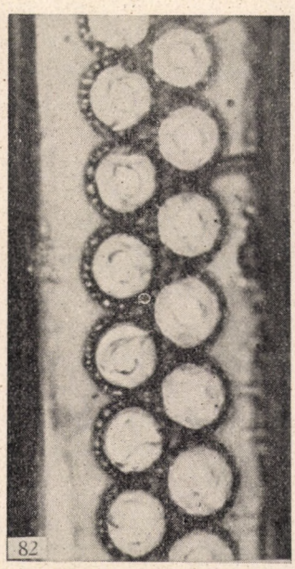
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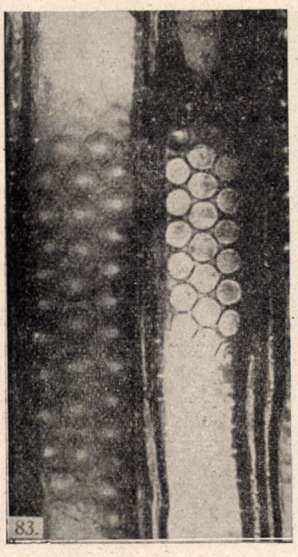
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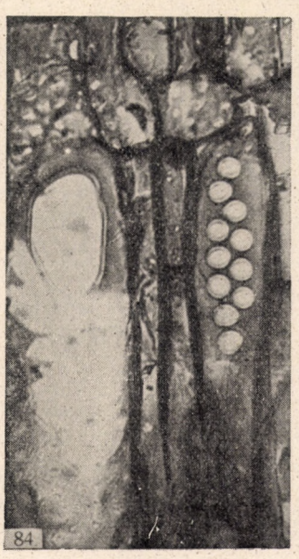
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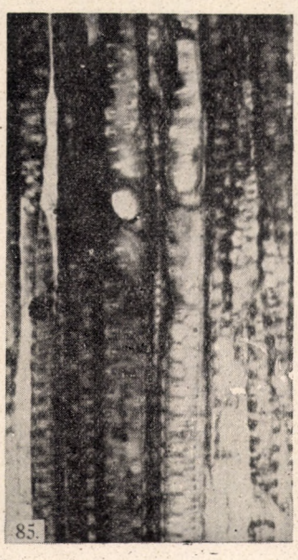
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of the tracheid walls in the autumn period of growth with consequential constriction of the lumina allows the conclusion that in the autumn, towards the end of the growing season, the main function of the tracheids is mechanical support rather than conduction of the increased water supply.

The thick-walled and narrow-lumened tracheids in the latewood are sometimes abruptly followed by thin-walled earlywood tracheids with considerably wider lumina. At other times, there is no marked autumnal thickening of the walls of the tracheids near the growth ring delimitation, merely constriction of the lumina, and even this is confined to the width of but one or two tracheids (Plate II, Fig. 4). All these attributes of the wood may be most useful in identification and have to be taken into account accordingly. Occasionally, cells entirely different in shape and size from the others align along the growth ring boundary. They may have arisen as the result of some injuries to the wood. Commonly they secrete resin (Plate II, Fig. 11).

In the cross section also should be observed the arrangement, structure, and width of the radially extending rays. In conifers they are commonly uniseriate, occasionally biseriate *(Sequoia, Keteleeria.* Plate IV, Fig. 42), and exceptionally triseriate in the body of the ray. In some species the rays are barrel-shaped, chiefly in *Araucaria* and *Abies* (Plate II, Fig. 5). As regards walls, the horizontal ones are quite smooth without any pitting in some species *(Araucariaceae, Podocarpaceae.* Plate II, Fig. 13), while in others they display numerous tiny simple pits following each other from sparse to abundant in one or two rows *(Pinaceae, Cupressaceae, Taxodiaceae.* Plate II, Fig. 14). The tangential walls and those radial walls which are in contact with tracheids are either smooth *(Araucariaceae, Podocarpaceae* and the genera *Callitris, Widdringtonia, Taiwania)* or provided with simple pits or nodular thickenings (Plate V, Figs. 50—52).

Not infrequently the tracheids are interspersed with thin-walled cells replete with cellular substance. These are parenchyma cells, and are either solitary, or scattered throughout the growth ring (Plate II, Fig. 4), or form practically uninterrupted strands parallel with the growth ring demarcation *(terminal parenchyma.* Plate II, Fig. 6). There are parenchyma cells in almost every member of the *Cupressaceae, Taxodiaceae, Cephalotaxaceae, Podocarpaceae*, except in *Phyllocladus* and *Sciadopitys.* In *Taxus, Araucaria*, and in the genera *Pinus* and *Picea* of the *Pinaceae* they only occur in highly exceptional cases, and are probably due to injuries to the wood near to them (Plate II, Fig. 11).

Another valuable diagnostic feature is whether the horizontal walls of the parenchyma cells are uniformly smooth (Plate III, Fig. 20), or whether they are provided with tiny pits (Plate III, Figs. 21—23). Thus, for instance, *Taxodium* with commonly well-discernible pits in these walls can readily be differentiated from *Sequoia*, where for the most part they are devoid of pits.

Longitudinal resin ducts that may be present in the growth rings are likewise best observed in the cross section. Their absence, or if present, their size and structure permit reliable conclusions regarding the wood in question (Plate II, Figs. 7—10). Of the living conifers they occur only in the *Pinaceae*, more exactly in *Pinus, Larix, Picea* and *Pseudotsuga.* They are largest in the genus *Pinus*, varying from 60 to 300 μ ; smaller in *Larix* (40 to 80 μ), in *Picea* (40 to 70 μ), and in *Pseudotsuga* (40 to 45 μ).

Thin-walled epithelial cells lining resin ducts definitely point to some *pine* (Plate II, Fig. 7), while thick-walled epithelial cells indicate that the wood is either *Larix, Picea*, or *Pseudotsuga.* If in cross section the resin duct appears as a radially slightly elongated ellipse and is seen to be surrounded by 10 to 15 epithelial cells, the wood under examination is probably a *Larix*, although there are some species in this genus that show circular resin ducts on the transverse surface (Plate II, Fig. 8). Is the resin duct rather circular and lined by 8 to 10 contiguous, mostly thick-walled epithelial cells, the sample is probably from a *Picea* (Plate II, Fig. 9), while ducts with a smaller diameter and therefore lined only by 5 or 6 epithelial cells, allow of concluding *Pseudotsuga. These statements are merely informative, without any claim to absolute validity.* Nevertheless, the properties outlined above do on the whole characterise the four genera with resin ducts and thus form a point of departure for the work of more substantial identification.

Distinction must be made between these true or normal resin ducts and the so-called *resin cysts* occasionally found in growth rings, for instance in certain cedars and *Abies.* Generally, there are many of these cysts disposed in short to long series parallel to the growth rings (Plate II, Fig. 10).

b) STUDY OF THE TANGENTIAL SURFACE OF SECTIONS

In the tangential section some other features of the tracheids, rays, and wood parenchyma cells are brought to light. As regards *tracheids*, their tangential walls are either smooth (Plate III, Fig. 20), or there are various patterns or pits in and on them, respectively. In the earlywood they are commonly smooth, in the latewood mostly provided with bordered pits. These bordered pits either have interstices between them and so form 1 or 2, occasionally 3, series — this is the so-called *modern pitting* (Plate IV, Figs. 28—31) — or they crowd alternate-fashion in 2 to 3 rows, in which case the wood is certainly that of one of the *Araucariaceae* and can belong to no other family. The latter type of pitting is the so-called araucaroid pitting, which is best seen in the radial walls of the tracheids (Plate IV, Figs. 32—34).

Also, the apertures of the bordered pits need to be examined with a view to establishing whether they are circular, rod-shaped, or slitlike, whether they are horizontal, vertical, oblique, or X-figured in position, because these features too are of decided diagnostic importance (Plate IV, Figs. 28—35).

Of equal importance is it to decide whether apart from pitting the walls of the tracheids are quite smooth or delicately punctate. The latter quality characterizes the genus *Actinostrobus* and some species in *Callitris* and *Widdringtonia* (Plate VII, Fig. 78).

In the tracheids of certain woods there are spiral thickenings present on the inner surface next to the lumen. Spiral bands of this sort extending lonely or in pairs suggest *Amentotaxus*, *Torreya*, *Cephalotaxus* and a few species of *Taxus*. If they are closely spaced, the wood is probably a *Taxus*, *Cephalotaxus* or, provided resin ducts are present, a species of *Pseudotsuga*, or even *Picea*. Notwithstanding the presence of spiral thickenings, the absence of resin ducts on the transverse surface excludes *Picea* and *Pseudotsuga*, leaving the other four genera for separation on the basis of the finer details to be studied in the radial section.

The minute structure of the rays is also best observed on the tangential section : their seriation, the number of stories through which they extend, their minimum and maximum height (Plate IV, Figs. 41—43). Rays vary considerably in height : they may be 2—3—5 (15) cells high as in the *Araucariaceae* and *Actinostrobus* (Plate III, Fig. 21), or 20—30 *(Abies)*, or attain as much as 60 cells eigh, e. g. in *Taxodium* (Plate IV, Fig. 43). The cross sectional picture of ray cells is also studied on the tangential surface. In *Araucariaceae*, *Actinostrobus* and *Ginkgo* it is wide and mostly barrel-shaped (Plate III, Fig. 24). The ray cells in *Cupressaceae* are commonly narrow elongate ellipses (Plate IV, Fig. 26), in other woods they are nearer to circular (Plate III, Fig. 22). Likewise on this surface is it to be established whether the horizontal, radial and tangential walls of ray cells are thin, or partially or wholly thickened, and whether they are pitted or not. The tangential walls are either smooth without any pitting (Plate III, Fig. 24), at most with a delicate punctate pattern as, e. g., in *Widdringtonia*, *Actinostrobus*, and *Sequoia*, or there are small pits in them. If pits are present they show a cribriform grouping, the so-called *sieve pitting* in which the meshes are either quite irregularly arranged or display a more or less star-shaped pattern. This type of pitting is suggestive of *Abies*, *Picea*, *Pseudolarix*, *Pseudotsuga* and *Keteleeria* (Plate IV, Fig. 37). These are typical *abietoid pits*. If, however, there are scalariform transverse bars in the tangential walls, the structure is characteristic in the first place of the *Cupressaceae* (Plate IV, Fig. 36), but not only of that family, since sometimes it can also be seen in some species of *Abies*. On the other hand, the tangential walls of rays of certain species belonging to the *Cupressaceae* not infrequently display abietoid pits.

The structure of the wider rays with resin ducts in them should also be observed on the tangential section. Again four types can be distinguished. In *Pinus* the rays with resin ducts located in their central portion are for the most part uniformly fusiform with thin-walled epithelial cells inside them (Plate III, Fig. 16). These rays are generally bordered at their upper and lower parts by thick-walled transverse tracheids seldom more than 2 or 3 layers in height. Rays with resin ducts located in them are invariably accompanied by uniseriate simple rays commonly bounded by transverse tracheids on the upper and lower margins. In some woods, these thick-walled transverse tracheids give way at places to thin-walled parenchyma cells (Plate IV, Fig. 39). The transverse tracheids are then smaller in cross section than the slightly widening thin-walled parenchyma cells. The rays containing resin ducts in *Pinus* definitely differ

from those in *Picea*, *Larix*, and *Pseudotsuga*. Those in *Larix* are commonly elongated spindles in shape, and the ducts in them are sheathed by up to 10—16—20 thin-walled epithelial cells. Often, but *not frequently enough to be regarded as a rule*, 6 to 10 uniseriate cell layers are above and below the ducts. In cross section, resin ducts resemble upright ellipses in several species (Plate III, Fig. 19). In *Picea*, 8 to 10 thick-walled epithelial cells encircle the resin ducts in the ray. In cross section the uniseriate ray cells are generally circles or flat ellipses, in contrast to the similar rays in *Larix*, which sooner resemble narrow upright ellipses. However, on this basis the two genera cannot be separated (Plate III, Figs. 18—19). As regards *Pseudotsuga*, the resin ducts in them are generally lined by 5 to 6 thick-walled epithelial cells. In cross section, here too the ducts are nearer circular. A feature facilitating separation is the invariable presence of spiral thickenings in all the tracheids of *Pseudotsuga* contrasted with their almost invariable absence in *Picea* and *Larix* (Plate III, Fig. 17).

c) STUDY OF THE RADIAL SURFACE OF SECTIONS

On this surface, too, the walls of the tracheids have to be examined for their smoothness or delicate dottedness, for pits or spiral thickenings on them. While bordered pits are not always present in the tangential walls of tracheids they appear invariably on one or the other of the radial walls. These bordered pits are arranged in loose rows with the pit borders not touching one another at all, or only slightly. This is the so-called *modern pitting*, to be found in most of the families of the Coniferae. In the *Araucariaceae* the bordered pits, even if they are disposed in a single row, are commonly in contact with one another, and the contact surfaces between them result in horizontal lines (Plate IV, Figs. 32—33). If in the members of families other than *Araucariaceae* two or more pits extend across the tracheid they are placed at about the same level without or only with slight contact between their borders. This is the *opposite pitting* characteristic in the first place of *Taxodiaceae* and within that family of *Taxodium* and *Sequoia* (Plate IV, Fig. 30).

Where two pits are at the same level of height, as in *Larix*, *Keteleeria*, and many members of *Podocarpaceae*, they are commonly bounded above and below by *crassulae*, formerly called *Bars of Sanio* (Plate IV, Fig. 29). In several *Podocarpaceae* the surface of contact between two pits mostly results in a vertical, sometimes in an oblique, and only exceptionally in a horizontal line (Plate IV, Fig. 31). On most rare occasions, in some *Podocarpaceae* or in *Keteleeria* one may encounter uniseriate *araucaroid* pitting. Araucaroid pitting differs from modern pitting in that the pits are hexagonal in shape due to crowding. As has already been mentioned, this type of pitting occurs only in *Araucaria*, *Agathis*, *Welwitschia*, and in the *cycads*. This fact appears to afford support for the assumption that the four genera are members of the same phylogenetic series.

As regards pit apertures, they are circular or rod-shaped. If rod-shaped, they are never extended but the apertures of both members of a pit pair may appear in the form of an X (Plate IV, Figs. 28—35).

Concerning the *tori* of bordered pits (Plate VII, Fig. 79), they are made recognizable by a second ring around the pit aperture. The margin of the torus is mostly unscalloped. A scalloped torus is suggestive of the genus *Cedrus*.

In some species of *Callitris* the apertures of bordered pits are bounded above and below by two narrow bars extending at right angles to the longitudinal walls of the tracheids: they are really portions of spiral thickenings. This type of pitting occurs exclusively in *Callitris* (Plate IV, Fig. 35).

The distribution of spiral thickenings is another feature best observed on the radial surface. Spirals extend either in pairs *(Amentotaxus, Torreya, Taxus, Cephalotaxus)* or in company with several others, or individually, but then closely spaced, and their helixes assume different angles to the longitudinal axis of the tracheids. In addition to the above-mentioned four genera, tracheids with this type of spiral thickening occur in *Picea* and *Pseudotsuga;* in the former mostly in the latewood only, and seldom in the earlywood, while in the latter all the walls of the tracheids are densely covered by spiral thickenings, which then coincide in position with the apertures of the bordered pits in these walls. Note should also be taken of whether the spiral thickenings spread out into branches or not, for branching definitely points to *Pseudotsuga*, and its absence to *Taxus*, *Amentotaxus* and *Cephalotaxus*, in which the spiral thickenings are never divisioned.

Peculiar spiral bars extend inside the tracheids of *Cycas* and *Ginkgo*. They depart from a broad base, are sometimes segmented, at some points thickened, then gradually taper until, finally, they end as simple spiral threads (Plate III, Fig. 25b).

Spiral thickenings should not be confused with the *spiral checks* which, although they follow the direction of the true spiral bands, are actually due to mechanical changes in the tracheids and are in fact cracks or fibrils bearing upon the micellar structure of tracheidal cell walls (Plate III, Fig. 25a).

Interspersed among the tracheids there are frequently wood parenchyma cells containing, as a rule, some resinous substance (Plate IV, Figs. 38 and 40). They always communicate with one another, with the tracheids, or the ray cells through simple pits.

The horizontal walls of wood parenchyma cells vary in structure. In certain families and genera they are quite smooth *(Araucariaceae, Podocarpaceae, Callitris, Callitropsis, Tetraclinis, Actinostrobus, Widdringtonia, Taiwania* and a few other members of the *Cupressaceae* (Plate III, Fig. 20). Mostly, however, they are very delicately verrucose, nodular, or with beadlike (Plate III, Fig. 21) or angular thickened portions in them (Plate III, Figs. 22—23). Angularly thickened horizontal walls are characteristic of *Abies, Keteleeria, Pseudolarix, Larix*, and a few species of the *Taxodiaceae*, while beadlike or slightly nodular thickenings feature chiefly *Cupressaceae, Taxodiaceae* and *Cephalotaxaceae*. Longitudinal parenchyma cells are mostly absent in the wood of *Taxus*, and on this basis the members of the *Taxaceae* can readily be separated from those in the *Cephalotaxaceae* and the species in *Pseudotsuga*. In the *Araucariaceae* and the *cycads* there are sometimes double T-shaped or ring-shaped thickenings the tracheids, rendering mechanical support mainly to the walls of ray cells (Plate V, Figs. 58—59). In the tracheids of the *cycads*, such rings sometimes lean to the cell walls like tripods. (Plate V, Fig. 57). In some cases they simulate the annular perforations of the wide vessels in dicotyledonous plants whe reas they have nothing in common with them.

Although they are of little diagnostic value, mention should be made of the trabeculae that afford inside support to the tracheids. Sometimes they are formed at the same height in each of as many as 20 to 25 tracheids, resulting in practically uninterrupted series (Plate VII, Fig. 79).

d) STRUCTURE OF RAYS

The most important part in the identification of woods is undoubtedly that of the rays. Almost all the generic and specific characteristics are so to say condensed in their radial structure. For the purpose of diagnosing a critical specimen of wood it must be first of all determined whether the rays in it are homogeneous or heterogeneous. Rays are homogeneous when consisting entirely of one kind of cell : parenchyma cells or tracheids. *All genera of* the *Coniferae* have homogeneous rays consisting of parenchyma cells only, except *Picea, Pinus, Cedrus, Tsuga, Pseudotsuga, Larix*, and a few of the *Taxodiaceae* and *Cupressaceae.*

Having established the presence of transverse tracheids in the rays the next step is to decide whether their walls are smooth (Plate V, Fig. 44) as, e. g. in the species of the *Haploxylon* group of *Pinus*, further in *Tsuga, Sequoia* and *Thujopsis ;* whether they reveal spiral thickenings as in *Pseudotsuga* and a few *Picea* and *Larix* species (Plate V, Fig. 47), and whether they are minutely dentate, as for instance in the *Diploxylon* group of *Pinus* (Plate V, Fig. 45), or show reticulate thickenings (Plate V, Fig. 46). The presence and structure of transverse tracheids, and particularly the extent to which their walls are thickened, constitute features of considerable diagnostic value. Significance likewise attaches to the tiny bordered pits in the transverse tracheids, their size, and the type and orientation of their apertures (Plate V, Figs. 44—46).

Not less important is an examination of the minute structure of *ray parenchyma cells.* The areas bordered by the horizontal walls of a ray cell and the vertical walls of a tracheid are called *cross fields* and their structure forms a prominent feature in identification work. The number of pits in the cross field varies from a single large one occupying the entire area to 2—3, or 1—16, small pits. If the cross field is occupied by a single large pit, the pit is called a *pinoid* pit (Plate V, Fig. 45). Such pits occur in many species of *Pinus*, and commonly in *Phyllocladus, Sciadopitys*, in a few *Dacrydium*, possibly in *Microcachrys* and in certain *Podocarpus*, but in the five last-mentioned there are no transverse tracheids. In some other woods there are 2—3, or 6—8, likewise pinoid, commonly circular or elliptic, small pits (Plate V, Fig. 46 and Plate VI, Fig. 62). In certain *Pinus* species *(Pinus halepensis, P. cembroides, P. aristata*, etc.) the cross field is

occupied by exceedingly minute, almost piceoid, pits but their apertures are neither slitlike nor of vertical orientation (Plate V, Fig. 55). A single circular pit in the cross field points to *Dacrydium* or *Podocarpus* (Plate VI, Fig. 67). A small-bordered tiny pit with an extended vertical aperture in each of the four corners of the cross field indicates *Picea* (Plate VI, Figs. 60 and 63). From 4 to 6, possibly 8, alternate pits in the cross fields suggest *Larix* (Plate VI, Fig. 61). While in *Picea* the pits are circular, the borders crescent-shaped, and the apertures oblique or vertical in position, in *Larix* the borders are much rather horizontal or somewhat oblique ellipses with the pit apertures aligned in the same direction (Plate VI, Fig. 61). A single larger pit in the cross field with border and aperture aligned in the same vertical or oblique position represent a *podocarpoid* pit characteristic in the first place of the genus *Podocarpus* (Plate VI, Fig. 69). From 3 to 5 pits in the cross field with their borders commonly the shape of an horizontal ellipse and the long axis of their apertures also horizontal, constitute *taxodioid* pits and are suggestive of *Taxodiaceae*, principally of *Taxodium*, *Sequoia*, and *Athrotaxis* (Plate VI, Figs. 72—73). Finally, when there are 1—2—4, possibly 6, minute pits in the cross field with their borders mostly oblique ellipses in outline and their apertures in the direction of the conjugate axis of these ellipses, i. e., at right angles to the long axis of the pit, we speak of *cupressoid* pits, characteristic in the first place of *Cupressaceae* (Plate VI, Figs. 65, 66, 70).

With one minute pit in the cross field, or two of them side by side or one above the other, one may conclude *Juniperus* or *Cupressus* (Plate VI, Fig. 65). On the other hand, if the pits in the cross field are slightly elongated horizontally, and scattered or disposed in a row of 2 or 3, then from this somewhat taxodioid-type pitting one may infer a species of the *Abies* (Plate VI, Fig. 64).

With 3—4—8—16 tiny pits per cross field, which are hexagonal due to crowding and have rod-shaped but not extended apertures, we are facing *araucaroid* pitting, characteristic in the first line of *Araucariaceae*, *Actinostrobus* and *Ginkgo*. A slight difference between *Agathis* and *Araucaria* should here be noted consisting in that the pits are commonly arranged in 2 or 3 horizontal rows in the former but in nearer to vertical rows in the latter (Plate VI, Fig. 74).

A similar structure can be observed in *Cycas*, except that there are always 10—15 pits in the cross field, that the apertures are invariably rod-shaped, and the borders elliptic in outline (Plate VI, Fig. 68). From these, the rays of *Ephedra* and *Gnetum* differ considerably in structure (Plate VII, Figs. 83—84).

Another point to be clarified in connection with ray structure is whether the walls of *all* the ray cells are of the same thickness and pitted. In some families all the species possess very thin and smooth ray-cell walls *(Araucariaceae, Callitris, Tetraclinis, Cycas.* Plate V, Fig. 53). In some others, the horizontal walls are pitted while the tangential ones are smooth *(Taxodiaceae)*. In most cases, however, all the walls, including the tangential walls, are pitted (Plate V, Figs. 51—52). Careful scrutiny of the tangential wall is all the more important as — we have already seen it — it can be quite smooth *(Araucariaceae, Ginkgo, Podocarpaceae, Callitris, Actinostrobus.* Plate V, Fig. 50), or display beadlike *(Cupressaceae.* Plate V, Fig. 51) or dentate thickenings *(Abies, Picea, Larix, Keteleeria, Pseudolarix.* Plate V, Fig. 52).

In some species of *Picea* and *Pinus* there are thick- and thin-walled parenchyma cells, the former provided with true pits, the latter unpitted but with the pits of the tracheids behind them showing through the thin walls (Plate V, Fig. 48). The thick-walled parenchyma cells of certain *Agathis* merit special interest for being veritable *idioblasts.* In their walls there appear simple pits and also spaces similar to bordered pits (Plate V, Fig. 56).

A PHYLOGENETIC SYSTEM OF THE GYMNOSPERMS IN THE LIGHT OF XYLOTOMY

The race history of the vegetable kingdom begins in the primeval days of the earth, in the *Pre-Cambrian*. Already the seas of that era were populated by innumerable forms of uni- and multicellular algae. In it and the subsequent *Cambrian*, frequently referred to as the *algal period*, some of the unicellular plants distinguished by various forms began to aggregate to more or less sizeable groups, clans, or colonies; some other grew filamentous, simple or branched; yet others became plates of cells or three-dimensioned bodies. If the simplest living *Thallophytes*, in the first place the algae, whose ancestors inhabited the *Cambrian* and *Silurian* seas in vast masses, are studied from the point of view of branching, three main systems will be found in them: the *monopodial*, chiefly among the green algae, or *Chlorophyceae;* the *dichotomous*, distinguishing the brown algae or *Phaeophyceae;* and the whorled or *verticillate* system, which is characteristic mostly of the red algae or *Rhodophyceae*, and of the stoneworts or *Characeae*. Paleobotany delivers ample evidence of these same three branching systems occurring in the *Silurian* and the *Devonian* periods, when the then continental coasts and shallow waters were peopled by the *Psilophytinae*. Present-day taxonomists and phytopaleontologists regard the *Psilophytinae* as the most primitive ancestors of the cormophytic plants, and it is from them that they deduce, as from a "unit", the three large groups of the vascular cryptogams, viz.: the *Sphenopsida*, *Lycopsida*, and *Pteropsida*. However, a closer study of their forms is soon bound to convince us that the *Psilophytinae* can by no means be considered a completely unified group of plants, because among them we find the monopodial *Rhynia*, *Hornea* and *Asteroxylon* with their small leaves originated from the epidermal emergences, because they include the genera *Protopteridium*, *Taeniocrada*, and *Zosterophyllum* of macrophyllous structure with processes that are lamelliform owing to a flattening out of the stalk, and finally because they also embrace the *Hyenia* and *Calamophyton* which were just drawing near to a verticillate system of branching. In view of the principles expounded further on in this chapter, it is well to keep in mind that these three entirely different types of plants were living near to one another and in the same period. Kristofovits is one of the authors who hold that the leaves of the *Filicales*, *Lycopodiales* and *Equisetales* cannot be regarded as homologous. (Cf. phylogenetical chart attached,)

The situation was the same in the *Carboniferous*, the period of the vascular cryptograms or *Pteridophyta*. Along with the fossil genera *Protolepidodendron*, *Lepidodendron*, and *Ulodendron* of microphyllous character and false dichotomy, we find in this period, in addition to a great variety of ferns such as the *Aneurophyton* and the *Archaeopteris*, the unbranched or always only dichotomous and, in the writer's view "macrophyllous", *Sigillaria*, as also the verticillate *Asterocalamites*, *Calamites*, *Pseudobornia*, and *Sphenophyllum*. Moreover, towards the end of the *Carboniferous* there lived in conjunction and simultaneously some representatives of the first *Pteridospermae*, this higher branch of evolution, further the microphyllous *Walchia* of the so-called primitive conifers, then the *Lepidocarpon*, the macrophyllous *Callipteris*, the *Neuropteris*, as also various forms of the now verticillate now unbranched *Calamites*. The primitive seed-producing forms of the latter are not yet known with certainty, though already there are data (M. Jeliasevitsh) to the effect that the spermatophytic form of the horsetail and scouring rush type *(Articulatae)* has been found at last. Should these data be confirmed, then in the present writer's opinion we have to do with one of the greatest discoveries made in the phylo- geny of the plant kingdom. (Cf. phylogenetical chart attached).

In the *Permian* and *Triassic*, at the beginning of the so-called age of gymnosperms, the *Cordaites*

became extinct, but along with the macrophyllous *Pterophyllum* there lived the *Ulmannia*, *Pleuromeia*, and the microphyllous *Voltzia*, side by side with some surviving spore-bearing forms of the *Articulatae*. In other words, in this initial age of the *Gymnospermae* the three main types continued to coexist, in many respects on an identical evolutionary level, the same as they had coexisted for several hundred millions of years. (Cf. phylogenetical chart attached).

This coexistence went on in the *Triassic*, *Jurassic*, and *Cretaceous*. Once more we find the verticillate type, represented by the *Neocalamites* (the seed-producing form of which is likewise unknown up to the present time), living together with the macrophyllous *Osmundaceae*, *Dipteridaceae*, *Matoniaceae*, *Caytoniaceae*, *Bennettitinae*, *Cycadaceae*, *Ginkgoales*, as also with the microphyllous younger *Coniferae*, as for instance the *Voltzia*.

As from the *Tertiary*, the verticillate *Equisetineae* seem to be relegated to the background, the *Cycadeae* and *Ginkgoinae* considerably diminish in number, in contradistinction to the conifers, which attain high evolutionary power, and there appear and begin to multiply the *Angiospermae*, i. e., the simplest forms of the *Mono-* and *Dicotyledones*. (Cf. phylogenetical chart attached).

Any attempt at studying the known fossil and the living forms of the *Gymnospermae*, or more precisely of the *Coniferae*, from the above-discussed viewpoints is bound to raise the question whether the ternary division into monopodial, dichotomous, and verticillate branching systems, which was seen to be a ruling principle in every one of the past periods, still obtains in the living forms ; one may well inquire whether the phyletic characteristics which persisted in the vegetable kingdom through millions of years in every period of evolution have disappeared in relatively recent times, or whether they are still present, if only in a few types and more deeply hidden from view.

One of the primary objects of this chapter is to disclose these possible phylogenetic correlations hidden within the *Coniferae*, to study and interpret them in the light of xylotomy, and to contribute in this manner some data to the clarification of the divergent views held in regard to the origin of the *Coniferae*.

Great is the number of textbooks and other publications on the origin of the *Coniferae*, yet a conclusive and reassuringly defined theory is still outstanding on this subject. In their efforts to arrive at a better understanding of this question of origin, many, if not most, of the authors investigated into the external and internal morphology of the reproductive organs, while others engaged in the study of the form and structure of the leaves, the processes of germination, or serological relationships, and so forth and so on. The result of course is that there are today those who conclude the *Coniferae* are of monophyletic origin, and those who, in the writer's view correctly, regard them as a polyphyletic group.

In the present work it is attempted to approach the problem by analysing the *Coniferae* on the ground of their wood structure. This, being least exposed to external influences, may be assumed to possess the most conservative properties, and to deliver constructive data conducive to the solution of the question. Since the relationships of origin and affinity of the *Gymnospermae* are of the utmost significance not only downwards with the *Pteridophyta*, but also upwards, i. e. with the *Chlamydospermae (Gnetales)* and the *Angiospermae*, they shall be duly considered in the following disquisitions.

A. THE SYSTEM OF SEED PLANTS

Contemporary taxonomists, as for instance GROSSHEIM and even PULLE, divide the *Spermatophyta* into four classes.

1. *Pteridospermae*
2. *Gymnospermae*
3. *Chlamydospermae (Gnetales)*
4. *Angiospermae*.

Including the *Pteridospermae* in the class of the *Gymnospermae*, other authors divide the latter into the following six subclasses, viz. :—

I. *Pteridospermae (Cycadofilices)*
II. *Cycadinae (Cycadales)*
III. *Bennettitinae (Bennettitales)*
IV. *Cordaitinae (Cordaitales)*
V. *Ginkgoinae (Ginkgoales)*
VI. *Coniferae*.

Of these, *Pteridospermae*, *Bennettitinae*, and *Cordaitinae* are extinct ; *Cycadinae* and *Ginkgoinae* have only a few living forms, while not less than about 550 known living species represent the *Coniferae*. Higher in the evolutionary scale stand the *Chlamydospermae* or *Gnetales* with three families,

SPOROPHYTA

SPERMATOPHYTA

RAMIF

ALGOPHYTA	BRYOPHYTA	PSILOPHYTA	PTERIDOPHYTA	PTERIDOSPERMAE	GYMNOSPERMAE	CHLAMYDOSP.	ANGIOSPERMAE
	Iso-homosporia	Iso- homosporia	Iso- homo- heterosporia	Iso- homospermia	Isospermia(Monoecia) Homospermia (Dioecia)	Homospermia (Dioecia)	Iso-homo- eusspermia
Palaeophyticum				Mesophyticum		Kainophyticum	

MONOPHYTA

Chlorophyceae, Pleurocarpi, Eriopus, Musci, Acrocarpi, Nostro, Lycopodium, Rhynia, Drepanophycus, Psilodendrion, Asteroxylon, Cyclostigma, Protolepidodendron, Hornea

DICHOTOPHYTA

Phaeophyceae, Hepaticae, Psilotum, Tmesipteris, Filicinae, Eusporangiatae, Filicinae, Leptosporangiatae, Parkeriaceae, Hydropteridales, Hepaticites, Cladoxylon, Sigillaria, Zosterophyllum, Aneurophyton, Megaphyton, Coenopteridales, Asterotheca, Foerstia, Taeniocrada, Pseudosporochnus, Protopteridium

VERTICILLATOPHYTA

Characeae, Rhodophyceae, Equisetaceae, Protocalamites, Cheirostrobus, Calamophyton, Hyenia, Pseudobornia, Asterocalamites, Sphenophyllum, Calamites, Equisetites

Selaginella, Lepidodendron, Lepidocarpon, Geinitzia, Pinaceae, Taxodiaceae, Sphenolepidium, Voltzia, Gnetum, Dialipetalae, Degeneria, Monochlamydeae

Isoëtales, Pleuromeia, Physostoma, Neuropteris, Medullosae, Lyginodendron, Callixylon, Odonopteris, Lebachia, Cycadinae, Taxales, Palaeotaxus, Archeopodocarpus, Williamsonia (Bennettites), Podocarpaceae, Araucariaceae, Welwitschia, Ginkgo, Cordaites, Baiera, Cycadeoidea (Bennettites), Cycadales, Palmae, Liliiflorae, Cyperales, Yuccites, Caytoniales

Schizoneura, Phyllotheca, Calamitocarpon, Neocalamites, (Chamaecyparis), Cupressaceae, (Callitris), Ephedraceae, Casuarinaceae

Rajzolta: DÖRFLINGER E. 1955.

of which the *Ephedraceae* and the *Gnetaceae* are represented each by about 35 living species, and *Welwitschiaceae* by a single one. At first, we shall attempt to subject the *Coniferae* to a xylotomical analysis, it being understood that our examinations will be limited to the wood (xylem) of these plants.

According to up-to-date phylogenetic systems, the *Coniferae* do not represent a uniform group. Earlier authors divided, and some authors still divide them into two subgroups : the *Taxaceae* and the *Abietaceae*. Viewed in the light of xylotomy, a division of this kind is unfounded, as will be seen later. In consideration of the external and internal characteristics the *Coniferae* are divided by P i l g e r into seven families, viz.: — 1. *Taxaceae*, 2. *Podocarpaceae*, 3. *Araucariaceae*, 4. *Cephalotaxaceae*, 5. *Pinaceae*, 6. *Taxodiaceae* and 7. *Cupressaceae*. By P u l l e and F l o r i n the *Taxaceae* and *Cephalotaxaceae* are taken collectively and treated as a whole under the name of *Taxales*, which is quite appropriate and in harmony with the xylotomical findings.

B. XYLOTOMICAL CHARACTERISTICS OF THE CONIFERAE

Xylotomically, there are in general two principal features characteristic of the living *Coniferae*, viz.: —

1. Only woody plants belong to this class ; the wood contains no true vessels, only tracheids with bordered pits in diverse arrangements in their walls. Although some authors claim the presence of vessels in the protoxylem, no such elements ever occur in the secondary wood.

2. In the secondary wood of all conifers there are rays greatly varying in structure.

Common as these two features are to all *Coniferae*, they are at the same time as divergent and typical in the individual families as to allow of their reliable separation, moreover, within them of differentiation between genera and even species. To these two principal characteristics distinctive features may add themselves peculiar only to one or the other of the families.

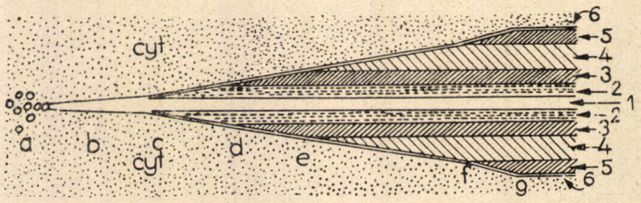
For example : spiral thickenings in addition to bordered pits in the tracheids, but no resin ducts are a structure only characteristic of *Taxales (Taxaceae)*. Alternate pitting in the tracheidal walls with the pits hexagonal due to crowding characterizes the *Araucariaceae* alone. With all the ray-cell walls and the horizontal walls of the longitudinal parenchyma cells thin and smooth but the tracheids with other than alternate pitting, the wood structure points to the *Podocarpaceae*. Slightly pitted or smooth horizontal ray-cell walls and a cupressoid type of pitting in the cross field testify affiliation with the *Cupressaceae*, whereas *Pinaceae* must be inferred from a mainly abietoid or pinoid, and *Taxodiaceae* from a principally taxodioid type of pits.

Since, quite obviously, these xylotomical features are not always sharply distinguishable from one another, and therefore not always sufficient to establish existing affinities, they need to be supplemented with morphological, physiological, and other traits. Undoubtedly, phylogenetical relationship cannot be regarded as reliably established unless and until all possible approaches to the problem yield the same results. In the following it is attempted to describe the individual families on the basis of xylotomy and to inquire into their origin and relationship in the light of our findings.

C. EVOLUTIONARY STAGES IN THE STRUCTURE OF RAYS

Before undertaking to give a xylotomical description of the *Coniferae*, certain fundamental laws of cell development have to be presented. With the spreading of life over the firm land it became gradually impossible for the thin-walled parenchyma cells, suited only for life in water, to take up and to convey to every cell the nutritive substances from the soil, and to perform the important task of affording mechanical support to the body of the plant. Therefore, it became imperative that an entirely new type of cell evolve from the homogeneous, smooth, and thin-walled parenchymalike cell complexes. Among the primitive conducting cells were the axially much elongated smooth-walled or simple-pitted parenchyma cells, the variously thickened tracheids, and the simple thin-walled ray cells with the function of radial transportation. The principal primeval functions of parenchyma cells were uptake, transmission, and, in part, storage of nutrients, while the tracheids that had evolved from them not only conveyed water and food but took the important function of rendering mechanical support.

These two elements existed already in the body of the most ancient land plants, the *Psilophyta*. Some of them contained a specially high number of thin-walled parenchymalike cells ; a phenomenon which is in perfect harmony with the evolution of the cell wall in general (Text Fig. 5), since it is always the very thin primary wall that is first developed, with no substantial pits, merely occasional thinnings in it. It is only at a later ontogenic stage that intensified metabolism provokes thickenings in the walls of the parenchyma cells, which thickenings then give rise to corresponding recesses or pits. Accordingly, the parenchymalike cells with thin smooth walls represent an earlier evolutionary stage than the abundantly pitted thick-walled parenchyma cells. From this it follows that plants with smooth- and thin-walled parenchyma cells must be regarded as definitely simpler types than those with pits of varying sizes and shapes in the walls of parenchyma cells. This statement equally applies, of course, to ray cells which, e. g. in the



Text fig. 5. Successive stages in the formation of cell wall (from *Sharp)*. a = origin of the middle lamella from micellae; b—1 = cell plate transformed into middle lamella; c—2 = deposition of the primary wall on the middle lamella ; desposition upon the primary wall of the inner (d—3), the median (e—4), and the inner (f—5) layer of the secondary wall ; g—6 = outermost plasma membrane in the tertiary layer; cyt = cytoplasm.

wood of the conifers, have passed in structure through several evolutionary stages in their advance to perfection. Thus, for instance, the exceedingly varied ray-cell structure in *Pinus*, known only as from the *Tertiary*, is capable of performing more superior and elaborate functions than that of *Cordaitales*, known as from the *Carboniferous*, or that of *Araucariaceae*, *Podocarpaceae*, and *Cycas* or *Ginkgo*, wich had gained their ground in the *Mesozoic*.

In addition, the same applies to longitudinal parenchyma cells. The solitary smooth-walled longitudinal parenchyma cells represent a simpler type than the pitted ones, particularly where the latter have developed into longitudinal resin ducts. In other words, conifers with resin ducts are phylogenetically more advanced, and therefore of later origin, than those without them. Incidentally, this accords with the findings of palaeontology that resin ducts occur only in the younger forms of conifers, while the wood of the older forms contains but parenchyma cells.

Tracheidal pitting likewise shows evidence of having passed through evolutionary stages. The so-called *araucaroid* pitting goes back to the *Devonian*, while the so-called *modern bordered pitting* did not become widespread until the *Triassic*, which proves the latter type to be younger than the former. The ray tracheids, making their appearance in the *Cretaceous*, are of course a still younger phenomenon. This also goes to prove that conifers with resin ducts and transverse tracheids are juvenile in comparison to those devoid of these elements. This gradual evolutionary advance reveals itself not only on the level of families, but also on that of genera. Comparing within the *Pinaceae* some of the genera with clustered needles, we find that there are thick-walled ray parenchyma cells and no transverse tracheids, for instance, in *Pseudolarix ;* transverse tracheids but as yet no resin ducts in *Cedrus ;* both transverse tracheids and resin ducts in *Larix*. All this obviously justifies the conclusion that *Larix* is the most recent form of those named. Of the single needled forms with long shoots *Keteleeria* and *Abies* commonly have neither transverse tracheids nor resin ducts, but resin cysts at best. In *Tsuga* there already appear transverse tracheids but not yet resin ducts, while in *Picea* and *Pseudotsuga*, the highest forms of the series, there are not only transverse tracheids and resin ducts but rather frequently also spiral thickenings in some of the ray tracheids. This phenomenon seems to be correlated with the spiral thickening in the longitudinal tracheids.

D. THE PHYLOGENETIC HISTORY OF THE RAYS

There are in the author's opinion several evolutionary stages through which rays must have passed in order to evolve the highest forms. These stages are given in the following. (Cf. Fig. 6).

1. Homogeneous rays consisting solely of parenchyma cells

1st stage. The horizontal, tangential, and radial walls of rays are thin and smooth, i. e. *primary*

walls, with only quite exceptional slight local thinnings, but no well-defined pits. This picture corresponds to the lowest step in the evolution of the cell wall (Text Fig. 4), although quite exceptionally the second or third step may appear in it. The pits in the cross fields, i. e. in the longitudinal tracheids at the back of the rays are araucaroid, podocarpoid, cupressoid or, rarely, taxodioid. Rays of this most simple structure characterize the primitive *Cycadaceae*, *Ginkgoaceae*, *Araucariaceae*, *Podocarpaceae*, and the genus *Callitris* of the *Cupressaceae*.

2nd stage. The secondary layer of the horizontal ray walls is thickened. These walls are smooth or provided with simple pits, whereas the tangential walls are always smooth and thin, most rarely with nodular thickenings. This condition corresponds to the second and third steps in the evolution of cell wall. The pits in the cross fields are taxodioid or cupressoid. The first, second and third stages are characteristic of the *Taxodiaceae* and in the *Cupressaceae* of *Thuja* with its nearest relatives. The fourth stage, too, may appear as a rare exception.

3rd stage. The walls of the ray parenchyma cells are unevenly thickened, display thinnings or simple pits, while the tangential walls are invariably thin and smooth ; at the same time, spiral thickenings evolved from the tertiary layer of the secondary walls extend in the longitudinal tracheids. There are no resin ducts either in the rays or in the xylem. The pits in the cross fields are cupressoid or podocarpoid. A ray structure of this kind occurs only in *Taxales*.

4th stage. The secondary layer in all the walls of the ray cells is relatively thick with numerous simple pits in them ; it is but very exceptionally that one or the other of the walls remains smooth and thin. The tangential walls display dentate or beadlike thickenings. The pits in the cross field are piceoid, cupressoid or taxodioid. This stage is characteristic chiefly of *Abies*, *Keteleeria*, *Pseudolarix* in the *Pinaceae*, and of *Juniperus* and its next relatives in the *Cupressaceae*.

2. Conifers with heterogeneous rays devoid of resin ducts

Besides simple-pitted ray parenchyma cells, there occur transverse tracheids.

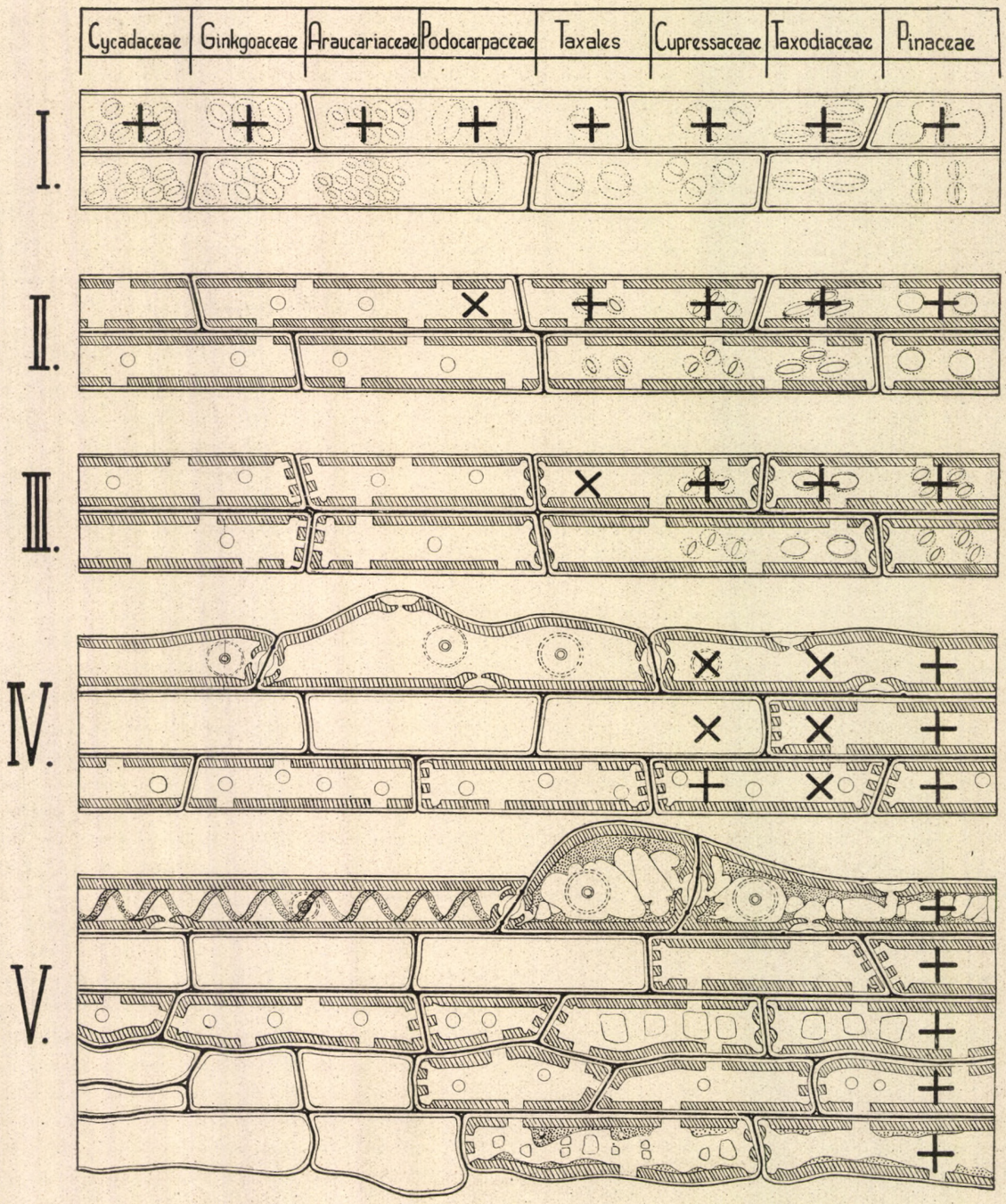
5th stage. All the walls of the parenchyma cells are thick and with simple pits. The inner face of the transverse tracheid walls is smooth. The pits in the cross field are taxodioid or piceoid. This ray structure is predominant in *Cedrus* and *Tsuga*, exceptionally in *Sequoia*, *Metasequoia*, and a few genera of the *Cupressaceae*.

3. Conifers with resin ducts in the rays

6th stage. All the walls of the ray parenchyma cells are thick and pitted. Exceptionally, there also occur thin- and thick-walled parenchyma cells. The walls of the transverse tracheids are seldom smooth : they are mostly either delicately dentate or spirally thickened. The walls of the epithelial cells lining the resin ducts are thick (in some species of *Pinus* thin) and pitted. This stage is characteristic of a part of the *Haploxylon* group of the *Pinus*, then of the *Picea*, *Pseudotsuga*, and *Larix*.

7th stage. The walls of the ray parenchyma cells are thick and pitted. Thin-walled parenchyma cells with pinoid pitting are not infrequent among them. The inner face of the transverse tracheid walls shows patterns from simple minute dentations to closely meshed reticulations. The walls of the epithelial cells lining the resin ducts are thin. Thiss tructure characterizes most species of the *Pinus* (Diploxylon group).

The foregoing xylotomical findings seem to afford support for the view that on the strength of their ray structures the 9 and 7 families of the living gymnosperms and conifers, respectively, can largely be separated into 3 fairly well delimited series, and that these 3 series permit of concluding the existence of phyletic connections with the 3 large tribes of the *Pteridophyta*, viz.: the *Pteropsida*, *Sphenopsida*, and *Lycopsida*. In ultima analysi, it becomes thus probable that the gymnosperms and within them the conifers are not of monphyletic but of polyphyletic origin.



Text fig. 6. Successive stages in the evolution of rays.

I. This *first* stage is the primitive stage in which all ray-cell walls are still smooth and thin, and the primary walls (narrow white stripes) deposit on the middle lamella (fat lines).

II. In the *second* stage the horizontal walls are already thickened, the primary walls (narrow white stripes) deposited on the secondary walls (hatched wider stripes), and simple pits arise with the exception of the tangential walls which are in the primary stage.

III. In the *third* stage all the walls are thickened and pitted, and the tangential walls display dentate or beadlike thickenings.

IV. In the *fourth* stage, besides the thin- and thick-walled parenchyma cells, there appear the smooth-walled transverse tracheids.

V. In the *fifth* stage there appear, in addition, the resin ducts lined with thin- or thick-walled epithelial cells ; the tertiary layer of the secondary walls in the transverse tracheids very often reveals spiral, dentate or reticulate thickenings (dotted areas).

THE GYMNOSPERMOUS DESCENDANTS OF THE PTEROPSIDA TRIBE

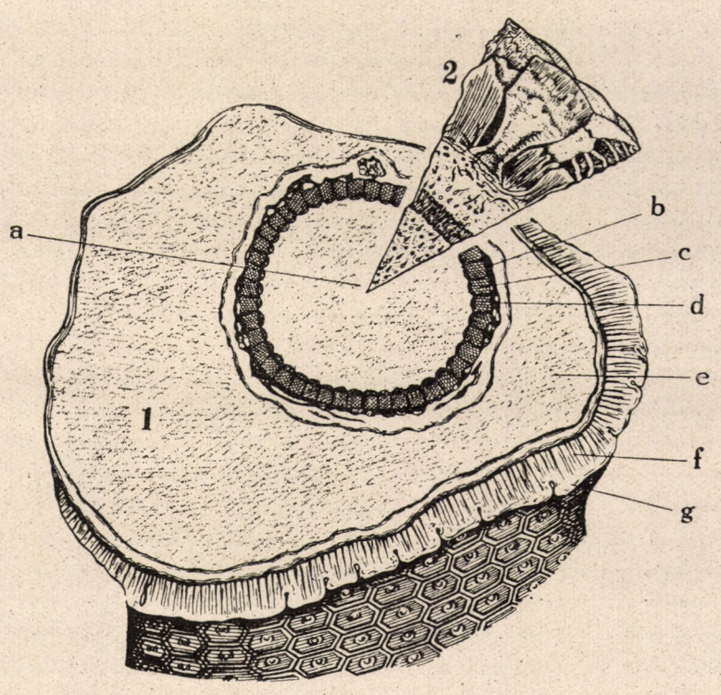
A. THE PHYLOGENETIC HISTORY OF THE CYCADACEAE

Although the *Cycadaceae* do not belong to the "*Coniferae*", they, being gymnosperms, reveal nevertheless so many features that point to the existence of a genetic relationship with the conifers that a treatise on the origin of the latter would be incomplete without their inclusion.

The *Cycadaceae* were characteristic plants of the Mesozoic, and 9 of their genera with 85 species, which combine many properties of ferns and gymnospermous plants, have survived to the present day. Their usually unbranched stem bears at the top a coma of spirally arranged foliage leaves, the individual leaves being pinnate. The young fronds are circinate, i. e., of a definite *Filicinae* character. Their developing polyciliate spermatozoids at the time of pollination is another feature common to ferns.

In the following, we are primarily concerned with the minute structure of the *Cycadaceae* and the phylogenetic correlations that can be inferred from it. The pith in their stem is relatively well developed, and invaded by numerous solitary vascular bundles derived really from leaf-trace bundles. The xylem is surrounded by a comparatively very thick cortex, which, too, is pervaded in all orientations by vascular bundles.

The narrow xylem encircling the pith is intersected by primary rays 3—4, occasionally 6, cell rows in width (Plate 1, Fig. 2), while the rays in the secondary wood are for the major part uni- or biseriate only. The ray-cell walls are quite thin, without a secondary wall and even the slightest pitting. This wood structure is entirely different from that of the *Coniferae* to be discussed later; the structure of certain elements reveals nevertheless many common features, especially with the living *Araucariaceae*. There are no pits developed in the ray-cell walls abutting each other, nor in those in contact with tracheids. The tangential walls are also perfectly smooth, and even high-power magnification reveals nothing but the sites of plasmodesmata. They are pure primary walls on the lowest step of the evolutionary ladder of cell-wall development.



Text fig. 7. 1. *Sigillaria menardi* Brongn. of well-preserved structure: *a*, pith cavity; *b*, protoxylem and centripetal metat xylem; *e*, secondary wood (centrifugal); *d*, phloem; *e*, middle cortex (destroyed); *f*, periderm; *g*, leaf scars. *(From Scott after Brongniart).* About half scale. 2. Stem of *Encephalartos (Cycadaceae)* in cross section showing two girths of bundles, on the outer face the bases of the leaves. *(From I. Schuster,* about 1 (3.) Recent *Cycads* (2) have a stem structure similar to that of the *Sigillariae* of the *Carboniferous* (1).

The wood is composed exclusively of tracheids with comparatively thick walls that are invariably provided with bordered pits, showing that the secondary wall is developed in them. Starting from within, there are spiral tracheids in the protoxylem followed by scalariform tracheids which are bounded by 2—6 rows of tracheids with bordered pits. The bordered pits are crowded, the apertures oriented horizontally. Among recent conifers, this type of pitting in the tracheids can only be observed in *Araucariaceae (Agathis palmerstonii)*, while among *Gnetales* it is *Welwitschia* alone in which the tracheary pitting is perfectly identical with that in the cycads. Since there appears an almost identical structure in the presumable ancestors of the living cycads, viz.: the *Cordaites* and *Cycadofilices*, it can be claimed that from

this point of view the *Cycadofilices*, *Cordaites*, *Araucariaceae*, *Cycadaceae*, and *Welwitschia* form a closed and complete group.

Beside this type of bordered pitting there occur, however, typical scalariform tracheids which, though absent in living conifers, are a frequent occurrence in *Pteridospermae*, *Cordaites*, *Lebachia*, as also in *Monocotyledones*, e. g., in palms. From the point of wood anatomy, it is therefore the *Araucariaceae* alone from amongst the living *Gymnospermae* with which the *Cycadaceae* can be said to be genetically related : downwards with diverse forms of the *Pteridospermae* and the *Cordaites*, upwards with *Williamsonia* and *Welwitschia*. In this connection it should be noted from the onset that the said phyletic affinity of the cycads does not extend to all *Pteropsida*, not even to all *Pteridospermae*. In the writer's view, in this respect only *Sigillaria* and *Pleuromeia* come into consideration. The xylotomical features seem to favour the conclusion that there exist phyletic correlations between the genus *Pleuromeia* with unbranched stems, the genus *Sigillaria* likewise with unbranched or at best moderately dichotomized stems, the *Cycadaceae* with stems unbranched but covered with leaf traces, (Cf. fig. 7) and, strange as it is, the monocotyledonous *Palmae* and *Dracaena*. Serological findings appear to confirm the existence of such phylogenetic relationships.

The foliage leaves of these types display a parallel venation. While, as is general in the narrow leaves of microphyllous plants, only a single principal vein developed in the leaves of the monopodial (pseudodichotomic!) *Lepidodendron*, two equivalent parallel veins extended in the leaves of *Sigillaria ;* a phenomenon which can probably be traced back to the dichotomic system of branching.

Thus, from a purely xylotomical point of view, the living *Cycadaceae* appear to be phylogenetically correlated on the one hand with the living *Araucariaceae*, on the other with *Cycadospadix*, *Microzamia*, *Pterophyllum*, *Cordaitales* and the *Pteridospermae*, but also resemble *Welw tschia* and, strange as it may sound, in some degree the *Monocotyledones*. This class may therefore be regarded as an independent evolutionary line, a living relict of the *Pteropsida*.

Xylotomically, there also exists great similarity between the *Cycadaceae* and the extinct *Bennettitinae*, although the latter developed along a quite different line and can be said to have reached a dead end. *Welwitschia*, with which they are xylotomically almost identical, is presumably one of their descendants.

It is remarkable that although both *Cycadaceae* and *Ginkgo* are polyciliate plants, the xylotomic analogy between them is much less marked. Accordingly, as regards their origin the *Ginkgo* can be brought into phyletic connection much rather with *Podocarpaceae* than with the *Cycadaceae*.

B. THE PHYLOGENETIC HYSTORY OF THE GINKGOACEAE

Only one species of this family has survived in its original habitat, a very small territory in East Asia. Remains of the leaves of the *Ginkgoaceae* are known from as early as the *Rothliegendes*, and the family was distributed all over the earth in the *Mesozoic*. So far, no reliable stem remains have been discovered. Apart from some slight differences the xylotomy of the *Ginkgoaceae* is very similar to that of the *Podocarpaceae*. A xylotomical feature common to both is that the growth rings are rather indistinct, although perhaps somewhat less so in *Ginkgo*. Very rarely there occur parenchyma cells amongst the tracheids, with solitary calcium oxalate druses in them. In the radial walls of the longitudinal tracheids there are bordered pits in pairs commonly uni- or biseriate and with crassulae between them. In the tangential walls of the longitudinal tracheids the bordered pits are somewhat smaller, not crowded, usually scattered, or aligned in longitudinal rows. The most characteristic feature of the wood of the *Ginkgo* is that the rays are homogeneous, consisting of parenchyma cells with thin and smooth walls devoid of pitting. The ray structure of *Ginkgoaceae* is thus almost identical with that of *Podocarpaceae*. The rays are 5—8 (12) cells high and barrel-shaped in cross section. In the cross field there are 1—2, exceptionally 4, or even 8 simple pits ; in the latter case they are angular from crowding (araucaroid). The apertures of the bordered pits are slitlike, obliquely inclined, but not extended. The bordered pits of the tracheids, particularly in the latewood, are of the same structure, having oblique apertures just like those in the *Podocarpaceae*. In spite of the pitting in the cross field, especially in the early wood, resembling that in *Araucariaceae* and *Podocarpaceae*, the wood structure as a whole is more like that of the *Podocarpaceae*. The wood structure of the *Ginkgoaceae* points therefore to a closer relationship with *Podocarpaceae* than with *Araucariaceae*. On the other hand, no phylogenetic relationship with other conifers

can be assumed to exist, if only because of their very simple ray structure.

It should further be borne in mind that occasionally there appear fairly distinct, nonetheless extremely delicate spiral threads or bars in the wood of *Ginkgo*, the structure of which (drawing in Plate 2) is exactly like that of the spiral thickenings in the genus *Cycas*.

Ginkgoaceae can be traced back to the *Carboniferous*, this being the earliest formation from which great quantities and abundance of diverse forms of leaf and seed remains and short-shoot rests have been unearthed. Their wood structure seems to refer their origin to the tribe from which also *Araucariaceae* and especially *Podocarpaceae* arose. The generative nuclei of *Ginkgo* are known to be polyciliate. Given the typically dichotomic venation of their leaves. and knowing polyciliation and dichotomy to be frequent characteristics of the *Pteropsida*, it is justified to regard the *Ginkgoaceae* as members of the *Pteropsida*. The further evolution of this type is unknown, and it is even doubtful whether there was a further evolution. However, there is no doubt about the external habit as well as the tissue anatomy of the *Ginkgoaceae* being fernlike, wherefore they can be assumed to represent the relics of ferns. (There are minute bordered pits in the tangential walls of the tracheids.) It should still be mentioned that *Ginkgo biloba*, exactly like the *Cycadaceae*, *Podocarpaceae*, *Taxaceae* and *Araucariaceae*, is a dioecious tree, and that it exists in East Asia in an area where the majority of monotypical conifers and relics, respectively, are found. As regards the more remote phyletic correlations of *Ginkgo biloba* of the extinct forms it is only the *Baiera* from the *Permian* and the *Cordaitales* which could come into consideration, although the bordered pitting in the tracheidal walls of *Ginkgo* is never hexagonal from crowding, but generally shows the modern pattern as seen in the *Podocarpaceae*. Both on this basis and that of the ray structure, the nearest relatives of the *Ginkgoaceae* should be sought for amongst the living *Podocarpaceae* or their ancestors.

C. THE PHYLOGENETIC HISTORY OF THE ARAUCARIACEAE

By reason of their most primitive ray structure the *Araucariaceae* represent an ancestral type among the living conifers. The family includes the genera *Araucaria* and *Agathis*. The species of both reveal so characteristic primitive xylotomical features that it is easy to distinguish them from the rest of the conifers (cf. Descriptions of woods by species pp. 000).

No other living family of conifers presents like anatomical features. It may occur in one or the other species of *Podocarpus* that the bordered pits in the radial walls of the tracheids yield straight horizontal surfaces of contact, such an occurrence is however very rare. Undoubtedly, as regards ray structure *Araucariaceae* resemble most of all the *Podocarpaceae* and *Ginkgo* as these, too, have perfectly thin and smooth ray cells devoid of pitting. Xylotomically, they have not even these characteristics in common with the other *Coniferae*.

As to the phylogenetic relationships of the *Araucariaceae*, the problem can be approached in either of two ways. Taking the cones to be simple flowers (regarded by some botanists as inflorescence) L o t s y refers the *Araucariaceae* to the "Florales" series of the conifers, and on this basis distinguishes them from the *Pinaceae* and *Taxodiaceae*. He denies any phyletic correlations to exist between these two families on the one side, and *Araucariaceae* on the other. The dissimilarity is still more pronounced by the alternate-type pitting, occasionally in 3—4 rows, in the radial walls of the tracheids in the *Araucariaceae*, for this type is hardly ever seen in the opposite group. This sharp morphological separation does not accord with M i e s c h k e's serological findings from which he assumes the existence of an affinity between *Araucariaceae* and *Abietinae*. Such a relationship is almost a xylotomical impossibility; as a matter of fact, some research workers have disproved M i e s c h k e's conception.

It is indisputable that the bordered pits in the tracheids of the *Araucaria* of today are hexagonal from crowding, and that this feature, as has already been mentioned, fully agrees with the type of pitting in the *Cordaites*, the *Cycadaceae*, and even the *Welwitschia*, so that it is justified on this basis to assume the existence of a phylogenetical relationship between the said genera. In addition to the araucaroid type of pitting the leaves of the *Cordaites*, *Araucaria*, *Cycas*, and also *Welwitschia* show a parallel venation, a striking characteristic of the recent *Monocotyledones*. As regards parallel venation, it is well to keep in mind the *Sigillaria*, in which there are two parallel veins, in distinction from the *Lepidodendrons* with but a single principal vein. This feature too favours the inclusion

of the *Lepidodendrons* in the microphyllous group, while *Sigillaria* should be rather referred to the group of macrophyllous plants. Leaf venation also permits to assume phyletic connections between the *Araucariaceae* and the *Podocarpaceae*, for whenever broad leaves are developed by the species of these families, the veins in them are parallel.

Some phylogenetic significance attaches perhaps to the fact that *Podocarpaceae*, quite like *Araucariaceae*, are dioecious in contrast, e. g., with the exclusively monoecious *Abietaceae* and *Taxodiaceae*. On the other hand, *Podocarpaceae* and *Araucariaceae* slightly differ in floral construction. In the former, the ovules are solitary and anatropous, while in the latter the individual carpels aggregate into conelike processes, although they, too, give rise to a single ovule only. These characteristics common to both families favour the conclusion that they are descendants of a common ancestor. The fact that wherever there are broad leaves they reveal parallel venation in both families, points to a definite macrophyllous feature, and indicates *Pteropsida*. Moreover, *Araucaria* have the tendency to develop blepharoblasts, i. e. polyciliate sperm nucle.

Wihile the *Podocarpaceae* alone can be regarded as the probable living relatives of the *Araucariaceae*, among the extinct forms there are several that are more likely to be related types. The most ancient relatives of the present *Araucariaceae* were doubtlessly the *Dadoxyla*, or *Cordaites*, the wood structure of which fully corresponded to the xylotomy of the *Araucariaceae* of today. The bordered pits in the radial walls of the tracheids in *Dadoxyla (Cordaites)* were arranged in 3—4 rows, with the pits hexagonal from crowding. The cell walls of the homogeneous rays were smooth and thin. In the *Araucariaceae* the number of pits per cross field is 8—10—16—20, the same as it was in the extinct *Cordaites*.

In addition to wood structure it is also in external appearance that the extinct *Cordaites* and the living *Araucaria* have much in common. Both develop broad, lanceolate leaves with parallel veins, etc. Phylogenetic correlation between the extinct *Dadoxyla (Cordaites)* and the living *Araucaria* is today generally accepted.

After the *Cordaites* have become extinct in the *Lower Permian* there appeared, likewise in the *Permian* as also in the *Triassic*, the so-called ancestral conifers, of which it was the genus *Lebachia* that showed the greatest resemblance to the recent *Araucariaceae*. We are indebted to Florin for the morphology of the *Lebachia*, and especially for the description of their floral structure. He demonstrated that the female flowers of *Lebachia* arose, one each, from the axils of bracts. These bracts are dichtomously branched at the tip ; an ancestral feature worthy of note. These bracts as well as the dichotomous leaves on the long shoots correspond, in the writer's view, to that primitive dichotomous system of braching which is seen to occur in members of the *Pteropsida* tribe. This makes it seem quite possible that the closest extinct relatives of the present *Araucaria* were the genera *Lebachia* and *Ernestiodendron*, respectively. The genus *Carpentiera*, too, belongs to this type, because the leaf tips in its species are likewise dichtomous, i. e., the tribal affinity manifests itself at the tip of the leaves.

Structure and arrangement of the stomata in the leaves represent another means by which to establish relationship. In the leaves of *Lebachia* the stomata are arranged in longitudinal rows in the same way as in *Araucaria*, *Welwitschia*, and in *Monocotyledones* in general. In this connection it needs to be mentioned that a similar stomatic arrangement occurs also in remote types, e. g., in *Lepidodendron*, in firs, etc. In conclusion, it can be claimed that the next relatives of *Araucaria* are *Podocarpaceae* among the present conifers, and *Dadoxyla (Cordaites)*, later *Burriadia*, *Gomphostrobus*, *Lecrosia* and *Carpentiera* among the extinct forms.

The existence of an affinity with *Podocarpaceae* is moreover confirmed by the fact that *Araucariaceae* are only found in regions where *Podocarpaceae*, too, are native plants, i. e., chiefly in Australia and the South Sea islands. *Araucaria* are distributed only at the southernmost point of South Asia, in Malacca on the Malay Peninsula, in the East Indies, in New Caledonia, over the northeastern part of Australia, and in the north of New Zealand ; there also exists one species in Brasil and Chile. On the other hand, they almost never coexist with recent *Pinaceae* and *Taxodiaceae*, and it is only on the Malay Peninsula that *Araucariaceae* are associated with *Pinus merkussii*, the sole native species of *Pinus* in these parts.

Ultimately, there is reason to suggest that although *Podocarpaceae* and *Araucariaceae* appear to have developed into independent lines, both must be regarded as the living descendants of the *Pteropsida*.

D. THE PHYLOGENETIC HISTORY OF THE PODOCARPACEAE

It is characteristic of all the genera of this family, too, that all the walls of the ray cells are smooth and thin. Only the horizontal walls are very rarely and very slightly thickened displaying pitlike recesses, by no means as distinct as, for example, in the *Pinaceae* and *Cupressaceae*. In this respect, the family under review differs decidedly from *Pinaceae*, *Cupressaceae*, *Taxodiaceae*, *Cephalotaxaceae* and *Taxaceae*, and from among the recent forms can be brought into xylotomical connection with *Araucariaceae*, *Ginkgoaceae* and *Cycadaceae*. But even from these the *Podocarpaceae* differ in that in most of the genera in this family there is, as a rule, a single pit in the cross fields (exceptionally there are 2—3 pits like in *Podocarpus minor* and *Microcachrys)*, whereas in *Ginkgo* there are 4—6, in *Araucaria* and *Agathis* 4—8 (16), and in *Cycas*, if any at all, as much as 18—22 pits per cross field. Neither the so-called podocarpoid pitting, so highly characteristic of the cross field in *Podocarpaceae*, nor the circular dacrydioid pitting with the pertinent smooth and thin walls appear in this manner in any other family.

Although the pitting in the *Pinus* species is predominantly the so-called "pinoid" pitting, the *Pinus* species cannot be confounded with the members of the *Podocarpaceae*, as there are always transverse tracheids, i. e., a heterogeneous ray structure, in *Pinus*, whereas *Podocarpus* are devoid of tracheids and always reveal a homogeneous ray structure. As will be discussed in the description of the *Pinaceae*, the appearance of transverse tracheids points to a quite recent evolutionary stage, while the ray structure of *Podocarpaceae* has not yet reached this peak in the evolutionary course. It being obvious that there is no essential agreement between the wood anatomy and especially the ray structure of the *Podocarpaceae* on the one hand, and of the *Pinaceae*, *Cupressaceae*, *Taxodiaceae*, *Taxaceae*, and *Cephalotaxaceae* on the other, the next relatives of the former should not to be looked for among these families, but are more likely to be found among the types resembling the *Araucariaceae*. However, also in this respect we must not go further than the statement that *Araucariaceae* too have ray cells in which all the walls are smooth and thin, i. e., are still in a primary stage of evolution. This sole feature common to both families is nevertheless important enough to serve as a landmark in our search for relationship. Close xylotomical examinations have, however, led to the conclusion that the *Podocarpaceae* do not constitute a uniform type. If we attempted to classify the genera of this family on the strength of their ray structure, we could distinguish 3 well-defined types. *Dacrydium* represents a well-distinguishable type, for while the ray-cell walls are very thin and smooth, there frequently are in the cross field not only typical podocarpoid pits but also a circular one, which frequently fills the entire field, i. e., is the *circopore* of K r ä u s e l. Only if the tracheids in the earlywood are markedly wide, is there a slight divergence from this pattern, as seen for example in *Dacrydium franklinii*, where the circular pits elongate into a slightly oblique ellipse. A similar structure can be seen in several *Phyllocladus* and *Podocarpus* as also in *Acmopyle (Sciadopitys)* and *Microcachrys*, so that a quite close relationship can be inferred from the wood anatomy of these genera.

Several types are, however, distinguishable within the genus *Podocarpus* itself, and B u c h h o l z divides the *Podocarpus* on the basis of their external morphology into 8 sections. Structurally identical rays not invariably correspond to this grouping. On the whole, there is a correspondence nevertheless, although there appear deviations in certain cases.

1. *Stachycarpus* section : the species included in it *(Podocarpus mannii*, *P. usambarensis*, *P. falcatus*, *P. gracilior*, *P. ferruginoides*, *P. ferrugineus*, *P. spicatus)* are characterized by a podocarpoid pitting, that is, the pits visible in the cross field are elliptic or circular in outline and relatively large (although they also may be small as, for example, in *Podocarpus ferrugineus)*, with rather narrow apertures almost vertical in position. It needs to be mentioned here that the pit aperture of *P. spicatus* is rather wide and in certain respects approaches the *Nageia* type, yet it can have no decisive bearing on the section as a whole.

2. *Dacrycarpus* section : the ray structure of *P. dacrydioides* and *P. javanicus* belonging to this section agrees in essence with that in the species belonging to the first section.

3. *Nageia* section : its members *(P. wallichianus*, *P. blumei*, *P. minor)* differ most markedly from those of all other sections in that they mostly develop a circoporoid type of pitting that makes them rather similar to the *Dacrydia*. But for the height of rays, there is hardly any difference

between their wood anatomy and that of the *Dacrydia :* in the latter the rays are as a rule 10, and maximally 20, cells high, while in *P. wallichianus* and *P. minor* they sometimes attain 30—50, in *P. blumei*, on the other hand, only 10—12 cells in height.

For the lack of material it was not possible to work up *Podocarpus ustus*, the only species of *Microcarpus*.

4. *Eupodocarpus* section : it is hardly possible to establish characteristic anatomical features that could be applied to every member of this section. In some species, circular pits occupy almost the entire area of the cross field *(P. elatus)*. In others, the pits are fairly large with oblique apertures, yet in others they are relatively small. Not infrequently there are 2—3 cross fields side by side or superposed without any pits in them at all.

In addition to these xylotomical characters, there are external morphological features typical of the *Podocarpaceae*. As indicated by the name of the family, the members develop no cones, and their ovules are either orthotropous or anatropous. The number of ovules may be one or more. They have no short shoots (except *Phyllocladus)*. The members of the *Nageia* section have broad foliage leaves with parallel venation not visible on the surface of the blade. In leaves of this kind the stomata are commonly aligned in longitudinal rows. All the *Podocarpaceae* are dioecious, with the exception of one or two *Phyllocladus* and a single *Dacrydium* species *(D. colensoi)*, which may occasionally be monoecious.

As regards the sexual arrangement, *Pherosphaera* and *Saxegothaea* alone are monoecious ; for this reason and for some other of their characters they do not fit into the family. Indeed, *Phaerosphaera* would be the only member to develop no epimacium and to give rise from the pollen grain to no prothallium, only to the two vegetative nuclei of the pollen tube.

If there exists no close relationship between *Podocarpaceae* on the one side, and *Taxaceae*, *Cephalotaxaceae*, *Pinaceae*, *Cupressaceae* on the other, and if the connection of the family with *Araucariaceae* is but a loose one, we are bound to ask : from what ancestors did *Podocarpaceae* descend after all? Evidently from ancestors that possessed the anatomical features which characterize the family, or at least the foundation of their subsequent development. In trying to solve our problem, we must not concentrate our attention on the anatomy of the wood to the exclusion of important external morphological features : we must bear in mind that although the leaves of *Podocarpaceae* are in fact of a macrophyllous structure, they nevertheless appear perfectly microphyllous in some cases, and that where they are broad and flattened, they invariably reveal a parallel, and never a reticular, nervation. Nor must the fact be disregarded that all members of the *Podocarpaceae* are dioecious.

In looking for ancestors of this description, the extinct types similar to the *Cordaites* should first of all be closely examined. Although these types had thin-walled ray cells, and leaves with parallel nervation, just like the *Podocarpaceae* and *Araucariaceae*, they differed from these families in the pitting of the tracheids. While pitting in the *Cordaites* was always typically araucaroid, it is mostly modern in the *Podocarpaceae* and only very exceptionally, and then very scarcely, araucaroid. Notwithstanding this difference the ancestors of the living *Podocarpaceae* are still to be sought amongst the *Cordaites*, or rather *Podocarpoxylon*, chiefly amongst *Circoporoxylon* and *Mesembrioxylon*, doubtful forms of which are known from as early as the *Triassic*. But even at that early stage, evolution seems to have followed two distinct lines.

There is no wood parenchyma in *Phyllocladus* so that, for instance, *Circoporoxylon chanense* may be regarded as the type from which the genus *Phyllocladus* arose, while *Circoporoxylon hortii*, *C. sewardi*, *C. goepperti*, *C. glyptostrobinum*, *C. woburnense*, *C. priscum*, and *C. megeei*, all having had wood parenchyma, are more suggestive of the *Podocarpus* type.

Evidence thus supports the assumption that the living *Podocarpaceae* are the descendants of a dioecious type with parallel nervation in which all the walls of the rays and the wood parenchyma were thin and smooth. The evolutionary centre of this type is thought to have been the area including the East Indies, New Zealand, Tasmania, New Caledonia, and the vanished continent that connected South Africa and South America.

Saxegothaea, classed with the *Podocarpaceae* and known to be monoecious, differs greatly in structure from the aforesaid genera. The horizontal walls of the ray cells in this genus are markedly pitted, the tangential walls usually smooth, exceptionally pitted. These features are rather of a cupressoid or taxodioid character. Neither do *Pherosphaera*, which will be discussed later, fit into this family.

Summing up, it is suggested that on the evidence of the morphological and xylotomical characteristics the *Podocarpaceae* appear to be phylogenetically related in the first place to *Araucariaceae* among recent conifers. Support is afforded for this suggestion chiefly by their primitive, thin-walled, homogeneous ray structure, their longitudinal parenchyma, the thinness and smoothness of their cell walls, their dioeciousness, and often also by their leaves with similarly parallel venation. On the other hand, the two families differ in the pitting of the longitudinal tracheids, which is nearly always opposite in *Podocarpaceae*, very rarely araucaroid, and if so, then restricted to scattered spots.

In view of the important common features mentioned, this difference is by no means an absolute segregating factor, the less so as it is precisely in the *Araucaria (A. bidwillii)* that side by side with the araucaroid type the so-called modern type of pitting is sometimes encountered *("Mischtypus")*, while some *Podocarpus* occasionally display araucaroid pitting. A further difference manifests itself in the pitting of the cross fields which is typically podocarpoid or circoporoid *("eiporig")* in the *Podocarpaceae*, and mostly araucaroid, quite exceptionally circoporoid, in the *Araucariaceae (Agathis)*. On the evidence of the ray structure it may be assumed that although descendants of the same tribe, *Podocarpaceae* and *Araucariaceae* have developed along different evolutional lines.

If we now attempt to find the extinct ancestors of the *Podocarpaceae* on the basis of xylotomical evidence, we have to assume that *Callixylon* was the earlier, while *Phyllocladoxyla* and *Podocarpoxyla* were the later of these ancestors. The *Phyllocladoxylon* type seems to have developed into *Phyllocladus* and *Microcachrys*, and the *Podocarpoxylon* type into *Dacrydium* and *Podocarpus*. Also *Acmopyle* and *Austrotaxus* can be assumed to have evolved from the same beginning along a separate line since on the strength of their anatomical structure both of them would perfectly fit the family. Ray walls in the wood of these two genera are likewise smooth and thin, and in the earlywood there is usually one dacrydioid, i. e. rather circoporoid, pit in the cross field, and 1 or 2 of them in the marginal cells. The horizontal walls of their wood parenchyma cells are also smooth and thin. *Acmopyle* fits the family not only because of its internal structure, but also in view of its external character; it is a dioecious tree like the rest of the *Podocarpaceae*. Its leaves are macrophyllous, broad, and have parallel venation; the seeds are fleshy, the ovule is almost erect, with the micropyle seated at the tip: hence the name of the plant.

The genera discussed so far have this in common within the family of the *Podocarpaceae* that their ray-cell walls as well as the horizontal walls of their longitudinal parenchyma cells are smooth and thin. This is, by the way, one of the most prominent characteristics of the *Podocarpaceae*, besides the feature that they produce no cones but solitary seeds.

Pherosphaera and *Saxegothaea*, which were described above as exceptions, show feature that differ essentially from these general characteristics. *Pherosphaera hookeriana* grows in the cataracted regions of the Tasmanian rocky mountains, while *Ph. fitzgeraldii* is a native plant of the Blue Mountains in Australia, and the sole species of *Saxegothaea* lives in the high mountains of Chile between the 35th and 40th degree of southern latitude. In distinction from the other genera of the *Podocarpaceae*, these two reveal the common anatomical feature of having simple pits in the horizontal walls of the rays. Pits are scarce and sparse in *Pherosphaera*, but abundant in the thick horizontal walls in *Saxegothaea*, where they appear as uneven coarse protuberances. The tangential walls of the rays are smooth in the main, but may be nodularly thickened in 1—3 (4—5) spots, particularly in *Pherosphaera*. All these are characters that point by no means to a podocarpoid, but much more to a cupressoid or taxodioid constitution.

There is also a difference between the female flowers of *Pherosphaera* and the *Podocarpaceae*: while those of the latter possess an epimacium, those of the former are devoid of it. In distinction to the other *Podocarpaceae*, *Pherosphaera* produces a very primitive type of cone in which the carpels have fleshy margins with the ovules embedded in them. This structure may be regarded as the sim- plest form of a cone of the *Taxodiaceae* type.

Saxegothaea, too, differs from the other *Podocarpaceae* partly because of the very small cones it bears, and partly because it is monoecious in contrast with the rest of the family which is dioecious. Though not essential, it merits mentioning that *Saxegothaea* abounds in wood parenchyma cells, which cannot be said of other *Podocarpaceae*. All this tends to show that on the evidence of its

xylotomical, and in part of its external morphological features the *Saxegothaea* ought not to be classed with the *Podocarpaceae* but, strange as it is, rather with the *Taxodiaceae*. Nor would it be justifiable to include it in the *Cupressaceae*, since the leaves in all genera and species of this family are verticillate and/or arranged in opposition, while in *Saxegothaea* their arrangement is more of the *Taxodium* type.

The geographical distribution of this tree is somewhat difficult to explain. The members of the *Taxodiaceae* occur, namely, in the western and eastern parts of North America, in the eastern part of Asia, and in Tasmania *(Athrotaxis)*. The difficulty disappears only if a circle is drawn round this whole area, as it includes the southern parts of South America as well, and could therefore represent that vanished continent over which these sporadic types were distributed in times long past and have survived as relicts up to our days.

In conclusion, the xylotomy of the *Podocarpaceae* makes it obvious that their ancestors are most likely to be found among the *Cordaites*.

E. THE PHYLOGENETIC HISTORY OF THE TAXALES

FLORIN, in support of PULLE, — in his work "*On the Morphology and Relationships of the Taxaceae*" — wishes to combine the *Taxaceae* and *Cephalotaxaceae* on the evidence of their quite peculiar characters in a special class, the *Taxales*. He writes : "I propose to exclude the taxads from the Coniferae and to include them into a separate class of the Gymnosperms. Provisionally this class might be called Taxales (or Taxinae) until the type of ending for group names of this rank has been fixed". FLORIN came to this result mainly in consideration of the floral structure. His conclusions are fully confirmed by the results of our xylotomical examinations, since the *Taxales* reveal such specific xylotomical features which make them differ from all other families. This means, at the same time, that the tribal characters of the *Taxales* are so profound that they cannot have sprung but from the most primitive types.

Under the denomination of *Taxales* come the *Taxaceae* and *Cephalotaxaceae*, because both their external morphology and xylotomy agree to such an extent that it is often rather difficult to distinguish the one from the other. They possess features nevertheless which render their separation possible. The *Taxaceae* include *Taxus*, *Nothotaxus*, and *Torreya ;* the *Cephalotaxaceae* embrace *Cephalotaxus* and *Amentotaxus*. Some taxonomists add *Austrotaxus* to the *Taxaceae*, but as there are no spiral thickenings in its wood and as its structure is more in harmony with that found in the *Podocarpaceae*, this tree should be regarded as a member of the *Podocarpaceae*. Taking wood anatomy alone as a basis for classification it would be more correct to regard only *Taxus* and *Nothotaxus* as belonging to the *Taxaceae*, as their wood hardly ever contains parenchyma, and to include *Amentotaxus*, *Cephalotaxus*, and *Torreya* in the *Cephalotaxaceae*, since there are parenchyma cells in their wood.

The most characteristic xylotomical feature of *Taxales* is the invariable presence in the longitudinal tracheids of spiral thickenings evolved from the tertiary layer and seen side by side with bordered pits. Although in this respect *Taxales* agree with some species in *Picea* and *Pseudotsuga*, it is xylotomically impossible to confound these forms, as there are neither regular resin ducts nor transverse tracheids in the *Taxales*. In the tracheids of the family under review spiral thickenings are either solitary, or they extend very closely spaced, or run in well-discernible pairs or fours *(Amentotaxus, Cephalotaxus, Torreya)*.

Another xylotomical feature of diagnostic value in *Taxales* is an occasional uneven thickening of the horizontal ray-cell walls with pitlike depressions visible in the latter *(Taxus) ;* in some cases these walls are more or less evenly thickened, but then there are simple pits in them *(Cephalotaxus, Torreya, Amentotaxus)*. Yet another aid in distinguishing *Taxales* is that the tangential ray-cell walls are always smooth and that indentures are fairly frequent. There are 3—4—6 relatively small cupressoid or podocarpoid pits in the cross field. In *Torreya* these pits are remarkably minute. The pit apertures are slitlike, oblique or vertical in position, never horizontal.

Wood parenchyma cells occur, but are missing in most *Taxus* and *Nothotaxus*. According to BLISS, parenchyma may be present in the stem of *Taxus baccata* and *T. brevifolia*, and in the roots of *T. cuspidata*. There are beadlike thickenings in the horizontal walls of the longitudinal parenchyma cells in *Cephalotaxus*, *Torreya*, and *Amentotaxus*.

Having become acquainted in broad outlines with the essential histological features of the *Taxales*, the question of the phyletic correlations of

this class with living or extinct types arises. Spiral thickenings do occur in the tracheids of the *Pinaceae (Picea, Pseudotsuga)*, but never in pairs or fours, and since in the *Taxaceae* there are neither resin ducts nor transverse tracheids, and as their floral structure differs essentially from that of the *Pinaceae*, it would be wrong to postulate phylogenetic relationship between the two families. This applies to the *Taxodiaceae* as well. On the other hand, rather closely spaced spiral thickenings occur in the wood of the *Cycadaceae*, chiefly in that of the roots, which at the same time is devoid of transverse tracheids and resin ducts ; since in addition all the genera in this family are dioecious, there are so many common features between it and the *Taxaceae* as to render phyletic connections much more likely.

In contrast, all *Taxodiaceae* and *Pinaceae* are monoecious. Nor can phylogenetic relationship with the *Cupressaceae* be assumed, since no member of that family has spiral thickenings and all its members have verticillate leaves, whereas the leaves in *Cephalotaxaceae* and *Taxaceae* are spirally arranged ; an important difference indeed. A further difference consists in that the flowers of *Taxaceae* and *Cephalotaxaceae* bear always one seed only, while the carpels in the flowers of the *Cupressaceae* are invariably multiple and verticillate, and always bear several seeds. The closest relatives of the *Taxales* ought therefore to be found amongst types which are dioecious and monospermous. The *Podocarpaceae* would seem to correspond to these requirements in the first place, a family which *Taxales* match in many external features, but from which they differ in wood structure. In the tracheids of the *Taxales* there are spiral thickenings, in those of the *Podocarpaceae* there are none.

On the other hand, some affinity seems to exist in the structure of the cross fields. The pits in the cross fields of the *Taxales* are in the main of a cupressoid type, the same as sometimes occur in the *Podocarpaceae*, but along with these the same circoporoid pits are encountered in certain *Taxus* species *(T. canadensis)*, which can be seen in *Dacrydium* and certain *Podocarpus*. This kind of pitting does not appear in any other family. Accordingly, cross-field structure, an exceedingly important point, seems to justify the assumption of a certain degree of affinity between the two families. Their ray structures are nevertheless somewhat different. All the ray-cell walls are thin and smooth in all the members of *Podocarpaceae*, and it is a rare exception that the horizontal walls are slightly pitted *(Podocarpus totara)*. In the *Taxales*, on the other hand, it is only the tangential wall which is thin and smooth, while the horizontal wall is smooth only in exceptional cases, is usually unevenly thickened, or provided with simple pits. Compared with the perfectly smooth walls of the *Podocarpaceae*, the ray structure as found in *Taxales* represents a higher stage of evolution, as is the case with several types of the *Cupressaceae* as well (*Callitris* are smooth-walled ; the tangential walls of *Chamaecyparis* are thin ; all three walls of *Juniperus* are pitted). In other words, on xylotomical evidence the *Podocarpaceae* represent a more ancestral, more primitive form of evolution, while the *Taxales* are a younger type, higher up on the evolutionary scale. In the writer's opinion thick and pitted walls must have evolved from smooth and thin ones, and tracheidal walls with spiral thickenings and bordered pitting cannot have arisen but from the thickened secondary wall. This process can never be reversed, as is proven by the most primitive, always smooth- and thin-walled, homogeneous ray cells. Accordingly, if nothing but structure and xylotomical features of rays are taken into consideration, the assumption that the *Taxaceae* are the descendants of some *Podocarpaceae*-like ancestors, seems to be acceptable.

Nor must external morphological properties be disregarded. Both families agree in all their members being dioecious, representing thus, in the writer's view, a primitive ancestral type. The trees in both families bear detached seeds instead of cones, which, too, is a significant genetical feature. Notwithstanding the fact that ovules are invariably orthotropous in *Taxaceae* and only sometimes so in *Podocarpaceae* (*Acmopyle*, *Phyllocladus*, *Dacrydium*), and that it is *Podocarpus* alone in which anatropous ovules are the rule, the female flowers of *Acmopyle*, for instance, are so very similar to those of the *Taxaceae* that it is rather difficult to make a distinction between them. There is thus a complete agreement between the two families in respect of this important phyletic feature.

A further analogy between the two families is the modern arrangement of the bordered pits in the tracheids as distinguished from the alternate pitting of the *Araucariaceae*, although there are some members in this family, which too display a more or less scattered pitting in the tracheids. All this is evidence that among the living gym-

nosperms it is the *Podocarpaceae* which must be considered in the first place when looking for the relatives of the *Taxales*. The probability of a direct affinity is, however, contradicted by the divergence of other characteristics, so that the most we are justified to say is that both families are descendants of a common ancestral tribe that goes back to the *Carboniferous* or, at least, to the *Permian*.

The question is now, which of the long extinct types should be considered in this connection ? Unfortunately, the records supplied by palaeontology are as yet insufficient to serve as definite clues in solving our problem although fossil *Cephalotaxus* forms from the *Jurassic* are known. One of the features in which the *Neuropterides* of the *Carboniferous* resembled living *Torreya* was the development of single seeds at the tip of the branches. It is the *Torreya taxifolia* which shows the closest resemblance with the *Neuropterides* in this respect although the leaves of *Neuropteris* showed a multiple-dichotomous system. The ancestors of *Torreya* are most probably to be found among the *Neuropterides*, although such of the stems of the latter as are known show xylotomical features that are very different from those of the *Torreya*.

Seed structure, as also other properties, make it possible to assume phyletic connections between the *Taxales* and the *Cycadales*. In *Cycas*, the ray structure is simple and characteristic. All ray-cell walls are very thin and smooth. The number of pits per cross field is relatively large (10—20). The bordered pits in the tracheids are of the araucarian type. In some tracheids, especially in those of the roots, there are marked spiral thickenings. It is now clear that in the structure of the seeds, in the presence of spiral tracheids, as also in other features, there is a remarkable similarity between the *Cycadaceae* and *Taxaceae*. This, however, should not be interpreted to mean that the *Taxales* have descended from the *Cycadaceae*. All we want to emphasize is that, as has already been mentioned in connection with the *Podocarpaceae*, in the *Paleozoic*, probably as early as the *Carboniferous*, there existed types (e. g., *Neuropteris)*, from which one evolutionary line may have led to the *Taxales*, another to the *Podocarpaceae*, and a third to the *Cycadales*. Moreover, it is quite likely that there also exists a phyletic connection with the *Dadoxylon* type, and thus with the *Araucariaceae*. Xylotomical considerations favour, therefore, the conclusion that while among the living forms *Podocarpaceae* and *Cycadaceae* may be said to be related with *Taxales* in the first place, no phyletic connection exists between the latter and the *Pinaceae*, *Taxodiaceae*, or *Cupressaceae*. Relationship with the first two families must be excluded, if only for the reason that their woody cones have arisen from several flowers, and with the third one because the cones in its members, though developed from a single flower according to some authors, produce verticillate carpels bearing several seeds.

While it is with the *Neuropterides* of the *Carboniferous* that the Torreya possess common characteristics, it is rather with their immediate ancestors, e. g., the *Palaeotaxus rediviva* known from the *Raethic*, or the *Taxus jurassica*, that *Taxaceae* appear to be in phyletic connection. It is noteworthy that remains of *Taxus* are known from the *Cretaceous* in North America and perhaps Europe ; *Taxoxylon* have only been unearthed from the *Tertiary* of East Asia. These facts permit the inference that the *Taxales* are a geologically younger type. It should further be mentioned that living *Cephalotaxaceae* are restricted to a small area in Southeast Asia, where they coexist with a few *Taxus* species. The geographical distribution of the latter is limited to the Northern Hemisphere. It is furthermore significant in this connection that in the very zone of the *Cephalotaxaceae* there exist also a few species of *Podocarpus*. The southeastern part of Asia is the very area in which every one of the seven families is represented by a few characteristic members ; there is no other such spot on the earth. This makes one ponder over the question whether this region may have been a "cradle" of the present conifers or, perhaps, a "grave" of some of the extinct types. May be some forms of conifers, such as the *Pinaceae*, *Taxodiaceae*, and *Cupressaceae* took their departure from this spot or that some others, the last representatives of a long extinct flora, took refuge here. The fact that in this small area there exist numerous monotypical genera, or such as are only represented by a few species, appears to favour the second assumption. It would be worth while to study this problem from a purely phylogenetic point of view.

From the point of view of xylotomy, it merits mentioning that in the wood of *Taxales* the growth rings are distinct, their delimitations readily determinable, and thus suggestive of a climate of more or less varying temperature.

Of the ancestors of the *Cephalotaxus* it is *Taxoxylon torreyanum* which is known from the East Asiatic *Pliocene*, while *T. antiquum* has been

described from the *Cretaceous* of North America, and *T. anglicum* from England. It is not impossible that the living *Torreya californica* have evolved from *Taxoxylon torreyanum*, while *T. antiquum* may have been the ancestor of a species of the present *Cephalotaxus*, possibly the *Torreya nucifera* or *T. grandis*, respectively. On the other hand, by the evidence of its leaves Kräusel has proved *Amentotaxus* to have occurred in the *Tertiary* of Germany.

To conclude briefly it can be stated with some probability that *Taxales* are the descendants of common *Podocarpaceae*-like ancestors, and that these two monospermous series evolved along parallel lines, independently of the lines taken by the *Pinaceae* and *Cupressaceae*. This theory seems to have found substantiation in Kirstein's serological experiments in which the *Ginkgo* gave positive reactions with the *Taxaceae*, *Podocarpaceae*, and *Araucariaceae*, apparently proving that there exists a close relationship between *Taxaceae* and *Podocarpaceae*, and that the origin of both can be traced back to the *Pteropsida* type.

THE GYMNOSPERMOUS DESCENDANTS OF THE SPHENOPSIDA TRIBE

THE PHYLOGENETIC HISTORY OF THE CUPRESSACEAE

One of the most characteristic xylotomical features of the *Cupressaceae* is the commonly cupressoid pitting in the cross field, i. e. that the pit aperture included within the limits of the vertically or obliquely placed, more or less elliptical border is at right angles to the major axis. It is further characteristic that, when pitted, the tangential walls of the ray cells are thickened beadlike, and practically never dentate. This however, means that the pit canal in the secondary walls appears not cylindrical, as it generally does in the *Pinaceae* and *Taxodiaceae*, but opening out towards the cell lumen becomes more the shape of a deeper dish. This phenomenon is also encountered in the horizontal walls of the longitudinal parenchyma cells.

In additon to these anatomical properties, it is a feature common to all species in the *Cupressaceae* that the leaves are never spirally arranged, but as has already been stated by Laubenfels, always verticillate or opposite. But further similarity is represented by the fact that their cones are produced from single flowers, as already observed by Pilger. This too, is a characteristic which sharply distuinguishes this family from a number of others in the *Coniferae*.

Although the features described above characterize all the genera and species of the family, on the strength of the anatomy of their wood they can nevertheless be divided into three very distinct groups; these are in partial agreement with the division based by Pilger on features of external morphology.

The first group includes *Actinostrobus*, *Callitris*, *Callitropsis*, *Tetrarclinis*, and *Widdringtonia* distinctly characterized by the perfect smoothness and thinnes of all the ray-cell walls, meaning that only the primary walls are developed. Likewise thin and smooth are the horizontal walls of the longitudinal parenchyma cells. It should be noted that these forms occur only in Australia and in the southernmost region of Africa. *Tetraclinis* alone exists as a relict in some places in South Spain and North Africa. Xylotomically, the said five genera stand apart from the other members of the *Cupressaceae*, and represent in all probability the most primitive evolutionary stage in this family.

The second group covers *Biota*, *Chamaecyparis*, *Fokienia*, *Microbiota*, *Thuja* and *Thujopsis*. This group, the members of which are very similar to one another also in external morphology, are anatomically characterized by having somewhat thicker horizontal ray-cell walls, comparatively well-developed and almost smooth, or from sparsely to more abundantly pitted secondary walls and, in contrast, invariably smooth, therefore still primary, tangential walls. It is also characteristic that the members of this group, in distinction to those of the first, are distributed over the Northern Hemisphere only, so that *the members of the two groups do not coexist anywhere on the earth* (Cf. map on p. 63.).

In the third group can be classed *Arceuthos*, *Cupressus*, *Diselma*, *Fitzroya*, *Juniperus*, *Libocedrus* and *Pilgerodendron*. In this group not only the horizontal but also the tangential ray-cell walls, and furthermore the horizontal walls of the wood parenchyma cells are pitted, while the tangential walls of the ray cells show beadlike thickenings,

it being a rare exception that one or the other of the walls should be smooth or dentate.

Indentures are the rule, though not always distinct. Accordingly, the secondary layer is already developed in all of the three walls.

Considering all these anatomical and external morphological properties it should not be too difficult to make a xylotomical distinction between the family of the *Cupressaceae* and the rest of the conifers.

The *Cupressaceae* cannot be allied phylogenetically with any of the other six families of the *Coniferae ;* the less so as there is only one kind of scale with several (3—11) ovules in the cones of the *Cupressaceae*, while no cones are developed in the *Taxaceae*, *Cephalotaxaceae* and *Podocarpaceae*, only a single ovule is born by the cone-scales of the *Araucariaceae*, whereas the cones of the *Taxodiaceae* and *Pinaceae* are composed of two kinds of scales. Several authors, including the present writer, regard therefore the cones of the two last named families as inflorescences, and those of the *Araucariaceae* and *Cupressaceae* as single flowers. Among others, PILGER and LOTSY favour this theory.

But, as has already been stated, the *Cupressaceae* are different from all other gymnosperms, also in that all their genera have opposite or verticillate leaves ; this is a characteristic of the *Cupressaceae* alone and of no other family. Moreover, the verticillate arrangement is seen also in the structure of the cones, i. e. the flowers. The stamens and the carpels appear always at the end of the branches, at the same height, and are decussate. Further features worthy of note are the following : stamens are shield-shaped like the sporophylls of the horsetails, although stamens of this type also occur in other conifers ; the sporangia are seated in both forms beneath the shield which may have from 3 to 6 angles ; the surface of the pollen grains is perfectly smooth like that of the spores of the horsetails or of the extinct *Calamites*. This multiple homology (and by no means analogy!) suggests a close phylogenetic alliance between the *Cupressaceae* with their verticillate or opposite leaves and verticillate floral structure on the one side, and the *Sphenopsida* with their likewise verticillate leaves and the spike-like strobilus with verticillate sporophylls on the other side. The author is of the opinion that the tribe of *Sphenopsida (Articulatae)* did not die out without descendants in the *Mesozoic*, but — apart from the *Equisetum* — is living forth, similarly to but independently from *Lycopsida* and *Pteropsida*, in the present *Cupressaceae*. Therefore, xylotomical considerations support the conclusion that the present *Cupressaceae* arose from the tribe of *Sphenopsida*, and that the living *Callitris* stands on the lowest, *Thuja* on a higher, and *Juniperus* on the highest rung of this evolutionary ladder.

The *Articulatae* character is still clearly discernible in the *Widdringtonia*, *Callitris*, *Callitropsis*, *Tetraclinis* and *Actinostrobus*, the young shoots of which articulate and break into pieces just in the same way and just as easily — almost of their own accord — as do the young shoots of the living *Equisetum* or did perhaps those of the extinct *Calamites*. There were diaphragms in the stems of the quondam *Calamites* the deteriorated remnants of which can still be seen, partly in the younger stems of the *Callitris* and *Widdringtonia* and partly, upwards, in those of the *Ephedra* and *Casuarina*.

On the strength of its external morphology, the *Casuarina*, too, should be included in this series ; taxonomists, however, class it as a unit without relatives under the head of the *Angiospermae* with which it seems to have many characteristic features in common.

As regards relationship between *Cupressaceae* and *Casuarina*, a significant phylogenetic and xylotomical feature should be mentioned. The primary rays in the *Calamites* of old, and in *Athroxylon* as well had always a width of from 6 to 10 cells, whereas the secondary rays were in the main uniseriate. The primary rays arose directly from the pith, and divided the primary collateral bundles. This is thus an ancestral xylotomical feature dating back to the *Carboniferous*. A similar xylotomical pattern can be seen in the *Ephedra* of the group of the *Chlamydospermae* (Plate 347) ; in *Ephedra* there are, as were in the *Calamites*, two kinds of rays : one very wide, and one uniseriate. We encounter a quite similar ray structure in the living *Casuarina*, yet with the difference that there appear in the wood of the latter not only tracheids but tracheae as well ; these are still primitive in the *Ephedra*, but perfectly dicotyledon-like in the *Casuarina*. On this ground the question seems to be justified whether in view of the external morphological and the xylotomical properties the *Cupressaceae*, as also *Ephedra* and *Casuarina*, should not be regarded as independent of the *Pteropsida* and *Lycopsida*, and as descendants of the *Sphenopsida*, with the restriction however, that the said forms did not evolve one from the other but arose

from a common tribe (Cf. phylogenetical chart attached).

It should furthermore be noted that in the *Libocedrus* biseriate rays are a frequent, and partly triseriate ones a very rare occurrence, which phenomenon points to an origin from wide rays. The species of the *Libocedrus* revealing this phenomenon exist exclusively in the western coastal regions of North and South America, in New Zealand, New Caledonia, on the island of Taiwan, the eastern coastal regions of China, and in Japan. If connected with one another, these habitats unfold the outlines of an unbroken continent, and this, too, is well worth being noted. The present distribution of the *Cupressaceae*, regarded from the viewpoint of xylotomy, is exceedingly interesting. As has already been mentioned, three types of *Cupressaceae* can be distinguished, to each of which corresponds a special geographical zone. The *Callitris* and their relatives, approximately 30 species, in which the horizontal walls of the ray cells and parenchyma cells are quite smooth and which, therefore, have to be regarded as the simplest phylogenetic forms, exist nowhere but in Australia and in the southernmost and northernmost regions of Africa. Practically nowhere do they reach the Equator and form, so to say, a sharply isolated group in the Southern Hemisphere (cf. map on p. 63).

The second, xylotomically somewhat more advanced, group covers those genera in which the walls of the ray cells are already thickened and remained smooth in places only. In the horizontal walls there appeared more or less pronounced recesses and, later, pits; or they became thick without developing any marked pitting. The tangential walls, on the other hand, have remained quite smooth. This group includes principally monotypical forms, such as *Biota*, *Microbiota*, *Fokienia*, and *Thujopsis*. These live exclusively in the coastal regions of East Asia. Included in this group may be further *Chamaecyparis* and *Thuja*, natives of the eastern coastal regions of East Asia and the west coast of North America, i. e., the shores of the Pacific Ocean.

In the third group, the horizontal walls of the wood parenchyma cells as also the horizontal walls of the ray parenchyma already display pits, while the tangential walls of the latter invariably show beadlike thickenings, it being a rare exception that these should have remained even and smooth. This group includes the *Arceuthos*, *Juniperus*, *Libocedrus*, *Pilgerodendron*, *Cupressus*, *Diselma*, and *Fitzroya*. Their distribution is rather varied. *Diselma* occurs in Tasmania, *Fitzroya* in South America, while *Libocedrus* grow partly in South and North America, partly in the East Indies, precisely in the regions which are also the habitats of the structurally much simpler *Chamaecyparis* and *Thuja*. The two most widespread genera of this group are *Juniperus* and *Cupressus*. There exist at present more than 70 species of *Juniperus*, mostly in North America, Middle East Asia, and Europe. They are spread over a zone that reaches from the 30th degree of southern to the 70th degree of northern latitude so that the members of this highest developed type have the comparatively widest distribution.

The *Juniperus* species spread practically over the entire Northern Hemisphere, and their great number is an indication of their having attained a high stage of evolution (PILGER). The other genera of the family are represented only by 1 or 2 species. The distribution of the *Cupressus*, too, deserves mention: the greatest part of their species, about ten, grow in the southern regions of North America, while a smaller part, about four species, live in South Asia. The anatomically well-developed *Cupressus* and *Juniperus*, which have many xylotomical features in common, live together, and are distributed mainly over the Northern Hemisphere, appear to have (except in a small area of North Africa) hardly any points of contact with the *Callitris* group of a very simple smooth ray structure. Their contact with the members of the second group is likewise very limited, viz. restricted to the coastal regions of East Asia.

To sum up: on the strength of the xylotomical and external morphological features three stages of xylotomical evolution can be distinguished in the *Cupressaceae* of opposite or verticillate distribution of the leaves on the axis.

In the first the ray cells have quite smooth walls, like *Actinostrobus*, *Callitris*, *Callitropsis*, *Tetraclinis*, and *Widdringtonia*.

In the second, the horizontal walls of the ray cells, while smooth or sparsely pitted, are already thickened, whereas the tangential walls are invariably smooth and thin. In this stage are *Biota*, *Chamaecyparis*, *Fokienia*, *Microbiota*, *Thuja*, and *Thujopsis*.

In the third, xylotomically most advanced, stage are the forms in which the horizontal ray-cell walls are usually pitted and remain smooth

Resin ducts absent									
Rays homogeneous									
All ray-cell walls thin and smooth; no true pitting, only rare local thinnings. Indentures absent. (Rays with *primary walls)*						Horizontal walls of ray cells thick *(secondary walls)*, smooth or pitted; tangential walls invariably smooth, very rarely nodular *(Sequoia sempervirens* and *Thujopsis dolabrata)*. Indentures present or absent			
						Spiral bars in tracheids			
						absent		present	
Type of cross-field pitting						Pits in cross field			
araucaroid	dacrydioid, podocarpoid	cupressoid, podocarpoid	taxodioid	piceoid	pinoid	taxodioid, occasionally cupressoid	cupressoid, occasionally taxodioid	podocarpoid or cupressoid	
								Wood parenchyma	
								present	absent
			Athrotaxis.			Cryptomeria Cunningh. Glyptostr. Metasequ, Sequoia. Taiwania Taxodium			
		Actinostrobus Callitris Callitropsis Tetraclinis Widdringtonia					Biota Chamaecyp. Fokienia Microbiota Thuja Thujopsis		
Araucaria Agathis Cycas Ginkgo	Austrotaxus Acmopyle Dacrydium Michrocachrys Phyllocl. Prumnopitys Sciadopitys Podocarpus (Ginkgo)							Amentotaxus Torreya taxus	Taxus Nothotaxus

		Resin ducts present						
		Rays heterogeneous						
Horizontal and tangential walls of ray cells thickened and pitted; tang. walls occasionally smooth. Cross-field pitting piceoid, cupressoid, or taxodioid		Horizontal ray cell walls smooth or pitted		All ray-cell walls thickened and pitted. Walls of epithelial cells in resin ducts thickened and pitted. Rays exceptionally composed of two kinds of parenchyma. Transverse tracheids with minute dentations or spiral bars *(tertiary lamellae)*		All ray-cell walls pitted, or in part smooth, in part pitted. Walls of epithelial cells of resin ducts thin. Ray parenchyma cell walls from thickened to thin or frequently alternating. Walls of transverse tracheids smooth or with dentate or reticulate thickenings *(tertiary lamellae)*		
		Tangential walls of ray cells smooth, quite exceptionally slightly nodular. Walls of transverse tracheids smooth. Cross-field pitting commonly taxodioid or cupressoid	Tangential walls of ray cells pitted. Walls of transverse tracheids invariably smooth. Cross-field pitting piceoid	Cross field with				
Tangential walls commonly with *dentate* thickenings or smooth. Pitting usually taxodioid or piceoid	Tangential walls commonly with *beadlike* thickenings or smooth. Pitting usually cupressoid or taxodioid			piceoid or taxodioid pitting. Transverse tracheids exceptionally with spiral bars.	piceoid or cupressoid pitting. Transverse tracheids with spiral bars.	pinoid, rarely piceoid pitting	pinoid pitting	
						Tangential walls of transverse tracheids		
						smooth (Haploxylon	with dentate or reticulate thickenings (Diploxylon)	
Abies Keteeleria Pseudolarix	Saxegothaea Pherosphaera	(Sequoia) (Metasequoia)	Cedrus Tsuga	Larix Picea	Pseudotsuga (Picea)	Pinus		Descendants of the *Lycopsida* line. Cone axis with spirally arranged carpels and two or more ovules on each of them. Monoecious families *(Taxodiaceae, Pinaceae;* conifers in the true sense) (Pseudanthia)
	Arceuthos Cupressus Diselma Fitzroya Juniperus Libocedrus Pilgerodendron	(Juniperus)			Thujopsis (Standishii)			Descendants of the *Sphenopsida* line. Cones with verticillate carpels *(Cupressaceae)* (Euanthia)
								Descendants of the *Pteropsida* line. Carpels uniovulate, spirally arranged on the cone axis, or solitary and apical. *(Ginkgoaceae, Araucariaceae, Podocarpaceae, Taxales;* in *Cycadaceae* carpels with two or more ovules). (Euanthia)

only in very exceptional cases, while the tangential walls mostly display beadlike thickenings and are practically never smooth. Such are: *Arceuthos*, *Cupressus*, *Diselma*, *Fitzroya*, *Juniperus*, *Libocedrus* and *Pilgerodendron*.

There are no living conifers with which, on xylotomical grounds, this family could be phylogenetically associated. As regards extinct forms, the *Calamites*, *Athroxylon*, and *Phylloteca* might be considered in the first place, with *Ephedra* and *Casuarina* from amongst the higher forms. In this conjunction, the idea may present itself that the line of evolution which began with the *Protoarticulatae* and passing, in the writer's view, through the stages of the *Sphenophylla*, *Asterocalamites*, and *Phyllotecae*, reached the *Cupressaceae* and the *Casuarina*, has perhaps further developed right up to the angiospermous types. The possibility should therefore be taken into consideration that several sympetalous species of the *Dicotyledons* in which a verticillate arrangement of the leaves is not infrequent may have some phyletic connections with the type in question which, as we have seen, shows the same arrangement of leaves. There are unfortunately so few available data concerning this problem that the very idea, as suggested here, appears to be problematic. Problematic but not quite impossible.

THE GYMNOSPERMOUS DESCENDANTS OF THE LYCOPSIDA TRIBE

A. THE PHYLOGENETIC HISTORY OF THE PINACEAE

In the *Pinaceae* there no longer exists a single genus with only smooth and thin walls in the ray cells, although in some species the tangential walls, but only they, are quite exceptionally smooth *(Abies)*. The simplest ray structure in this family is encountered in *Abies*, *Keteleeria*, and *Pseudolarix*. In the rays of these three genera there are, as a rule, only thick-walled parenchyma cells; the rays are homogeneous. The canals in the simple pits are either cylindrical or dish-shaped. *Abies* species are mentioned in the literature with transverse tracheids in the rays. On examining samples from young trees of forty species the writer has found real transverse tracheids in 4 or 5 of them. None were encountered in the two examined species of *Keteleeria (K. davidiana* and *K. fortunei)* or in the monotypical *Pseudolarix*. Phylogenetically, it would be in any case justified to expect a more frequent occurrence of transverse tracheids in the said genera.

In the wood, on the other hand, longitudinal parenchyma cells are more frequent. They are particularly frequent in *Keteleeria*, somewhat less so in *Abies;* in a few genera they seem to be missing altogether. A special feature of the *Abies* is that their wood parenchyma abounds in calcium oxalate crystals. So far, no species of *Abies*, *Keteleeria*, or *Pseudolarix* has been found in which the presence of thick- and thin-walled parenchyma cells in the rays would point to a certain evolutionary stage.

In the *Pinaceae*, these three genera represent, therefore, the simplest and lowest organisational forms, at least from the anatomical point of view. It is therefore among forms with such a ray structure that we first have to look for the most primitive ancestors of the *Pinaceae*. In this family the ray-cell structure with simple pits may have arisen, similarly to cell-wall thickening in general, through the deposition of the secondary onto the primary wall and through the more powerful development of the second layer of the former, with simple pits forming only at the few unthickened places. The canals of these simple pits are in the thick cell walls commonly cylindrical; viewed from the radial side, the tangential walls of the ray cells appear to be dentate. A further characteristic feature of the three genera under review is that the marginal cells below and above the rays are externally in many respects similar to the transverse tracheids that likewise border rays; but these marginal parenchyma cells are invariably provided with simple, and in no case with bordered, pits.

In these three genera, the pitting in the cross field is typically taxodioid or piceoid. A pit is piceoid if its walls in the secondary wall are always perpendicular to the primary wall which separates the cells; it appears circular if viewed from above, and cylindrical, exceedingly seldom dish-shaped, if viewed laterally. Taxodioid pits are usually the shape of procumbent ellipses, with the slitlike or moderately wide aperture following the orientation of the pit itself.

A higher stage of evolution in the family of *Pinaceae* is represented by the genera with simple transverse tracheids, such as *Cedrus* and *Tsuga*, while still higher on the evolutionary scale stand the genera with resin ducts, such as *Pseudotsuga*, *Larix*, *Picea*, and *Pinus*. Beside the thick-walled and simple-pitted ray parenchyma, in *Cedrus* and *Tsuga* there are only simple transverse tracheids with walls smooth but for their bordered pitting; thus, the transformation of the longitudinal tracheids into ray tracheids, being but a change from a vertical to a horizontal position, means no essential modification in the wood structure. These transverse tracheids contain namely the same type of bordered pits as the longitudinal tracheids, though considerably smaller.

The above-described evolutionary stage can also be observed in a number of species in the *Haploxylon* group of *Pinus*, but in them the ray parenchyma cells communicate with one another and with the longitudinal tracheids not through minute pits only, but also through substantially larger socalled pinoid pits, although in this respect the structure in the members of the *Balfouriana* section has much in common with that in *Cedrus* and *Tsuga*. It is quite possible that the *Cedrus*-type was the point of departure from which the *Haploxylon* group of the *Pinus* have evolved on the one side, and the *Diploxylon* group on the other. Though led by different considerations, BUCHHOLZ arrived at an almost identical conclusion and regards *Cedrus* as the point of departure for *Pinaceae*. The present distribution of the species of *Cedrus* is rather scattered: *Cedrus atlantica* grows in Algiers and the Atlas of Morocco, *C. libatonica* in the Taurus and mostly in Lebanon, *C. deodara* in the Western Himalayas and in Afghanistan. These may have been the areas from which also the other genera of the *Pinaceae* took their origin. This point will be dealt with in greater detail later in this work.

In *Cedrus* and *Tsuga*, the tertiary layer in the secondary cell wall of the transverse tracheids has not as yet changed essentially. In *Larix* and *Picea*, on the other hand, modifications have already taken place. In some of their species, the tertiary layer has made its appearance in the longitudinal tracheids, particularly in the latewood, in the form of spiral bands; this is probably a recent acquisition in the family. In some species of *Picea* these spiral thickenings occur not only in the ate- but also in the earlywood, wherefore it is rather difficult to separate them from *Pseudotsuga* on the basis of xylotomy. Such spiral thickenings also occur in the transverse tracheids and here, too, certain gradations can be observed. On the inner walls of the transverse tracheids of almost every species of *Larix* and *Picea* there are tiny spicules which not infrequently continue in the form of spirally running fine bands. In this respect, the two genera stand quite close to each other, too.

The tertiary layer has not developed into spiral bars in the *Diploxylon* group of the genus *Pinus*. In this, plates have developed instead, which arising from fairly broad bases invade the inside of the transverse tracheids and thereby greatly enlarge the water-absorbing surface of the cell. In radial section, these plates appear as spikes and ribs varied in shape, their size depending on the species. On the whole, species growing near the Equator and in the Mediterranean present ribs more closely spaced and higher than those living in colder regions. This is probably due to increased metabolism.

The extent to which the cell walls of the transverse tracheids are thickened varies according to the species within the genus *Pinus*, and can therefore be regarded as a feature of diagnostic value.

A gradation similar to that characterizing the development of the transverse tracheid walls can also be observed in the evolution of the ray parenchyma cells. In this respect, again, the type is to be regarded as the most primitive one in which there appear only homogeneous ray parenchyma cells, viz. only thick-walled cells (*Balfouriana* group) or only thin-walled ones (*Cembra* and *Strobus* groups).

An organizational gradation manifests itself also in the development of the pitting in the cross field. In some species, a single, large, so-called pinoid pit occupies the entire field; in others, there lie two or three pits side by side or above one another; while yet in others, there occur as many as 3—4—6, even 8, pits, in which case the many small pits are arranged so as to lie within the contours of a single large pit.

More advanced and, therefore, geologically younger are those genera in the *Pinaceae* in which there are resin ducts in the rays in addition to the aforementioned elements: these are the genera *Pseudotsuga*, *Larix*, *Picea* and *Pinus*. But even these resin ducts show structural and evolutionary degrees. In *Pseudotsuga*, *Larix* and *Picea* they are, as a rule, smaller and sheathed by thick-walled

and abundantly pitted epithelial cells, while in *Pinus* they are usually larger and lined with thin-walled and unpitted epithelial cells. The number of the latter is usually 6—8 in *Psudotsuga*, 6—10 in *Picea* and between 10—16 in *Larix ;* from these numbers conclusions may be drawn as to the functioning of the resin ducts. The fact that in some rays there are occasionally two, even three, resin ducts extending one above the other, points to increased secretory activity.

In the author's view, the most advanced and, therefore, the geologically youngest ray structure is that to be found in *Pinus*. It is in the rays of *Pinus* that one encounters practically all the evolutionary gradations of transverse tracheids (except spirally thickened tracheids), the two kinds of parenchyma cells, possibly the various patterns of their arrangement, as also the resin ducts lined with thin-walled epithelial cells. If we correlate ray structure with geographical distribution it will strike us that the *Pinaceae*, i. e. the most highly developed conifers, grow only on the Northern Hemisphere. That there must exist some correlation between structure and geographical distribution seems to be further substantiated by the fact that the present habitat of the *Pinus* extends mainly from the 23rd to the 60th degree of northern latitude, although one of the 90 known species *(P. merkusii)* is living on the Equator and also grows in South East India, Borneo, and the Philippines. Not a single *Pinus* species does occur either in South America, Africa (except in the North), or Australia ; reliable fossils of *Pinus* have, to our knowledge, never been found on the Southern but exclusively on the Nnorthern Hemisphere, and never in formations older than the *Cretaceous*. All these facts afford support for the assumption that the evolution of *Pinus* must have taken place on the Northern Hemisphere where their distribution is the widest at present, most probably in North America, where 70 species, i. e. 80% of the recent species of this genus are still indigenous.

On the other hand, the evolution of the *Picea* can be assumed to have taken place in Asia, more precisely in China, since about 30 to 35 of the 40 to 43 known *Picea* species are natives of East Asia, notably China. Not more than 10 species of this genus exist in North America, and only 2 to 3 in Europe. Not a single *Picea* species is to be found in Middle or South America, in Africa, in the East Indies, in Australia, or in the South Sea islands ; like the *Pinus* in North America, *Picea* appears to have reached the highest stage of its evolution in East Asia.

Pseudotsuga, too, may be traced for its starting point to East Asia or the western part of North America. The wood structure in some of its species is so similar to that of the *Picea*, especially because of the spiral thickening of the longitudinal and transverse tracheids, that it is rather difficoult to distinguish them on xylotomical considerations. These spiral thickenings must not be confounded with those observed in the *Taxaceae*, whose origin must be looked for in a different direction, if only because in *Taxus* there are neither transverse tracheids nor resin ducts.

The number of the recent species of *Larix* is comparatively small : no more than about 10 to 12 of them are known. Their distribution extends over North Europe, the Middle European high mountains, and North America, where six, and North Asia, where ten occur. Of the *Pinaceae*, it is the *Larix* species that reach the highest latitudes : *L. americana* grows up to the 67th, and *L. sibirica* to the 70th degree. They do not grow south of the 30° northern latitude, and are therefore unknown near the Equator and on the Southern Hemisphere. Compared with those in *Picea* and *Pseudotsuga*, the species in *Larix* have more advanced types of resin ducts, and it is presumable that this is the manifestation of an acclimatisation to cooler continental climatic conditions. While in *Pseudotsuga*, as has already been mentioned, only 6—8, in *Picea* 6—10 cells empty their contents into the canals, in *Larix* these cells number as much as 6—16. From a xylotomical point of view, these three genera are closely allied, *Picea* and *Pseudotsuga* probably more closely with one another than either of them with *Larix*, even if we disregard the short and long shoots, the single or tufted acicular leaves, and hibernal defoliation.

From what has been said above it follows that on the basis of xylotomy 3 lines of evolution can be distinguished in the living *Pinaceae.* In the first line there are 3 stages. The lowest stage is represented by *Keteleeria* and *Abies* with only long shoots, and having only tracheids and, very rarely, simple but thick-walled parenchyma cells in their wood, and only thick-walled parenchyma cells in the rays. The representative of the next stage is *Tsuga*, in which in addition to the aforeenumerated elements there appear transverse tracheids. The third and highest stage is shown in *Picea* and *Pseudotsuga*, also with long shoots, in

which there are already resin ducts in both the wood and the rays; moreover, in some species there appear tracheids with spiral thickenings along with tracheids that have smooth walls. In a search for the ancestors of these forms, *Strobilifer frummentata* is the first to be sonsidered, for by the standard of present knowledge this species had likewise but long shoots and solitary microphyllous leaves on them, exactly like the 5 living genera mentioned in this paragraph.

The second line of evolution is that represented by the short- and long-shooted series in which the short shoots are densely covered with acicular leaves. At the lowest stage of this line we find the *Pseudolarix* with only thick-walled parenchyma cells in their rays, and without transverse tracheids. At a higher stage stand *Cedrus*, already with smooth-walled transverse tracheids but still without resin ducts, at best with resin cysts. (Resin ducts appear exceptionally in the young *Cedrus)*. The highest stage in this polyphyllous line is represented by *Larix*. Beside the aforesaid elements there appear minutely dentate transverse tracheids as also resin canals in its wood and rays. It is worthy of note that in this evolutionary line both *Pseudolarix* and *Larix* are deciduous trees.

The third and most advanced line of evolution is represented by the genus *Pinus*. Morphologically, this genus is similar to the aforementioned type in that it has both short and long shoots, but the short shoots commonly develop one needle, and never more than five.

Xylotomically, the genus itself splits into two groups. The *Haploxylon* group covers the five-needled conifers in the first place. Of these, *Aristata (Balfouriana)* section may be segregated because there is much in common between the ray structure of these trees and the wood structure of the *Cedrus* classed with the forms representative of the second line of evolution. Xylotomically, the section *Pinus-Aristata* and the *Cedrus* are thus in close connection. In the *Balfouriana* section, too, the cross fields reveal minute piceoid pits as in *Cedrus*, while those in the *Cembra* and *Strobus* sections are occupied by very large pits. It is further characteristic of the members of the *Haploxylon* group that the structure of the cell walls of the transverse tracheids is quite similar to, and just as smooth as, that of the *Cedrus* which, too, points to the probability of an affinity between these forms.

Essentially different from the *Haploxylon* group are the members of the *Diploxylon* group. In the latter, the cell walls of the transverse tracheids are more or less thickened, in the *Ponderosa* section even reticular, and the cross fields are occupied by 3—6, or even 8, simple pits. The structure of the transverse tracheids and the ray parenchyma cells is so characteristic in these forms that it is possible to identify the particular species on their evidence, which was done by the author in a previous work. Speaking of conifers with resin ducts, it merits mentioning that there is usually no parenchyma in their wood. In the course of evolution, the function of the parenchyma seems to have been taken over by the resin ducts.

Acquainted with the xylotomy of the *Pinaceae*, we may now raise the problem which families or genera of the rest of the living conifers can be regarded as closely akin to the *Pinaceae?* It goes without question that some genera classed in the *Taxodiaceae* show the greatest resemblance to them, chiefly in regard to their ray structure. The existence of a close kinship between these two families has repeatedly been pointed out, e. g., by LOTSY. In the following it is attempted to clear up the affinity between them by means of the xylotomical structure of the *Pinaceae*.

B. THE PHYLOGENETIC HISTORY OF THE TAXODIACEAE

Xylotomically, the *Taxodiaceae* are well distinguishable from the other families. Guided by their external morphology, PILGER includes the following genera in this family: *Athrotaxis*, *Cunninghamia*, *Cryptomeria*, *Glyptostrobus*, *Metasequoia*, *Sciadopitys*, *Sequoia*, *Taiwania* and *Taxodium*. As regards *Sciadopitys*, it had been suggested quite a long time ago by ARNOLDI and BUCHHOLZ that it should be classed in a family of its own, because of its differing external morphology. Its xylotomical architecture is nearly identical with that of the *Phyllocladus* in the *Podocarpaceae*. The genus still awaits its final classification.

Several genera in this family are monotypic, and some include only 2 or 3 recent species. Being common to all species within the family, distinct growth rings and smooth tangential walls in the ray cells are the outstanding characteristic features. The readily definable growth rings point to a habitat with a climate of varying temperatures. True, smooth tangential walls in the rays constitute a characteristic also of the *Podocarpaceae* and *Arau-*

cariaceae, but in them the horizontal walls, too, are smooth and, besides, the pitting in their cross field is of an entirely different type. Longitudinal parenchyma is present in every species, except *Sciadopitys*, with the horizontal cell walls thick and more or less pitted *(Taxodium distichum)*; or evenly or unevenly smooth; or perfectly smooth; the simple pits in the tangential and radial walls are either scattered or arranged in rows *(Cunninghamia)*. Transverse tracheids have only been encountered in *Metasequoia*, *Sequoia gigantea*, and *Sequoia sempervirens*. The horizontal walls of the ray parenchyma are either smooth and thin as in *Taiwania*, or pitted as in *Taxodium*; their thickness is from 0,4 to 5 μ, that of the invariably thin and smooth tangential walls from 1,5 to 2 μ.

The pitting in the cross field is also characteristic. The pits are typically taxodioid (except in the *Sciadopitys)*, the aperture being usually parallel to their longitudinal axis. The pits are mostly procumbent ellipses or circles *(Glyptostrobus.)* They vary in size practically from genus to genus; a feature of value in generic identification. The number of pits per cross field is 1—5 (6), with commonly more in the marginal cells. They are variably arranged. In some species 2—3 (4) pits are arranged in one or two horizontal rows, in others they are aligned diagonally, or placed irregularly.

The pit apertures are slitlike, or wide and short elliptical, with horizontal *(Taxodium)* or vertical *(Cunninghamia)* orientation; occasionally they are orbicular with the border outlines hardly, or not at all, visible (glyptostroboid pitting). In *Sciadopitys* a single large pit occupies almost the entire area of the cross field; a feature sufficient in itself to make this genus not fit the *Taxodiaceae*.

For all these general xylotomical properties common to all members of the *Taxodiaceae*, three distinct evolutionary lines can be distinguished in the same manner as was done in connection with the *Pinaceae*, the three types corresponding also to morphological properties.

1. The first line is represented by *Taxodium*, *Metasequoia*, and *Glyptostrobus*, which stand out most sharply from the other forms. A common charateristic of these three genera is the taxodioid or glyptostroboid pitting of the ray cells. This common xylotomical feature is accompanied by a common morphological one, viz. that the trees of this type develop two kinds of shoots of limited and illimited growth, respectively. Although a similar phenomenon was said to characterize also the *Pseudolarix* and *Pinus*, the position is quite different in the present case inasmuch as the leaves on the shoots of limited growth do not grow either alone or in fives and groups but are arranged in spiral rows (even in *Metasequoia!)*. Too, these three genera shed their short shoots, and not their leaves, in the autumn.

2. The representatives of the second evolutionary line, *Sequoia*, *Taiwania*, *Cryptomeria* and *Athrotaxis* form a xylotomically well-defined group. Separating these genera from *Taxodium*, BUCHHOLZ classes them in an independent group. Apart from cones, these genera only develop shoots of illimited growth. Viewed xylotomically, *Athrotaxis* and *Taiwania* display the simplest structure, since both the tangential and the horizontal walls of their ray cells are smooth and thin. In *Sequoia* and *Cryptomeria* the horizontal walls are comparatively thick and usually smooth, very rarely with simple pits in them. In addition to these xylotomical traits, *Taiwania* and *Cryptomeria* have also this in common that their leaves are slightly incurved towards the axis, similarly to those in *Geinitzia* from the *Cretaceous*, so that the ancestors of the *Taiwania* and *Cryptomeria* may be expected to be found among the *Geinitzia*-type of trees.

3. *Cunninghamia* and *Sciadopitys* are classed in the *Taxodiaceae*, although they are somewhat different from the other members of the family, partly in their wood structure and partly in their external morphology. Because of the verticillate arrangement of the leaves, it has repeatedly, and not without reason, been suggested that the *Sciadopitys* should be segregated into a special family.

If in consideration of the afore-mentioned xylotomical and external morphological properties, and in view of the various features that characterize the three evolutionary types of the family, it is now attempted to trace phyletic correlations between the *Taxodiaceae* and the rest of the conifers, one is surprised to find that the wood anatomy of this family shows the comparatively closest resemblance to that of the *Pinaceae* and, within that family, to the genera *Abies* and *Keteleeria*. The only anatomical difference consists in that all ray-cell walls show simple pits in *Abies*, *Keteleeria*, and *Pseudolarix*, whereas in *Taxodiaceae* the tangential and radial walls are invariably smooth and only the horizontal walls pitted, a feature which,

by the way, is not infrequently encountered in the genus *Abies*.

An additional common characteristic is the lack of resin ducts in the wood of the *Taxodiaceae*, *Abies*, *Keteleeria* and the *Pseudolarix*.

There exists a striking resemblance in the structure of the cross field of certain *Taxodiaceae*, such as the genera *Taxodium*, *Glyptostrobus* and *Metasequoia*, and that of certain *Pinaceae*, viz., *Abies*, *Keteleeria* and *Pseudolarix :* in all of them there appear almost invariably taxodioid, piceoid, or glyptostroboid pits. The pitting in *Cryptomeria* and *Taiwania* is slightly different, not typically taxodioid, and to this difference in pitting corresponds a difference in the external habit of the plants in the two genera.

It has been mentioned that the pitting of the rays in *Cunninghamia* and *Sciadopitys* differs most essentially from that in the other genera. The pits in the former are nearer to the podocarpoid type and, apart from other features, this alone would suffice to class the two genera in the *Podocarpaceae*, as has already been attempted by some authors.

There is a remarkable phenomenon that also points to a phyletic connection between the two families. From among the conifers it is only in *Taxodium*, *Metasequoia* and *Glyptostrobus* of the *Taxodiaceae*, and in *Pinus*, *Cedrus*, *Larix*, and *Pseudolarix* of the *Pinaceae* that they possess two kinds of shoots. Of these, the three first-named genera shed their shoots of limited growth at the end of the vegetative period in quite the same manner as *Larix* and *Pseudolarix* shed their leaves.

The wood anatomy in *Sequoia*, *Taiwania*, and *Cryptomeria* suggests a different line of evolution : the apertures of the pits in the cross field are very short ellipses, almost circles, and only in *Sequoia gigantea* are they more frequently slitlike. Considerations of wood anatomy forbid therefore to regard *Taxodium* and *Sequoia* as close relatives ; the same conclusion has been reached by BUCHHOLZ on the evidence of external morphology. The said considerations make it apparent that certain genera of the Taxodiaceae and the *Pinaceae* are in closer affinity with one another than with any other family of the *Coniferae*.

Because of their apparently simpler ray structure, due to the perfect smoothness of the tangential walls, the *Taxodiaceae* must be regarded as standing on a lower evolutionary stage and geologically older than the *Pinaceae*. It should be added that the two families nonetheless reveal profound common tribal characteristics ; for example, both are of microphyllous character and resemble the *Voltzia* types ; a fact which in this particular respect points to the *Lycopsida* tribe.

The assumption of a common origin seems to be further corroborated by the fact that, confined to the Northern Hemisphere, the members of the two families grow near to each other ; *Athrotaxis*, three species of which grow in Tasmania, is an exception. The distribution of the *Taxodiaceae* extends only from the 30 to the 40th, that of the *Pinaceae* to the 60 or 70th degree of northern latitude. This might, perhaps, explain the lack of resin ducts in both the wood and the bark of the *Taxodiaceae*, which obviously have not yet attained the stage of an architecture with resin ducts.

Of the *Pinaceae*, the genera *Keteleeria*, *Abies*, *Pseudolarix*, *Cedrus*, and *Tsuga* are devoid of resin ducts. In addition, it is conspicuous that *Glyptostrobus* and *Metasequoia* in East Asia, and *Taxodium* and *Sequoia* in North America occur almost exactly at the same degree of latitude as do *Pseudolarix*. This, too, seems to substantiate the theory that somewhen in the *Tertiary* a now vanished continent must have bridged the present East Asia and West America.

The genus *Athrotaxis* represents the third evolutionary line in the *Taxodiaceae*. Although presenting typically taxodioid pits, this genus is different from all the others in the family, chiefly in that all the walls of its ray cells are thin, so that it is the most primitive member. The very simplicity of its structure and its outward appearance do not make this form fit to be in the same company with *Taxodium*, *Sequoia*, *Metasequoia*, and *Glyptostrobus*. The difference in structure may be explained in part by the fact that not more than three species of *Athrotaxis* are known, and that they are limited to the Southern Hemisphere, notably to Tasmania, where this type has survived as a relict from the Gondwana land.

In conclusion, one more characteristic feature common to both families should be noted, viz. that their female inflorescences are cones, so that they are true conifers in which there grow always two or more ovules on the spirally arranged carpels.

Summing up now the problem of the affinity between the *Pinaceae* and *Taxodiaceae*, it has been found that there are several evolutionary lines in each of these two families, and that these lines possess common anatomical as well as morpholo-

gical features. Piceoid, pinoid or taxodioid pits in the rays, and microphyllous leaves are characteristic of all of them. Seeing that many anatomical and external morphological features, characteristic of both families, point to phyletic connections with the *Geinitzia*, *Voltzia*, *Strobilifer* and *Elatides (Cunninghamia!)*, all of them microphyllous plants that had a wide distribution in the *Mesozoic* and belonged undoubtedly to the *Lycopsida* type, it is justified to regard the *Pinaceae* and *Taxodiaceae*, independently of the other conifers, as descendants of the microphyllous *Lycopsida*.

As easy and simple it apparently was to detect the phyletic relations of the *Pinaceae* and the *Taxodiaceae* to each other and to the primitive *Coniferae*, as difficult and complicated seems it to be to trace such relations to the *Angiospermae*. There is little doubt that no direct phylogenetic tie exists between the *Pinaceae* and the *Angiospermae*, at least as regards recent and known extinct forms. True, the *Chlamydospermae* stand higher on the evolutionary scale than the *Pinaceae*, or the *Gymnospermae* in general, yet so far no intermediate form has been discovered among them that would plausibly prove the existence of a phylogenetic connection. The problem is made still more difficult by the fact that, while no fossil *Chlamydospermae* have yet been found, numerous remains of mono- and dicotyledonous plants, together with those of a few geologically younger conifers, have come to the light from the later *Mesozoic*. Attempts, then, to find the phyletic connections sought for must for the time being be restricted to these primitive forms. All the members of the *Pinaceae* and *Taxodiaceae* are known to be monoecious. Among the living *Dicotyledons* it is mainly the *Monochlamydeae* which, apart from occasional dioecious individuals, are monoecious, too. Thus, this would be at present the sole phylogenetically significant characteristic to connect the *Coniferae*, taking this term in its strict construction, with the *Monochlamydeae*. However, several examples are known among the recent *Pinaceae* where, like in the heterosporous *Selaginella* and *Lepidostrobus*, we find macrosporophylls at the lower, and microsporophylls at the upper, end of the cones, which means that the latter have developed into hermaphrodite flowers. But in this we have before us the course which might have been taken in the transformation of a diclinous into an androgynous plant; no doubt a very significant moment in the evolution of hermaphrodite flowers. Particularly well can this transformation be studied in the *Magnoliaceae* that played a much more important part in the *Tertiary*. In these plants, all the floral elements of the same flower arranged spirally, the stamens being above the perianths, that show a gradual transition, and the apocarpous sporophylls above the stamens. To be noted is the fact that the macrosporophylls are not seated beneath the microsporophylls but at the tip of the floral axis. Since the said spiral arrangement is common to all members of the tribe, it seems to be justified to assume that the *Pinaceae* and the *Taxodiaceae*, or their ancestors, continued their evolution partly in the *Monochlamydeae* and partly in the series of the *Ranales-Polycarpicae*. It must be added that quite a number of authors refuse to accept this "antiquated" theory, while others, amongst them the present writer, have adopted it.* In any case, the theory in question has, for instance, been accepted by MÄGDEFRAU who deduces the *Monochlamydeae* from the tribe of the *Lycopsida*. We may regard, therefore, the *Monochlamydeae* and the *Ranales*, i. e. a great part of the *Dicotyledones*, as the highest forms of the *Lycopsida*. Such a conception excludes, of course, the possibility of an origin common with the *Monocotyledones*. It can be assumed that the *Gnetum*, an intermediary form, represents a side line of the same evolutional series; this type has, however, not yet attained the stage of androgynous dicotyledonous plants. Further investigations are needed to prove or disprove this theory.

SUMMARY

On the strength of their tracheids and ray structure, the conifers can be divided into at least three well-defined groups. Although these groups embrace different morphological features, the anatomy of their members enables us to order them in an evolutionary sequence.

1. Are conifers ranked according to the development and the gradual transformation of the ray cells, those forms will have to be regarded as most primitive in which the cell walls are still in their original unpitted state. This is the perfectly thin and smooth-walled homogeneously primitive ray structure. Of the living conifers, only the

* P. Greguss: Ein Gedanke zur polyphyletischen Entwicklung der Pflanzenwelt. Beihefte z. Bot. Centralblatt 1918.

Cupressaceae, *Podocarpaceae*, *Araucariaceae*, further the *Ginkgo* and *Cycas*, stand at this point of the evolutionary scale ; in other words, there appears the same lowest organisational stage as in the simplest group of the *Cupressaceae*, with their opposite or verticillate leaves, in the *Podocarpaceae*, *Araucariaceae*, *Ginkgo*, and *Cycas*, and, finally, in the *Athrotaxis* of the family of *Taxodiaceae*. It is interesting to note that this most primitive, thin-walled, unpitted, homogeneous ray structure does not occur in any member of the *Pinaceae*, and among the *Taxodiaceae* can only be observed in the Asiatic *Taiwania* and the *Athrotaxis* of Australia. There seems to be some sonnection between this most primitive, thin-walled, homogeneous ray structure and the likewise primitive dioeciousness. (It needs to be added that the *Ahrotaxis* and the *Callitris* group of the *Cupressaceae*, an exception in this respect, is monoecious, whereas all members of the *Podocarpaceae* and *Araucariaceae* are dioecious.

2. A higher stage of organization is shown by ray cells with pitted horizontal but still smooth tangential walls. This condition is found in the *Taxodiaceae* with a spiral arrangement of the leaves, in the conifers with opposite or verticillate leaves and evolved from a single flower, in *Thuja*, in the *Taxaceae* with apical ovules and fleshy aril, and finally, in the *Cephalotaxaceae*, the ovules of which are penetrated by furcated vascular bundles.

3. The third organisational stage is reached by forms in which all the walls of the ray cells are pitted. This condition is found in the geologically younger *Pinaceae*, viz. the *Abies*, *Keteleeria*, *Pseudolarix*, further in the *Saxegothaea* and *Pherosphaera*, two forms which have but recently been classed with the *Taxodiaceae*, as also in the members of the *Cupressaceae*, such as *Arceuthos*, *Cupressus*, *Diselma*, *Fitzroya*, *Juniperus*, *Libocedrus* and *Pilgerodendron*. A ray structure of this kind does not appear either in the *Araucariaceae* or in the *Taxaceae*, *Cephalotaxaceae* and *Podocarpaceae*, i. e. in none of the dioecious trees. This group has not yet attained this third evolutionary stage.

But there are differences even within the individual evolutionary stages. One of the simplest forms of thickening of the tangential ray-parenchyma walls is that which is sporadic and beadlike. This condition can be seen mainly in the *Cupressaceae*, and to a less extent in one or two forms of the *Taxodiaceae*, such as *Saxegothaea*, *Pherosphaera*, *Sequoia*. A dentation of the tangential walls and a cylindrical shaping of the pits appears, on the other hand, chiefly in the *Pinaceae*.

Apart from the ray structure it is important to observe through what kind of pits the rays and the adjacent tracheids communicate in the cross field. The species of the *Cupressaceae* contain, as a rule, cupressoid, those of the *Pinaceae* mostly piceoid or taxodioid pits : it should, however, be borne in mind that a sharp and clear distinction in this respect is not always feasible.

The thickenings in the tangential walls of the ray parenchyma are usually beadlike in the *Cupressaceae*, and nearer to dentate in the *Pinaceae*. They differ because in the *Cupressaceae* the inner pit apertures widen dishlike in the cell wall and thereby give rise to beadlike thickenings, whereas in the *Pinaceae* the pit canals are the shape of a more or less regular cylinder and so the inner and outer pit apertures are roughly the same in diameter, in consequence whereof the remaining parts of the secondary wall appear as cogs of a wheel in radial section.

The three evolutionary stages described above are characterized by a homogeneous ray structure, the absence of resin ducts in the wood, the occasional presence of resin cysts, the scattered arrangement of the longitudinal parenchyma cells, or their sporadic aggregation to groups varying in size, which groups really represent the first stage in resin duct formation. (Exceptionally, there appear resin ducts and transverse tracheids in one or two forms, e. g. in *Sequoia*, *Metasequoia*).

4. But there are still higher evolutionary stages, and the fourth is represented by forms in which owing to the division of labour heterogeneous rays are evolved from the homogeneous, i. e. the thin-or thick-walled, simple-pitted ray parenchyma cells are bordered with thick-walled water-conducting transverse tracheids. The present writer suggests that the transverse tracheids are not transformed parenchyma cells but arise from longitudinal tracheids ; the way in which this process happens may be the following : first, the elongated ends of the longitudinal tracheids string themselves on to the ray cells, whereafter, having by a simple change become horizontal, they conduct the nutrient substances no longer upwards but in an horizontal direction. But even within this evolutionary stage there are gradations. The lowest step is occupied by *Cedrus*, *Tsuga*, and *Sequoia*, *Matasequoia*, respectively. The walls of the transverse tracheids in these trees are, like those of the longitudinal

tracheids, perfectly smooth and only minute bordered pits are formed in them through which they communicate partly with the adjacent longitudinal tracheids, partly with the ray parenchyma cells.

Such transverse-tracheidal rays are a great rarity in the *Cupressacaeae*. Nor are transverse tracheids to be found in the *Podocarpaceae*, *Araucariaceae*, *Taxaceae*, *Cephalotaxaceae*, the *Ginkgo*, or the *Cycas*.

5. A still higher organisation present the rays in which the inner face of the walls of the transverse tracheids are either delicately dentate or, like in the longitudinal tracheids, spirally thickened; a pattern connected, no doubt, with increased water conduction. The most primitive forms in this series are represented by *Larix* and, in part, by *Picea*, in which spiral thickenings are occasionally clearly visible not only in the longitudinal but also in the transverse tracheids.

6. Still more advanced is the ray structure in *Larix*, *Picea* and *Pseudotsuga*, where there are already resin ducts in the rays sheathed by special thick-walled epithelial cells. Transverse tracheids and resin ducts in the rays are absent in *Podocarpaceae*, *Taxaceae*, *Cephalotaxaceae* as also in *Ginkgo* and *Cycas;* they are particular characters of the geologically youngest *Pinaceae*.

7. The very highest stage in the evolution of rays and thus the most recent type of ray structure is found in the *Pinaceae*. In addition to trasverse tracheids there appear in them ray parenchyma cells which are thick-walled and pitted, or both thin- and thick-walled and pitted, or quite thin-walled and unpitted. These various kinds of parenchyma cells are bordered by transverse tracheids with thin or differently thickened walls, while in some cases we encounter alternating parenchyma cells and transverse tracheids. (This phenomenon occurs also in certain *Picea* species, e. g. *P. pungens.)*

These differences in the ray structure serve to distinguish the *Haploxylon* from the *Diploxylon* group in the genus *Pinus*. From the viewpoint both of phylogeny and the division of labour, it is this stage which must be regarded as the highest in the evolution of the ray structure, so that the family *Pinaceae*, and notably the genera *Larix*, *Picea*, *Pseudotsuga* and *Pinus*, seem to be provided with rays of the highest organisation. That this structure is the most intricate and at the same time the most perfectly organized, is also proved by palaeontology, according to which the simplest conifers found in the earliest layers had no transverse tracheids, and rays with resin ducts are unknown from before the *Cretaceous*, and even from there are only known from the Northern Hemisphere. Rays provided with resin canals, transverse tracheids, and two kinds of ray parenchyma represent thus the highest form of organisation.

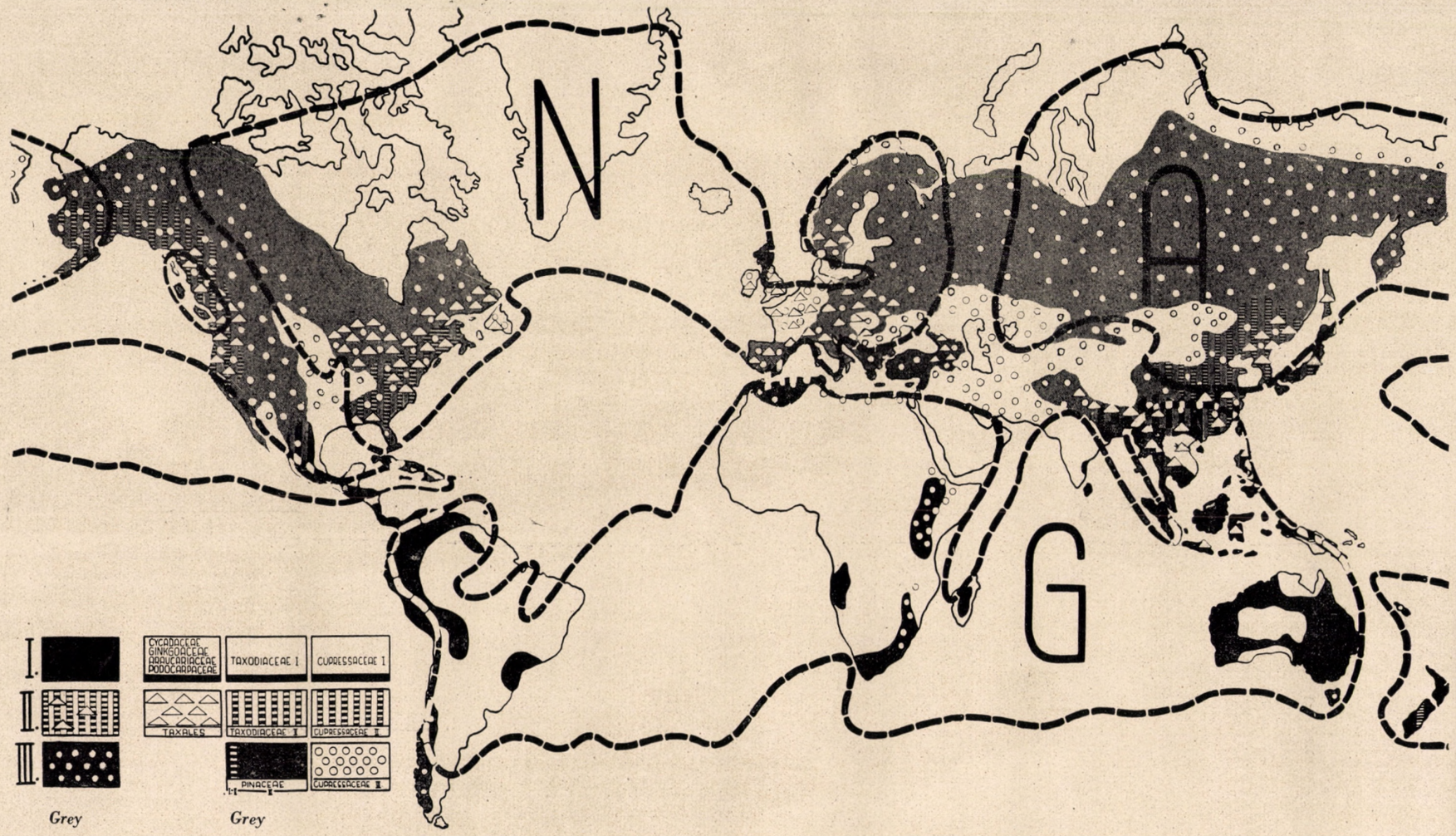
CONCLUSION

The evidence of the xylotomical and other morphological features specified in the foregoing favours the conclusion that the 7 families of the *Coniferae*, together with the *Cycas* and *Ginkgo*, can be divided into three large phylogenetic groups. Each of these groups has its particular xylotomical characteristics and special morphological features of its own. The structure of the rays has gone through more or less identical stages of evolution in each of the three groups, until in one of them and in our days it has reached the highest point of the evolutionary scale in the form of heterogeneous rays provided with resin ducts.

1st group. Cycas, *Ginkgo*, *Araucariaceae*, *Podocarpaceae* (and *Taxales)* are definitely dioecious and have identical ray structure. Their sporophylls, with the exception of the *Cycadaceae*, develop a single seed. The original dichotomy is still frequent in the finer leaf venation and in the vascular bundles invading the sporophylls. Since they display a certain similarity to the *Pteridospermae*, they can be classed in the *Pteropsida* type. In the author's view, *Welwitschia*, too, belongs to them, and this evolutionary line has reached its highest stage in the *Monocotyledones*.

2nd group. This group is represented by the *Cupressaceae* with their opposite or verticillate leaves. In the writer's opinion *Ephedra* and *Casuarina*, too, belong to it, and on the ground of their verticillate leaves all of them are in phyletic connection with the different forms of the *Sphenopsida* and, therefore, the descendants of the latter.

3rd group. Including the *Taxodiaceae* and *Pinaceae*, this is not only a peculiar and sharply isolated group but at the same time that which stands on the highest rung of the evolutionary ladder. The homogeneous and heterogeneous ray structure in the trees of this group and its phylogenetic evolution are decidedly different from those covered by the first two groups. The ancestors of the members of this group can be expected to be found among the *Lepidocarpon*, *Voltzia*, etc. The highest



Geographical distribution of the living Gymnospermae on the basis of their ray structure, according to Greguss. (Cf. text fig. 5)

In the first evolutionary stage of rays all the ray-cell walls are still smooth and thin and devoid of any pitting (primary walls). This primitive ray structure is found in the *Cycadaceae*, *Ginkgoaceae*, *Araucariaceae*, *Podocarpaceae*, further in *Athrotaxis* of the *Taxodiaceae*, and the *Callitris* and *Widdringtonia* species of the *Cupressaceae*. The present distribution of Gymnospermae with this type of ray structure corresponds exactly to the area of the hypothetical Gondwana land (G) in the SouthernHemisphere. Areas in full black on the map.

In the second stage of evolution the horizontal walls of ray cells are already thickened (secondary wall), while the tangential walls are still in the primitive state. This type of ray structure is common to the *Taxales*, *Taxodiaceae*, and to the. *Thuja* and *Chamaecyparis* species of the *Cupressaceae*. A wide distribution these conifers have only in the Northern Hemispheree. The distribution of these families and genera, respectively, is marked on the map by small triangles and alternating black and white horizontal bars.

In the third stage of evolution all the walls of the ray cells are thickened (secondary walls) and pitted. A structure of this type is only seen in the *Pinaceae* and *Cupressaceae*. On the map, the distribution of such *Cupressaceae* is marked by minute circles, and areas of a grey undertone indicate that of the *Pinaceae* with transverse tracheids and resin ducts (the fourth and fifth evolutionary stages), which are confined to the Northern Hemisphere. The distributional range of gymnosperms with resin ducts being restricted to the Northern Hemisphere, it is presumably there that their area of origin is to be sought. It is striking that eight families of the *Gymnospermae* should be represented in Southeastern China and in the nearby South Sea islands, that is, percisely in the postulated area of contact of the Gondwana land (G) with Angara (A). The massive mainland in the North is marked N.

The areas included by fat interrupted lines represent the situation of the continents during the *Upper Carboniferous* according to *Frech* and *Vendl.*

living forms of the group are, in the author's opinion, apparently represented by the *Gnetaceae*, further, among the angiospermous forms, the *Monochlamydeae* in the one, and the *Ranales* in the other direction, i. e. by the greatest part of the *Dicotyledones*.

It seems to follow from the above that the *Monocotyledones* and the *Dicotyledones* had in all probability different ancestors, but one should keep an open mind on this assumption until further investigation has been made.

To sum up : the xylotomical findings of the present writer lead him to the conclusion that on the evidence of the ray structure of their members, the 9 or 7 existing families of the *Gymnospermae* and *Coniferae*, respectively, can be divided into three fairly well circumscribed evolutionary series each of which shows phyletic correlations with one of the three types of the *Pteridophyta*, víz. : 1. *Cycas*, *Ginkgo*, *Araucariaceae*, *Podocarpaceae*, and probably *Taxales* with the *Pteropsida ;* 2. *Cupressaceae* with the *Sphenopsida ;* 3. *Taxodiaceae* and *Pinaceae* with the *Lycopsida*. All this makes it probable that the *Gymnospermae*, including the *Coniferae*, are, like the *Pteridophyta*, not of monophyletic but at least triphyletic origin.

The theory of the gradual evolution of the ray structure as expounded in the foregoing appears to be substantiated by the present geographical distribution of the conifers. Examining the relationship between the type of ray structure and the geographical distribution of the existing genera and families in which they are found, it becomes clear that forms with the ancestral type of homogeneous and smooth-walled rays exist only on the Southern Hemisphere and in the coastal regions of East Asia. An unbroken line encompassing the present regions of the distribution of these forms on the Southern Hemisphere suggests conclusions regarding the remnants of Gondwanaland, a long vanished, immense continent (indicated in the map on p. ... by the letter "G").

Forms belonging to the second evolutionary series, i. e. in which the horizontal ray-cell walls are thickened, smooth or possibly pitted, the tangential walls invariably smooth and spiral thickenings still absent, are at present confined to very limited regions in East Asia and North America. The *Taxodiaceae* and the *Thuja*-like forms of the *Cupressaceae* grow in these places (indicated in the map by the letter "A").

The representatives of the third evolutionary series, i. e. the *Coniferae* with resin ducts in the rays, grow exclusively on the Northern Hemisphere. There exists only one species of *Pinus* that reaches the Equator.

Conifers with resin ducts are unknown south of the Equator. It is very probable that such conifers never existed on the Southern Hemisphere, for no reliable fossil conifers of this type have ever been unearthed there. It may be of interest to add that the primitive conifers existing at present on the Southern Hemisphere are all dioceious (except *Callitris* and *Widdrıngtonia*), whereas the geologically younger monoecious forms (except *Taxus* and species of the *Juniperus)* are limited in the main to the northern half of the globe. It merits special mentioning that 6 families of the *Coniferae* are represented by one ortwo, possiblyeven more, species in Southeast China. This territory (in the author's opinion a remnant of the Gondwana land) seems to have played an important part in the phylogenetic history of the conifers : types of the *Tertiary*, or even earlier periods, appear to have found a refugium there and survived.

On consideration of the xylotomical characteristics of the *Gymnospermae and Chlamydospermae* the writer conceives the evolution of the plant kingdom as represented by his phylogenetic chart inserted after p. 34. A division of the two groups according to evolutionary lines and their classification into evolutionary stages, is presented by his following system.

Evolutionary stage	**I.**	**Virophyta**		
	II.	**Anucleophyta**		
	III.	**Monadophyta**		
	IV.	**Algophyta**		
	1. Rhodophyta (?)	2. Phaeophyta (?) (Mykophyta	3. Chlorophyta (?) Lichenes)	
	V.	**Bryophyta**		
	?	2. Hepaticae	3. Musci	
	VI.	**Psilophyta**		
	1. Prosphenopsida	2. Propterpsida	3. Prolycopsida	
	VII.	**Pteridophyta**		
	1. Sphenopsida	2. Pteropsida	3. Lycopsida	
	VIII.	**Pteridospermae**		
	1. Calamitospermae	2. Pterispermae	3. Lepidospermae	
	IX.	**Gymnospermae**		
	1. Cupressospermae	2. Homospermae	3. Isospermae (Coniferae)	
	X.	**Chlamypospermae**		
	1. Ephedrales	2. Welwitschiales	3. Gnetales	
	XI.	**Angiospermae**		
	1. Verticillatae	2. Monocotyledones a) Liliflorae etc. b) Palmae etc.	3. Dicotyledones a) Dialipetalae etc. b. Monochlamydeae etc.	

*

In the opinion of the referees the writer's novel phylogenetic conceptions are of an individual character and they regret being unable to share his views.

CIRCUMSTANTIAL PART

A. KEY FOR THE IDENTIFICATION OF THE LIVING GYMNOSPERMAE AND CHLAMYDOSPERMAE, BASED ON XYLOTOMY

I. True vessels absent. Tracheids arranged in closely spaced parallel radial rows. Rays 1 (2) or 1—3 seriate. (Plate II, Figs. 1—15.)

I. Gymnospermae
(Cf. p. 67)

II. True vessels with wide lumina present, also other narrow-lumened wood elements. Distinct rays either absent *(Welwitschia)*, or 1, or up to 4—10, cells wide *(Gnetum, Ephedra)*. Ephedroid perforation (Pl. VII, Figs. 83—84).

II. Chlamydospermae
(Cf. p. 124)

I. KEY FOR THE IDENTIFICATION OF THE CLASSES OF THE LIVING GYMNOSPERMAE

A. Pith extensive. Wood not substantial and with no distinct growth rings. Rays 1—2, or 5—6, cells in width, occasionally very high. Bordered pits on radial and tangential walls of tracheids 2—4 seriate, alternate, araucaroid (Pl. IV, Fig. 34). In many tracheids very delicate, flattened spiral thickenings (Pl. 1.). Walls of parenchyma cells in homogeneous rays conspicuously thin and smooth. 4—20 minute araucaroid pits per cross field (Pl. VI, Fig. 68).

I. Cycadinae (Cycadales)
(Cf. p. 124)

B. Pith not extensive. Wood substantial. Bordered pits in tracheids opposite; twin pits and crassulae rather frequent. In wood parenchyma cells sporadically druses consisting of calcium oxalate (Pl. VII, Fig. 77). Occasional flattened spiral thickenings (Pl. III, Fig. 25b). Resin ducts absent.

II. Ginkgoinae (Ginkgoales)
(Cf. p. 125)

C. Wood substantial. Bordered pitting alternate or opposite. If present in wood parenchyma cells or rays calcium-oxalate crystals always prismatic (Pl. VII, Figs. 75—76).

III. Coniferae
(Cf. p. 67)

KEY FOR THE IDENTIFICATION OF THE FAMILIES OF THE CONIFERAE

I. *Cross section (C).* Growth rings indistinct (Pl. II, Fig. 3). In cross section tracheids commonly rounded. Resin ducts absent. In some species wood parenchyma with resin contents.

Radial section (R). Bordered pitting in radial walls of tracheids uni- or 2—5 seriate and alternate; pit borders hexagonal from crowding. Surface of contact between pits in a vertical row always a horizontal line (Pl. IV, Figs. 32—33). In the cross field 2—16 minute pits, occasionally scattered, sometimes in contact with one another, but mostly hexagonal from crowding (Pl. VI, Fig. 74). All walls of ray- and wood-parenchyma cells smooth and thin (Pl. VI, Fig. 68). Spiral thickenings

in tracheids commonly absent, in some species present but hardly discernible. Resin ducts absent.

Tangential section (T). Rays 1—20 cells high. Ray cells more or less barrel-shaped in cross section (Pl. III, Fig. 24), tangential walls occasionally pitted.

1. *Araucariaceae*

(Cf. p. 69)

II. *C.* Growth rings mostly indistinct. Tracheids in cross section commonly angular (Pl. II, Figs. 4—8), sometimes rounded (Pl. II, Fig. 3). Resin ducts absent. Wood parenchyma from abundant to missing.

R. Bordered pits in radial walls of tracheids 1—2—3 seriate, opposite, seldom contiguous (Pl. IV, Fig. 31); when touching, surface of contact between them commonly a vertical, very rarely a horizontal line. No spiral thickenings. In the cross field commonly 1—2 large, occasionally 3—4 smaller, circular or elliptical podocarpoid, rarely dacrydioid pits (Pl. VI, Figs. 67, 69). Pit aperture commonly a circle or an ellipse occupying almost the entire cross-field area, not infrequently slitlike with invariably oblique or vertical orientation. Occasionally a single pit occupies the whole area of the cross field (Pl. VI, Fig. 67). Rays being homogeneous are devoid of transverse tracheids. Horizontal and tangential walls of ray parenchyma cells smooth (Pl. VI, Fig. 67) with quite exceptional primary pitting in the horizontal walls and delicate punctate thickenings on the tangential walls. Indentures absent, or very rarely present in some species.

T. Rays 1—60 cells high, commonly uniseriate, sometimes with 1—2 paired cells in the body.

2. *Podocarpaceae*

(Cf. p. 75)

III—IV. *C.* Growth rings distinct or indistinct. Tracheids rounded or angular in cross section. Resin ducts absent. In some genera occasionally wood parenchyma.

R. In all tracheids relatively delicate spiral thickenings; spirals solitary, in pairs, in fours, or more closely spaced (Pl. III, Figs. 25—27). In the cross field 1—3 (4—6) round or obliquely positioned elliptical podocarpoid or cupressoid pits (Pl. VI, Fig. 71). In some species occasionally wood parenchyma with smooth, slightly thickened or nodular horizontal walls. Tangential walls of ray parenchyma always smooth (Pl. VI, Fig. 71), horizontal walls smooth, sporadically thickened, or sparsely pitted. Indentures rare. Transverse tracheids absent (Pl. V, Fig. 49).

T. Rays 1—28 cells high, biseriate in places.

3—4. *Taxaceae* and *Cephalotaxaceae (Taxales)*

(Cf. p. 83)

V. *C.* Growth rings distinct. Tracheids in cross section angular (P. II, Fig. 6) or rounded. Resin ducts absent. Wood parenchyma frequent, commonly with resin content (Pl. IV, Fig. 38).

R. In some species all walls of ray parenchyma smooth and thin (Pl. V, Fig. 53), in some others horizontal walls pitted and tangential walls smooth; but in most of them the horizontal walls are pitted while the tangential walls are thickened, unevenly punctate or beadlike (Pl. V, Fig. 51), or quite exceptionally dentate (Pl. V, Fig. 52). Horizontal walls of longitudinal parenchyma smooth or from slightly to markedly thickened, nodular (Pl. III, Figs. 20, 21). In the cross field 1—3 (4—5) *cupressoid*, *taxodioid*, or *podocarpoid* pits. Spiral thickenings absent. Transverse tracheids in some species rarely present.

T. Rays 1—30 cells high. Cells in cross section circles or upright ellipses. Tangential walls of ray cells smooth or with scalariform or sievelike thickenings (Pl. IV, Figs. 36, 37).

5. *Cupressaceae*

(Cf. p. 86)

VI. *C.* Growth rings markedly distinct. Tracheids in cross section always angular (Pl. II, Fig. 4). Resin ducts absent.

R. Bordered pits in radial walls of tracheids 1—2—3 (5) seriate (Pl. IV, Fig. 30), mostly scattered and *opposite*. Horizontal walls of ray parenchyma from smooth (Pl. III, Figs. 20) to sparsely or fairly pitted (Pl. III, Fig. 21, 22). Tangential walls commonly smooth, with 1—2 punctate thickenings. Spiral thickenings and resin ducts absent. Wood parenchyma present (except in *Sciadopitys)*, in some species also transverse tracheids *(Sequoia sempervirens)*. In the cross field 1—5 (6) mostly taxodioid pits (Pl. VI, Fig. 72), i. e. the wide apertures included in the procumbent elliptical border are as a rule horizontally oriented. The apertures are round (Pl. V, Fig. 50), occasionally slitlike. Indentures commonly absent, in some species occasionally present.

T. Rays 1—60 cells high (Pl. IV, Fig. 43), sometimes with 1—2 or 8—10 paired cells in the body. Tangential walls of ray cells generally smooth.

6. *Taxodiaceae*
(Cf. p. 103)

VII. *C.* Growth rings invariably distinct (Pl. II, Figs. 2, 7—12, 15). Tracheids in cross section always angular (Pl. II, Fig. 7), exceptin the latewood of some species where they are rounded. Resin ducts present (Pl. II, Figs. 7—9, 12) or absent (Pl. II, Fig. 5). Walls of epithelial cells lining resin ducts thin or thick (Pl. II, Figs. 7—9).

R. Rays homogeneous (Pl. IV, Fig. 42) or heterogeneous (Pl. IV, Fig. 39). Homogeneous rays with commonly minute simple pits in all three walls (Pl. V, Fig. 52), but then the wood is without resin ducts *(Abies, Keteleeria, Pseudolarix)*. In some species thick- and thin-walled ray parenchyma *(Picea, Pinus, Abies.* Pl. V, Fig. 48). Tangential walls of ray cells in radial section generally thickened dentate, occasionally beadlike, exceptionally smooth (Pl. V, Figs. 50—52). In the cross field 1—6 (8) pinoid (Pl. V, Figs. 45, 46), or 1—4 (8) piceoid (Pl. V, Fig. 55) or taxodioid pits. Wood parenchyma present or absent. Spiral thickenings frequently absent, occasionally present, especially in latewood tracheids of some species ; sometimes present in all tracheids but then accompanied by transverse tracheids and resin ducts *(Pseudotsuga)*.

T. Rays 1—45 cells high and uniseriate, occasionally 2—5 seriate, particularly those containing resin ducts.

7. *Pinaceae*
(Cf. p. 107)

KEY FOR THE IDENTIFICATION OF THE GENERA AND SPECIES OF THE FAMILY IN THE CONIFERAE

1. KEY FOR THE IDENTIFICATION OF THE GENERA AND SPECIES OF THE ARAUCARIACEAE

This family includes two genera : *Araucaria* and *Agathis*, each readily separated from the other coniferous genera by virtue of exceedingly characteristic xylotomical features in their species and equally detectable in sections cut in either of the three main planes.

A study of the *transverse section* reveals that while in some species, primarily in those of the *Araucaria*, the growth rings are indistinct and the delimitations practically imperceptible, in others, in the first place in those of *Agathis*, they are clearly defined and the transition from early- to latewood is gradual ; moreover, in a few species the tracheary walls are markedly thinner in the early- than in the latewood. These discrepancies may be regarded as an aid in separating the two genera, but remain a rather unreliable aid in view of the existence of an *Agathis* species *(A. ovata)* with practically imperceptible growth rings and delimitations, and of an *Araucaria* species *(A. balansae)* in which the limits of the growth rings are fairly conspicuous.

In contrast with other coniferous genera where they have commonly rounded corners, the lumina of the tracheids are angular. Since the primary layers of the wall of tracheids are smooth and the *secondary* walls are thicker in the corners, the wall structure in this case appears to be collenchyma-like. However, at other times the tracheary lumina are angular without collenchymatous thickenings in their walls.

The lumina of the tracheids vary in diameter from 20—30—50 to 100 μ. The number of tracheids per sq. mm varies accordingly. Changing with the age and the habitat of the tree this number is of little diagnostical value, except in a very few species where it is otustanding.

The horizontal walls of the *rays* are perfectly smooth and unpitted. The tangential and radial walls of rays likewise appear to be smooth.

Resinous material is sometimes accumulated in the tracheids. Occasionally the walls of cells containing resin are very thin, suggesting that these cells are really *parenchyma cells*. Parenchyma cells of this kind have not yet been observed except in the species of *Agathis*.

The *tangential section* supplies information concerning the structure of tracheids and rays. The tangential walls of the tracheids are commonly smooth, yet sometimes with uniseriate, or biseriate

and always alternate pitting. The pits in the tangential walls are always smaller (5—12 μ) than those in the radial walls. The apertures are circular, short-elliptical or slitlike ; occasionally, those of complementary pits form X figures. In the tracheids of some species *(Araucaria balansae)* there are spirals, referred to by GOTHAN as striations, which he attributes to mechanical and chemical changes in the wood. It is remarkable that their appearance is restricted to a few species, and that as a rule they follow one another at regular intervals. Transverse resin plates and trabeculae appear occasionally in fairly large numbers.

Rays commonly vary in height from 1 to 15 cells. Higher rays (20—25) are rare. Particularly high rays are to be found in *Agathis microstachya* (25—40) and *A. palmerstonii* (20—32). In cross section the ray cells are generally barrel-shaped, occasionally elongate or circular. Their tangential walls are always devoid of pitting, perfectly smooth, apart from occasional sporadic dots. On the other hand, the walls of some individual marginal cells, e. g. in *Araucaria balansae*, thicken considerably and make the cells look as if they were idioblasts; they are, in all probability, thick-walled parenchyma cells.

Depending on age and, to some extent, on habitat, ray height is not always a useful diagnostic feature. As regards the number of rays and ray cells per square millimeter, this sometimes varies widely with the individual species, as can be seen from the pertaining table attached to this book.

In the *radial walls* of the tracheids the bordered pits are 1—4 (6) seriate. When uniseriate, the pits are generally contiguous and the lines of junction between them are horizontal straight. In some cases the pits are angular. Uniseriation appears to be a characteristic of certain species, but it is not impossible that in aged trees this feature, too, undergoes a change. When 2—3—4—5 seriate, particularly in the earlywood, the bordered pits suggest a design made in mosaic, or a honeycomb, the inner ones being penta- or hexagonal from crowding ; this is the typical araucaroid pitting.

The apertures of the bordered pits are circles or somewhat oblique short ellipses and are always included. It is interesting to note the pit structure in *Agathis robusta*, in which the apertures, instead of being oblique or vertical in alignment, are horizontal, i. e. identical with those observed in the extinct *Cycadofilices* and *Cordaites*. This remarkable phenomenon seems to favour the existence of some connection between *Cycadofilices*, *Cordaites* and *Araucariaceae*.

Wood parenchyma has so far not been observed except in *Agathis* species. The walls of the parenchyma cells are very thin (0,5—1 μ), the horizontal walls smooth, and the tangential walls sometimes provided with elliptical to circular simple pits *(Agathis microstachya* and *A. palmerstonii)*.

Rays normally consist solely of parenchyma cells. Their horizontal and tangential walls are quite thin and smooth, without any indentures. Exceptionally, in a few species the walls of one or the other marginal cell are rather thick *(Araucaria balansae)* with minute pits in them corresponding in shape and arrangement to the pits in the thin-walled ray cells. The rays in some species *(Agathis macrophylla)* contain thin- as well as thick-walled cells ; the pits in the thick walls sometimes appear as bordered, sometimes as simple pits. These cells are in all probability sometimes rather elongated, at other times quite short, thick-walled parenchyma cells.

The pitting in the ray cells is very characteristic, but it should be borne in mind that the pits visible in the cross field are really those in the tracheary walls in back of the thin-walled ray cells, and showing through the latter. The pits in the cross field vary in number and arrangement. Some species are characterized by 1—6—8, others by 8—12, yet others by as much as 16, pits per cross field. The pits are either apart or crowded to form 2—3 horizontal or as many vertical rows. This type of arrangement may be an aid in specific identification. The apertures are normally short ellipses or blunt rods, occasionally slits, but never extended.

In pits standing apart, the circular or elliptical apertures are encircled by an annular border *(Araucaria bidwillii)*. In *Agathis robusta* the apertures are horizontal similarly to those in *Cycadofilices* and *Cordaites* already mentioned.

In the ray cells yellowish or reddish brown contents are sometimes present ; these substances are identical with those in some longitudinal tracheids and wood parenchyma cells, respectively. The rays of some species show quite thin resin plates and trabeculae. These are true resin plates, and not the horizontal walls of parenchyma cells, since their two ends adhere like thin plates on a fairly long stretch to the thick longitudinal walls of the tracheids.

Summarizing what has been said above it would appear that by virtue of their xylotomical charac-

teristics the *Araucariaceae* are readily distinguished from all the other families of the *Coniferae*. From the point of view of xylotomy it would be justified to class them in a family of their own.

The situation is different in regard to differentiation within the family by genera and species. Xylotomically, the species included in the genera *Agathis* and *Araucaria* have so many features in common that their separation is not easy at all; one may say it is very difficult and doubtful, almost impossible. In the following, separation is attempted nonetheless and at the risk that, since the xylotomical features are subject to changes and modifications dependent on the age and habitat of the tree as also on whether the sample examined is from a stem or a limb, the key suggested may in many instances fail to yield reassuringly exact results. About 18 species are known of *Agathis* and 16 to 17 of *Araucaria*, and 15 have been worked up by the writer of the former and 14 of the latter to furnish the basis for the following

KEY

for use in determining the genera: —

I. Growth rings indistinct. Diameter of lumina and wall-thickness of tracheids roughly the same throughout the genus, therefore no sharp distinction between early- and latewood (e. g., *Agathis robusta)*. In some individual tracheids resinous contents and minute resin plates. Number of pits per cross field 2—8 (10), rather congested and commonly aligned in 2—3 vertical rows. Ray pits 5—13 μ in diameter. Wood parenchyma absent or very sparse.

Araucaria
Pls. 16—29, p. 134

II. Growth rings inconspicuous, yet definable, their delimitations occasionally clear *(Araucaria araucana, A. cunninghamii)*. Transition from early- to latewood gradual. Occasional wood parenchyma. Number of pits per cross field 2—8 (10—16), arranged in 1, 2, 3 horizontal, rarely vertical, rows, usually hexagonal from crowding, yet sometimes almost apart.

Agathis
Pls. 3—15, p. 127

In the following is presented the

KEY

for use in the identification of the *Araucaria* species.

I. Number of pits per cross field 1—6 (8). If pits not contiguous, the circular or elliptical apertures (measuring 6 ×4 μ to 10 ×11 μ), surrounded by a roughly annular border (7—11 μ in size). In these cases the pits are aligned in 1 or 2 horizontal rows, in others, the large pits are polygonal from crowding and usually arranged in 2 vertical rows. Number of tracheids per sq. mm. 1100—1150; of rays 18—20; of ray cells 30—40.* Height of ray cells 22—24 (26) μ. (*Y.*, *M.*, 56.)**

Araucaria bidwillii HOOK
Pl. 20, p. 136

II. Number of pits per cross field 6—8 (10—14), aligned in 2—3 vertical rows. Pit diameter 6,5—7 μ, but in tangential walls of tracheids only 5,5—6 μ. Spiral striation in places readily discernible, particularly in early tracheids. In cross section, tracheary lumina with rounded corners. Number of tracheids per sq. mm. 1700; of rays 25—30; of ray cells 55—60. Height of ray cells 25—40 μ, width 16—18 μ. Marginal cells in some rays quite thick-walled; walls with 10—12 flattened angular pits similar in form and size to those found in inner ray cells. (*Y.*, *M.*, 56.)

Araucaria balansae BRONGN. et GRIS.
Pl. 18, p. 135

III. In the cross field 4—10 comparatively large pits (10—13 μ) crowded or arranged somewhat loosely *(A. klinkii, A. columnaris, A. montana, (A. angustifolia, A. excelea.)*

A. Number of pits per cross field 2—3 (4), in marginal cells. 5—6. Diameter of pit borders 10—12 μ; height of apertures 6—7 μ, their width 2—3,5 μ. Slitlike aperture practically always vertical. Height of rays 1—16 cells. Number of tracheids per sq. mm. 700; of rays 12—13; of ray cells 65—70. Height of ray cells 25—35 μ, their width 16—18 (20) μ. Vertical diameter of bordered pits in radial walls of tracheids 15—18 μ. Bordered pits in radial walls of tracheids commonly uniseriate or biseriate. (*M.*, 56.)

Araucaria klinkii LAUTERB.
Pl. 26, p. 139

B. Number of pits per cross field 2—12, their short, linear or elliptical apertures almost vertical. Per sq. mm.: 600 tracheids, 15—18 rays, and 90—95 ray cells. Height of ray cells 30—35

** *M.* = mature wood, *J.* = young wood.

* Number of tracheids counted on transverse surface, that of rays and ray cells on tangential section.

(40) μ, width 18 μ. Bordered pits in radial walls of tracheids usually biseriate and 16—17 μ in diameter; in tangential walls uni- or biseriate, and only 12—13 μ in diameter. (*Y.*, *M.*, 56.)

Araucaria columnaris (FORSTER) HOOK.
Pl. 21, p. 137

C. In the cross field 3—9 loosely arranged or crowded pits (10—11 μ). Pit apertures slitlike and commonly vertical, in earlywood oblique ellipses. Per sq. mm.: 550—560 tracheids, 25—30 rays and 90—100 ray cells. Height of ray cells 30—40 μ, width 13—14 μ. Height or rays 1—20 (22) cells. In radial walls of tracheids bordered pits (11—12 μ) in 2—3 rows, those in the tangential walls (11—12 μ) sporadically in 1—2 only. (*M.*, 56.)

Araucaria montana BRONGN. et GRIS.
Pl. 27, p. 140

D. In the cross field 1—5 (7—9) large contiguous pits, 7—9 μ in diameter. Apertures short linears or slitlike, vertical or canted from the vertical orientation. Singly occurring pits sometimes conspicuously large, 10—11 μ in diameter. Height of rays 1—10 (15) cells. Per sq. mm: 1200 tracheids with rounded lumina. About 28—30 rays and 110—125 ray cells per sq. mm. Height of ray cells 20—22 μ. (*M.*, 56.) *Araucaria angustifolia (Bertoloni)* O. KTZE.

A. brasiliana RICH.
Pl. 16, p. 134

E. In the cross field 1—4 congested pits, 8—9—10 μ in diameter. Apertures circular or almost upright short ellipses. Height of rays 1—8 cells. About 3500 tracheids, 80—90 rays, and 260—270 ray cells per sq. mm. Height of ray cells 20—25 (28) μ, width 16—18 μ. Diameter of bordered pits in tangential walls 7—7,5 μ, in radial walls 9—10 μ. Frequent occurrence of resin plates in rays and tracheids. (*M.*, *Y.*, 56.)

Araucaria excelsa R. BR.
Pl. 24, p. 138

IV. Pits in cross field relatively small (5—10 μ).

A. In the cross field 1—4, in the marginal cells 6—8 loosely connected pits, each 5—6 μ, in two vertical rows. Tracheids in cross section rounded, squarish in the latewood. Per sq. mm. 2900—3000 tracheids, 32—33 rays, and 60—62 ray cells. Height of rays 1—4 (6) cells. Height of ray cells 18—20 μ, width 9—10 μ. Bordered pits in radial walls of tracheids commonly uniseriate, rarely biseriate, 12—13 μ in diameter. Spiral thickenings or striations in some tracheids.

Araucaria rulei F. MÜLL.
Pl. 29, p. 141

B. In the cross field 3—5, exceptionally 9 pits, 6—8 μ in diameter. Number of rays per sq. mm. 15—20, of ray cells 70—80. Rays always uniseriate, 1—6, very rarely 20, cells high. Height of ray cells 21—27 μ, but, when single, up to 40 μ; they attain 13—27 μ in width. Bordered pits in radial walls of tracheids 13—14 μ in diameter, commonly uniseriate, occasionally biseriate and then alternate. Longitudinal parenchyma absent. All ray-cell walls thin. Number of tracheids per sq. mm. 1000. (*M.*, 56.)

Araucaria beccarii WARB.
Pl. 19, p. 136

C. Lumina of tracheids, at least in earlywood, squarish.

a. In the cross field 3—5, in the marginal cells 5—6 (7) congested pits, 7—7,5 μ in diameter. Apertures short elliptical. Height of rays 1—10 cells. Per sq. mm. 1900 tracheids, 55—60 rays, and 180—190 ray cells. Height of ray cells 22—24 (35—40) μ. Resin contents frequent in ray cells. Pits uniseriate, rarely biseriate in radial walls of tracheids, 11—12 μ in diameter. Identically arranged in tangential walls, 10—11 μ in diameter. *Araucaria cunninghamii* SWEET *var. glauca (Lodd.)* (*Y.*, 56.) ANTOINE
Pl. 23, p. 138

b. In the cross field 4—8 (12) congested pits, 7—8 μ in diameter. Height of rays 1—7 (8) cells. Per sq. mm. 2300 tracheids, about 25 rays, and 60—65 ray cells. Height of ray cells 20—22 (40) μ. Bordered pits in radial walls of early tracheids generally biseriate, in late tracheids uniseriate, 13—14 μ in diameter; in tangential walls sparse and uniseriate, 8—9 μ in diameter. (*M.*, 74.)

Araucaria cunninghamii SWEET
Pl. 22, p. 137

c. In the cross field 1—6 (8) pits commonly standing apart, 4,5—5 (6) μ in diameter. Rays 1—8 cells high. Height of ray cells 24—35 μ, width 17—18 μ. Ray cells barrel-shaped. Per sq. mm. 1900—2000 tracheids, 70—75 rays, and 170—180 ray cells. Bordered pits in radial walls of tracheids commonly uniseriate, 14—15, exceptionally 18, μ in diameter. Diameter of pits in tangential walls 10—11 μ. (*M.*, *Y.*, 56.)

Araucaria araucana (Molina) K. Koch
(A. imbricata Pav.)
Pl. 17, p. 135

d. In the cross field 2—4, in the marginal cells 5—6 congested pits, commonly in two vertical rows, 6,5—7 μ in diameter. 1400 tracheids, 55 rays, and 100—110 ray cells per sq. mm. Height of rays 1—4 (7) cells. Height of ray cells 20—22 (28—30) μ, width 17—18 μ. Bordered pits in radial and tangential walls of tracheids commonly uniseriate, 11 μ in radial and 6 μ in tangential walls. (*Y.*, 56.)

Araucaria humboldtiensis Buchh.
Pl. 25, p. 139

e. In the cross field 4—6, in the marginal cells 6—8 congested pits, commonly in 2 vertical rows, 6,5—7 μ in diameter. Per sq. mm. 2100 tracheids, 50—52 rays, and 110—120 ray cells. Rays 1—6 (10) cells high, Height of ray cells 22, cometimes 30—32 μ, width 17—18, sometimes 24—26 μ. Bordered pits in radial walls of tracheids 1—2 seriate and 10—12 μ in diameter; in tangential walls uniseriate, in smaller fields sometimes biseriate and 10—12 μ in diameter. (*M.*, 56.)

Araucaria mulleri Brongn. et Gris.
Pl. 28, p. 140

In the following is presented the

KEY

for use in identification of the *Agathis* species : —

I. In the cross field 1—3 (6), in the marginal cells 2 isolated pits in 2—3 horizontal rows. The elliptical pits 7,5—8,5 (11) μ in diam.; apertures oblique and 2—3 μ wide. Rays with thick- and thin-walled parenchyma cells. Thick-walled parenchyma cells 26—28 μ high, their walls 6,5—7 μ thick. Diameter of bordered pits 7—8 μ, that of apertures 3—4 μ. 850—900 tracheids, 25—30 rays, 80—90 ray cells per sq. mm. Rays 1—18 cells high. Height of ray cells 26—32 μ, width 20—22 μ. Pits showing through the tangential walls of wood parenchyma 8—9 μ in diam. and commonly aligned in a single row. (*M.*, 56.)

Agathis macrophylla Mast.
Pl. 10, p. 130

II. Rays only with thin-walled parenchyma cells. Wood parenchyma commonly present, rarely absent.

A. In the cross field 2—4—12 pits in 1—3 horizontal rows. Diam. of pits 7—8 μ, size of apertures 5—6 $\times$ 2—3 μ. Height of rays 1—25 (40) cells. 500—550 tracheids, 18—20 rays, and 115—120 ray cells per sq. mm. Rays 22—30 high, 18—20 μ in width. (*M.*, 56.)

Agathis microstachya Bailey et White
Pl. 11, p. 131

B. Rays 1—25 cells high.

a. In the cross field 6—16 (22) contiguous pits in 1—3 horizontal rows, and 9—11 μ in diam. 450—500 tracheids per sq. mm. Lumina of tracheids in earlywood rather angular, tetra- or penta- or polygonal, only rounded in 1—2 rows of latewood. 12—15 rays, 120—130 ray cells per sq. mm. Certain ray cells conspicuously different in size, 20—28 (30) μ, in width 10—18 μ. Bordered pits in radial walls of tracheids in 2—3 (4) rows, in 1—2 rows on tangential walls.

Agathis lanceolata (Pancher) Warb.
Pl. 9, p. 130

b. In the cross field 4—10 (12) pits, generally in 2, in the marginal cells in 3, horizontal rows; pits in earlywood hardly in contact. Pits 7,5—9 μ, apertures 4,5—5,5 μ in diam. Ray cells roughly identical in cross section. 480—500 tracheids, 20—25 rays, and 100—120 ray cells per sq. mm. Height of ray cells 30—32 μ, width 18—20 μ. Bordered pits in radial walls of tracheids in 2—4 (5—6) rows and 11—12 μ in diam. (*M.*, 56.)

Agathis palmerstonii F. v. Mueller
Pl. 14, p. 133

c. In the cross field 3—6 (10—12) pits, commonly in 2—3 horizontal rows. Pit diameter 10—11 μ, that of almost vertical apertures 8—9 μ. Pits seldom contiguous. Rays 1—10 (12), exceptionally 20 cells high. Certain rays biseriate in the middle. 700—800

tracheids, 30 rays, and 180—190 ray cells per sq. mm. Height of ray cells 20—35 μ, width 18—22 μ. Bordered pits in radial walls of tracheids 1—3 seriate, regularly penta- or sexagonal, some of them vestured. Pit apertures short ellipses, 6,5—7 μ (14—16) in diam., those of complementary pits occasionally forming X figures.

Agathis australis SALISB.
Pl. 4, p. 127

C. Height of rays 1—8 cells.

a. In the cross field 1—3 (6—10) pits, 7—9 μ in diam., with apertures of 4,5—6 μ. Per sq. mm 2200—2300 tracheids, 110 rays, and 180—190 ray cells. Tracheids in cross sections round or hexagonal; lumina always round. Height of ray cells 24—26 (30—34) μ, width 16—17 μ. Apertures of bordered pits in radial and tangential walls of tracheids as well as apertures of pits of rays horizontal. (*M.*, 56.)

Agathis robusta MAST.
(*A brownii* L. H. BALEY)
Pl. 15, p. 133

b. In the cross field 4—6 contiguous pits, 7—8 μ in diam. Apertures short, .inear and almost vertical, 5—6,5 μ in diam. Per sq. mm. 2500—2600 tracheids, 80 rays, 120 ray cells. Tracheids thin-walled, angular or hexagonal in cross section. Wood parenchyma sparse, occasionally with round simple pits in the radial walls. Rays 1—2 (4) cells high. Height of ray cells 16—30 μ. Pits in radial walls of tracheids 12—13 in diam.

Agathis hypoleuca C. MOORE
Pl. 8, p. 129

III. Wood parenchyma absent or very rare.

A. In the cross field 4, in the marginal cells 5—6, fairly large pits compressed in 2 vertical rows; pits 10—11, apertures 6—6,5 μ in diam. Lumina of tracheids nearer 4—5 sided than rounded. Per sq. mm. 2100 tracheids, 55 rays, and 125—130 ray cells. Rays 3—5 (7—8) cells high. Height of ray cells 23—30 μ. Bordered pits in radial walls of tracheids uni- or biseriate, 12—14 μ in diam. Pits on tangential walls sparse and uniseriate, 11—12 μ in diam. (*M.*, 56.)

Agathis moorei (Lindley) MAST.
Pl. 12, p. 132

B. Lumina of tracheids in cross section, even in earlywood, nearer to rounded than to squarish. Rays 1—8 cells high.

a. In the cross field 1—3 fairly isolated pits, in the marginal cells 6—8 (10) pits crowded, commonly in two rows. Pits 7,5—9, apertures 6,5—7,5 μ in diam. Per sq. mm. 3600—3700 tracheids, 80—90 rays, and 150—160 ray cells. Rays 1—7 cells high. Height of ray cells 18—24 μ, width 14—16 μ. Pits in radial walls of tracheids 1 (2) seriate. Tracheids occasionally with resinous contents. Wood parenchyma very rare. (*M.*, 56.)

Agathis alba (Rumphius) WARB.
Pl. 3, p. 127

b. In the cross field 1—8, in the marginal cells 14—16 pits in 2—4 close vertical rows. Pits 6—7 μ, apertures 4,5—5 μ in diam.Rays 1—8 cells high.

(*M.*, *Y.*, 56.) *Agathis ovata (Moore)* WARB.
Pl. 13, p. 132

c. In the cross field 1—5 pits 6—8 μ in diam. Number of rays per sq. mm. 25—30, that of ray cells 120—125. Rays commonly 3—6, exceptionally 15, cells high and always uniseriate. Height of ray cells 16—35 μ, width 13—18 μ. Tangential walls with bordered pits 13—14 μ in diam. Bordered pits in radial walls 1—2 seriate and 16—18 μ in diam. All ray-cell walls thin. About 1000 tracheids per sq. mm. (*M.*, 56.)

Agathis celebica WARB.
Pl. 7, p. 129

d. In the cross field 2—5, exceptionally 15, pits 5—8 μ in diam. Number of rays per sq. mm. 12—15, that of ray cells 60—65. Rays normally 2—4, exceptionally up to 12, cells high and always uniseriate. Ray cells 21—27 (40) μ high and 8—16 μ wide. In tangential walls bordered pits, 10—13 μ in diam. In radial walls of tracheids pits 13—16 μ in diam., usually in one, not infrequently aligned in 2—3 rows. All ray-cell walls thin. Indentures absent. About 750 tracheids per sq. mm. (*M.*, 56.)

Agathis beccarii WARB.
Pl. 5, p. 128

e. In the cross field 2—4 (5) pits 8—10 μ in diam. Number of rays per sq. mm. 12—15, that

of ray cells 80—85. Rays 4—6 (12) cells high and uniseriate. Ray cells usually 16—27 μ high and 8—16 μ wide. In tangential walls pits 10—13 μ in diam. In radial walls pits 13—17 μ, commonly 1—2 seriate. All ray-cell walls smooth. Indentures absent. About 950—1000 tracheids per sq. mm. (*M.*, 56.) *Agathis borneensis* WARB.

Pl. 6, p. 128

2. KEY FOR THE IDENTIFICATION OF THE GENERA AND SPECIES OF THE PODOCARPACEAE

According to PILGER, this family includes the genera *Acmopyle*, *Dacrydium*, *Microcachrys*, *Pherosphaera*, *Phyllocladus*, *Podocarpus*, *Prumnopitys* and *Saxegothaea*. Apart from *Pherosphaera* and *Saxegothaea*, these genera display fairly uniform xylotomical features: the growth rings are distinct or indistinct; the rays vary in height from 5—6 to as many as 50 cells: they are uniseriate, but occasionally have 1—2 (3) paired cells in the body: in cross section they are uprightly elliptical or nearly circular; the tangential walls of tracheids are generally with bordered pits, but sometimes smooth; the cells occasionally contain a resinous substance.

The bordered pits in the radial walls of tracheids are commonly arranged in one, frequently in two, exceptionally in three rows; when in one or two, the pitting is opposite, never alternate. When uniseriate, the pits either stand apart, or touch, or press against each other with horizontal surfaces of contact between them. When biseriate, the contact surfaces mostly form a vertical line. Spiral thickenings absent; in the early tracheids of some species occasional spiral striation.

Rays composed of parenchyma cells only. Transverse tracheids and resin ducts absent. Commonly, all ray-cell walls thin and smooth; an important feature characterizing the family. Very rarely, in some species, there are thinnings or simple pits in the horizontal and radial walls *(Podocarpus macrophyllus)*, but the tangential walls are always smooth except for a very few nodules of pin-prick size. Cross field sometimes occupied by a single large rounded, or squarish, or elliptic pit *(Phyllocladus* and *Podocarpus spicatus)*; sometimes by one that is nearly circular *(Dacrydium)*, „*circoporoid*" according to KRÄUSEL. On other occasions, the cross field is occupied by several minute *podocarpoid* or *taxodioid* pits, i. e., in the somewhat obliquely placed pit the aperture, too, is oblique *(Podocarpus)*. Not infrequently there are no pits at all in some of the cross fields. Horizontal pits have more or less horizontal apertures *(Podocarpus minor)*.

Tangential ray-cell walls commonly at right angles, occasionally at slightly oblique angle to the horizontal walls. Indentures absent.

Horizontal walls of wood parenchyma thin and smooth in all genera; this, too, is a characteristic feature of the family.

Saxegothaea and *Pherosphaera* are grouped by several authors with the *Podocarpaceae*, but on the evidence of their xylotomy they do not fit this family, primarily because the horizontal ray-cell walls in them, and particularly in *Saxegothaea*, are markedly pitted, and the horizontal walls of the wood parenchyma are also invariably provided with pits, whereas these two features are absent in all the members of the *Podocarpaceae*. In addition, the pits in their cross fields are more *cupressoid* than *podocarpoid* in character. Lastly, their tangential ray-cell walls display almost beadlike thickenings, which is a feature characterizing eminently the *Cupressaceae*. Obviously, then, on the basis of their xylotomy these two genera cannot be attached to the *Podocarpaceae* unless as supplements. Besides, both of them are monotypic, and PILGER himself assigns them an isolated place in the family. Xylotomically, there would be more justification for their being classed in the *Cupressaceae*, from which their external morphology apparently excludes them. The best way out would be to create for them a family of their own.

On the other hand, xylotomical evidence seems to favour the inclusion into this family of *Sciadopitys*, which show great likeness to the *Phyllocladus*, and also of *Austrotaxus*, which definitely are podocarp in character. The only reliable xylotomical feature by which to separate *Sciadopitys* from *Phyllocladus*, is the difference in the size of the bordered pits in the radial tracheary walls. In the first, these pits are commonly 13—15 μ, in the latter, only 9—13 (15) μ in diam. The idea of inclusion seems to find additional support in the interesting fact that while *Sciadopitys* possess leaflike cladodes, *Phyllocladus* have likewise leaflike

phylloclades; in other words, neither of them develops regular foliage leaves. In view of their remarkable xylotomical similarity and in order to facilitate comparing them, these two genera are placed side by side in this work. Xylotomically, *Austrotaxus* should by all means be referred to this family, as has been emphasized by several authors, amongst them by PHILLIPS and VIEILLARD.

In the following is presented a

KEY

for the identification of the genera of the *Podocarpaceae*.

I. Wood parenchyma absent.

a. Bordered pits in radial walls of tracheids 9—13 μ in diam. In the cross field a single, in the marginal cells sometimes two, large pits of the *Pinus silvestris* type, 10—14—24 μ in diam. and occupying the entire area. Rays 1—14 (20) cells high.

Phyllocladus
Pls. 40—43, p. 145

b. Bordered pits in radial and tangential walls of tracheids scattered, the former 13—15 μ, the latter 8—9 μ in diam. Per sq. mm. 2000 tracheids, 32—35 rays, and 110—115 ray cells. Tracheids in cross section definitely squared. Growth rings distinct. Width of late zones 10—14 cell layers. Rays 1—7 (9—10) cells high. Height of ray cells 14—20 (24) μ, width 12—18 μ. Cross-field area occupied by 1 (2) large pit, the shape of a procumbent ellipse and 15—20 (22) μ in diam; in latewood, pit rather an upright ellipse. (*M*., 126, 44, 74)

Sciadopitys verticillata SIEB. et ZUCC.
Pl. 72, p. 147

II. Wood parenchyma present; horizontal walls of ray parenchyma always smooth.

A. In the cross field commonly one large pit, squarish with rounded corners or elliptical and 7—14 μ in diam.; occasionally, principally in the marginal cells, 3—4 pinoid-like pits, also 7—14 μ. Per sq. mm. 3700 tracheids, 100—110 rays, 330—310 ray cells. Tracheids in cross section squared. Growth rings narrow, 4—20 cells in width. Growth ring delimitation marked by 2—3 rows of flattened tracheids. Rays 1—8 (10) cells high. Height of ray cells 14—17 (18) μ, width 7—8 (9) μ. On tangential ray-cell walls here and there 1—2 almost imperceptible nodules. In the cross field 1—2—3 (4) pinoid pits, 7—14 μ in diam. Wood parenchyma scarce. Bordered pits in radial and tangential walls of tracheids scattered; the former 12—14, the latter 7—8 μ in diam. (*M*., 129, 54)

Microcachrys tetragona HOOK. F.
Pl. 39, p. 144

B. Cross-field area occupied by one, seldom two, circular or short-elliptical (dacrydioid) pits, 8—24 μ in diam., attaining from 3/4th to 4/5th of the height of the ray cells (18—24 μ). Some cross fields without pits.

Dacrydium
Pls. 32—38, p. 143

C. In the cross field commonly one, seldom two, *podocarpoid* pits of less than half the height of the ray cells (7—18 μ); when circular or short-elliptical, they may attain ray-cell height (e. g., in *Podocarpus wallichianus*, *P. elatus*).

Prumnopitys, *Podocarpus*
Pls. 45—71, p. 145—146

D. In the cross field 1—2, in the marginal cells 3—4, pits with 8—10 μ diam., commonly in diagonal arrangement, with apertures included or just reaching the pit annulus. Rays 1—3 (5—6) cells high. Number of tracheids per sq. mm. 3000——3300. In cross section, lumina of tracheids nearly circular in latewood, squared in earlywood but with the corners rounded; they measure 30 $\times$40 μ. Growth rings almost indiscernible. Wood parenchyma scattered. Per sq. mm 75—80 rays, 100—110 ray cells. Height of ray cells 30—34 μ, width 12—15 μ. Bordered pits in radial walls of tracheids scattered, 10—12 μ in diam. Apertures sometimes extended, those on tangential walls 6—7 (10—12) μ in diam. Slits vertical. Resin contents present in rays and wood parenchyma. (*M*., 129, 54)

Austrotaxus spicata COMPT.
Pl. 31, p. 142

E. In the cross field 1 (2) podocarpoid pits with diameters of 14—15 and 9 $\times$6 μ, respectively. Rays generally 1—3, sometimes up to 6, cells high. Number of tracheids per sq. mm. 2500. Growth rings fairly distinct. Diam. of early tracheids 25——30 μ; their wall thickness 1,5—2 μ. Radial

diam. of late tracheids 9 μ; tangential diam. 22—24 μ. Tracheids in cross section tetra- or polygonal, normally with rounded corners. Wood parenchyma scarce. Number of rays per sq. mm. 100—110, that of ray cells 170—175. Height of ray cells 20—28 μ, width 10—12 μ. Horizontal and tangential walls of rays smooth, with occasional thinnings. Pits in radial walls of tracheids scattered, sometimes appressed araucarian fashion and with horizontal lines of contact between them. Pits included, their diam. 13—14 μ. Apertures measure 6 $\times$4 μ. In tangential walls diam. of pits 10—11 μ; apertures vertical. In radial walls of wood parenchyma simple pits, 6—7 μ in diam. (*M.*, 129, 51)

Acmopyle pancheri PILGER.
Pl. 30, p. 142

In the following is presented a

KEY

for the identification of the species of the individual genera.

Dacrydium (about 20 known species).

I. In the earlywood, entire area of cross field occupied by one or two large pits. Rays 1—20 cells high.

A. Wood parenchyma absent or very rarely present. In the cross field generally one, in the marginal cells sometimes two, superposed, large, *Pinus silvestris* type pits with a diam. of 16—24 μ occupy almost the entire area. Pit apertures oblique ellipses or lachrymiform. Rays 1—12 (18) cells high. Height of ray cells 14—16 (20) μ, width 9—10 μ. Number of tracheids per sq. mm. 3000. Tracheids in cross section squared, in the latewood occasionally with rounded corners. Growth ring delimitation fairly distinct. Latewood 8—10 tracheids in width, with walls thicker than in early tracheids. Number of rays per sq. mm. 90—100, that of ray cells 340—360. Bordered pits in radial walls of tracheids scattered and 11—14 μ, those in tangential walls 7—8 (10) μ in diam. (*M.*, 51)

Dacrydium colensoi HOOK.
Pl. 34, p. 144

B. Wood parenchyma present. Large apertures nearly procumbent ellipses, or squares with rounded corners. Rays 1—8 (10—20) cells high. Height of ray cells 17—20 μ, width 7—11 μ. Tracheids in cross section squared, only the thicker-walled tracheids in the latewood with rounded corners. Growth rings distinct; transition from early- to latewood gradual. Number of rays per sq. mm. 50—55, that of ray cells 190—200. In the cross field generally one large pit, measuring 16—20 $\times$ $\times$10—14 μ, and the shape of a procumbent ellipse. Bordered pits in radial walls of late tracheids scattered, occasionally paired, 18—20 μ in diam., those on tangential walls 7—8 μ in diam. (*M.*, 129, 74, 51)

Dacrydium franklinii HOOK. F.
Pl. 37, p. 143

II. In the early wood, 1—2 (3—4) circular pits in the cross field not occupying its entire area; where there are two, particularly in the marginal cells, there they are generally side by side.

A. Rays 1—8 cells high.

a. In the cross field 1—2 (3—4) circular or short-elliptic pits, 8—10 (11) μ in diam. Rays 1—5 (7) cells high. Tracheids in cross section nearer to rounded. Growth rings indistinct. Number of rays per sq. mm. 100—120, that of ray cells 230—240. Height of ray cells 14—18 (27) μ. Bordered pits in radial walls of tracheids 13—16 μ in diam. (*M.*, 51)

Dacrydium araucarioides BRONGN. et GRIS.
Pl. 32

b. In the cross field large circular pits with 10—14 μ diam., mostly isolated. Some fields without pitting. Number of tracheids per sq. mm. 2200. Tracheids in cross section squarish. Growth rings indistinct. Wood parenchyma abundant. Number of rays per sq. mm. 80—85, that of ray cells 240—250. Rays 1—6 (8) cells high. Height of ray cells 10—14 (18—30) μ. Tangential and radial walls of wood parenchyma sparsely provided with round simple pits. In radial walls of tracheids bordered pits, 14—18 μ in diam.; in tangential walls pits absent or very sparse. (*M.*, *Y.*, 51)

Dacrydium taxoides BRONGN. et GRIS.
Pl. 38

B. Rays 1—20 cells high.

a. Diameter of largest pits in rays 13—14 μ. In radial walls of tracheids paired pits rare. Rays 1—6 (20) cells high. Per sq. mm. 1200 tracheids, 65—70 rays, and 280—300 ray cells. Tracheids in cross section squared, with rounded corners in latewood. Growth rings indistinct. Height of ray cells 14—16 (20) μ. In the cross field 1—2 large circular or elliptical pits, 10—13 μ in diam. Diam-

eter of bordered pits in radial walls of tracheids 16 μ. Large simple pits in radial walls of wood parenchyma. (*M.*, 129, 51)

Dacrydium cupressinum SOLAND.
Pl. 35

b. Diameter of the largest pits in rays 10—11 μ. In radial walls of tracheids paired pits fairly frequent, with diam. of 16—17 μ. Per sq. mm. 900 tracheids, 90—100 rays, and 400—420 ray cells. Tracheids in cross section rounded. Wood parenchyma abundant. Rays 1—15 (18) cells high. Height of ray cells 8—10 μ, width 15—18 μ. (*M.*, 51)

Dacrydium elatum (Roxb.) WALL.
Pl. 36

c. Maximum diameter of pits in rays 6—8 μ. Number of tracheids per sq. mm. 1700. Tracheids in cross section rounded. Growth rings moderately distinct. Parenchyma frequent. Rays 1—17 cells high. Height of ray cells 13—18 μ, width 8—13 μ. Bordered pits in tangential ray-cell walls 12—13 μ, in radial walls 12—14 μ in diam. Horizontal walls of longitudinal parenchyma cells smooth or slightly nodular, radial walls provided with exceedingly minute round pits. Number of rays per sq. mm. 70—75, that of ray cells 295—300. Pits in cross field orbicular, dacrydioid (circoporus), or podocarpoid. *(M.)*

Dacrydium pierrei HICKEL
Pl. 37a.

C. Rays 1—25 cells high.

Number of tracheids per sq. mm. 1900. Tracheids angular in cross section. Growth rings moderately distinct. Per sq. mm. 65—70 rays and 330—340 ray cells. Rays 1—25 cells high and uniseriate. Height of ray cells 13—16 μ, width 5—8 μ. In tangential walls of tracheids bordered pits 7—8 μ, in radial walls of early tracheids, where they are sometimes biseriate, 8—13 μ in diam. All ray-cell walls thin and smooth. Indentures wanting. Cross field with 1—2 (3) pits, 5—8 μ in diam.

Dacrydium balansae BRONGN. et GRIS.
Pl. 33

Phyllocladus (about 6 known species)

I. Entire cross-field area occupied by a single, large, *Pinus silvestris* type pit, elliptic or squared with rounded corners. In tangential walls of tracheids pit apertures commonly vertical. Wood parenchyma absent.

A. Growth rings relatively narrow: 6—20 tracheids in width. Rays 1—10 cells high. Number of tracheids per sq. mm. 2600. Tracheids in cross section squares. Growth rings distinct, with gradual transition of early- to latewood. Early tracheids measure 30—35 $\times$18—20 μ, late tracheids 4—6 $\times$ $\times$18—20 μ. Number of ray cells per sq. mm. 90— —100. Height of ray cells 13—18 (22—24) μ, width 7—9 μ. Cross-field area occupied by a single pit, 11—17 μ in diam. Bordered pits in the radial walls of the late tracheids scattered, 11—13 μ in diam., those in the tangential walls 6—8 μ, and with vertical apertures. Tracheids occasionally with resin contents. Resin plates frequent.

Phyllocladus alpinus HOOK. f.
Pl. 40

B. Growth rings markedly distinct and generally 30—40 tracheids in width; transition to latewood gradual. Walls of tracheids considerably thicker in late (3—3,5 μ) than in early tracheids (1—2 μ). Rays 1—12 (15) cells high.

a. In radial walls of tracheids bordered pits variably sculptured, 9—11 μ in diam. Resin plates frequent. Rays 1—12 (18) cells high. Number of tracheids per sq. mm. 2900. Tracheids in cross section definitely squares, their diam. in earlywood 25—30, in latewood 18—20 μ. Late zone 10—15 tracheids in width. Wall thickness in latewood 3—4 μ, in earlywood 1—2 μ. Number of rays per sq. mm. 120—130, that of ray cells 400—410. Rays with 1—2 paired cells in the body. In the cross field a single large pit, a procumbent or somewhat oblique ellipse, or circular: 10—14 (16) μ in diam. Height of ray cells 14—17 (18) μ, width 4—6 (7—8) μ. Tangential walls of tracheids frequently pitted; pit diameter 4—6 μ; pit apertures slitlike and vertical. (*M.*, 51)

Phyllocladus glaucus CARR.
Pl. 41

b. In radial walls of tracheids pits not markedly or variably sculptured; their diameter 10—13 (15) μ; in tangential walls pits numerous, 8—10 μ in diam.; pit apertures vertical. Rays 1—8 (16) cells high, occasionally biseriate. Number of tracheids per sq. mm. 1850. Tracheids in cross

section squared. Growth rings distinct; transition from early- to latewood, which is about 8—10 cell layers thick, is gradual. Wall thickness in late tracheids 5—7 μ, in early tracheids 2—2,5 μ. Number of rays per sq. mm. 75—80, that of ray cells 320—330. Height of ray cells 10—14 (18—20) μ, width 6—8 μ. In the cross field a single, circular or elliptical, pit with 16—24 μ diameter. (*M.*, 74, 51)

Phyllocladus asplenifolius (Labill) HOOK. F. *(Phyllocladus rhomboidalis* RICH.*)*
Pl. 42

II. Not the entire area of the cross field occupied by the aperture of the only pit in it. Aperture fairly wide and slitlike, with the border crescent-shaped on both sides of it and clearly discernible. Rays 1—12 (15) cells high. Number of tracheids per sq. mm. 1700. Growth rings distinct. Walls of tracheids in latewood 4—6 μ, in earlywood 3—3,5 μ thick. Tracheids measure 20—35—40 $\times$ 18—20 μ in earlywood, and 5—6—16 $\times$ 18—20 μ in latewood. Number of rays per sq. mm. 50—52, that of ray cells 280—290. Ray cells 12—16 (20) μ high, 7—8 μ wide. In the cross field 1—2 large pits. Pits obliquely elliptical, 14—18 (22) μ in diam.; apertures wide and oblique, sometimes extended. Bordered pits in radial walls of tracheids scattered, 13—18 μ in diam., their apertures occasionally extended. (*M.*, 129., 51)

Phyllocladus trichomanioides D. DON
Pl. 43, p. 145

Podocarpus (about 80 known species)

I. Wood parenchyma absent. Growth rings fairly distinct. Tracheids in cross section more or less rounded. Per sq. mm. 1600 tracheids, 65—70 rays, and 380—390 ray cells. Rays 1—15 (32) cells high. Height of ray cells 15—17 (22) μ, width 10—12 μ. In the cross field but a single, in the marginal cells exceptionally two, large, *Pinus silvestris* type pits with 13—18 μ diam., and occupying almost the entire area. The cross-field structure is reminiscent of that in *Phyllocladus*. All ray-cell walls thin, not more than 0,5—1 μ and smooth, exceptionally slightly uneven or with creases on the surface. (*M.*, 129, 51)

Podocarpus spicatus R. BR.
Pl. 67

II. Wood parenchyma present.

A. In the cross field a single round pit, 16—18 μ, exceptionally 10—16 μ in diam., occupying the half or the whole of the area.

a. Rays 1—40 cells high. Height of ray cells 12—18 μ, width 8—10 (11) μ. Diameter of pits in rays 10—16 (18) μ. In tracheids paired pits frequent. Bordered pits on radial walls 18—22 μ in diam, in tangential walls 16—20 μ. Growth rings distinct. Number of tracheids per sq. mm. 720. Radial width of early tracheids 40—60 μ, tangential width 42—45 μ; radial width of late tracheids 8—10 μ. Number of rays 65—68, that of ray cells 470—480 per sq. mm. In rays and wood parenchyma resinuous substance. (*M.*, 51)

Podocarpus wallichianus C. PRESL
Pl. 70

b. Rays 1—9 (10) cells high. Height of ray cells 11—13 μ (16—20) μ. Diameter of pits in rays 9—14 μ. Paired pits rare. Growth ring delimitation almost imperceptible. In cross section tracheids squared, sometimes with rounded corners. Per sq. mm. 2500 tracheids, 110—120 rays, and 230—240 ray cells. (*M.*, 51)

Podocarpus elatus R. BR.
Pl. 47

c. Rays 1—10 cells high. Paired pits frequently present. Growth ring delimitation almost imperceptible. In the cross field commonly one *Pinus silvestris* type pit 12—20 μ in diam., rarely two pits with 8—10 μ diam. Wood parenchyma abundant. Height of ray cells 14—16 (22) μ. Number of tracheids per sq. mm. 1300. Tracheids in cross section squarish with slightly rounded corners. Per sq. mm. 75—80 rays and 240—250 ray cells. In the tangential walls of wood parenchyma the pits 6—8 μ in diam. and scattered. (*M.*, 51)

Podocarpus blumei ENDL.
Pl. 44*

B. In the cross field 1—2—3 (4) elliptical podocarpoid or taxodioid pits *side by side*; pit diam. 10—12 μ.

a. In the cross field 2—3 (4), in the marginal cells 4—5, taxodioid pits side by side. Rays 1—20

* Magnification of Fig. 1 is not 100×, as stated in this Plate, but 30×.

(40) cells high. Number of tracheids per sq. mm. 720. Radial width of early tracheids 60—65 μ, tangential width 24—30 μ; radial width of late tracheids 6—8 μ, tangential width 25—28 μ. Tracheids in cross section nearer to squarish. Wood parenchyma abundant. Horizontal walls of wood and ray parenchyma only 0,5—1 μ thick. In radial walls of tracheids 2—3 (4) rows of bordered pits; pit diam. 13—14 μ. (*M.*, 51)

Podocarpus minor PARL.
Pl. 63

b. In the cross field commonly one, ocassionally none, not infrequently two, pits *side by side.* Rays 1—60 cells high.

a Bordered pits in radial walls of tracheids *frequently in two, sometimes in three rows.* Diameter of pits 16—18 (2) μ. Wood parenchyma abundant. Diameter of pits in cross field 8—10 (11) μ. Pits absent in some fields. Per sq. mm. 1100 tracheids, 50—60 rays, and 490—500 ray cells. Horizontal walls of ray cells occasionally thinned or with simple pits. (*M.*, 129, 51)

Podocarpus totara D. DON.
Pl. 68

β Bordered pits in radial walls of tracheids commonly uniseriate, 14—16 μ in diam. Wood parenchyma sparse. Commonly 1—2 pits in the cross field, unpitted fields rare. Number of tracheids per sq. mm. 1400. Tracheids in cross section nearly squares. Latewood 8—10 cell rows wide and distinct from earlywood. Per sq. mm. 70—75 rays and 660—670 ray cells. Height of ray cells 15—17 (24) μ. Very rarely slight nodular thickening in horizontal walls of wood parenchyma. (*M.*, 129, 51)

Podocarpus dacrydioides A. RICH.
Pl. 46

c. In the cross field 1—2 podocarpoid pits, 7—8 μ in diam.; pit apertures wide ellipses or nearly circular. Rays 1—15, commonly 1—7 cells high. Growth rings indistinct. Per sq. mm. 200—210 rays and 630—640 ray cells. Ray cells in cross section circular or short elliptic. In radial and tangential walls of wood parenchyma numerous circular simple pits. Parenchyma with resin contents. (*Y.*, *M.*, 51) *Podocarpus javanicus* BL.
Pl. 55

C. In the cross field commonly a single pit, exceptionally two in the marginal cells. Pits of rays 5—13 μ in diam.

a. Rays 1—20 (25) cells high, uniseriate, sometimes with 1—2 paired cells in the body. Horizontal walls of ray cells with sporadic simple pits. Wood parenchyma abundant; its horizontal walls commonly smooth and thin, occasionally with 1—2 slight nodules; its radial and tangential walls with minute simple pits. In the cross field 2—3 horizontally elongated pits. Number of tracheids per sq. mm. 2500. Tracheids in cross section squarish. Growth rings distinct, latewood 10—15 cell layers wide. Per sq. mm. 160—170 rays and 580—590 ray cells. Height of ray cells 15—18 (22) μ. In the cross field no pit, or a single one, 6—7 μ in diam. (*M.*, 51)

Podocarpus macrophyllus (Thunb.) D. DON
Pl. 59

b. Rays 1—15 (24) cells high. In radial walls of tracheids paired pits not infrequent.

a Diameter of individual pits 7—14 μ.

1. Horizontal ray walls sporadically thinned or with simple pits.

x. Relatively numerous cross fields devoid of pits. Rays 1—10 (12) cells high. Number of tracheids per sq. mm. 1200. Tracheids in cross section squarish. Growth rings discernible; latewood 4—5 cell layers wide. Per sq. mm. 100—110 rays, 340—350 ray cells. Height and width of ray cells varies from 8—10 (14—15) to 14—20 (22) μ, respectively. In the cross field, pits 7—8 μ in diam., pit apertures generally linear and almost horizontal. (*M.*, 129 51)

Podocarpus henckelii STAPF
Pl. 54

xx Pits present in almost every cross field. Rays 1—8 (12) cells high. Number of tracheids per sq. mm. 1500. Tracheids in cross section nearer to rounded. Growth rings rather indistinct, hardly discernible. Latewood 1—2 cell layers wide. Per sq. mm. 72—75 rays and 210—220 ray cells. Height of ray cells 18—22 (38), width 9—11 (13) μ. Bordered pits in radial walls of tracheids uni- or biseriate, 10—22 μ in diam. In the cross field commonly a single pit 10—13 μ in diam. Diameter of the almost vertical aperture 4—6 μ. In horizontal walls of ray parenchyma occasional thinnings or simple pits. *Podocarpus neriifolius* D. DON
Pl. 65

2. Horizontal walls of rays very thin and entirely smooth.

x. Rays 1—8 (12—16) cells high. Number of tracheids per sq. mm. 1050. Tracheids in cross section squarish; 30—35 × 28—30 μ in size. Growth rings indistinct. Per sq. mm. 110—120 rays and 450—460 ray cells. Height of ray cells 16—17 (20) μ, width 7—8 (10) μ. Wood parenchyma with resinous contents. One pit per cross field. (*M.*, 129, 51)

Podocarpus gracilior PILGER
Pl. 53

xx Rays 1—10 (20—24) cells high. Number of tracheids per sq. mm. 730. Tracheids in cross section nearer to rounded. Radial diameter of early tracheids 45—60 μ, of late ones 20—30 μ. Growth rings indistinct. Bordered pits in radial walls of tracheids uni- or biseriate; pit diameter 16—20 (22) μ. Per sq. mm. 90—100 rays and 640—650 ray cells. Height of ray cells 10—20 (26) μ, width 6—12 μ. In the cross field 1—2 pits side by side and 8—12—14 μ in diam; diameter of the almost vertical pit apertures 8,3 μ. In horizontal walls of wood parenchyma occasional slight thickenings; in radial walls simple pits in vertical rows. (*M.*, 129, 51)

Podocarpus usambarensis PILGER
Pl. 69

β Diameter of pits in rays 6—9 μ.

1. Horizontal walls of rays thinned in places, or with simple pits. Rays 1—8 (10) cells high. Number of tracheids per sq. mm. 2900. Tracheids in cross section nearer to rounded. Growth rings indistinct. Wood parenchyma scattered. Per sq. mm. 85—90 rays and 280—290 ray cells. Height of ray cells 12—16 μ, width 12—13 μ. In the cross field commonly a single pit 6—7 μ in diam. Pit apertures short ellipses or circles. Diameter of bordered pits in radial walls of tracheids 8—12 μ. In rays and wood parenchyma resin contents. (*M.*, 51)

Podocarpus ferrugineous D. DON
Pl. 50

2. Horizontal ray walls very thin and perfectly smooth. Wood parenchyma abundant. Rays 1—5 (7—10) cells high. Height of ray cells 13—14 (20) μ. Number of tracheids per sq. mm. 2300. In cross section tracheids squarish. Growth rings almost imperceptible. Per sq. mm. 230—240 rays and 500—510 ray cells. In the cross field 1 (2) pits, 7—9 μ in diam., with slitlike or linear apertures. Simple pits in radial walls of wood parenchyma rather like procumbent ellipses. (*Y.*, 129. 51)

Podocarpus falcatus (Thunb.) R. BR.
Pl. 49

c. Rays 1—10 (15) cells high.

α In radial walls of tracheids paired pits not infrequent. Pit diameter 6—12 (17) μ.

1. Apertures of pits in ray cells almost vertical. Rays 1—6 (12) cells high, partly biseriate at times. Number of tracheids per sq. mm. 2300. Tracheids in cross section squares with rounded corners. Early tracheids measure 28—30 × 22—24 μ, late ones 5—6 × 15—18 μ. Growth rings indistinct, latewood 3—4 cell layers in width. Per sq. mm. 140—150 rays and 220—230 ray cells. Wood parenchyma with resin contents. In the cross field 1 (2) pits, sometimes none. (*Y.*, 51)

Podocarpus ferruginoides COMPT.
Pl. 51

2. Pit aperture in ray cells obliquely oriented and short-elliptical. Growth rings distinct, latewood 4—5 cell layers wide. Number of tracheids per sq. mm. 2500. Tracheids in cross section squarish with rounded corners. Radial diameter of early tracheids 35—50 μ, of late ones 15—25 μ. Per sq. mm. 90—95 rays and 200—210 ray cells. Rays 1—11—12 cells high. Height of ray cells 16—18 (22) μ, width 7—10 (12) μ. Wood parenchyma with resin contents. In the cross field no pit, or but one, 8—12 μ in diam. with its aperture short-elliptical and 7—13 μ in size. Bordered pits in radial walls of tracheids fairly apart and arranged in one or two loose rows; 18—22 μ in diam. (*M.*, 51)

Podocarpus longifoliatus PILGER
Pl. 57

3. Growth rings indistinct. Tracheids in cross section 4—5 sided to polygonal. In some rows the tracheids differ significantly in the width of their lumina from the tracheids in the rows by their side. In the growth layers scattered parenchyma cells with dark resinous content. Average width of tracheids 27—32 μ. Rays 1—5 cells high; 10—12 cells high rays very rare. Height of ray cells 13—27 μ, width 8—13 μ. In the cross field 1, very xceptionally 2, podocarpoid pits; unpitted cross field not infrequent. Circular dacrydioid pits

take the place of some podocarpoid ones. (*M.*, 129, 51)

Podocarpus milanjianus RENDLE
Pl. 62

4. Growth rings almost indiscernible. Tracheids in cross section rounded. Parenchyma cells in growth ring layer fairly abundant. Rays 1—8 cells, occasionally 14—16 cells high. Height of ray cells 29—30 μ, width 5—9 μ. Horizontal walls of longitudinal parenchyma very thin and smooth. Similarly all walls of ray parenchyma smooth and thin. In the cross field a single podocarpoid pit with the rod-shaped aperture vertical in position. Circular dacrydioid pits take the place of some podocarpoid ones. Cross fields devoid of pits fairly frequent. Cross-field pits sometimes procumbent ellipses with vertical apertures coincident with the minor axis of the ellipse, i. e. cupressoid in character. Pit diameter 6—8 μ.

Podocarpus montanus LODD.
Pl. 64

5. Tracheids in cross section 4—5 sided to polygonal with rounded corners and 40—45 μ in diam. Outer edges of growth rings marked by 2—3 rows of slightly flattened and rounded tracheids. Wood parenchyma frequent, sometimes aligned in terminal plates. Parenchyma cells with dark resinous contents. Rays generally 1—6, exceptionally up to 24, cells high. Height of ray cells 13—20 (30) μ, width 8—16 μ. Diameter of bordered pits on tangential walls 13—14 μ, on radial walls 13—21 μ. In the cross field commonly 1 podocarpoid pit with linear apertures, vertical or nearly vertical in position. Unpitted cross fields frequent. Cross fields of marginal cells also with only one pit, most rarely with two side by side. Bordered pits in the walls of longitudinal tracheids uniseriate, or opposite, or sporadically in groups of 3—4—5, araucarian fashion.

Podocarpus oleifolius D. DON
Pl. 66

β In radial walls of tracheids paired pits rare. Bordered pits commonly uniseriate.

1. Pit diameter 13—16 μ. Number of tracheids per sq. mm. 1900, squarish in cross section with rounded corners. Growth rings indistinct. In tangential walls of tracheids bordered pits frequent and 13—14 μ in diam. Horizontal walls of ray cells with occasional thinnings or simple pits. Per sq. mm. 150—160 rays and 420—430 ray cells. Rays 1—8 (10) cells high. Height of ray cells 12—14 (22) μ, width 8—10 (14) μ. Generally a single pit in the cross field, occasionally none. Pit diameter 9—12 μ, apertures linear, nearly vertical. Tangential and radial walls of wood parenchyma with simple pits. (*M.*, 51)

Podocarpus mannii HOOK. f.
Pl. 61

2. Pit diameter 10 (13) μ. Number of tracheids per sq. mm. 1800, in cross section squarish with rounded corners. Apertures of bordered pits nearly vertical. Per sq. mm. 110—115 rays and 240—250 ray cells. Rays 1—6 (7—8) cells high. Height of ray cells 18—20 (24) μ, width 4—7 (9) μ. In the cross field 0—1 (2) pits. Wood parenchyma with resinous content. In radial and tangential walls of wood parenchyma round simple pits. (*M.*, 51)

Podocarpus coriaceus RICH.
Pl. 45

d. Rays 1—7 (10) cells high.

α Diameter of pits in rays 6—8 μ. Number of tracheids per sq. mm. 4200. Tracheids in cross section rounded. Early tracheids measure 20—25 $\times$ $\times$ 15—20 μ; radial diameter of late ones 5—7 μ. Growth rings definable. Per sq. mm. 170—180 rays and 330—340 ray cells. Height of ray cells 16—18 μ, width 10—15 μ. Number of pits per cross field 1 (2). In radial walls of tracheids bordered pits generally uniseriate, occasionally flattened araucarian fashion with horizontal lines of contact between them. Pit diameter 16—18 μ. Horizontal walls of ray parenchyma with occasional thinnings or simple pits. (*Y.*, 51)

Podocarpus latifolius (Thunb.) R. BR.
Pl. 56

β Diameter of pits in rays 6—10 (12) μ.

1. Number of pits per cross field 1 (2) with 6—8 μ diameter and a short-elliptical aperture measuring 7—8 $\times$ 4—5 μ. Per sq. mm. 5600 tracheids, 265—270 rays, and 540—550 ray cells. Tracheids in cross section rounded. Early tracheids measure 20—25 $\times$ 12—18 μ, late ones 4—6 $\times$ 12—18 μ. Growth rings almost imperceptible; latewood 2—3 cell layers wide. Height of ray cells

13—15 (24) μ, width 8—10 μ. In tangential walls of tracheids bordered pits frequent, 12—13 μ in diam. (*M.*, 74, 51)

Podocarpus elongatus (Ait.) L'HÉR.
Pl. 48

2. Number of pits per cross field 1 (2); the two in the marginal cells of the latewood side by side; their diameter 8—10 (12) μ. Per sq. mm. 3300 tracheids, 75—80 rays, and 150—155 ray cells. Height of ray cells 16—17 (20)μ. Tracheids in cross section squarish. Growth rings rather indistinct. In tangential and radial walls of wood parenchyma scattered circular simple pits. (*Y.*, 51)

Podocarpus lycopodioides
Pl. 58

3. Number of pits per cross field 1 (2) with 7—11 μ diameter and apertures from short- to long-elliptical measuring 6—7 × 2—5 μ. Per sq. mm. 4800 tracheids, 240—250 rays, and 520—530 ray cells. Tracheids in cross section squared. Radial width of early tracheids 25—30 μ, of late ones 4—6 μ. Growth rings almost imperceptible; latewood 4—5 tracheids in width. Height of ray cells 13—15 (18) μ, width 8—10 μ. In tangential and radial walls of wood parenchyma circular simple pits. In radial walls of tracheids occasionally crowded araucarian pitting; bordered pits frequent also on tangential walls, 7—8 μ in diam. (*M.*, 51, 54)

Prumnopitys elegans PHILIP *(P. andinus* POEPP.*)*
Pl. 71, p. 146

4. Growth rings almost indiscernible. Tracheids in cross section rounded and 13—20 μ in diam. Wood parenchyma scarce. Ray 1—2—3, exceptionally up to 9, cells high, some of them partly biseriate. Height of ray cells 10—20 μ, of those in single rows up to 29—30 μ; ray-cell width 5—9 μ. In tangential walls of tracheids bordered pits 10—13 μ in diam. All walls of ray parenchyma cells smooth, thin, and devoid of pitting. In the cross field 1, very seldom 2, pits; in the marginal cells the two pits are occasionally superposed. Pits generally procumbent ellipses; apertures rod-shaped and vertical in position. Circular dacrydioid pits frequently take the place of podocarpoid ones. In radial walls of tracheids bordered pits interspaced and aligned in a single row, but sometimes contiguous and araucarian. Diameter of pits on radial walls 13—21 μ, on tangential walls 10—13 μ. (*M.*, 51)

Podocarpus macrostachyus PARL.
Pl. 60

5. Wood close-textured. Growth rings indistinct. Tracheids commonly 25—35 μ wide. Rays mostly only 1—3, very rarely up to 10, cells high. Height of ray cells 13—18 μ, width 6—10 μ. In tangential walls of tracheids bordered pits 8—9 μ, in radial walls 12—16 μ in diam. Wood parenchyma with resinous contents. In the cross field one podocarpoid pit, 4—8 μ in diam. Pits in latewood significantly smaller, and some of them quite dacrydioid in character. (*M.*, 51)

Podocarpus glomeratus D. DON
Pl. 52

3—4. KEY FOR THE IDENTIFICATION OF THE GENERA AND SPECIES OF THE TAXACEAE AND CEPHALOTAXACEAE (TAXALES)

In his paper "On the Morphology and Relationships of the Taxaceae" (Bot. Gaz. Vol. 110, 1948), H. FLORIN, in conformity with PULLE's revised classification, interlinks *Taxaceae* and *Cephalotaxaceae*, and places both in *Taxales* on the strength of their external morphological features. The grouping together of the two families appears to be equally justified on the evidence of their xylotomical characteristics, which are discussed below.

Many research workers have dealt with the xylotomical features of the genera and species in *Taxaceae* and *Cephalotaxaceae*. Recent works are KRÄUSEL's "Die fossilen Koniferenhölzer" (1949), and PHILLIPS' "Identification of Softwoods" (1946). Of the earlier ones, GOTHAN's "Zur Anatomie lebender und fossiler Gymnospermenhölzer" (1905), and the works of HOLLENDONNER merit special mentioning. But all these publications are concerned with a part only of the members of these families, wherefore in the following an attempt is made to complement the results hitherts achieved.

According to PILGER, *Taxus*, *Torreya*, and *Nothotaxus* belong to the *Taxaceae*, while *Amentotaxus* and *Cephalotaxus* are members of the *Cephalotaxaceae*. (As regards the *Nothotaxus*, which has been discovered only a few years ago by CHENG and not yet studied xylotomically, we have now worked it up on some specimens of this rare wood for which we are indebted to Professor R. FLORIN.)

PILGER classes *Austrotaxus* with the *Taxaceae* although, as has been pointed out by PHILLIPS and other workers, this genus in no way fits this family, if for no other reason than for the lack of spiral thickenings in the tracheids, the presence of which is undoubtedly one of the most characteristic features of the *Taxaceae* and *Cephalotaxaceae*. Indeed, our own studies confirm that the anatomical structure of the wood of *Austrotaxus* shows a much closer affinity to the xylotomy of the *Podocarpaceae* than to that of either *Taxaceae* or *Cephalotaxaceae*. For this very reason, in this work, and at least from the point of view of xylotomy, *Austrotaxus* is not included in either of these two families, but with the *Podocarpaceae*.

PILGER, then, classifies *Taxus*, *Torreya*, and *Austrotaxus* with the *Taxaceae*, and refers *Amentotaxus* and *Cephalotaxus* to the *Cephalotaxaceae*. However, considering the great similarity of the xylotomical structure in the individual genera one is bound to accept fully the view of FLORIN (1943) and PULLE, who place the two families in the same order: the *Taxales*.

Xylotomical resemblance is the greatest, on the one hand, between *Taxus* and *Nothotaxus*, in which there is never any wood parenchyma and, on the other hand, between *Torreya*, *Amentotaxus*, and *Cephalotaxus*, in which wood parenchyma is always present.

Concerning the key that follows, it is well to keep in mind that in distinguishing among the genera, the features included cannot in every case be regarded as final and absolute. This particularly refers to *Taxus*. The reason is that in many instances the material available was insufficient for comparative purposes. However, the wood sections from which this

KEY

to the genera and species of *Taxaceae* and *Cephalotaxaceae (Taxales)* was prepared, were taken from accurately identified material.

General xylotomical characteristics. Spiral thickenings present in all tracheids throughout the wood, occurring singly, or arranged in twos or threes; they are spaced ± widely, or else quite closely. Tangential walls of ray parenchyma always smooth; horizontal walls unevenly thickened or sparsely pitted. Wood parenchyma either present or absent. Transverse tracheids and resin ducts absent. This constitutes another distinguishing feature from *Pseudotsuga* and most *Picea* species. Indentures generally present. *(Amentotaxus, Cephalotaxus, Nothotaxus, Taxus, Torreya.)*

1. Wood parenchyma present.

A. Wood parenchyma in conspicuous groups varying in size; average diameter of cells twice that of the adjacent tracheids. Commonly 1—2 circular pits in the cross field, and 2—3 in the marginal cells. Spirals in tracheids sometimes solitary, but mostly extending in twos or fours, and widely spaced. Pairs of spirals usually cross the bordered pits, one strand passing above and the other below the pit aperture. Horizontal walls of ray cells and wood parenchyma cells smooth, occasionally pitted or nodular. (*M.*, 129, 54)

Amentotaxus argotaenia PILGER
Pl. 73, p. 147

B. In cross section, no essential difference between wood parenchyma cells and cells of adjacent tracheids.

a. Number of cupressoid pits per cross field 1—2, in marginal cells 1—3. Tangential walls of ray parenchyma smooth or slightly thickened, respectively nodular.

Cephalotaxus (5—6 known species).

α Horizontal walls of ray parenchyma conspicuously pitted in places, thickened, almost beadlike. Usually one minute cross-field pit (4—5 μ) with 2—3 (4) pits in marginal cells. Indentures marked. Tangential walls smooth and thin. *(M.)*

Cephalotaxus pedunculata SIEB. et ZUCC.
(*C. Harringtonia* K. KOCH)
Pl. 77, p. 150

β Horizontal walls of ray parenchyma thick, conspicuously even, not nodular, with but few simple pits in them. Tangential walls thin and smooth. Indentures marked. Wood parenchyma scarce, with smooth horizontal walls, slightly thickened or almost imperceptibly pitted. Usually one pit per cross

field, with two in marginal cells, where they are superposed. Pit diameter 5—6 μ. (*M.*)

Cephalotaxus fortunei HOOK.
Pl. 75, p. 149

γ Horizontal walls of ray parenchyma usually smooth and uniformly thickened. In horizontal walls pits and thin areas rather frequent. Tangential walls smooth and slightly thickened. (*M.*, 129, 74)

Cephalotaxus drupacea SIEB. et ZUCC.
Pl. 74, p. 148

δ Horizontal walls of ray cells with numerous simple pits. In the cross field 1—2 pits in the internal, and 2—4 in the marginal cells. Pit diam. 4—5 μ. Longitudinal parenchyma normally absent. (*M.*)

Cephalotaxus oliveri MAST.
Pl. 76, p. 149

b. In the cross field 2—4 (6) minute pits, 4—5 μ in diam. Spirals extending in pairs, in threes, or are closely spaced. Horizontal walls of wood parenchyma smooth or slightly nodular.

Torreya (5—6 known species)

α Rays up to 30—36 *cells high.* Growth rings distinct. Latewood only a few tracheids in width. Horizontal walls of ray parenchyma smooth, occasionally unevenly thickened, frequently with simple pits. Number of pits per cross field 3—4 (6); pit diameter 4,5 μ. Height of ray cells 22—30 μ. (*M.* 129.)

Torreya taxifolia ARNOTT
Pl. 89, p. 157

β Rays up to 10 *(15) cells high.*

1. In cross section, ray cells nearer circles than upright ellipses. They are 14—16 μ in height, 15—18 μ in width. Rays 6—8 (10) cells high. Horizontal walls of ray cells generally smooth, pits rather frequent in some places. Tangential walls thin and smooth. Indentures present. Number of minute pits per cross field 1—3 (5—6), 5 μ in diam. (*Y.* 129, 74)

Torreya grandis FORTUNE
Pl. 87, p. 156

2. Ray cells in cross section nearly upright ellipses, 18—24 (35—40) μ high.

x Usually 2 minute pits per cross field, but 4—5 in marginal cells, mostly superposed and regular in arrangement. Rays 1—8 (10) cells high. (*M.* 129, 51)

Torreya californica TORREY
Pl. 86, p. 155

xx In the cross field 2—3 (4—6) minute (4—5 μ) pits, mostly arranged in squares or irregularly. Pit apertures oblique rods. Horizontal walls of wood parenchyma smooth or slightly nodular. Horizontal walls of ray parenchyma usually smooth, with occasional pits and thin areas. (*M.*, *Y.*, 128)

Torreya nucifera (L.) SIEB. et ZUCC.
Pl. 88, p. 156

II. *Wood parenchyma absent. Taxus* (7—8 known species), *Nothotaxus* (single known species).

A. In the cross field usually one, in marginal cells two, very exceptionally four pits. Where there are two, they are mostly superposed *(T. canadensis, T. baccata, T. wallichiana).*

a. Sometimes a single large-sized pinoid pit, measuring 6—8 × 16—18 μ, occupies the whole of the cross-field area, while at other times there are two pits side by side or superposed. Pit apertures included and assuming the shape of the borders, making the latter not infrequently appear annular. Rays 1—10 (14) cells high. Horizontal walls now smooth, now unevenly thickened. *(M.)*

Taxus canadensis MARSH.
Pl. 81, p. 152

b. Horizontal walls of ray cells unevenly thickened, with simple pits funnel-shaped in outline. Rays 5—15, exceptionally 22—30, cells high. Indentures present. Number of rays per sq. mm. 80—85, that of ray cells 195—200. Wood parenchyma very exceptional. (*Y.*, *M.*, 74)

Taxus baccata L.
Pl. 79, p. 151

c. Horizontal ray-cell walls commonly smooth, occasionally unevenly thickened and sparsely pitted. Rays 1—10 (15) cells high. Per sq. mm. 280—290 rays and 680—690 ray cells. Indentures present. *(Y.)*

Taxus wallichiana ZUCC.
Pl. 85, p. 154

B. In the cross field usually 2 pits side by side, in marginal cells 3—4, mostly in diagonal arrangement.

a. Horizontal walls of ray cells 3—3,5 μ thick, unevenly thickened and sparsely pitted. Rays 1—12 (14) cells high. Pits on radial walls of tracheids 16—18 μ; apertures 10 μ in diam. Negative pits frequent. Indentures present. (*M.*, 170)

Taxus chinensis REHDER
Pl. 82, p. 153

b. Pits on radial walls of tracheids 16—18 μ, circular apertures 4—5 μ in diam. Rays 1—32 cells high. Diameter of bordered pits in tangential walls of tracheids 8—10 μ. Negative intercellular spaces present. (*M.*, 24)

Taxus cuspidata SIEB. et ZUCC.
Pl. 83, p. 153

c. Pits on radial walls of tracheids 12—14 μ, circular apertures 3—3,5 μ in diam. Rays 1—14 cells high. Diameter of bordered pits in tangential walls of tracheids 5—6 μ. Horizontal ray-cell walls unevenly thickened, with sparse pitting. Indentures present. Wood parenchyma exceptional. *(M.)*

Taxus brevifolia NUTTAL
Pl. 80, p. 151

C. In the cross field usually 2 (4) pits *superposed in pairs*, in marginal cells 2—3, arranged similarly. Rays 6—8 (10) cells high. Spirals commonly solitary. Bordered pits on tangential walls of tracheids 6—7 μ, on radial walls 13—14 μ in diam. All walls of ray parenchyma thin; horizontal ones only 1—1,5 μ thick with occasional simple pitting. Indentures absent or obscured. *(Y.)*

Taxus speciosa FLORIN
Pl. 84, p. 154

D. Growth rings distinct. Tracheids rounded in cross section. Earlywood tracheids 18—20 μ in diam. Rays 1—8 (10) cells high. Spiral thickenings closely spaced at intervals of 6—8 μ, oriented almost horizontally or slightly slanting. Height of ray cells 18—24 μ, width 6—7 μ, their horizontal walls occasionally pitted. Tangential walls smooth. Occasional indentures. Number of pits per cross field 2—4, in marginal cells 4—6, mostly superposed; 5—6 μ in diam. Pit apertures 4 μ, oriented obliquely or vertically. (*Y.*, 55)

Nothotaxus chienii (Cheng) FLORIN
Pl. 78, p. 150

5. KEY FOR THE IDENTIFICATION OF THE GENERA AND SPECIES OF THE CUPRESSACEAE

In ENGLER—PRANTL's "Die natürlichen Pflanzenfamilien" the genera of the *Cupressaceae* are divided by PILGER into three subfamilies on the basis of their external morphology. In the first subfamily, the *Thujoideae*, he includes *Actinostrobus* (2 species), *Biota* (1), *Callitris* (20), *Callitropsis* (1), *Diselma* (1), *Fitzroya* (1), *Fokienia* (3), *Libocedrus* (9), *Tetraclinis* (1), *Thuja* (6), *Thujopsis* (2), and *Widdringtonia* (5). To the second, the *Cupressoideae*, he refers *Cupressus* (12), *Chamaecyparis* (6), and *Cupressocyparis* (1). In the third, the *Juniperioideae*, he classes *Arceuthos* (1), *Juniperus* (60) and *Microbiota* (1). On gross inspection, the genera of these three subfamilies show considerable likeness in their wood anatomy, but on subjecting them to minute examination we arrive at results not quite in harmony with this classification. *Actinostrobus*, *Callitris*, *Callitropsis*, *Tetraclinis*, and *Widdringtonia* will be found to differ very essentially from the other genera. A common characteristic of these five genera is that all their ray-parenchyma walls are thin and smooth, apart from a few exceptions such as *Callitris glauca* in which the horizontal walls are occasionally provided with simple pits. In addition, at present they are all confined to the Southern Hemisphere, living mostly in Australia, Tasmania and South Africa. An exception in this respect is *Tetraclinis*, which lives as a relic in the south of Spain, further in Morocco, Algeria and Tunis. The five genera, with their peculiar almost verticillate foliage often reminiscent of the *Equisetaceae* and the *Casuarina*, appear to represent a perfectly segregate evolutional group.

From the point of view of wood anatomy, *Chamaecyparis*, *Microbiota*, *Biota*, *Fokienia*, *Thuja*,

and *Thujopsis* would deserve to be regarded as an independent group, since the horizontal walls of ray parenchyma in them are in some cases smooth, slightly pitted in the main, while the tangential walls are usually smooth : features of significant diagnostical value. A third, anatomically more or less independent, group would involve *Arceuthos*, *Cupressus*, *Diselma*, *Fitzroya*, *Juniperus*, *Libocedrus*, and *Pilgerodendron* on the common ground that (apart from one or two rare exceptions) wood parenchyma is present in all of them, the horizontal walls of which are never perfectly smooth, but verrucose, slightly nodular, or thickened beadlike. The horizontal walls of their ray cells are likewise uneven, nodular, or pitted, while the tangential walls are commonly with beadlike thickenings. In no member of this group do the tangential walls display dentate thickening, excepting a few *Juniperus* on the rarest occasions. Indentures are mostly present. In some of these genera, e. g. in *Thujopsis*, there are occasionally transverse tracheids.

In his work on the *Cupressaceae*, PEIRCE (1938) does not touch upon these differences, giving only a brief characterization of the individual genera.

A remarkable feature is represented by the so-called callitroid pitting in some *Callitris*, the pattern of which is formed by a delicate barlike structure passing above and below the aperture of a bordered pit and extending further to the next pit, encircling its aperture in the same way (Plate IV, Fig. 35).

On the evidence of their wood anatomy, *Saxegothaea* and *Pherosphaera* are also included into this family by some authors, because the horizontal walls of the ray parenchyma in them are sometimes conspicuously pitted and the tangential walls smooth or nodular, which features are by no means characters of the podocarps, with which these two genera are usually classed on the strength of their external morphology. Since their leaves are not verticillate or opposite, but governed by the phyllotaxy in the *Taxodiaceae*, they should much rather be classified with the latter. The phytogeographical point still merits mentioning that while the genera in the *Cupressaceae* which display perfectly smooth-walled ray cells, are confined to the Southern Hemisphere, those with pits in the ray-cell walls are for their major part distributed on the Northern Hemisphere, with only one or two species represented in the southernmost part of South America and in the higher mountains of Chile. (Cf. map on page 63.)

Xylotomically, the following additional features of this family are of significance, viz.: — Transition from early- to latewood gradual or abrupt. Growth rings distinct or indistinct. Tracheids in cross section rounded or angular and 10—35 μ in diam. Rays uni- or biseriate, with their horizontal walls smooth or abundantly pitted. Tangential walls of ray cells rarely smooth, mostly uneven, nodular, beadlike, or dentate. Tangential walls of rays as seen in tangential view are smooth, sievelike, or scalariform. Ray cells in cross section circular or upright-elliptical. Horizontal walls of wood parenchyma cells rarely smooth, mostly thickened, uneven, delicately nodular or beadlike. Resin contents frequent in parenchyma cells. In the cross field 1—3 (4—8) simple pits, 6—10 μ in diam., standing apart or in pairs. Where they are in pairs, there they are superposed or side by side ; where they are in fours, there they are disposed diagonally or irregularly ; and sometimes there are up to 4 pairs of superposed pits *(Actinostrobus)*. The pitting is *cupressoid*, *taxodioid*, or very rarely *podocarpoid*. Bordered pits in radial walls of tracheids mostly uniseriate, exceptionally biseriate. Above and below the pit apertures sometimes a delicate barlike structure (in some *Callitris)*. Bordered pits on tangential walls commonly uniseriate. Indentures absent (as in *Actinostrobus*, *Callitris*, *Callitropsis*, *Tetraclinis*, *Widdringtonia)*, or present and distinct or indistinct *(Juniperus*, *Cupressus)*. Rays 1—60 cells high. Transverse tracheids an exception *(Thujopsis standishii)*. Spiral thickenings and resin ducts absent. The genera belonging to this family are *Actinostrobus*, *Arceuthos*, *Austrotaxus*, *Biota*, *Callitris*, *Callitropsis*, *Chamaecyparis*, *Cupressocyparis*, *Cupressus*, *Diselma*, *Fitzroya*, *Fokienia*, *Juniperus*, *Libocedrus*, *Microbiota*, *Pilgerodendron*, *Tetraclinis*, *Thuja*, *Thujopsis*, *Widdringtonia*.

In the following is represented the

KEY

for the identification of the genera and species.

I. Horizontal and tangential walls of ray parenchyma as well as horizontal walls of wood parenchyma, smooth, but horizontal walls occasionally slightly thickened, very exceptionally pitted, in which case the bordered pitting of tracheids callitroid *(Callitris glauca)*. Tracheids in cross section angular or rounded. Indentures absent or very rare (except in *Callitris glauca*, *Widdringtonia schwarzii)*. Growth rings commonly indistinct.

Transverse tracheids absent *(Actinostrobus, Callitris, Callitropsis, Tetraclinis, Widdringtonia).*

A. Tracheids in cross section, at least in the earlywood, commonly angular. Growth rings distinct (Actinostrobus, Widdringtonia).

a. Rays 1—8 (27?) cells high. In the cross field 2—6 (8—10) pits, single or crowded, arranged in 1—2 rows, commonly superposed. Tracheids in cross section more or less rounded in latewood, angular in earlywood.

Actinostrobus MIQUEL
Pls. 90, 91

α Rays 1—6 cells high. Per sq. mm. 100—110 rays and 120—130 ray cells. Ray cells barrel-shaped and 16—37 μ high, those of one cell high rays exceptionally 40—80 μ high and 8—13 μ wide. Diameter of bordered pits on tangential walls of tracheids 6—10 μ, on radial walls 12—13 μ. In the cross field 4—8 (10) cupressoid, slightly appressed, almost araucaroid pits, 6—8 μ in diam. Bordered pits in radial and tangential walls of tracheids sometimes biseriate. All walls of ray parenchyma as well as horizontal walls of wood parenchyma smooth and thin. (*Y.*, 127, 55)

Actinostrobus acuminatus PARL.
Pl. 90, p. 157

β Rays 2—8 (14) cells high. Per sq. mm. 95—100 rays and 280—290 ray cells. Height of ray cells 13—24 (36) μ, width 10—13 (15) μ. Diameter of bordered pits on tangential walls of tracheids 8—11 μ, on radial walls 11—13 μ. In the cross field 2—5 appressed cupressoid pits, 6—8 μ in diam. Horizontal walls of wood parenchyma smooth and thin. Entire surface of longitudinal walls of tracheids delicately punctate or verrucose. (*Y.*, 74)

Actinostrobus pyramidalis MIQUEL
Pl. 91, p. 158

b. Rays 1—15 (35) cells high. All tracheids angular in cross section. In the cross field 1—2 (3—4) cupressoid pits, standing apart or in pairs side by side, or if more than two then arranged diagonally. Pits 1—10 μ in diam. Ray cells 13—27 (40) μ high and 8—21 μ wide.

Widdringtonia ENDL.

α Rays 1—6 (30) cells high. Per sq. mm. 100—110 rays and 230—240 ray cells. Ray cells 16—24 (44) μ high, 13—21 μ wide. Bordered pits in tangential walls of tracheids 5—6 μ, in radial walls 10—14 μ in diam. Number of pits per cross field 2—4 (6) with 4—8 μ diameter. (*M.*, 127. 54)

Widdringtonia juniperoides ENDL.
Pl. 180, p. 173

β Rays 1—17 (33) cells high. Per sq. mm. 10—20 rays and 150—160 ray cells. Higher rays partly biseriate. Diameter of bordered pits in radial walls of tracheids 13—18 μ. In the cross field 1—2 (3—7) pits, 5—8 (10) μ in diam. Indentures inconspicuous. (*M.*, 127)

Widdringtonia schwarzii MARL.
Pl. 181

γ Rays 4—15 cells high. Per sq. mm. 80—85 rays and 320—330 ray cells. Ray cells 10—18 (32) μ high, 5—10 μ wide. Radial and tangential walls of tracheids very delicately punctate. Bordered pits in radial as well as tangential walls of tracheids 12—13 μ in diam. In the cross field occasionally 1, commonly 2—3 (4), in the marginal cells 4—6, cupressoid pits, 6—8 μ in diam. Wood parenchyma with resinous contents. Horizontal walls smooth. *(M.)*

Widdringtonia dracomontana STAPF
Pl. 179

δ Rays 4—8 (16) cells high. Per sq. mm. 30—35 rays and 210—220 ray cells. Ray cells 16—27 (35) μ high, 10—18 μ wide. Apart from pitting, radial and tangential walls of tracheids smooth, the bordered pits in them 12—14 μ in diam. In the cross field, commonly 1, exceptionally 2 (3), cupressoid pits, 5—8 μ in diam.; in the marginal cells 2—3, occasionally 4, pits disposed diagonally. Ray cells in cross section more like circles than upright or elongate ellipses. All walls of ray parenchyma very thin and unpitted. Horizontal walls of wood parenchyma smooth and thin. *(M.)*

Widdringtonia cupressoides ENDL.
Pl. 178

ε Tracheids in cross section 4—5—6 sided. Near the outer edge of the growth layers occasionally terminal parenchyma, throughout the growth layer solitary parenchyma cells more common. Rays 2—4—8 cells high. Height of ray cells 16—32 μ, width 5—17 μ. Tangential walls perfectly smooth

in tangential view. In the longitudinal tracheids pits of 5—8 μ diameter aligned in single interspaced rows; in some they are callitroid with the trails of the bars visible as minute dentations. In the radial walls of some tracheids punctate thickening on the tertiary lamella of the secondary wall. Some longitudinal tracheids are quite short, occasionally with 2—3 bordered pits in their horizontal walls, and sometimes conterminous with wood parenchyma. Longitudinal parenchyma cells with completely smooth horizontal walls. All walls of ray parenchyma very thin and smooth, at most somewhat uneven. In the cross field commonly 1—2, in the marginal cells 4—5 (6), cupressoid pits. Indentures absent. *(M.)*

Widdringtonia whytei RENDLE
Pl. 182

B. Tracheids in cross section commonly rounded in both early- and latewood (Callitris, Callitropsis, Tetraclinis). Growth rings hardly discernible.

a. Cross-field pits varying in size and shape: 1—2 (4—6) pits per field, 7—13 μ in diam. and cupressoid, taxodioid, or podocarpoid in shape. Diameter of bordered pits in radial walls of tracheids 13—18 μ. Horizontal walls of wood parenchyma found mostly in latewood smooth. Resinous contents in parenchyma. Rays 2—12 cells high, sometimes partly biseriate. Ray cells in cross section elliptical or circular. Ray cells 13—24 (35) μ high. Two bordered pits possibly biseriate in tracheidal walls. Crassulae fairly discernible. (*M.*, 127, 54)

Callitropsis araucarioides COMPT.
(Neocallitropsis araucarioides (Compt.) FLORIN
Pl. 101, p. 160

b. Cross-field pits commonly uniform in size and shape. Growth rings almost imperceptible. Rays 1—6 (17) cells high, sometimes biseriate; cells in cross section circular, occasionally hexagonal. Number of pits per cross field 2—3 (4), pit diam. 6—12 μ. No callitroid pitting. Per sq. mm. about 1500 tracheids, 170—180 rays, and 260—265 ray cells; index number 1,5. Height of ray cells 13—40 μ, width 6—13 μ. Bordered pits in radial walls of tracheids uniseriate, 13—18 μ in diam., in tangential walls 8—13 μ. Horizontal walls of wood parenchyma smooth. Horizontal walls of ray parenchyma smooth, very rarely with primary pitting. Growth rings distinct. Latewood only a few tracheids in width. (*M.*, 74, 51)

Tetraclinis articulata (Vahl) MAST.
Pl. 172, p. 170

c. Rays 1—35, but frequently only 1—8 (10), cells high, uniseriate, very rarely partly biseriate. Height of ray cells 10—35 μ, width 4—18 μ, very exceptionally 22 μ. Pits in tangential walls of tracheids usually uniseriate and 6—15 μ, in radial walls 7—21 μ in diam. Some so-called bars of *Kleeberg* present, absent, however, in some species. Number of pits per cross field 1—2 (3—4), in marginal cells sometimes 8; pit diameter 3—13 μ. Indentures absent or very rare *(Callitris glauca)*. Wood parenchyma frequent, with resinous contents and always smooth horizontal walls.

Callitris
Pls. 94—100

α Bars of *Kleeberg* present on bordered pits in the walls of tracheids *(Callitris verrucosa, C. robusta, C. glauca)*.

. Horizontal walls of ray parenchyma smooth, sporadically pitted. Rays 1—8 (13) cells high. Height of ray cells 14—24 μ, width 8—12 μ. Bordered pits in tangential walls of tracheids 8—12 μ, in radial walls 13—16 μ in diam. Number of pits in cross field 1—2 (3—4), with 6—9 μ diam. (*Y.*, *M.* 127)

Callitris glauca R. BR.
Pl. 95

.. Horizontal and tangential walls of ray parenchyma perfectly smooth. Rays 1—10 (24—26) cells high, occasionally partly biseriate. Height of ray cells 11—17 μ, width 9—11 μ. In tangential walls of tracheids bordered pits scarce; their diam. 13—21 μ. Horizontal walls of wood parenchyma as well as horizontal and tangential walls of ray parenchyma smooth. Indentures absent. Number of pits per cross field 2—3, 8—9 μ in width. Growth rings indistinct. Tracheids in cross section more or less rounded. Per sq. mm. 2000 tracheids, 50—55 rays, and 100—105 ray cells. (*M.*, 127)

Callitris robusta R. BR.
Pl. 98

... Horizontal walls of wood parenchyma smooth. Scarce primary pitting in horizontal walls

of ray parenchyma. Rays 6—8 (14) cells high. Height of ray cells 17—22 μ, width 5—13 μ. Bordered pits in tangential walls of tracheids 11—13 μ, in radial walls 13—14 μ in diam. Number of pits per cross field 1—2 (3—4) measuring 6—9 μ in diam. Wood parenchyma fairly abundant in latewood. Per sq. mm. 3000 tracheids, 60—65 rays, and 260—265 ray cells. (*Y.*)

Callitris verrucosa R. Br.
Pl. 100

β Bars of *Kleeberg* absent *(Callitris oblonga, C. cupressiformis, C. intratropica, C. sulcata).*

. Rays 1—35 cells high, occasionally partly biseriate. Height of ray cells 8—22 μ, width 4—18 μ. Bordered pits scarce on tangential walls of tracheids, 6—13 μ in diam., on radial walls 15—17 μ. Paired pits sometimes present, surface of contact vertical. Horizontal walls of wood parenchyma as well as horizontal and tangential walls of ray cells perfectly smooth. Indentures absent. In the cross field 1—2 (4—8) pits, 6—7 μ in diam. Per sq. mm. 900 tracheids, 25—30 rays, and 220—240 ray cells. (*M.*, 121)

Callitris cupressiformis Vent.
Pl. 94, p. 159

.. Rays 1—10 (15) cells high.

+ Bordered pits in radial walls of tracheids 13—21 μ in diam. Rays 5—6 (9) cells high. Height of ray cells 13—26 μ, width 12—18 μ. Horizontal and tangential walls of ray parenchyma as well as horizontal walls of wood parenchyma smooth. In the cross field 1—2 (3—4) pits, 8—13 μ in width. In tangential walls of tracheids bordered pits abundant, 13—15 μ in diam. Per sq. mm. 15—20 rays and 65—70 ray cells. Growth rings distinct due to 2—3 cell layers of latewood. Tracheids in cross section angular. Resin contents present in parenchyma. (*M.*, 127)

Callitris sulcata Schlech.
Pl. 99

++ Bordered pits in radial walls of tracheids 7—8 μ in diam., on tangential walls 6—8 μ. Per sq. mm. 8000 tracheids, 110—120 rays, and 410—420 ray cells; index number 3,72. Rays 3—5 (15) cells high, occasionally partly biseriate. Height of ray cells 11—17 (24) μ, width 6—13 μ. Horizontal walls of wood parenchyma smooth, with occasional primary pitting. Indentures absent. In the cross field 1—2 (3) pits, 3—4 μ in diam. Wood parenchyma frequent, mostly arranged in tangential rows, particularly near the outer edges of the growth layers. *(Y.)*

Callitris oblonga Rich.
Pl. 97

+++ Bordered pits in radial walls of tracheids 11—13 μ in diam. Per sq. mm. 4200 tracheids, 230—240 rays, and 420—430 ray cells; index number 1,9. Rays 1—4 (9—10) cells high, uniseriate. Height of ray cells 15—37 μ. Horizontal walls of wood and ray parenchyma smooth, occasionally with traces of primary pitting. Indentures absent. In the cross field 1—2 (3—4) pits, 7—8 μ in diam. (*Y.*, *M.*, 127)

Callitris intratropica Benth. et Hook.
Pl. 96

II. Horizontal walls of ray parenchyma smooth *(Chamaecyparis lawsoniana, Ch. thyoides, Fokienia)*, or with very sparse primary pit fields. Tangential walls smooth *(Chamaecyparis, Microbiota, Biota, Fokienia, Thuja* and *Thujopsis).* Horizontal walls of wood parenchyma rarely smooth, commonly uneven or distinctly nodular. Indentures present or absent. Tracheids in cross section angular. Growth rings distinct. Occasional transverse tracheids *(Thujopsis standishii).*

A. Tangential walls of ray parenchyma smooth. Indentures absent *(Microbiota, Chamaecyparis).*

a. Tangential walls of ray parenchyma as well as horizontal walls of wood parenchyma always smooth. Indentures absent. Tracheids in cross section angular, 16—20 μ in diam. Rays 1—5 (8) cells high, uniseriate. Height of ray cells 13—21 (35) μ, width 7—8 μ; in rays a single cell row high: 24—26 and 6—8 μ, respectively. Horizontal walls of ray parenchyma pitted. Wood parenchyma with resinous contents. In one cross field commonly 2, in the marginal cells 4—6, pits, 4—6 μ in diam. with apertures of 3—4 μ. Per sq. mm. 9800 tracheids, 90—100 rays, and 310—320 ray cells. (*Y.*, 55)

Microbiota decussata Komarov.
Pl. 170, p. 168

b. Horizontal walls of ray parenchyma smooth or pitted, tangential walls always smooth. Horizontal walls of wood parenchyma smooth or uneven, usually with 1—2 minute pits. Rays 1—6 (16)

cells high. Height of ray cells 11—30 (40) μ. In the cross field 1—2, in the marginal cells 2—4, pits, 4—6 μ in diam. Growth rings distinct. Indentures absent or present.

Chamaecyparis SPACH
Pls. 102—108.

α Horizontal walls of ray parenchyma smooth (Ch. lawsoniana, Ch. formosensis, Ch. taiwanensis, Ch. thyoides), or uneven, or very rarely with 1—2 pitlike thinnings *(Ch. nootkaënsis, Ch. obtusa, Ch. pisifera)*.

. Commonly 1 (2) pit in the cross field, 1—2 pits in the marginal cells, mostly superposed; pit diameter 4—5 μ. Pit apertures measure 4,5 × 1—2 μ. Rays 1—6 (10), exceptionally 25, cells high. Height of ray cells 11—17 (22) μ, width 8—13 μ, upright ellipses in cross section. Biseriate rays rather frequent. Indentures absent. In horizontal walls of wood parenchyma sometimes nodular thickenings, 2—4 μ in diam. Per sq. mm. 110—120 rays and 200—210 ray cells. (*M.*, *Y.*, 127, 74, 54)

Chamaecyparis lawsoniana PARL.
Pl. 103, p. 161

.. In the cross field commonly 2 pits mostly side by side; in the marginal cells 4—6; pit diameter 5—6 μ. Horizontal walls of wood parenchyma smooth, or slightly thickened, or with 1—2 nodules. Rays 1—5 (12) cells high. Height of ray cells 11—16 (33) μ, width 5—8 μ. Per sq. mm. 82—90 rays and 240—250 ray cells. (*Y.*, *M.*, 127)

Chamaecyparis thyoides BRITT.
Pl. 108

·.· Cross field sometimes without pits. When pits are present, they stand apart or side by side in pairs; in the marginal cells very rarely as much as 4 pits; pit diameter 5—8 μ. Pit apertures mostly almost horizontal. Horizontal walls of ray cells smooth. Rays 1—6 (12) cells high, uni- or biseriate. Heigth of ray cells 10—13 (18) μ, width 10—13 μ. Indentures absent. Horizontal walls of wood parenchyma exceptionally smooth, commonly thickened beadlike. Per sq. mm. 30—35 rays and 120—125 ray cells. Bordered pits in radial walls of tracheids 12—14 μ, on tangential walls 10—14 μ in diam. (*M.*, 127)

Chamaecyparis formosensis MAST.
Pl. 102

.. In the cross field usually 1, exceptionally 2,
·· cupressoid pits side by side; in the marginal cells likewise 2, sometimes 3—4, pits, commonly also in juxtaposition; pit diameter 5—6 μ. Rays 1—8 (12) cells high. Per sq. mm. 75—80 rays and 230—240 ray cells. Height of ray cells 13—22 μ, width 8—13 μ. Ray cells in cross section short-elliptical or circular. Horizontal walls of wood parenchyma smooth or slightly thickened, beadlike. Tracheary bordered pits 10—13 μ in radial, and 8—11 μ in tangential walls. All ray-cell walls thin and smooth, the horizontal ones sometimes with delicate pitlike thinnings. (*M.*)

Chamaecyparis taiwanensis MASAMUNE et SUFUKI
Pl. 107

β Horizontal walls of rays sparsely pitted or uneven.

. Rays commonly 2—4 (6) cells in height. Per sq. mm. 160—170 rays and 340—350 ray cells. Height of ray cells 11—17 (33) μ, width 4—8 μ. Commonly 1 (2) pit in the cross field, 2—4 pits in the marginal cells. Pit diameter 4—5 μ. In horizontal walls of wood parenchyma 1—2 nodular thickenings. (*Y.*, 127)

Chamaecyparis pisifera ENDL.
Pl. 106

.. Rays generally 1—4 (8—16) cells in height.
+ In the cross field as a rule 1 (2) pit, in the marginal cells 2 (4) pits, 5—6 μ in diam. Height of ray cells 11—22 (37) μ, width 5—10 μ. In horizontal walls of ray parenchyma 3—4 nodulelike thickenings fairly frequent. Transverse tracheids occasionally present. Tangential walls of ray cells sometimes slightly nodular. (*Y.*, *M.*, 127, 53)

Chamaecyparis nootkaënsis SPACH
Pl. 104

++ In the cross field 1—2 (4), in the marginal cells 1—4 (6) pits, 4—6 μ in diam. Rays 1—3 (9) cells high. Height of ray cells 11—18 (44) μ, width 4—8 (13) μ. Wood parenchyma frequent in latewood with slightly thickened or nodular horizontal walls; pits negative. Wood parenchyma with resinous contents. (*M.*, 127)

Chamaecyparis obtusa ENDL.
Pl. 105

+++ In the cross field 1—2, in the marginal cells 3—4, cupressoid pits, 4—6 μ in diam. Per sq. mm. 80—85 rays and 225—230 ray cells. Rays normally 1—4, quite exceptionally up to 12, cells high and uniseriate. In adult trees rays higher throughout. Height of ray cells 10—21 μ, width 10—13 μ. Pit diameter in radial and tangential walls 8—10 μ. Horizontal walls of longitudinal parenchyma nodular, those of ray parenchyma pitted. Tangential walls normally smooth, very seldom punctate. Indenture distinct. Number of tracheids per sq. mm. about 4900. (*Y.*)

Cupressocyparis leylandii DALLIMORE
Pl. 109, p. 162

B. Tangential walls of ray parenchyma commonly smooth, very seldom with delicate and almost imperceptible beadlike nodules. Indentures present, sometimes obscure. Horizontal walls smooth or scarcely pitted. Horizontal walls of wood parenchyma generally uneven, indistinctly knotted or delicately nodular, rarely smooth. Growth rings distinct. In the cross field 1—2 (3—4—5) cupressoid pits, which are circular, or procumbent or somewhat oblique ellipses in the early wood *(Biota, Fokienia, Thuja, Thujopsis).*

a. In the cross field pits usually circular or of the cupressoid type. Rays more or less uniseriate, partly biseriate in places and 1—8 (15) cells in height. Bordered pits in radial walls of tracheids uniseriate, sometimes biseriate in earlywood tracheids. Simple pits frequent in horizontal walls of ray parenchyma. Indentures frequent and conspicuous. Horizontal walls of wood parenchyma slightly thickened or nodular. Resinous contents in parenchyma. Ray cells 10—20 (22) μ high, 4—9 μ wide. (*M.*, *Y.*, 127, 76)

Biota orientalis ENDL.
(Thuja orientalis L.)
Pl. 93, p. 159

b. In the cross field, pits and pit apertures nearly procumbent ellipses and of *taxodioid* type *(Thuja, Thujopsis).*

α In the cross field 2—3 (4) taxodioid pits, 4—6 μ in diam., arranged in pairs, or in threes, side by side; in the marginal cells aligned diagonally. Wood parenchyma scarce. Per sq. mm. 4600 tracheids, 70—75 rays, and 230—240 ray cells. Rays 1—4 (18) cells high. Height of ray cells 8—18 (24) μ, width 4—8 μ. Diameter of bordered pits in tangential walls of tracheids 6—8 μ, in radial walls 10—13 μ. Indentures distinct. (*M.*, *Y.*, 127, 76)

Thuja occidentalis L.
Pl. 174, p. 171

β In the cross field 1—2 (3—4) taxodioid pits, 6—8 μ in diam. Per sq. mm. 4800 tracheids, 90—95 rays, and 250—256 ray cells. Rays 1—6 (15) cells high. Height of ray cells 8—13 μ, width 2—5 μ. Diameter of bordered pits 8—11 μ in tangential walls, 9—13 μ in radial walls of tracheids. Tangential walls of ray parenchyma smooth. Indentures readily discernible. Wood parenchyma very few or absent. *(M.)*

Thuja plicata D. DON
Pl. 175

γ In the cross field commonly 2 pits superposed; in the marginal cells occasionally 3, but within the earlywood 2×3, pits. Pit diameter 4—6 μ. Per sq. mm. about 8000 tracheids, 120—130 rays, and 400—410 ray cells. Rays 1—4 (10) cells high. Height of ray cells 8—18 (24) μ, width 5—10 μ. Horizontal walls of longitudinal parenchyma cells, as well as tangential walls of ray cells, commonly smooth, very rarely with 1 or 2 barely perceptible nodules.

Thuja koraiensis NAKAI
Pl. 173

δ In the cross field 1—2 pits side by side or superposed, in the marginal cells 2—3 (4) as a rule, arranged diagonally.

Thujopsis SIEB. et ZUCC.
Pls. 176—177

. In the cross field, pits apart or side by side in pairs; in the marginal cells sometimes as many as 6; pit diameter 4—6 μ. Transverse tracheids present, with exceedingly delicate spiral thickenings in them. Indentures conspicuous. Per sq. mm. 1500 tracheids, 100—110 rays, and 240—250 ray cells. Rays 1—5 (15?) cells in height and uniseriate. Height of ray cells 9—22 μ, width 3—11 μ. Diameter of bordered pits in tangential walls of tracheids 4—5 μ, in radial walls 12—14 μ. *(M.)*

Thujopsis (Thuja) standishii GORD.
Pl. 177

.. In the cross field, pits in the internal cells commonly isolated, in the marginal cells in pairs and superposed ; pit diameter 5—8 μ. Horizontal walls of ray parenchyma thick, quite occasionally with 1—2 pits. Wood parenchyma abundant. Transverse tracheids absent or very rare. Per sq. mm. 5000 tracheids, 55—60 rays, and 130—140 ray cells. Rays low, 1—5 (?) cells high, sometimes biseriate. Height of ray cells 10—22 (48) μ, width 5—10 μ. Diameter of bordered pits in tangential walls of tracheids 6—8 μ, in radial walls 6—10 μ. (*Y.*, *M.*, 127, 74, 53)

Thujopsis dolabrata SIEB. et ZUCC.
Pl. 176, p. 172

C. Horizontal walls of ray cells smooth and thin, very rarely with 1—2 primary thinnings. Cross-field pits slightly oblique ellipses ; pit apertures also oblique.

a. Rays 1—6 (9) cells high. Height of ray cells 13—22 (27) μ, width 7—12 μ. In the cross field 1—3, in the marginal cells 4—6 simple pits, 5—6 μ in diam. Indentures distinct or indistinct. Per sq. mm. 4100 tracheids, 60—65 rays, and 150—160 ray cells Bordered pits in radial walls of earlywood tracheids frequently biseriate Horizontal walls of wood parenchyma smooth, or thickened, or delicately nodular. (*M.*, *Y.*, 127, 53)

Fokienia Lodginsii HENRY et THOMAS
Pl. 123, p. 165

b. Rays normally low : only 1—7, quite exceptionally up to 30, cells high, uniseriate, sometimes partly biseriate. Height of ray cells 15—18 μ, width 10—13 μ. Longitudinal tracheids with bordered pits having a diameter of 5—8 μ in the tangential, and 13—14 μ in the radial walls. In the cross field 1—2, in the marginal cells sometimes 3, cupressoid pits, 5—8 μ in diam. *(M.)*

Fokienia Kawai HAYATA
Pl. 124

III. Horizontal walls of ray parenchyma commonly pitted, occasionally smooth *(Juniperus californica)*. Tangential walls in general markedly pitted or almost imperceptibly rough, beadlike, exceptionally smooth in certain cells. Horizontal walls of wood parenchyma very rarely smooth, usually thickened, knotted, or beadlike. Indentures distinct or indistinct. In the cross field 1—3 (5—6) cupressoid or taxodioid pits. Tangential walls of ray cells in tangential view with sievelike or scalariform pitting. Ray cells and wood parenchyma with resinous contents. *(Arceuthos, Cupressus, Diselma, Fitzroya, Juniperus, Libocedrus, Pilgerodendron.)* Growth rings distinct. Tracheids in cross section angular. Occasional transverse tracheids.

A. Growth rings generally 2—4, rarely attaining 10—12, tracheids in width. Rays commonly 1—8 cells high. Wood parenchyma mostly terminal, sometimes nearly platelike. In the cross field 1—2 (3—4) cupressoid pits, mostly superposed. Horizontal walls of ray parenchyma frequently smooth, sometimes nodularly thickened, and beadlike at other times. Tangential walls in tangential view generally scalariform. Horizontal walls of wood parenchyma nodular or dentate. Per sq. mm. 5500 tracheids, 160—170 rays and 330—340 ray cells. (*M.*, 127, 54)

Diselma archeri HOOK. F.
Pl. 121, p. 164

B. Growth rings generally 8—10, rarely attaining more than 20, tracheids in width. Tracheids in cross section commonly square. Wood parenchyma sporadical. About 1200 tracheids, 40—45 rays, and 120—130 ray cells per sq. mm. Rays 1—10 cells, very exceptionally 19, cells high. Tangential walls of ray cells smooth or quite frequently cribriform or scalariform. Diam. of ray cells 20—24 (35) μ. In radial walls of tracheids bordered pits scattered. Vestured pits not infrequent. Pit diameter 13—16 μ. In the cross field 1—3, in the marginal cells exceptionally 4—8, cupressoid pits, 4—6 (8) μ in diam. Horizontal walls of wood parenchyma coarse, smooth, or slightly nodular.

Fitzroya cupressoides (Molina) JOHNSTON
Pl. 122*, p. 164

Cupressus species

C. Growth layers commonly more than 20—30 cells wide. Rays 1—45 cells in height, usually uniseriate. Horizontal walls of wood parenchyma pitted, or nodular, or smooth. Horizontal walls of ray parenchyma commonly pitted, sporadically smooth. Tangential walls thickened beadlike, or coarse, or smooth, in tangential view sometimes scalariform. Cupressoid pitting. Rays 1—45 cells high. Parenchymatous cells commonly resinous.

* Magnification of Fig. 4 not 100×, as stated on this plate, but 300×

Indentures generally present, sometimes scarcely noticeable *(C. funebris)*. Occasional transverse tracheids. *Cupressus* L.

. Highest rays exceed 1—20 cells *(C. arizonica, C. lusitanica, C. torulosa)*.

+ Rays 1—45, commonly 6—12, cells high. Per sq. mm. 2400 tracheids, 70—75 rays, and 430—450 ray cells. (Index number 6.) Height of ray cells 8—17 μ, in single-row rays 24 μ; ray-cell width 4—11 μ. Bordered pits in tangential walls of tracheids 6—8 μ, in radial walls 8—12 μ in diam. Horizontal walls of wood parenchyma smooth, or coarse, or thickened beadlike. Horizontal walls of ray parenchyma smooth in places, tangential walls with beadlike thickenings. Indentures present. In the cross field 1—2 (3) cupressoid pits, 6—8 μ in diam. Growth rings indistinct. (*M.*, 127)

Cupressus torulosa D. Don
Pl. 119

++ Rays 1—33, commonly 3—8, cells high. Per sq. mm. 3500 tracheids, 110—120 rays, and 210—220 ray cells. (Index number 1,9.) Rays uniseriate, in places partly biseriate. Height of ray cells 13—22 μ, in single-row rays sometimes 28 μ; ray-cell width 5—13 μ. Pits in tangential walls of tracheids 8—10 μ in height. Horizontal walls of wood parenchyma with beadlike thickening or smooth. Horizontal walls of ray parenchyma pitted, tangential walls thickened beadlike. Indentures present. In the cross field 1—2 pits, 5—8 μ in diam. Growth rings not evident, only a few tracheids in width. (*M.*, 127)

Cupressus arizonica Greene
Pl. 110

+++ Rays 1—25, commonly 2—16, cells high. Per sq. mm. 5500 tracheids, 100—110 rays, and 160—170 ray cells. Some rays partly biseriate. Height of ray cells 11—17 (22) μ, width 6—11 μ. Pits of tracheids on tangential walls 11—13 μ, on radial walls 10—16 μ in diam. Horizontal walls of wood parenchyma thickened beadlike. Horizontal walls of rays sparsely pitted, tangential walls smooth or with beadlike thickenings. Indentures present. In the cross field 1—2 (3—4) pits, 5—9 μ in diam. Growth rings readily definable. Latewood a few tracheids in width. (*M.*, 127)

Cupressus lusitanica var. benthamii Carr.
Pl. 114

.. Rays 1—20 cells high *(C. sempervirens, C. ludley, C. duclouxiana)*.

+ Rays 1—15 (20), commonly 1—8, cells high. Per sq. mm. 5200 tracheids, 100—110 rays, and 170—175 ray cells. (Index number 1,7.) Rays uniseriate, high ones partly biseriate. Height of ray cells 13—25 μ, in single-row rays up to 35 μ; width of rays 6—15 μ. Bordered pits uni- or biseriate in tangential walls of tracheids, 6—8 μ in diam.; on radial walls 8—13 μ. Horizontal walls of wood parenchyma smooth, rarely beadlike thickened. Horizontal walls of ray parenchyma sparsely pitted, tangential walls mostly arching and smooth, or beadlike thickened. Indentures present. Fairly frequently traces of scalariform thickenings seen on tangential walls in tangential view. In the cross field 1—2 (4—6) pits, in the marginal cells generally more. Growth rings indistinct; latewood 4—5 tracheids in width. (*Y.*, *M.*, 127, 53, 74)

Cupressus sempervirens L.
Pl. 118, p. 163

++ Rays 1—8 (16) cells high. Per sq. mm. 6000 tracheids, 110—115 rays, and 325—330 ray cells. Growth rings distinct; slightly flattened, narrow-lumened latewood tracheids followed directly by wide-lumened early tracheids. Transition from early- to latewood gradual. On inner edge of latewood zone longitudinal parenchyma cells frequent, sometimes arranged terminally. Rays commonly uniseriate. Ray cells 13—21 μ high and 10—12 μ wide. Pit diameter in radial tracheary walls 10—12 μ, in tangential walls 8—9 μ. Horizontal walls of longitudinal parenchyma cells usually smooth or with slight beadlike thickenings. Horizontal ray-cell walls generally smooth, very rarely with one or two simple pits; tangential walls for the greater part smooth, quite exceptionally with almost imperceptible nodular thickening. Indentures occasional. Transverse tracheids absent. In the cross field 1—2, in the marginal cells 3—4, cupressoid pits, mostly diagonally disposed; pit diameter 3—5 μ. Longitudinal and ray parenchyma cells frequently resinous. (*M.*, 127, 55)

Cupressus macnabiana Murr.
Pl. 115

+++ Rays 1—14, commonly 4—5, cells high, generally uniseriate. Per sq. mm. 6800 tracheids, 170—180 rays, and 470—480 ray cells. Growth rings distinct. Wood parenchyma abundant. Height

of ray cells 13—18 μ, width 9—16 μ. Diameter of pits in radial walls of tracheids 9—12 μ, in tangential walls 8—10 μ. Horizontal walls of wood parenchyma usually smooth, exceptionally with slight beadlike thickening. Identures present. In the cross field 2—3 superposed pits, in the marginal cells 5—6, in two vertical rows, as a rule ; pit diameter 4—6 μ. Wood parenchyma resinous. (*Y.*)

Cupressus duclouxiana HICKEL
Pl. 111

∴ Rays 1—10 cells high *(C. funebris, C. goveniana, C. macrocarpa, C. whitleyana).*

+ Per sq. mm. 4700 tracheids, 100—105 rays, and 220—225 ray cells. (Index number 2,2.) Rays commonly 2—4 cells high, seldom attaining a height of 10 cells, uniseriate. Height of ray cells 13—20 μ, in single-row rays 36 μ ; ray width 6—12 μ. Diameter of bordered pits on tangential walls of tracheids 8—12 μ, on radial walls 9—16 μ. Horizontal walls of wood parenchyma with beadlike thickening ; horizontal walls of ray parenchyma sparsely pitted ; tangential walls smooth or beadlike thickened. Indentures absent, or present and rather indistinct. In the cross field 2—3 (4) pits, mostly in quadratic arrangement. Pit diameter 4—6 μ. Growth rings indistinct or distinct. (*M.*, *Y.*, 127)

Cupressus funebris ENDL.
Pl. 112

++ Rays 1—10 (17), generally 2—4, cells high. Per sq. mm. 4000 tracheids, 65—70 rays and 230—240 ray cells. Rays uniseriate, sometimes partly biseriate. Height of ray cells 12—22 μ, width 7—12 μ. Diameter of bordered pits on tangential walls of tracheids 8—12 μ, on radial walls 8—18 μ. Horizontal walls of wood parenchyma smooth or slightly pitted. Horizontal walls of ray parenchyma sparsely pitted, tangential walls smooth or pitted delicately beadlike. Indentures absent, or present and hardly discernible. In the cross field 1—2 (3—4) pits, 5—6 μ in diam. (*Y.*, 127)

Cupressus goveniana GORD.
Pl. 113

+++ Rays 1—10, commonly 1—6, cells high, uni- or, rarely, biseriate. Per sq. mm. 5100 tracheids, 100—110 rays, and 170—180 ray cells. Height of ray cells 13—18 (22) μ, width 5—13 μ. Diameter of bordered pits on tangential walls of tracheids 8—9 μ, on radial walls 9—12 μ. Horizontal wal of wood parenchyma commonly smooth, rarely slightly pitted, beadlike. Horizontal walls of ray parenchyma coarse, sparsely pitted ; tangential walls smooth or thickened beadlike. Indentures absent, or present and indistinct. In the cross field 1—2 (3—4) pits, 4—7 μ in diam. Transverse tracheids scarce. Growth rings indistinct. (*M.*, 127)

Cupressus macrocarpa HARTWEG
Pl. 116
et C. m. var. quadalupensis MAST.
Pl. 117.

++++ Rays 1—5 (12) cells high. Per sq. mm 3300 tracheids, 100—110 rays, and 240—250 ray cells. Height of ray cells 10—24 μ, width 6—9 μ. Bordered pits in radial walls of tracheids 7—11 μ, in tangential walls 8—13 μ in diam. Tangential walls of ray cells rarely smooth, mostly marked with 1—3 nodules. Sometimes scalariform thickenings on tangential walls in tangential view. Horizontal walls of wood parenchyma with delicate beadlike thickening. Indentures present. In the cross field 2—4 cupressoid pits ; the same arrangement in marginal cells ; 2 pits superposed. Pit diameter 4—8 μ.

Cupressus whitleyana CARR.
Pl. 120*

LIBOCEDRUS SPECIES

D. Rays commonly biseriate. Tracheids in cross section squared. Ray cells in cross section generally low ellipses, sometimes circular or slightly elongate upright ellipses, or hexagonal. Horizontal walls of ray parenchyma smooth *(L. austrocaledonica, L. bidwillii, L. chilensis, L. plumosa)*, or slightly or markedly pitted. Horizontal walls of wood parenchyma smooth or pitted. Wood parenchyma mostly resinous. Indentures present, occasionally indistinct or absent.

Pilgerodendron et Libocedrus ENDL.
Pls. 163—169, 171

. Horizontal and tangential walls of rays with simple pits ; tangential walls sporadically with nodular thickenings. Occasional indentures.

*Owing to a regrettable mistake in the compilation the drawing pertaining to this species appears on Plate 264 with the photographs of *Picea polita* Carr., while those belonging to that species appear on Plate 120.

+ In the cross field 1—2, in the marginal cells 2—3 (4) pits. Per sq. mm. 2600 tracheids, 110—115 rays, and 230—240 ray cells. Rays 2—4 (6) cells high. Height of ray cells 10—20 μ, width 5—10 μ. (*M.*, *Y.*, 14a, 129)

Libocedrus macrolepis BENTH. et HOOK.F.
(*Heyderia macrolepis* (Kurz) LI)
Pl. 168

++ In the cross field 2—5, in the marginal cells 4—6 (7) simple pits, 4—5 μ in diam. Per sq. mm. 5500 tracheids, 115—120 rays, and 330—340 ray cells. Rays 2—6 (18) cells high. Height of ray cells 10—22 μ, width 4—13 μ. Diameter of bordered pits in tangential walls of tracheids 6—10 μ, in radial walls 8—10 μ. (*M.*, 74, 52.)

Libocedrus decurrens TORREY
Pl. 166, p. 177

+++ In the cross field commonly 1—2, in the marginal cells 1—4, very rarely 5, pits of 5—8 diam.; some cross fields without pits. About 3000 tracheids, 85—90 rays and 200—210 ray cells per sq. mm. Rays typically 1—10, exceptionally 15, cells high; uniseriate, occasionally partly biseriate. Internal ray cells 16—21, external ones 27 μ high; ray cell width 10—15. μ Diameter of pits in tangentinal as well as radial walls 10—14. μ Horizontal walls of longitudinal parenchyma cells slightly nodular; tangential walls of ray cells appearing as strings of beads; in some of them as many as 7—8 beadlike thickenings visible. (*M.*)

Libocedrus formosana FLORIN
(*Heyderia formosana* (FLORIN) LI)
Pl. 167

++++ In the cross field 1—3, in the marginal cells 4—5 pits irregularly placed, 6—7 μ in diam. Pit aperture horizontal or oblique, 4—5 μ long. Tracheids in cross section square. Size of earlywood tracheids 40—60 μ. Rays 2—4 (12) cells high, uniseriate, high ones partly biseriate. Ray parenchyma resinous. Horizontal walls of rays either smooth or slightly nodular. Height of ray cells 13—17 μ, width 13—16 μ. Horizontal walls of ray cells smooth or sparsely pitted. Tangential walls smooth or with delicate beadlike thickening. Indentures absent, or present and indistinct. (*M.*, 14a, 129, 55)

Pilgerodendron uviferum FLORIN
(*Liboredrus uvifera* PILGER)
Pl. 171, p. 169

. . Horizontal walls of ray parenchyma cells usually smooth, practically unpitted. Tangential walls smooth or with very sparse, hardly discernible nodules. Horizontal walls of wood parenchyma smooth or evenly thickened. Indentures absent, or present and indistinct.

+ In the cross field 1—2 (4) pits, 8—10 μ in diam. Per sq. mm. 3200 tracheids, 40—45 rays, and 70—75 ray cells. Rays 1—4 (6) cells high. Height of ray cells 22—37 μ, width 6—16 μ. Bordered pits on tangential walls of tracheids 9—10 μ, on radial walls 10—13 μ in diam. (*Y.*)

Libocedrus austrocaledonica BRONGN. et GRIS.
Pl. 163

++ In the cross field 1—2 (4) pits, 4—5 μ in diam. Per sq. mm. 20—30 rays and 50—60 ray cells. Rays 2—4 (6—8) cells high. Bordered pits on tangential walls of tracheids 4—6 μ, on radial walls 8—10 μ in diam. Horizontal and tangential walls of rays smooth. Sometimes minute cubiform calcium oxalate crystals in rays. Resin very abundant. Horizontal walls of wood parenchyma smooth. (*M.*, 137, 14a)

Libocedrus bidwillii HOOK.
Pl. 164

+++ In the cross field 1—4 (6) pits, 5—9 μ in diam. Per sq. mm. 110—115 rays, 280—290 ray cells. Horizontal walls of ray cells thin, tangential walls smooth. In radial walls of tracheids paired pits frequent. Crassulae well discernible. Rays 1—4 (8) cells high. Height of ray cells 13—26 μ, width 6—15 μ. Bordered pits on tangential and radial walls of tracheids 8—11 μ. (*Y.*, *M.*)

Libocedrus plumosa DRUCE (*Libocedrus doniana* ENDL.)
Pl. 169

++++ In the cross field 1—2, in the marginal cells 2—4 (6) pits, 4—5 μ in diam. Horizontal ray-cell walls 3—4 μ thick. Horizontal and tangential

walls smooth. Horizontal walls of wood parenchyma also smooth. Resin contents abundant. (*M.*, 127, 14a)

Libocedrus chilensis ENDL.
Austrocedrus chilensis (D. Don) FLORIN et BOUTELJE)
Pl. 165.

JUNIPERUS SPECIES

E. Pits in the cross field large, 6—8 μ in diam.

+ In the cross field of inner ray cells commonly one single large pit sometimes attaining more than half of the ray-cell height, 6—8 μ in diameter. When there are two pits in the cross field, they are *side by side.*

x Rays 1—4 (12) cells high. Ray cells in tangential section rather upright ellipses. Height of ray cells 10—22 μ, width 3—8 μ. Ratio about 3 : 1. Per sq. mm. 3800 tracheids, 110—120 rays, and 380—390 ray cells. Horizontal walls of wood parenchyma rarely smooth, commonly nodular. (*Y.*, *M.*, 127)

Juniperus virginiana L.
Pl. 161

xx Rays 1—10 (24) cells high. Ray cells in cross section upright ellipses, 8—23 μ in height and 4—6 (8) μ in width. Per sq. mm. 3500 tracheids, 95—100 rays, 280—290 ray cells. In the cross field commonly a single large pit, 6—8 μ in size, sometimes two side by side. In the marginal cells 2—4 pits placed diagonally. Pit apertures wide. Wood parenchyma resinous. Horizontal walls of wood parenchyma slightly nodular. Indentures definite. (*M.*, 127)

Juniperus rigida SIEB. et ZUCC.
Pl. 154

++ In the cross field one pit, not infrequently two, mostly superposed, 6—8 μ in diam.

x Rays 1—12 cells high. Height of ray cells 13—22 μ, width 4—6 μ. (Ratio 3 : 1.) Diameter of bordered pits in tangential walls of tracheids 4—5 μ, in radial walls 11—13 μ. Per sq. mm. 4500 tracheids, 90—95 rays, and 350—360 ray cells. Horizontal walls of wood parenchyma smooth or very delicately nodular. (*Y.*, *M.*, 127, 74, 53)

Juniperus communis L.
Pl. 130, p. 166

xx Rays 1—4 (12) cells high. Height of ray cells 11—13 (43) μ, width 5—8 μ. (Ratio 2 : 1.) Bordered pits in tangential walls of tracheids 6—8 μ, in radial walls 11—13 μ. Per sq. mm. 7800 tracheids, 170—175 rays, and 350—360 ray cells. Horizontal walls of wood parenchyma smooth or slightly nodular. Intentures present. (*M.*, 127)

Juniperus communis var. saxatilis PARL.
(*Y. c. var. nana* LOUD)
Pl. 131

xxx Rays 1—6 (13) cells high. Per sq. mm. 8100 tracheids, 100—110 rays, 330—340 ray cells. Height of ray cells 10—24 μ, width 5—10 μ. (Ratio 2 : 1). Horizontal walls of ray parenchyma coarse, sparsely pitted, tangential walls with fairly discernible beadlike thickening. Tangential walls of ray cells frequently with scalariform thickenings in tangential view. Horizontal walls of wood parenchyma smooth, or coarse, or beadlike thickened. In the cross field a single pit in the internal, and usually two superposed in the marginal cells ; pit diameter 4—7 (8) μ. (*Y.*, 127)

Juniperus phoenicea L.
Pl. 147

xxxx Rays 1—12 cells high. In the cross field exceptionally 2 (3—4) superposed pits ; in the marginal cells 2 pits common, likewise superposed. Tangential walls of ray cells beadlike thickened. Horizontal walls of wood parenchyma always nodular. Per sq. mm. 6900 tracheids, 100—110 rays, and 290—300 ray cells. Tangential walls of ray cells with cribriform or scalariform thickenings in tangential view. (*M.*, 127)

Juniperus oxycedrus L.
Pl. 145

xxxxx Rays 1—8 (12) cells high. In the cross field usually 1, occasionally 2 or 4 pits, in the marginal cells mostly 4. Tangential walls of ray cells markedly dentate. Tangential walls with scalariform pitting in tangential view. Horizontal walls of wood parenchyma smooth, or with slight beadlike thickening. Per sq. mm. 6000 tracheids, 120—125 rays, and 260—265 ray cells. (*M.*, 127)

Juniperus sabina L.
Pl. 155

xxxxxx Rays 2—6 (10) cells high. In the cross field generally 2 (1) superposed pits, 6—8 μ in diam. In the marginal cells 3—6 pits fairly frequent. Per sq. mm. 3800 tracheids, 50—60 rays, and 170—180 ray cells. Tangential walls of ray parenchyma frequently smooth, rarely nodular. Horizontal walls of wood parenchyma smooth as a rule, rarely nodular. Height of ray cells 13—20 (33) μ, width 5—9 μ. Indentures present. (*M.*)

Juniperus conferta PAR.
Pl. 132

xxxxxxx Rays 1—3—14 cells high. In the cross field normally 1—2 pits, 5—8 μ in diam., superposed or in juxtaposition ; in the marginal cells mostly 2, seldom 3—4, pits. Per sq. mm. about 6000 tracheids, 110—115 rays, 325—330 ray cells. Ray cells 16—21 μ high, 13—14 μ wide. Bordered pits in radial walls 10—13 μ, in tangential walls 10—12 μ. In tangential walls of ray parenchyma nodules common. Horizontal walls of longitudinal parenchyma with beadlike or dentate thickening. Indentures present. (*M.* 170)

Juniperus tibetica KOMAR.
Pl. 160a

. Pits in cross field relatively small, 4—6 (7) μ in diam.

\+ Commonly one pit per cross field ; 2 superposed pits in marginal cells.

x Rays 1—6 (12) cells high.

△ Cross-field pits 4—5 μ in diam. Ray cells in cross section short-elliptic, 13—21 (37) μ in height, 6—8 μ in width ; ratio about 2 : 1. Per sq. mm. 9500 tracheids, 150—155 rays and 260—270 ray cells. Horizontal walls of wood parenchyma nodular. Horizontal walls of rays pitted, tangential walls definitely nodular. (*Y.* 127)

Juniperus pachiphloea TORREY
(*Y. deppeana* STEUD.)
Pl. 146

△△ Rays 2—3 (7) cells high. Per sq. mm. 130—140 rays and 320—330 ray cells. Height of ray cells 10—18 (27) μ, width 5—10 μ. Horizontal walls of rays pitted, tangential walls dentate in radial, and cribriform or scalariform in tangential, view. Horizontal walls of wood parenchyma with beadlike thickening. *(M.)*

Juniperus pinchoti SUDW.
Pl. 148

△△△ Per sq. mm. 85—90 rays and 250—255 ray cells. Height of ray cells 13—21 (27) μ, width 8—13 μ ; their horizontal walls pitted, the tangential walls, viewed from the tangential side, with scalariform thickening. In the horizontal walls of the longitudinal parenchyma 2—3 beadlike thickenings. *(M.)*

Juniperus recurva BUCH.-HAM.
Pl. 153

xx Rays 1—24 cells high.

△ Ray cells in cross section circles or ellipses, 8—20 μ in height, 6—8 μ in width. Ratio 1 : 1 or 2 : 1.

o Rays 1—4 (7) cells high. Parenchyma commonly terminal. Per sq. mm. 100—110 rays and 300—310 ray cells. Height of ray cells 13—18 (27) μ. Horizontal walls of rays sparsely pitted, tangential walls beadlike in radial, cribriform or scalariform in tangential view. Normally a single pit in the cross field of inner cells ; 1—2 pits in marginal cells, when two then superposed. Pit diam. 4—5 μ. Horizontal walls of wood parenchyma with slight beadlike thickening. Parenchyma abundantly resinous. (*M.* 127)

Juniperus ashei BUCH.-HAM.
Pl. 126

o o Rays 1—4 (8) cells high. Per sq. mm. 5500 tracheids, 130—140 rays, and 250—260 ray cells. Horizontal walls of ray cells smooth, very rarely with a pit in them ; tangential walls dentate, scalariform in tangential view. Horizontal walls of wood parenchyma smooth or thickened beadlike. A single pit per cross field as a rule, 2 pits in marginal cells, commonly superposed. Pit diameter 4—6 μ. Indentures possible. (*Y. M.* 127)

Juniperus californica CARR.
Pl. 128

o o o Rays 1—6 (13) cells high. Per sq. mm. 6500 tracheids, 70—75 rays, and 210—220 ray cells. Height of ray cells 13—30 μ. Horizontal walls of ray cells conspicuously pitted. Indentures present.

Tangential walls dentate, commonly scalariform in tangential view. Horizontal walls of wood parenchyma smooth or thickened beadlike. Wood parenchyma frequent. Latewood only a few cell layers. In the cross field of inner cells 1 (2) pit, in the marginal cells 2 (3) superposed pits; pit diameter 4—6 μ. (*M*)

Juniperus formosana HAYATA
Pl. 135

oooo Rays 1—4 (10) cells high. Per sq. mm. 7000 tracheids, 160—170 rays, and 380—390 ray cells. Height of ray cells 8—15 (27) μ, width 5—8 μ. Horizontal walls of ray cells sparsely pitted. Indentures occasional. Tangential walls of rays beadlike, in tangential view commonly only scalariform. Horizontal walls of wood parenchyma smooth or with beadlike thickenings. Wood parenchyma frequent. One pit in cross field of inner cells, usually two pits in marginal cells. Pit diameter 5—6 μ. Rays and wood parenchyma resinous. (*Y*)

Juniperus macrocarpa SIBT.
Pl. 140

++ In the cross field commonly 2 relatively small pits side by side, 4—6 μ in diam.; in the marginal cells 3—4 pits, usually placed diagonally.

x Rays 1—6, exceptionally 14, cells high. Diameter of bordered pits in radial walls of tracheids 9—16 μ. Per sq. mm. 2000 tracheids, 60—65 rays, and 340—350 ray cells. Height of ray cells 8—12 μ, width 5—7 μ. Horizontal walls of rays pitted. Indentures definite. Tangential walls thickened beadlike, sievelike, or scalariform in tangential view. Horizontal walls of wood parenchyma beadlike thickened. Sometimes terminal parenchyma. Commonly 2 (1) pits in the cross field, 3—4 pits in the marginal cells, 5—7 μ in diam. Parenchyma abundantly resinous. (*M*. 127)

Juniperus occidentalis HOOK.
Pl. 144

xx Rays 1—8 cells high, exceptionally 24 cells and then partly biseriate. Diameter of bordered pits in radial walls of tracheids 13—14 μ. Per sq. mm. 65—70 rays and 200—210 ray cells. Horizontal walls of ray cells relatively thick, coarse, and sparsely pitted. Indentures frequent. Tangential walls smooth or delicately nodular. Number of pits per cross field usually 2 side by side, but in the marginal cells 3—4 pits placed diagonally; pits 4—6 (7) μ in diam. Wood parenchyma frequently resinous. Where the horizontal walls of ray cells are in contact with tracheids, X-figured negative pits are fairly frequent. (*M.*)

Juniperus silicicola (Small.) BAILEY
Pl. 158

xxx Rays 1—10 (16) cells high. Per sq. mm. 2400 tracheids, 80—85 rays, and 350—360 ray cells. Height of ray cells 10—18 (27) μ, width 8—10 μ. Horizontal walls of rays pitted, occasionally disjunctive; tangential walls with sparse, dentate, and viewed from the tangential side, with commonly scalariform thickenings. Indentures present. Horizontal walls of wood parenchyma smooth or delicately nodular; cells resinous. Generally one pit per cross field, 2—3 (4) pits in marginal cells, placed side by side or diagonally, 4—6 μ in diam. Sometimes terminal parenchyma. (*M*. 127)

Juniperus scopulorum SARG.
Pl. 157

xxxx Ray cells in cross section low-elliptic or circular, 6—8 (26) μ in height, 6—8 (17) μ in width. Per sq. mm. 5600 tracheids, 120—130 rays, and 420—430 ray cells. Horizontal walls of ray parenchyma sparsely pitted. Indentures present. Tangential walls beadlike thickened, commonly cribriform or scalariform in tangential view. Horizontal walls of wood parenchyma slightly pitted. Usually 2 (1) pits side by side per cross field, 3—4 pits in the marginal cells. Wood parenchyma frequent, sometimes terminal. (*M*. 127)

Juniperus monosperma SARG.
Pl. 143

xxxxx Ray cells in cross section elongate upright ellipses, 11—21 μ high, 5—8 μ wide. Per sq. mm. 4500 tracheids, 100—110 rays, and 240—280 ray cells. Horizontal walls of ray parenchyma with fairly numerous pits; tangential walls beadlike thickened, with sievelike or scalariform pitting in tangential view. Indentures present. Horizontal walls of wood parenchyma smooth or thickened

beadlike. In the cross field normally 1 (2) pit, in the marginal cells 2—3—4 pits, arranged irregularly. (*Y.*, *M.*, 127) *Juniperus bermudiana* L.
Pl. 127

+++ Commonly (1) 2 (3) superposed pits per cross field. Rays 1—6 (12) cells high.

x Rays 1—7 (15) cells high. Per sq. mm. 10 000 tracheids, 110—115 rays, and 210—220 ray cells. Height of ray cells 13—18 (32), width 5—6 μ. Horizontal walls of ray cells frequently pitted; indentures rare or almost imperceptible. Tangential walls dentate with sievelike or scalariform thickenings in tangential view. Horizontal walls of wood parenchyma smooth or slightly nodular. Commonly 2 superposed pits per cross field; 2 (3) pits in marginal cells. Pits minute, 4—5 μ in diam. *(Y.)*

Juniperus przewalskii KOMAROV
Pl. 151

xx Rays 1—7 (12) cells high. Per sq. mm. 10 500 tracheids, 120—130 rays, and 300—310 ray cells. Height of ray cells 13—21 (43) μ, width 8—10 μ. Horizontal walls of rays pitted; tangential walls thickened beadlike or dentate; sievelike or scalariform in tangential view. Horizontal walls of wood parenchyma slightly or markedly nodular. Commonly 2 (3) superposed pits in the cross field, occasionally 3 superposed pits in the marginal cells. Pit diameter 5—8 μ. Wood parenchyma frequent. *(Y., M.)*

Juniperus ramulosa FLORIN
Pl. 152

xxx Rays 1—5 (13) cells high. Per sq. mm. 8200 tracheids, 160—165 rays, and 310—320 ray cells. Height of ray cells 13—18 (29) μ, width 8—16 μ. Horizontal walls of ray cells frequently pitted; pits in tangential walls numerous. Tangential walls in tangential view scalariform. Horizontal walls of wood parenchyma nodular or smooth. Indentures absent or almost indistinct. Commonly 2 pits per cross field, 2—3 superposed pits in the marginal cells. Pit diameter 4—5 μ. Growth rings relatively narrow. Wood parenchyma frequent. Tangential walls of earlywood tracheids abundantly pitted. (*Y.*, 170)

Juniperus saltuaria REHD. et WILS.
Pl. 156

xxxx Rays 1—4 (6) cells high. Per sq. mm. 8000 tracheids, 190—200 rays, and 300—310 ray cells. Height of ray cells 10—18 μ, width 4—8 μ. Horizontal walls of ray cells near to perfectly smooth, very rarely with a pit in them. Tangential walls now smooth, now with almost imperceptible nodular thickenings, but smooth or scalariform in tangential view. Pits scarce, elliptic. Horizontal walls of wood parenchyma slightly nodular. In the cross field 1—3 superposed pits, usually the same number in the marginal cells; pit diameter 4—6 μ. Wood parenchyma sometimes terminal. (*Y.*, 127)

Juniperus thurifera L.
Pl. 160

xxxxx Rays 1—7 (10) cells high. Per sq. mm. 5600 tracheids, 140—150 rays, and 350—360 ray cells. Horizontal walls of ray cells sparsely pitted, tangential walls thickened beadlike, conspicuously cribriform in tangential view. Indentures absent or barely visible. Horizontal walls of wood parenchyma smooth or thickened beadlike. In the cross field 2—3 minute superposed pits, 4—5 μ in diam.; as many in the marginal cells. Growth rings comparatively narrow. *(Y.)*

Juniperus zaidamensis KOMAROV
Pl. 162

$\frac{xxx}{xxx}$ Rays 1—8 (18) cells high. Per sq. mm. 7000 tracheids, 220—230 rays, and 510—520 ray cells. Height of ray cells 11—27 (37) μ, width 5—13 μ. Horizontal walls of ray cells pitted, tangential walls beadlike thickened. Horizontal walls of wood parenchyma nodular. In the cross field 2—3, in the marginal cells occasionally 4, pits placed diagonally; pit diameter 5—6 μ. Ray cells in cross section subcircular. Cells of rays in single rows considerably higher than cells of higher rays. *(Y.)*

Arceuthos drupacea ANTOINE
(Juniperus drupacea LABILL)
Pl. 92, p. 158

$\frac{xxxx}{xxx}$ Growth rings distinct. Last rows of late tracheids markedly flattened radially. Parenchyma cells frequently with resinous, usually dark contents. Some rows of tracheids, especially those extending in the vicinity of rays, conspicuously larger than the rest. Rays 1—9, exceptionally 18, cells in height. Ray cells 16—24 μ high, 8—17 μ

wide. Bordered pits in tangential walls of tracheids 8—10 μ in diam. Horizontal and tangential walls of ray cells strongly pitted; tangential walls sometimes with 4—5 beadlike thickenings. In the cross field 1 pit, but in the latewood 2 pits side by side or superposed; in the marginal cells generally 3—4 cupressoid pits; pit apertures 2—4 μ in diam. Indentures well discernible. Bordered pits of longitudinal tracheids occasionally flanked by coiled thickenings of the cellular walls. Horizontal walls of wood parenchyma cells very rarely smooth, generally with 1—3 nodular thickenings. Tangential walls of ray cells scalariform in tangential view. Bordered pits in radial walls of tracheids 10—16 μ, in tangential walls 8—10 μ in diam. *(M.)*

Juniperus macropoda Boiss.
Pl. 141

++++ Usually 2 superposed pits per cross field, but 2—4 pits in marginal cells. Ray cells in cross section circles or short ellipses.

x Rays 1—8 (20) cells high, biseriate in places. Wood parenchyma terminal. Per sq. mm. 8500 tracheids, 160—170 rays, and 310—320 ray cells. Ray cells 13—20 (44) μ high, 11—14 (20) μ wide; their horizontal walls pitted; tangential walls thickened beadlike, cribriform or scalariform in tangential view. Indentures present. Horizontal walls of wood parenchyma with beadlike thickenings. In the cross field 2—3 pits generally superposed or irregularly arranged; pit diam. 3—5 μ. *(Y.)*

Juniperus mexicana Schlech.
Pl. 142

xx Rays 1—10 (20) cells high, biseriate in places. Wood parenchyma rather scattered. Per sq. mm. 6500 tracheids, 260—265 rays, and 420—430 ray cells. Ray cells 8—10 (27) μ high, 6—10 μ wide. Horizontal walls of ray cells occasionally pitted, tangential walls with beadlike thickenings, cribriform in tangential view. Horizontal walls of wood parenchyma beadlike thickened. In the cross field 1—2 (3) superposed pits, in the marginal cells sometimes 6 pits arranged in 2 rows or irregularly; pits 4—5 μ in diam. *(M.)*

Juniperus foetidissima Willd.
Pl. 136

xxx Rays 1—6 (8) cells high. Per sq. mm. 8000 tracheids, 200—210 rays, and 420—425 ray cells. Ray cells 11—24 μ high, 5—8 μ wide. Horizontal walls sparsely pitted, tangential walls thickened beadlike. Indentures present. Horizontal walls of wood parenchyma with beadlike thickenings. Per cross field 1—2 (3) minute pits, 4—5 μ in diam. Wood parenchyma scarce. (*Y.*, *M.*, 127)

Juniperus excelsa Bieb.
Pl. 134

xxxx Rays 1—6 (11) cells high. Per sq. mm. 6500 tracheids, 80—90 rays, 260—270 ray cells. Height of ray cells 10—27 μ, width 5—9 μ; ratio 2,5 : 1. Horizontal walls of ray cells slightly uneven with sparse pitting. Indentures present. Tangential walls of ray cells commonly scalariform in tangential view. Horizontal walls of wood parenchyma thickened beadlike. In the cross field 2—3 pits, superposed or in triangular formation; 5—6 pits in marginal cells; pits 4—6 μ in diam. (*Y.*, 127)

Juniperus chinensis L.
Pl. 129

xxxxx Rays 1—5 (8) cells high. Per sq. mm. 6500 tracheids, 160—170 rays, and 600—610 ray cells. Ray cells 10—17 μ high, 4—8 μ wide; ratio 2,5 : 1. Horizontal walls of ray cells pitted; tangential walls dentate, scalariform in tangential view. Horizontal walls of wood parenchyma thickened beadlike. Wood parenchyma resinous. Per cross field 1—2 (3) minute superposed pits, 4—5 μ in diam. (*Y.*, *M.*, 127)

Juniperus squamata Buch.-Ham.
Pl. 159

xxxxxx Rays 1—6 (18) cells high. Per sq. mm. 6900 tracheids, 210—220 rays, and 500—510 ray cells. Horizontal walls of ray cells frequently pitted; tangential walls thickened beadlike, scalariform, rarely cribriform in tangential view. Ray cells 10—18 μ high, 5—10 μ wide. In horizontal walls of wood parenchyma 1—2 beadlike thickenings. Per cross field 1—2 superposed pits, 3—4 in marginal cells; pit diameter 4—5 μ. *(M.)*

Juniperus pingii Cheng
Pl. 149

++++++ Commonly (1) 2—3—4 minute pits per cross field, 4—6 μ in diam., in diagonal or irregular arrangement; more or less the same arrangement in marginal cells.

x Tangential walls of ray parenchyma fairly frequently smooth, or with only 3—4 minute, almost imperceptible nodules. Rays 1—3 (9) cells high. Per sq. mm. 5500 tracheids, 110—120 rays, and 210—220 ray cells. Height of ray cells 13—30 (40)μ, width 6—13 μ. Horizontal walls of ray parenchyma pitted ; tangential walls either smooth or with very indistinct nodular thickenings, commonly also smooth in tangential view. Horizontal walls of wood parenchyma either smooth or with very faint nodules. In the cross field 2—3—4 minute pits, 4—5 μ in diam. Indentures absent or very indefinite. (*Y.*, 127.)

Juniperus procera HOCHST.
Pl. 150

xx Tangential walls of ray parenchyma nearer to dentate ; viewed from the tangential side the thickening is more scalariform.

△ Rays 1—4 (16) cells high. Per sq. mm. 7200 tracheids, 170—180 rays, and 350—360 ray cells. Horizontal walls of ray parenchyma sparsely pitted. Tangential walls dentate, with scalariform or sievelike pitting in tangential view. Horizontal walls of wood parenchyma smooth or nodular. Ray cells 8—17 (26) μ high, 4—8 μ wide. In the cross field 1—3 (4) pits, arranged irregularly or diagonally, and 5—6 μ in diam. *(Y., M.)*

Juniperus horizontalis MOENCH
Pl. 138

△△ Rays 1—5 (12) cells high. Per sq. mm. 4500 tracheids, 120—125 rays, and 255—260 ray cells. Ray cells 16—20 μ high, 10—13 μ wide. Pits fairly frequent in horizontal walls of ray parenchyma ; tangential walls dentate with cribriform or scalariform thickenings in tangential view. Indentures present. Horizontal walls of wood parenchyma thickened beadlike. In the cross field (1) 2—3 (4) pits arranged irregularly or diagonally and 2—5 μ in diam. Wood parenchyma commonly terminal. *(M.)*

Juniperus lemeeana LEVL. et BLIN.
Pl. 139

+++++ Up to 3 (4) superposed pits per cross field of inner cells, as well as in marginal cells, but sometimes 6 pits, arranged in two vertical rows.

x Rays 2—6 (24) cells high. Per sq. mm. 4500 tracheids, 100—110 rays, and 280—290 ray cells. Ray cells 11—24 μ high, 5—10 μ wide. Horizontal walls of ray parenchyma pitted, tangential walls dentate with cribriform or scalariform thickenings in tangential view. Indentures scarce or almost indistinct. Horizontal walls of wood parenchyma delicately nodular. In the cross field 2—3, in the marginal cells 4, superposed pits. *(Y.)*

Juniperus arenaria (Wils.) FLORIN
Pl. 125

xx Rays 2—4 (20) cells high. Per sq. mm. 4000 tracheids, 130—140 rays, and 310—320 ray cells. Height of ray cells 16—20 (27) μ, width 10—13 μ. Horizontal walls of ray cells slightly nodular ; tangential walls definitely dentate, mostly scalariform or smooth in tangential view. Indentures present. Horizontal walls of wood parenchyma delicately nodular. In the cross field 2—4 (6) pits, generally in two rows ; in the marginal cells exceptionally 6—7 (8) pits mostly in vertical rows ; pit diameter 4—6 μ. *(M.)*

Juniperus distans FLORIN
Pl. 133

xxx Rays 1—4 (12) cells high. Per sq. mm. 9000 tracheids, 130—135 rays, and 340—350 ray cells. Height of ray cells 13—2 μ, width 6—8 μ. Horizontal walls of ray cells pitted ; tangential walls dentate ; smooth or scalariform in general in tangential view. Horizontal walls of wood parenchyma smooth or delicately nodular. In the cross field 2 (3) superposed pits ; in the marginal cells occasionally 3—4 ; when 4, they are diagonally arranged. Pit diameter 4—5 μ, Wood parenchyma scattered in the latewood.

Juniperus glaucescens FLORIN
Pl. 137

6. KEY FOR THE IDENTIFICATION OF THE GENERA AND SPECIES OF THE TAXODIACEAE

From the point of view of xylotomy, the *Taxodiaceae* are fairly distinctly detached from the other families of the *Coniferae*. On the evidence of their external morphology, PILGER includes the following genera into this family: *Athrotaxis* (3—5),* *Cunninghamia* (2—3), *Cryptomeria* (2—3), *Glyptostrobus* (1), *Metasequoia* (1), *Sciadopitys*, *Sequoia* (2), *Taiwania* (1) and *Taxodium* (3). As regards *Sciadopitys*, it has been recommended (ARNOLDI and BUCHHOLZ) long ago that they should be classed in a family of their own, because in external morphology they differ from the other 8 genera. Moreover, xylotomically they appear to agree in every respect with the *Phyllocladus* of the *Podocarpaceae*. No doubt, the *Sciadopitys* still await more adequate classification.

One may note that almost all the genera of the *Taxodiaceae* are monotypic or represented by only 2—3 known species.

Being common to all its members, the xylotomical features most characteristic of this family are distinct growth rings and smooth tangential walls of ray cells. True, tangential ray-cell walls are smooth also in the *Podocarpaceae* and the *Araucariaceae*, but in them the horizontal and radial walls are likewise smooth and in addition the cross-field pitting is of a different type.

From among all the structures visible on the transverse surface the most common to all the members of the *Taxodiaceae* is the distinctness of the growth rings and growth ring delimitations, which is less pronounced only in *Taxodium ascendens*, *T. mucronatum*, and the two species of *Sequoia*. In these four species, the tracheary walls in the latewood of one season are roughly as thick as those in the earlywood of the next, except for a few rows of flattened, narrow-lumened cells which alone indicate the growth ring edges. In the other members of the family, on the other hand, the transition from early- to latewood is generally gradual, the latter being composed of quite flattened and considerably thicker-walled cells at the outer margins of the growth rings. In this respect, differences in the climatic conditions exert of course a marked influence.

* The numerals in brackets following to the generic names indicate the number of known species belonging to the respective genus.

On the transverse surface, too, the lumina of the tracheids are seen to be invariably angular, 4, 5, or 6 sided, and never with rounded corners. They are fairly variable in diameter, which in the early tracheids ranges from 30 to 80 μ. Wall thickness of early tracheids, 1—5 μ; of late tracheids, 2—12 μ. The number of tracheids per sq. mm. varies accordingly. There are approximately 5000—6000 tracheids per sq. mm. in *Taiwania*, which is the most closely textured wood in the family. Depending on age and habitat, data concerning the number of tracheids are of no diagnostic value, unless they are quite outstanding in one or another of the species.

Resin ducts absent, except for occasional traumatic cysts *(Sequoia, Athrotaxis, Metasequoia)*. Rays uniseriate, occasionally biseriate *(Sequoia, Cryptomeria)* and extending at different intervals from one another. Horizontal walls of rays very rarely smooth *(Athrotaxis, Cryptomeria, Sciadopitys, Taiwania)*. Primary or simple pits, differently interspaced, common in the walls.

Wood parenchyma cells are easy to recognise by their transverse walls. These cells are scattered, or crowded in groups varying in size. Sometimes they appear only in the closest vicinity of the growth ring delimitation amongst late tracheids. Whenever, in cross section, the horizontal wood-parenchyma walls appear as an even surface, it follows that they are smooth *(Sequoia)*; are they, on the other hand, pitted, the pitting invariably shows sievelike *(Taxodium)*.

On the tangential surface, the bordered pits in the walls of tracheids are seen in single file or scattered. When in a single row, they are seldom contiguous, merely touching. They vary in diameter on the tangential walls between 6—13 μ, on the radial walls between 9—17 μ; in the *Metasequoia* they are 20—22 μ in diam. Spiral thickenings wanting. Apertures of bordered pits circular, short- or long-elliptic, forming X figures in complementary pits. Rays 1—60 cells high. In *Taxodium distichum* is the maximum height attained; in all the other genera and species the rays are 1—30 cells high. They are generally uniseriate, in one or the other species not infrequently biseriate *(Sequoia gigantea)*. Ray cells in cross section generally elliptic, not infrequently circular, exceptionally hexagonal. They are fairly variable

in height (13—24 μ) and width (7—18 μ). Tangential ray-cell walls devoid of pitting, occasionally minutely punctate; horizontal walls commonly thicker than radial ones and sometimes pitted.

The number of rays and ray cells per square millimeter is no real aid in identification, except where there are heavy differences in respect of it between individual species.

The features most characteristic of the *Taxodiaceae* are brought out on the radial surface. The radial walls of tracheids are devoid of spiral thickenings; the bordered pits in them are in 1—3—4 rows or, occasionally, scattered and always definitely opposite. In some species, e. g. *Taxodium ascendens*, particularly in the latewood, they are pressed closely against one another. The pits in the radial walls are generally larger, 10—17 (20—22) μ, than those in the tangential walls, which are only 6—16 μ in diam. The pit apertures are circular or short-elliptic and predominantly included, very rarely extending to the annulus.

Wood parenchyma is present in every genus and species of the family, except in *Sciadopitys*. The horizontal walls may be more or less markedly pitted *(Taxodium distichum)*, nodular, evenly or sporadically thickened, or perfectly smooth. The tangential and radial walls are with simple pits, scattered or arranged in series *(Cunninghamia)*.

Ray cells 11—24 (36) μ high. Marginal cells as high as internal ones, but sometimes differing in structure. Indentures present in a few genera, e. g. in *Sequoia*. As a rule, rays consist solely of parenchyma cells. Transverse tracheids have been found by the writer in *Metasequoia*, *Sequoia gigantea*, and *S. sempervirens* only. Horizontal walls of ray parenchyma smooth *(Taiwania)*, or pitted *(Taxodium)*, 1,5—4 μ thick; tangential walls always thin and smooth, and 0,5—2 μ thick.

Pitting of the ray cells is another characteristic. Pit apertures are generally parallel with the long axis of the pit, i. e. the pitting is typically taxodioid, with *Sciadopitys* an exception. The pits are mostly procumbent ellipses, or circles *(Glyptostrobus)*. They vary in size almost from genus to genus: a feature useful in identification. The number of pits per cross field ranges from 1 to 5 (6); there are commonly more pits in the marginal than in the internal cells. They are variable in arrangement, there being 2—3 (4) pits either in one *(Taxodium distichum)* or in two horizontal rows *(Sequoia sempervirens)*, sometimes diagonally disposed, at other times irregularly placed. They are never contiguous. The pit apertures are slitlike or short-elliptic, oriented horizontally *(Taxodium)* or vertically *(Cunninghamia)*, or they are circular *(Glyptostrobus)*, with the border outlines from barely visible to imperceptible. In *Sciadopitys* a single large pit and its aperture occupy the whole area of the cross field, this being one of the reasons why this genus does not fit this family. In the tracheids of some species trabeculae and even resin plates.

In the following a

KEY

is presented for the identification of the genera and species.

Wood parenchyma present. Growth rings distinct. In the cross field 1—2—4 (6) taxodioid, cupressoid, or glyptostroboid pits. Indentures occasional *(Athrotaxis, Cryptomeria, Cunninghamia, Glyptostrobus, Metasequoia, Sequoia, Taiwania, Taxodium)*.

A. Horizontal walls of wood parenchyma commonly nodular, dentate or beadlike, rarely smooth. Tangential walls of ray cells thin and always smooth, but horizontal walls definitely pitted and comparatively thick (2—4 μ). Pits in radial walls of tracheids 1—2, occasionally 3—4 seriate. Indentures absent or very obscure. Rays 1—30 (60) cells high *(Taxodium, Glyptostrobus)*.

a. Rays 1—30 cells high, uniseriate, sporadically biseriate. Number of glyptostroboid pits in the internal cells in the cross field 1—2 (3), usually side by side, in the marginal cells 3—4, arranged diagonally; cross field pits in the earlywood 6,5—8 μ. The pit apertures sometimes subcircular, the borders barely visible. Ray cells 18—20 μ high, occasionally resinous, their horizontal walls 2—3 (4—5) μ thick. Indentures absent or very obscure. (*M.*, 126, 53)

Glyptostrobus pensilis K. Koch
Pl. 186, p. 176

b. Rays 1—60 cells high. Number of *taxodioid* pits in the cross field of earlywood 2—4 (6), 5,5—10 μ in height. Pit apertures predominantly horizontal or slightly oblique. Horizontal walls of ray cells 2—4 μ thick, frequently pitted. Tangential walls smooth; indentures absent or barely visible. Walls of latewood tracheids sometimes 6—8 (10) μ thick.

Taxodium
Pls. 191—193

a Rays 1—60 cells high, sometimes biseriate. Ray cells in cross section circular, or short upright ellipses, 18—20 μ in height, 10—12 μ in width. Wood parenchyma abundant; horizontal walls sometimes with as many as 5—6 nodules in them. In radial walls of earlywood tracheids 1—4 rows of opposite pits, 12—14 μ in diam. Pits in tangential walls of tracheids uni- or biseriate, 9—10 μ in size. Tangential walls of ray parenchyma perfectly smooth; horizontal walls also smooth, very rarely with 1—2 minute pits. Indentures absent or barely visible.

Taxodium distichum RICH.
Pl. 192, p. 180

β Rays 1—20 cells high.

1. Growth rings comparatively narrow, 10—20 tracheids in width. Walls of tracheids thin, 1—2 μ. Latewood composed of only 1—3 rows of flattened tracheids. In the cross field 1—2 (3), in the marginal cells 2—5 (6), taxodioid pits, 5,5—9 μ in diam. Pits in radial walls of tracheids uni- or biseriate, 10—12 μ in diam., those in tangential walls 8,5—9 μ. Horizontal walls of wood parenchyma with 1—2 conspicuous nodular thickenings. Horizontal walls of ray cells 3—4 μ thick, frequently pitted, particularly in the latewood. Ray cells radially comparatively short, sometimes only 20—30 μ. Per sq. mm. 70—75 rays and about 360 ray cells. *(Y.)*

Taxodium ascendens BRONGN.
Pl. 191, p. 179

2. Pits in radial walls of tracheids commonly uni- or biseriate, 13—15 μ in diam. in earlywood; on tangential walls 9—11 μ. Latewood 8—10 or more cell layers wide. In the cross field 1—2 (3), in marginal cells 2 (4) pits, 8—10 μ in diam. Per sq. mm. 65—70 rays and 280 ray cells. Horizontal walls of wood parenchyma smooth or with 1—2 nodules. Horizontal walls of ray parenchyma in earlywood perfectly smooth and even, with only an occasional pit in them. Elsewhere, particularly in the latewood, pits fairly numerous. *(M.)*

Taxodium mucronatum TENORE
Pl. 193, p. 181

B. Horizontal walls of wood parenchyma commonly smooth or evenly thickened, or almost indistinctly beadlike. Horizontal walls of ray parenchyma 2—4 μ thick, usually smooth, with occasional simple pits. Smooth-walled transverse tracheids and indentures not uncommon *(Metasequoia, Sequoia).*

a. In the cross field 1—2—4, in the marginal cells 1—3 (6—10), pits, procumbent ellipses in shape and 5,5—6,5 μ in diam. Pit apertures wide and conforming to the outline of the border. Rays commonly 6—16 (30) cells high, uniseriate, occasionally bi- or triseriate. Per sq. mm. 35 rays and 290—300 ray cells. Horizontal walls of ray parenchyma 2—4 μ thick, perfectly smooth, occasionally with 1—2 pits in latewood. Horizontal walls of wood parenchyma smooth, slightly thickened or distinctly nodular. Transverse tracheids occurring, but only as marginal cells; they are 12—14 μ high and their walls are smooth. Bordered pits in radial walls of early tracheids 14—16 μ in diam. Indentures occasional. (*M.*, 74, 53)

Sequoia sempervirens (Lamb.) ENDL.
Pl. 189, p. 178

b. Commonly 1 (2) pit per cross field, 2—3 pits in marginal cells. Bordered pits in radial walls 1 (2—3) seriate; in tangential walls 11—13 μ, in radial walls 14—17 μ in diam. Pits short, somewhat procumbent ellipses, 4,5—8 μ in size. Rays 1—5—12 (30) cells high, 1—2—3 seriate. Per sq. mm. 40 rays and 200—210 ray cells. Height of ray cells 18—22 (26) μ, horizontal walls 2—4 μ thick. (*M.*, 126, 174, 53)

Sequoia gigantea (Lindl.) DECNE.
Pl. 188, p. 177

c. Rays 1—26 (30) cells high, sometimes 6—8 paired cells in the body. Horizontal walls of wood parenchyma predominantly smooth. In the cross field 2—4 elliptic, mostly superposed, taxodioid pits in the earlywood, 1 (2) pit in the latewood. In the radial walls of tracheids paired pits not infrequent, they are 20—22 μ in diam.; in the tangential walls they are 1—2 seriate and 9—10 (13) μ in diam. Occasional resin cysts. Indentures absent. Horizontal walls of ray parenchyma sparsely pitted, tangential and radial walls smooth. Thin- and smooth-walled transverse tracheids occasional. Crassulae well discernible. (*Y.*, *M.*, 102, 45)

Metasequoia glyptostroboides HU et CHENG
Pl. 187, p. 177

C. Horizontal walls of wood parenchyma commonly smooth, occasionally with gradual thickenings appearing as very slightly beadlike nodules. Horizontal walls of ray cells relatively thin (1—2,5 μ) and smooth, very rarely with pits in them; tangential walls always smooth. Rays 1—24 cells high *(Cryptomeria, Athrotaxis, Taiwania, Cunninghamia).*

a. Rays 1—20 cells high, sometimes biseriate. Bordered pits in radial walls of tracheids 2—3 (1) seriate, 13—14 μ in diam.; in tangential walls 10—12 μ. Horizontal walls of ray parenchyma cells smooth, with occasional thinnings, very rarely pitted, up to 1—3 μ thick. In the cross field 1 (2), in the marginal cells 2—3 (5), taxodioid or glyptostroboid pits, mostly in diagonal arrangement; pit diameter 6,5—8 μ. Pit apertures in earlywood circular, in latewood rather procumbent ellipses. Indentures sometimes well discernible. Resin cysts occasional. Per sq. mm. 3600 tracheids, 40—45 rays, and 150—160 ray cells. (*Y.*, *M.*, 126, 74, 53)

Cryptomeria japonica D. Don
Pl. 184, p. 174

b. Rays 1—12 (14) cells high, uniseriate, occasionally partly biseriate. In radial walls of tracheids bordered pits in one or two series, 11—13 μ in diam., in tangential walls 10—12 μ. Horizontal ray-cell walls 1—2,5 μ thick with occasional thinnings and delicate nodules in them. In the cross field 1—2 (3), in the marginal cells 2—3 (4—6), procumbent-elliptic, typically taxodioid pits, 5,5—7 μ in diam. Orientation of the pit apertures the same as that of the pits. (*M.*, 126, 53)

Athrotaxis selaginoides D. Don
Pl. 183, p. 179

c. Rays 1—7 (9) cells high, uniseriate. Bordered pits in radial walls of early tracheids uni-or biseriate, 10—11 μ in diam.; in tangential walls 7—8 μ. Horizontal walls of wood parenchyma and ray cells 1—3 μ thick and perfectly smooth, or creased in places. In the cross field 1 (2), in the marginal cells 2 (5) cupressoid pits, with rod-shaped oblique apertures. Indentures absent. Wood parenchyma resinous. (*Y.*, *M.*, 126, 53)

Taiwania cryptomerioides Hayata
Pl. 190, p. 179

d. Rays 1—7 (20—24) cells high, uniseriate, sometimes 5—7 paired cells in the body. Horizontal walls of ray cells smooth, occasionally coarse or, very rarely, with simple pits. In the cross field 1 or 2—5 small-sized cupressoid pits (5—6 μ). Horizontal walls of wood parenchyma smooth, or coarse, or slightly nodular; simple pits in radial walls (5,5—6 μ) in one row or scattered. In radial walls of tracheids pits occasionally flattened, 13—14 μ in diam.; in tangential walls 9—11 μ. Indentures very rarely present. (*Y.*, *M.*, 126, 74, 53)

Cunninghamia lenceolata (Lamb.) Hook.
Pl. 185, p. 175

* * *

Appendix

a. Growth rings commonly 15—30 cells in width. Wood parenchyma usually scattered. In the cross field 2—4 pits, 2—5 μ in diam. Per sq. mm. 8500 tracheids, 250—260 rays, and 460—470 ray cells. Tangential walls of ray cells with sievelike or scalariform thickenings in tangential view; nodular or beadlike in radial view. Horizontal walls of wood parenchyma nodular. In tangential walls of wood parenchyma simple pits procumbent ellipses in shape. Some rays conspicuously widened in cross section, and with slightly pitted horizontal walls. (*M.*, 129, 74, 53)

Pherosphaera hookeriana Archer
Pl. 194, p. 182

b. Rays 1—6 (?) cells high. Horizontal walls of ray cells densely and variably thickened and pitted, respectively; tangential walls smooth, occasionally with 1—2 (4) nodules, in tangential view also smooth, but sometimes with scalariform thickenings. Radial walls of ray cells pitted. Indentures possible. Horizontal walls of wood parenchyma smooth, or variably thickened, or with 1—2 nodules. Simple pits sparse in tangential walls. Resin contents present. In the cross field 1—2 (4) cupressoid pits, with the border flanking the apertures in the shape of two crescents. In radial walls of tracheids bordered pits single or in file, very exceptionally crowded araucarian fashion with straight lines of contact between them. In tangential walls bordered pits sparse and with circular or slitlike apertures; when slitlike, they appear in the two members of a pit pair in the form of an X. (*M.*, 129, 74, 54)

Saxegothaea conspicua Lindley
Pl. 195, p. 183

c. Rays predominantly 1—3, seldom 10, cells high. Horizontal ray-cell walls thickened and abundantly pitted; tangential walls normally thin, in rare instances delicately nodular. Indentures occasional. Number of rays per sq. mm. 125—130, that of ray cells 270—280. Ray cells 13—20 μ high and 8—13 μ wide. In the cross field 1—2, in the marginal cells 3—4 round cupressoid pits. Longitudinal parenchyma frequent; horizontal walls of its cells smooth and thin or slightly nodular. Wood parenchyma resinous. (*M.*)

Saxegothaea gracilis HORT.
(Podocarpus nubigenus LINDLEY)
Pl. 195a, p. 183

7. KEY FOR THE IDENTIFICATION OF THE GENERA AND SPECIES OF THE PINACEAE

The family of the *Pinaceae* is the richest in the number of species, and commercially the most important among all the *Coniferae*. Largely, its members are confined to the Northern Hemisphere and for the most part do not drift down to the Equator. They are not represented in South America, Arabia, India, New Guinea, and in Australia, and only three *Pinus*, one *Cedrus*, and two *Abies* species are living in Africa. All the wider is their distribution in North America, the northern part of Europe and Asia, and in East Asia. In the family, the richest in members is the genus *Pinus* with about 80, followed by *Abies* with 50, and by *Picea* with 40 known species. The genus *Cedrus* is represented by 4, *Keteleeria* by 2, *Larix* by 22, *Pseudolarix* by 1, *Pseudotsuga* by 2, and *Tsuga* by 10 species. They generally range in temperate and colder zones, and even there in higher regions.

PILGER divides the *Pinaceae* into two subfamilies; into the first, the *Abietoideae*, he includes *Abies*, *Keteleeria*, *Pseudotsuga*, *Tsuga*, *Picea*, *Pseudolarix*, *Larix*, and *Cedrus;* to the second, the *Pinoideae*, he refers the genus *Pinus* alone.

Viewed xylotomically, these nine genera segregate into several groups varying in size. The transverse surface shows largely the same picture throughout the family. Distinct growth rings and a sharp contrast between early- and latewood clearly indicate that these trees abide mostly in temperate climates. When viewed in cross section, there are always simple pits conspicuous in the horizontal ray-cell walls, which are only smooth in the thin-walled cells of certain *Pinus* species. The size and form of resin ducts as also the presence or absence of resin cysts on cross sections may also serve for one's guidance in identification *(Abies, Cedrus)*. Ray structure offers a further means of separating genera, inasmuch as in the rays of some of them there occur transverse tracheids along with the ray parenchyma *(Cedrus, Larix, Picea, Pinus, Pseudotsuga,* and *Tsuga)*. On the other hand, *Abies, Keteleeria,* and *Pseudolarix* are devoid of transverse tracheids. From the point of view of wood anatomy, these three genera are very much alike, and their structure would really permit regarding them as a separate evolutionary unit. Xylotomically, it is often rather difficult to keep them apart.

Athough rays with transverse tracheids and wood parenchyma cells are common to all of them, the other 6 genera differ in that some are with, and some without, resin ducts. Resin ducts are present in *Pseudotsuga, Larix, Picea,* and *Pinus;* and absent in *Cedrus* and *Tsuga*. Differentiation between the first four genera is done on the basis of whether the walls of the epithelial cells sheathing the resin ducts are thin *(Pinus)*, or more or less significantly thickened *(Larix, Picea, Pseudotsuga)*. The latter may then be further differentiated, though with some doubts, by the number of epithelial cells lining the ducts.

The structure of transverse tracheids also affords an interesting criterion for generic separation. Apart from the pitting, the transverse tracheids in the *Pinus* are smooth *(Haploxylon* group), or variably dentate, or reticulate *(Diploxylon* group); in the *Picea* they are delicately dentate or spirally thickened, and most rarely smooth-walled. Both *Pinus* and *Picea* are without, or with very few, wood parenchyma cells. The ray tracheids in *Larix* are roughly of the same structure. Their walls are minutely dentate in some species, and perfectly smooth in others. *Pseudotsuga* are readily distinguished by the usually spirally thickened walls of their transverse tracheids. In *Picea* and *Larix*, the minute projections on the inner surface of the walls occasionally continue in very fine spirals, and in this manner the structure greatly agrees with that in *Pseudotsuga*. On the evidence of their anatomy, these three genera, too, appear to be in close affinity with one another. On the other hand, apart from the pitting in them, the walls

of the transverse tracheids are mostly smooth in *Cedrus* and *Tsuga*. These two genera are distinguished from each other by the structure of the torus, which in the longitudinal tracheids of *Cedrus* is scalloped, and intact in those of *Tsuga*. The spiral thickenings in the longitudinal tracheids may also serve for one's guidance. They are present in the latewood, not infrequently also in the earlywood, tracheids of almost all the *Picea* species. In *Larix*, they are commonly encountered in the latewood only, while in *Pseudotsuga*, *Taxus*, and *Cephalotaxus* they occur in all the longitudinal tracheids. But while in the two last-mentioned genera they never ramify, they do branch out several times in the genus *Pseudotsuga*.

As regards *Abies*, they are characterized, in addition to the absence of resin ducts, by the presence in the cross field of 1—2 commonly circular or somewhat oblique elliptical pits. The same refers to *Pseudolarix* and *Keteleeria*, although in the former the number of cross-field pits is occasionally 4—5.

Besides by their resin-duct structure, the *Picea* are to some extent distinguishable by the pitting in the ray-cell walls. Commonly, there is a minute, circular, *piceoid* pit in each of the four corners of the cross field, with apertures usually vertical in position. Other types of pitting are, however, not infrequent in this genus. Apart from their peculiar resin ducts, the *Larix*, too, are characterized by the pitting in the cross field, which contains (rarely) 4, in the early tracheids mostly 6—8, and exceptionally as much as 10, simple pits mostly in 2 rows and alternate. The marked winding and frequent bulging of the external walls of their transverse tracheids offers an additional means by which to keep the *Larix* apart from the *Picea*, while from the *Pseudotsuga* they can be distinguished by the presence of spiral bars in the early, late, and transverse tracheids. It should be noted that such spirals also occur in certain *Picea*, when it is always the resin-duct structure that furnishes the decisive evidence in identification.

As simple and easy generic differentiation of the *Pinaceae* appears, as great are the difficulties in separating the species. These difficulties are aggravated by the fact that specific features are liable to change with the age of the tree and the changes in the weather conditions. For this reason the key that follows cannot be relied upon to yield in each case sufficiently reliable results, but successful generic determination appears to be quite probable.

In the following is presented a

KEY

for the identification of the genera of the *Pinaceae*.

I. Rays heterogeneous *(Cedrus, Larix, Picea, Pinus, Pseudotsuga, Tsuga)*.

A. Horizontal and vertical resin ducts present *(Pseudotsuga, Larix, Picea, Pinus)*.

a. Walls of epithelial cells in resin ducts thin.

Pinus
Pls. 270—337, p. 214

b. Walls of epithelial cells in resin ducts thick *(Pseudotsuga, Larix, Picea)*.

α Number of parenchyma cells lining resin ducts generally 5—7. In the walls of the longitudinal and transverse tracheids closely spaced spiral thickenings. Rays 4—10 (15) cells high. Wood parenchyma frequent; horizontal walls dentate. External walls of transverse tracheids slightly wavy.

Pseudotsuga
Pls. 339—340, p. 248

β Number of parenchyma cells lining resin ducts 8—10. Closely spaced spiral thickenings chiefly in walls of latewood tracheids. In radial walls of latewood tracheids bordered pits uniseriate; paired pits very rare. Wood parenchyma absent or very rare. Walls of transverse tracheids minutely dentate, very rarely spirally thickened or smooth. In the cross field 2—6 minute piceoid pits. Height of rays 8—10 (25—40) cells. In very rare instances thin- and thick-walled parenchyma together in the rays. External walls of transverse tracheids slightly wavy and not bulging markedly.

Picea
Pls. 244—269, p. 198

γ Number of parenchyma cells lining resin ducts 10—14. Longitudinal parenchyma scarce, present mainly in the vicinity of growth ring boundaries. Paired pits and crassulae fairly frequent in walls of early tracheids. Walls of transverse tracheids sometimes minutely dentate, mostly smooth. In the cross field 2—6 (8—10) piceoid, sometimes taxodioid, pits. Rays 10—20 (25) cells

high. External walls of transverse tracheids often markedly wound and bulging.

Larix
Pls. 234—243, p. 194

B. Resin ducts absent *(Cedrus, Tsuga).*

a. Rays 2—20 (30) cells high. Torus of bordered pits commonly scalloped. Apart from pitting, walls of transverse tracheids always smooth. In the cross field 1—2 (3—5) piceoid pits. Wood parenchyma present.

Cedrus
Pls. 228—231, p. 192

b. Rays 1—12 (18) cells high. Torus of bordered pits not scalloped or invisible. Walls of ray tracheids smooth or very delicately dentate. In the cross field 3—4 (7—8) minute, circular piceoid pits.

Tsuga
Pls. 341—345, p. 249

II. Rays homogeneous, consisting of parenchyma cells only. In all the ray-cell walls several simple, generally piceoid, or cupressoid, or circular, or elliptical taxodioid pits. Tangential walls very seldom smooth, normally with dentate, most exceptionally with beadlike thickenings. Tangential walls in tangential view almost sievelike, with 3—10 simple pits : scalariform pitting very rare. Longitudinal resin ducts absent, cysts present in some species. Wood parenchyma present or absent. Indentures present, sometimes obscure. Growth rings generally more than 40 cells in width *(Abies, Keteleeria, Pseudolarix).*

A. Rays 15—32 cells high. Narrow earlywood in many cases abruptly followed by wide latewood. Walls of latewood tracheids thick, angular or rounded in cross section. In radial walls of early tracheids paired pits not uncommon. Wood parenchyma frequent.

Keteleeria
Pls. 232—233, p. 194

B. Rays 4—45 cells high. Transition from early- to latewood gradual. Wood parenchyma not infrequent, sometimes absent. Resin cysts occasional. Wood parenchyma generally non-resinous. Pits inclined to taxodioid. Cells bearing calcium oxalate crystals. Rays very exceptionally with both thin- and thick-walled parenchyma.

Abies
Pls. 196—227, p. 183

C. Rays 4—10 (24) cells high, commonly uniseriate. Radial walls of early tracheids sometimes with paired pits. Late tracheids and marginal cells abounding in crystals. Bordered pits on radial walls sometimes in tight-set longitudinal rows. Torus not scalloped. In the cross field 3—6 circular piceoid or taxodioid pits.

Pseudolarix
Pl. 238, p. 247

Abies species

I. In the cross field of the earlywood generally 1—2 pits side by side, varying in size, spaced not less than 2—3 pit diameters apart *(Abies alba, A. balsamea, A. concolor, A. grandis, A. homolepis, A. lasiocarpa, A. procera, A. spectabilis, A. venusta).*

A. Rays 1—15 cells high.

a. Rays commonly 3—4, at most 12 cells high, in the main uniseriate. Height of ray cells 6—13 μ, of marginal cells up to 27 μ ; width 4—8 μ. Diameter of bordered pits in tangential walls of tracheids 6—8 μ, in radial walls 10—12 μ. Commonly 1—2, exceptionally 3, pits in the cross field, 3—8 μ in diam. Calcium oxalate crystals in parenchyma. Indentures present. Resin cysts comparatively frequent. (*M.*)

Abies concolor LINDLEY et GORD.
Pl. 202, p. 186

b. Rays 1—6, occasionally up to 14, cells high, uniseriate, rarely biseriate. Height of ray cells 10—21 μ, width 8—12 μ. Bordered pits in tangential walls of tracheids 5—8 μ, in radial walls 12—18 μ in diam. In the cross field 1—2, exceptionally 3, pits, 4—6 μ in diam. Horizontal walls of wood parenchyma smooth or pitted. (*M.*)

Abies grandis LINDLEY
Pl. 206, p. 187

c. Rays 1—5, exceptionally 8, cells high, uniseriate. Ray cells 13—21 μ, marginal cells sometimes 30 μ in height, 8—16 μ in width. Bordered pits on tangential walls 10—12 μ, on radial walls 10—13 μ in diam. Horizontal walls of ray cells smooth or pitted. Indentures present. Per cross field 1—2 (3—5) pits, 4—5 μ in diam. (*Y.*)

Abies homolepis var. umbellata (*Mayr*) WILSON
Pl. 208

d. Rays 6—8 (10) cells high, uniseriate, some of the higher ones with 1—2 paired cells in the middle of the body. Height of ray cells 10—21 μ, in marginal and single-row rays up to 27 μ; width 6—8 μ. Bordered pits in tangential walls of tracheids 5—8 μ, in radial walls 10—16 μ. In the cross field generally 2 minute pits side by side, 5—6 μ in diam. Pit apertures subcircular. Tangential walls of ray cells with sievelike pitting in tangential view. Per sq. mm. 40—50 rays and 180—210 ray cells. Calcium oxalate crystals abundant. (*Y.*, *M.*, 74)

Abies balsamea MILLER
Pl. 198, p. 185

e. Rays 4—6, exceptionally 18, cells high and uniseriate. In the cross field 1—2, in the marginal cells fairly frequently as many as 4, slightly inclined elliptical pits, 4—8 μ in diam. Number of rays per sq. mm. 17—18, that of ray cells 120—130. Height of ray cells 9—12 μ, width 10—16 μ. Bordered pits in radial walls of tracheids 10—13 μ, in tangential walls 8—10 μ. Horizontal and tangential ray-cell walls distinctly pitted. Indentures clearly visible. (*M.*)

Abies kawakamii ITO
Pl. 209

B. Rays 1—40 cells high.

a. Rays 6—12, very rarely 40, cells high, commonly uniseriate. Ray cells 10—21 (27) μ high, 5—10 μ wide. Bordered pits in tangential walls of tracheids 6—8 μ, in radial walls 13—16 μ. Horizontal walls of wood parenchyma pitted. Horizontal walls of ray cells smooth or pitted. Indentures present. Per cross field 1—2, chiefly in marginal cells very rarely 3, pits with 6—8 μ diam. Some tracheids with calcium oxalate crystals. (*M.*, 74, 53)

Abies alba MILLER
Pl. 196, p. 183

b. Rays 4—6 (12) cells high, occasionally biseriate at about the middle. Ray cells in cross section short-elliptical or subcircular. Wood parenchyma fairly abundant. In the cross field 1—2, in the marginal cells sometimes 3 pits somewhat elongated horizontally and of taxodioid type. Bordered pits in radial walls of tracheids 10—13 μ. Torus conspicuous. Pit apertures circular or short-elliptical. (*Y.* 74.)

Abies cephalonica LOUDON
Pl. 199, p. 185

c. Rays 1—12, rarely 32, cells high, occasionally biseriate at about the middle. Height of ray cells 10—18 μ, in marginal cells sometimes 27 μ; width 8—15 μ. Bordered pits in tangential walls of tracheids 9—10 μ, in radial walls 16—21 μ. Horizontal walls of wood parenchyma nodular. Horizontal walls of ray cells smooth or pitted. Indentures present. In the cross field 1—2, exceptionally 3, pits 5—6 μ in diam. Pitting in tangential ray walls sievelike. (*Y.*, *M.*)

Abies spectabilis SPACH
Pl. 223

d. Rays 1—10, exceptionally 36, cells high, uniseriate, higher ones fairly frequently with 2—4 paired cells in the body. Height of ray cells 13—27 μ, width 10—20 μ. Bordered pits in tangential walls of tracheids 13—18 μ, in radial walls 16—21 μ. Horizontal walls of wood parenchyma pitted. Indentures present. In the cross field 1—2 (3) conspicuously large pits, 5—9 μ in size. Paired pits frequent in radial walls of earlywood tracheids. (*Y.*, *M.*)

Abies venusta K. KOCH
(*A. bracteata* D. DON)
Pl. 226

C. Rays 1—45 cells high.

a. Rays 1—20 (49) cells high, uniseriate. Ray cells comparatively low, 10—26 μ in height, and 8—10 μ in width. Bordered pits very rare in tangential walls of tracheids; their diameter in radial walls 12—16 μ. Horizontal walls of wood parenchyma pitted. Indentures present. Per cross field 1—2 pits, 4—6 μ in diam. Thin-walled transverse tracheids exceptional. (*M.*, *Y.*)

Abies lasiocarpa NUTTAL
Pl. 211, p. 188

b. Rays 1—16 (45) cells high, uniseriate, but sometimes with 5—7 paired cells in the body. Ray cells 10—16 μ, some marginal cells 25 μ high, and generally 8—13 μ wide, short-elliptical or circular in cross section. Bordered pits in tangential

walls of tracheids 6—8 μ, in radial walls 13—18 μ. Indentures present. Per cross field 1 (2—3) pit, 4—7 μ in diam. *(M.)*

Abies procera REHDER
Pl. 220

II. In the earlywood commonly 1—2 fair-sized (4—7 μ) pits in the cross field, spaced 1—1,5 pit diameters apart. Rays 1—6 (10) cells high, uniseriate. Ray cells 10—18 μ, marginal cells sometimes 25 μ high and 4—8 μ wide. Bordered pits in tangential walls of tracheids 4—5 μ, in radial walls 10—13 μ. Horizontal walls of wood parenchyma smooth or pitted, with frequent calcium oxalate crystals. Resin cysts not uncommon. *(Y.)*

Abies lasiocarpa var. arizonica LEMM.
Pl. 212

III. In the earlywood 1—2 (4) fair-sized (3—8 μ) superposed pits per cross field, 1—1,5 pit diameters apart *(A. firma, A. nephrolepis, A. numidica, A. pinsapo, A. veitchii)*.

A. Ray cells 4—5 μ in width.

a. Rays 1—7 (12) cells high, uniseriate. Height of ray cells 13—21 μ, width 4—8 μ. Bordered pits in tangential walls of tracheids 5—8 μ, in radial walls 8—12 μ. Indentures present. In the cross field (1) 2 (3—4) pits, 4—6 μ in diam. Calcium oxalate crystals comparatively frequent in tracheids. *(Y.)*

Abies nephrolepis MAXIMOVICZ
Pl. 215, p. 189

b. Rays 1—6 (10—12) cells high, uniseriate. Height of ray cells 13—18 μ, in single- or double-rowed rays up to 48 μ; width 4—8 μ. Bordered pits in tangential walls of tracheids 5—8 μ, in radial walls 10—13 μ. Horizontal walls of wood parenchyma smooth or pitted. Some tracheids and wood parenchyma cells with calcium oxalate crystals. Indentures present. In the cross field commonly 1—2 (3), in the marginal cells 3, rarely 6, pits, 4—7 μ in diam. Ray cells in cross section occasionally barrel-shaped. (*Y.*)

Abies veitchii LINDLEY
Pl. 225, p. 192

B. Ray cells 5—10 μ in width.

a. Rays 2—6 (10) cells high, biseriate in places. Height of ray cells 10—21 μ, exceptionally 32 μ. Bordered pits in tangential walls of tracheids 8—9 μ, in radial walls 8—13 μ. Per cross field 2—3 (4) pits, 4—5 μ in diam. Occasional resin cysts. (*Y.*, *M.*)

Abies firma SIEB. et ZUCC.
Pl. 204, p. 186

b. Rays 1—7 (12) cells high, uniseriate. Height of ray cells 10—18 μ, that of marginal and single-row cells 32 μ; ray-cell width 5—13 μ. Bordered pits in tangential walls of tracheids 6—8 μ, in radial walls 10—15 μ. Horizontal walls of wood parenchyma smooth or nodular. Indentures present. In the cross field 1—2 (3—5) pits, 4—6 μ in diam. Wood parenchyma with calcium oxalate crystals. Tangential walls of ray parenchyma with sievelike or scalariform thickenings. (*Y.*, *M.*)

Abies numidica DE LANNOY
Pl. 217, p. 190

c. Rays 1—8, exceptionally 10, cells high, uniseriate. Height of ray cells 13—18 μ, in marginal and single-row rays up to 27 μ; the width, which may vary in one and the same ray, is from 6 to 13 μ. Bordered pits in tangential walls of tracheids 6—8 μ, in radial walls 8—13 μ. Indentures present. Calcium oxalate crystals in tracheids and wood parenchyma cells. Tangential walls of ray cells with cribriform and scalariform thickenings. In the cross field (1) 2 (5) pits, 4—8 μ in diam. (*Y.*)

Abies pinsapo BOISS.
Pl. 219, p. 191

IV. In the earlywood generally 1—2 (4) pits in the cross field, 4—5 μ in diam.; when they are 3 or 4 in number, each one occupies a corner; very seldom are they astray in the field.

A. Rays 1—6 (10) cells high, uniseriate. Height of ray cells 10—20 μ, in marginal and single-row rays attaining 32 μ; ray-cell width 5—10 μ. Bordered pits in tangential walls of tracheids 5—8 μ, in radial walls 10—15 μ. Indentures present. In the cross field 1—2 (4), exceptionally 6, pits, 4—5 μ in diam. Horizontal walls of wood

parenchyma markedly pitted. Tangential walls of ray cells with sievelike pitting. (*Y.*, *M.*)

Abies koreana WILSON
Pl. 210

B. Rays 1—12, exceptionally up to 18, cells high, uniseriate. Height of ray cells 13—18 μ, in marginal and single-row rays up to 40 μ; width 5—10 μ. Bordered pits in tangential walls of tracheids 5—6 μ, in radial walls 10—13 μ. Horizontal walls of wood parenchyma commonly pitted. Indentures present. In the cross field 1—2 (4) pits, 4—5 μ in size. (*M.*, *Y.*)

Abies sibirica LEDEBOUR
Pl. 222, p. 191

V. In the earlywood commonly 1 smaller pit in the cross field, 4—5 (6) μ in diam.; sometimes 2 pits one above the other at a distance of 1—2 pit diameters. In the marginal cells 2—4 pits, when 4, then diagonally arranged.

A. Rays 1—8, exceptionally 20, cells high, uniseriate, occasionally partly biseriate. Ray cells in cross section slightly elongate ellipses, 13—18 μ in height; in marginal and single-row rays 25 μ high; width of ray cells 7—10 μ. Bordered pits in tangential walls of tracheids 6—8 μ, in radial walls 10—13 μ. Tangential walls of ray cells with sievelike or scalariform pitting. Horizontal walls also markedly pitted. In the cross field 1—2 (4—5) pits, 2—6 μ in diam. (*Y.*)

Abies squamata MAST.
Pl. 224

B. Rays 1—8 (12) cells high.

a. Per sq. mm. 85—90 rays and 360—370 ray cells. Rays 1—8 (12) cells high, uniseriate, higher ones partly biseriate. Height of ray cells 13—18 μ, in single-row rays 21 μ; width 8—13 μ. Bordered pits in tangential walls of tracheids 8—9 μ, in radial walls 10—13 μ. In the cross field 1—2, in the marginal cells 5—6, pits varying in diam. between 5 and 10 μ. Calcium oxalate crystals frequent in longitudinal tracheids and wood parenchyma cells. Tangential walls of ray cells with sievelike or scalariform pitting. (*M.*)

Abies chensiensis VAN TIEGHEM
Pl. 200

b. Per sq. mm. 110—120 rays and 280—290 ray cells. Rays 1—8 (12) cells high, uniseriate. Height of ray cells 13—18 μ, in single-ray rows attaining as much as 27 μ; width 4—10 μ. Bordered pits in tangential walls of tracheids 5—8 μ, in radial walls 8—10 μ. Indentures present. In the cross field 1—2 (3—4) pits, 4—6 μ in diam. (*Y.*)

Abies holophylla MAXIMOVICZ
Pl. 207

c. Per sq. mm. 150—160 rays and 510—520 ray cells. Rays 1—8, exceptionally up to 15, cells high. Height of ray cells 10—18 μ, of those in marginal and single-row rays up to 27 μ; width 5—8 μ. Bordered pits in tangential walls of tracheids 5—6 μ, in radial walls 9—13 μ. Indentures present. In the cross field 1—2 or 4 pits, 2—5 μ in diam. Tangential walls of ray cells with sievelike thickening. Tracheids with calcium oxalate crystals. (*Y.*)

Abies nordmanniana SPACH
Pl. 216, p. 189

d. Per sq. mm. 210—220 rays, 340—345 ray cells. Height of rays 1—6, maximum 12, cells, uniseriate. Ray cells 13—18 μ, in single- and double-rowed rays up to 27 μ high; width 4—8 μ. Bordered pits in tangential walls of tracheids 5—6 μ, in radial walls 10—12 μ. Indentures present. In the cross field 2—3 pits, 2—4 μ in diam. (*Y.*)

Abies sachaliensis MAST.
Pl. 221, p. 191

e. Per sq. mm. 80—85 rays and 180—200 ray cells. Rays 1—6 (10) cells high, uniseriate. Height of ray cells 10—16 μ, width 5—8 μ. Bordered pits in tangential walls of tracheids 6—9 μ, in radial walls 10—13 μ. Indentures present. In the cross field 1—2 (4) pits, 5—6 μ in diam. (*Y.*)

Abies fraseri POIRET
Pl. 205, p. 187

f. Per sq. mm. 70—80 rays and 160—170 ray cells. Rays 1—6 (11) cells high, uniseriate. Height of ray cells 16—27 μ, in single-row rays up to 50 μ; width 8—15 μ. Bordered pits in tangential walls of tracheids 9—10 μ, in radial walls 10—16 μ. Indentures present. In the cross field 1—2 (3—4) pits, 4—8 μ in diam. Tangential walls of ray cells

with cribriform thickenings. Curiously, in this species the rays are made up of both thin- and thick-walled parenchyma cells ; the thin-walled are between the thick-walled cells or on the margins. (*Y.*)

Abies vilmorinii MAST.
Pl. 227

g. Per sq. mm. 50—60 rays and 120—125 ray cells. Rays 1—4 (6) cells high. Height of ray cells 13—18 μ, in marginal and single- or double-rowed rays exceptionally attain 50 cells ; width 5—10 μ. Bordered pits in tangential walls of tracheids 6—8 μ, in radial walls 8—10 μ. In the cross field 1—2—4 pits, 2—5 μ in diam. (*Y.*)

Abies pindrow SPACH.
Pl. 218

VI. In the earlywood 1—2 pits in the cross field, 3—5 μ in diam. or slightly larger ; in the marginal cells usually 2, one above the other.

A. In the cross field commonly one pit. In the marginal cells 1—2 (3—4) pits in a diagonal row.

a. Per sq. mm. 115—120 rays and 370—380 ray cells. Rays 1—6 (13) cells high, uniseriate. Height of ray cells 13—21 μ, attaining as much as 54 μ in single- or double-rowed rays ; width 8—13 μ. Tangential walls of ray cells with sievelike pitting. Pits relatively small and closely spaced. Bordered pits in tangential walls of tracheids 6—8 μ, in radial walls 9—15 μ. Minute pits in tangential walls of wood parenchyma cells. Number of pits in the cross field 1—2 (3—5). Orientation of apertures horizontal or oblique. Pit diameter 5—8 μ. (*Y.*)

Abies cilicica CARR.
Pl. 201

b. Per sq. mm. 70—80 rays and 240—250 ray cells. Rays 1—8 (10) cells high, uniseriate. Height of ray cells 15—16 (18) μ, width 6—8 μ. Bordered pits in tangential walls of tracheids 9—10 μ, in radial walls 10—13 μ. Indentures present. In the cross field commonly 1 pit, in the marginal cells 2—4; 5—6 μ in diam. Tangential walls of ray cells cribriform or scalariform. Smooth-walled transverse tracheids an exception. (*M.*)

Abies lowiana A. MURRAY
Pl. 213

c. Per sq. mm. 80—90 rays and 390—400 ray cells. Rays 1—8 (27) cells high, uniseriate. Height of ray cells 10—18 μ, in marginal and single-row rays 27 μ high ; width 5—12 μ. Bordered pits in tangential walls of tracheids 8—10 μ, in radial walls 8—13 μ. Indentures present. In the cross field 1 pit, in the marginal cells 2—4 pits, 4—5 μ in diam. All walls of wood parenchyma pitted. Calcium oxalate crystals in parenchyma cells. (*Y.*)

Abies magnifica A. MURRAY
Pl. 214, p. 189

B. In the cross field commonly 1 pit, in the marginal cells 2 pits, mostly superposed.

a. Horizontal walls of ray cells sometimes significantly thickened. Per sq. mm. 80—90 rays and 350—400 ray cells. Rays 1—8, exceptionally 20 (25) cells high, sometimes biseriate in the middle. Height of ray cells 13—18 (21) μ, width 5—8 μ. Bordered pits rare in tangential walls of tracheids ; 10—13 μ in diam. in radial walls. Horizontal walls of wood parenchyma pitted. Indentures present. In the cross field 1—2, in the marginal cells sometimes 3, pits, mostly superposed, 4—6 μ in diam. Tangential walls of ray cells with sievelike pitting. (*Y.*, 70)

Abies fabri CRAIB.
Pl. 203

b. Horizontal walls of ray cells not conspicuously thick, but frequently with simple pits. Per sq. mm. 140—150 rays and 410—420 ray cells. Rays 1—6, exceptionally 14, cells high, uniseriate. Height of ray cells 13—18 μ, in marginal and single-row rays up to 27 μ ; width 6—8 μ. Bordered pits in tangential walls of tracheids 5—8 μ, in radial walls 8—14 μ. Indentures present. In the cross field commonly 1, in the marginal cells 2—3, superposed pits, 2—5 μ in diam. Tangential walls of ray cells with sievelike pitting. (*Y.*)

Abies amabilis FORBES
Pl. 197

Cedrus species

A. About 5000 tracheids, 100—110 rays, and 390—400 ray cells per sq. mm. In the cross field 1—2 (3) pits, 4—6 μ in diam. Rays commonly 1—8, exceptionally 18, cells high, uniseriate, occasionally partly biseriate. Height of ray cells 10—27 μ, exceptionally 54 μ, width 8—16 μ. Pits

in tangential walls of tracheids 9—10 μ, in radial walls 9—13 μ. Torus well discernible, its scalloped margin also in places. Indentures well defined.

(*M.*, 74, 129) *Cedrus libani* LOUDON
Pl. 231, p. 193

B. About 3000—3200 tracheids per sq. mm.

a. Per sq. mm. 35—40 rays and 270—280 ray cells. Rays 1—10, rarely 32, cells high, partly biseriate. Ray cells 13—24 μ high, 5—18 μ wide. Bordered pits in tangential walls 10—13 μ, in radial walls 10—18 μ. In the cross field 1—2 (3) pits, 5—6 μ in size. Indentures relatively well defined. (*M.*, 129)

Cedrus deodara LOUDON
Pl. 230, p. 193

b. Per sq. mm. 65—70 rays and 390—400 ray cells. Rays 1—12 (22) cells high, commonly uniseriate. Height of ray cells 13—16 μ, width 8—13 μ. Bordered pits in tangential walls of tracheids 10—13 μ, in radial walls 13—16 μ. Horizontal walls of wood parenchyma smooth or nodular. In the cross field 2—3 (4—5) pits, 5—6 μ in diam. *M.*, 53, 129)

Cedrus atlantica MANETTI
Pl. 228, p. 192

c. Per sq. mm. 30—35 rays, 230—235 ray cells. Rays commonly 1—10, exceptionally up to 32, cells high, uniseriate, not infrequently partly biseriate. Height of ray cells 15—30 μ, width 12—16 μ. Bordered pits in radial walls of tracheids 16—21 μ, in tangential walls 10—13 μ. In the cross field mostly 1—2, in the marginal cells 4—5, pits with 4—8 μ diam. In cross section resin cysts fairly large, attaining 50—90 μ in diam. Number of tracheids per sq. mm. 1500. Transverse tracheids often with calcium oxalate crystals. (*M.*, 129.)

Cedrus brevifolia HENRY
Pl. 229, p. 194

Keteleeria species

A. Rays 1—6 (15) cells high, uni- or biseriate. Height of ray cells 10—27 μ, width 10—18 μ. Bordered pits in tangential walls of tracheids 9—10 μ, in radial walls 12—16 μ. In the cross field 1—2 (4—5) pits, 4—6 μ in size. (*M.* 53)

Keteleeria fortunei CARR.
Pl. 233, p. 194

B. Rays 1—12 (32) cells high, uniseriate, occasionally partly biseriate. Height of ray cells 13—18 (43) μ, width 5—18 μ. Bordered pits in tangential walls of tracheids 8—9 μ, in radial walls 10—16 μ. Indentures present, sometimes poorly defined. In the cross field 1—2 (4) pits, 5—8 μ in size. (*M.*, 129.)

Keteleeria davidiana BEISS.
Pl. 232, p. 194

Larix species

I. Transverse tracheids with very delicate spiral thickenings. Growth rings distinct, latewood 5—6 cell layers in width. Resin ducts penetrating the latewood ; they measure 40x 40 μ. Rays commonly 1—16, those with resin ducts up to 30, cells high. Per sq. mm. 60—65 rays and 300—310 ray cells. Height of ray cells 13—18 μ, width 8—13 μ. Bordered pits in tangential walls of tracheids scattered, fairly small, only 5—6 μ in diam. Rays heterogeneous, transverse tracheids generally marginal. Walls of transverse tracheids smooth or with closely spaced spirals extending their whole length. In the cross field 3—6 minute pits, commonly near the horizontal walls in diagonal arrangement ; pit diameter 4—6 μ. Horizontal walls of wood parenchyma markedly pitted. Tangential walls of ray cells with sievelike pitting. Bordered pits in tracheids in longitudinal rows or in twos. Torus well defined. (*M.*)

Larix lyallii PARL.
Pl. 239

II. Walls of transverse tracheids smooth or very minutely dentate.

A. Resin duct 70—80 μ in diam. Tracheids in latewood relatively powerful. About 800 tracheids, 25—30 rays, and 150—160 ray cells per sq. mm. Rays 1—10 (26) cells high. Height of ray cells 10—13 (18) μ, with only 4—6 μ in width. In radial walls of longitudinal tracheids bordered pits solitary, scattered, or in twos ; in the latter case, crassulae well discernible. Readily separated from the other *Larix* spp. by the presence of 6—10 pits in the cross field. Pit diameter 5—6 μ. In transverse tracheids spiral reticulation not uncommon. (*M.*, 74)

Larix occidentalis NUTTAL
Pl. 240, p. 197

B. Resin ducts up to 20—60 μ in diam. Cross field with 3—6 pits.

1. Wood parenchyma absent or very sparse. About 1300 tracheids, 35—40 rays, and 270—280 ray cells per sq. mm. Height of ray cells 13—24 μ, width 4—6 μ. Rays generally 1—12, those with resin ducts up to 26, cells high. Bordered pits in tangential walls of tracheids 8—10 μ, in radial walls 18—27 μ. Wood parenchyma present. In the cross field 3—4 (6) pits, 6—7 μ in diam. Diameter of resin ducts 50—60 μ, exceptionally 80 μ. (*M.*)

Larix gmelini (Ruprecht) LITVINOV
Pl. 235, p. 196

2. Wood parenchyma present, sometimes very scarce. Number of pits in cross field 2—4 (6), with 2—5 μ diam.

a. Vertical resin ducts comparatively small, only 20—30 μ in diam.

α Cross field with 2—4 (6) pits, 2—5 μ in diameter. Latewood conspicuously wide. About 3400 tracheids, 75—80 rays and 220—230 ray cells per sq. mm. Rays 1—10, those with resin ducts up to 20, cells high. Height of ray cells 13—27, exceptionally 40 μ, width 6—8 μ. Bordered pits in tangential walls 8—10 μ, in radial walls somewhat larger, 13—16 μ in diam. Tangential walls of rays with sievelike pitting. Horizontal walls of wood parenchyma exceptionally smooth, generally scarcely pitted. Walls of transverse tracheids smooth or almost imperceptibly dentate. (*Y.*)

Larix gmelini var. japonica (REGEL) PILGER
Pl. 236

β Cross field with 3—4 (7) pits, 4—6 μ in diam. Latewood not more than 6—8 cell layers wide. Resin ducts comparatively small, measuring only 31 x 37 μ. About 5400 tracheids, 50—60 rays, and 190—200 ray cells per sq. mm. Rays 1—12, those with resin ducts up to 24, cells high. Ray cells in cross section markedly elongate ellipses, 16—24 μ high and 5—16 μ wide. Bordered pits in tangential walls 5—10 μ, in radial walls 13—18 μ. Wood parenchyma scarce. Walls of transverse tracheids very delicately dentate. (*Y.*, *M.*)

Larix laricina K. KOCH
Pl. 237

b. Resin ducts 30—40 μ in diam.

α Cross field with 1—2 (3) pits. About 3100 tracheids, 40—50 rays, and 310—320 ray cells per sq. mm. Diameter of resin ducts 32—40 μ. Rays 1—16, those with resin ducts up to 30, cells high. The higher simple rays partly biseriate in the middle. Height of ray cells 10—16 (21) μ, width 5—13 μ. Bordered pits in tangential walls of tracheids 5—6 μ, in radial walls 13—18 μ. Wood parenchyma fairly frequent; horizontal walls markedly pitted. Some transverse tracheids with clearly visible spiral thickenings. Cross field pits 4—5 μ in diam. (*M.*, 171.)

Larix potanini BATALIN
Pl. 242

β Cross field with 2—3 (4) pits, mostly diagonally disposed. About 5000 tracheids, 50—60 rays, and 200—210 ray cells per sq. mm. Resin ducts 29—35 μ in diam. Rays relatively low, only 1—8, those with resin ducts up to 16, cells high. Height of ray cells 10—16 (22) μ, width 5—10 μ. Bordered pits in tangential walls 5—6 μ, in radial walls 8—16 μ. Walls of transverse tracheids smooth or minutely dentate. Horizontal walls of wood parenchyma nodular or dentate. Tangential walls of ray cells with sievelike pitting. Cross field pits 4—6 μ in diam. (*Y.*, *M.*)

Larix sibirica LEDEBOUR
Pl. 243

γ In the cross field 4—6 pits, 4—5 μ in diam. About 5000 tracheids, 70—75 rays, and 310—320 ray cells per sq. mm. Resin ducts 35—40 μ in diam. Rays 4—10, those with resin ducts up to 14—16, cells high. Height of ray cells 10—16 (27) μ, width 4—13 μ. Bordered pits in tangential walls 4—9 μ, in radial walls 13 μ. Horizontal walls of wood parenchyma smooth or slightly pitted. Walls of transverse tracheids smooth or very minutely dentate. (*M.*)

Larix pendula SALISB.
Pl. 241

c. Resin ducts up to 40—60 μ in diam.

α Rays 1—8, exceptionally 12—14, those with resin ducts up to 20—25, cells high, occasionally partly biseriate. Height of ray cells 13—18, exceptionally 40 μ, width 6—10 μ. Bordered pits in tangential walls of tracheids 5—8 μ, in radial walls 10—21 μ. Walls of transverse tracheids generally smooth or almost imperceptibly dentate. Horizontal walls of wood parenchyma smooth or nodular.

Cross field with 3—4 (6) pits, 4—6 μ in diam. Per sq. mm. 90—100 rays and 320—330 ray cells.

(*Y.*, *M.*, 74, 53) *Larix decidua* MILLER
Pl. 234, p. 194

β Rays 1—12, those with resin ducts up to 24, cells high; in the body of the latter occasionally 4—5 paired cells. Resin ducts 54 μ in diam. Ray cells 13—20 μ, in single-row rays up to 32 μ, high; width 4—8 μ. Bordered pits in tangential walls of tracheids 9—10 μ, in radial walls 13—21 μ. Horizontal walls of wood parenchyma slightly pitted. Walls of transverse tracheids generally smooth. In the cross field 2—4 (5) pits, mostly occupying the corners; 4—6 μ in diam. (*M.*)

Larix leptolepis MURRAY
Pl. 238, p. 196

Picea species

From among the conifers with resin ducts, xylotomically the genus *Picea* stands nearest to *Pseudotsuga* and *Larix*. From *Pinus* it is readily separated by its thick-walled epithelial cells lining the resin ducts. From *Larix*, and particularly from *Pseudotsuga*, it has hitherto been customary to distinguish the *Picea* on the ground that they do not always contain spiral thickenings, whereas *Pseudotsuga* have them in all longitudinal tracheids. The present writer's investigations tend to show, however, that this difference affords no reliable distinction, as one *Picea* species, *P. likiangensis*, has been found to possess spiral thickenings not only in the longitudinal but also in the transverse tracheids. True, this too is but an exception, and cannot therefore be regarded as a distinctive feature of general validity. Under these circumstances, generic separation is commonly based in part on the number of cross-field pits, and in part on the number of epithelial cells lining the resin ducts, though, again, the latter is of no absolute value as has been convincingly proved by the latest results of DIANNELIDIS (22). The number of cross-field pits in *Pseudotsuga* is commonly 1—3, whereas in *Picea* it is 1—6, and occasionally higher. Their great likeness would appear to permit the conclusion of an affinity between *Pseudotsuga* and *Picea*, although they can be differentiated, with some doubt, by the number of epithelial cells which, according to PHILLIPS (129), is as a rule 5—7 in *Pseudotsuga* and 8—10 in *Picea* and *Larix*.

The generally accepted view on spiral thickening also needs to be slightly modified. HOLLENDONNER (74), HABERLANDT (62) and many other wood anatomists hold that in *Picea* spiral thickening is confined to the latewood in the first few growth rings. According to BURGERSTEIN, it is encountered up to the 15th annual increment and then gradually disappears depending on the habitat of the tree. (Cf. WIESNER: Rohst. (162). In contrast with these statements, the present writer has found that in some *Picea* species spiral thickening does occur beyond the 15th annual ring; a feature which undoubtedly is an aid in the separation of species.

It is slightly less difficult to distinguish *Picea* from *Larix*, for while there is no longitudinal parenchyma on the outer limits of the growth rings in the former, it is rather frequent in the latter. Besides, paired pits are fairly common in the longitudinal tracheids of *Larix*, but practically always absent in those of *Picea*. Finally, while in the tannic-acid reaction the wood of *Picea* stains green with ferrochloride, that of *Larix* stains black. And yet, differentiation between these two genera by the longitudinal parenchyma is not quite reliable, for there are *Picea* species in which true longitudinal parenchyma appears in addition to the parenchymatous elements near the resin ducts *(P. wilsoni)*.

The longitudinal parenchyma cells here discussed are not to be confounded with those cells arising in the wood in consequence of some injury or excessive tissue proliferation, which is a not infrequent phenomenon and occasionally spreads throughout the growth layers. Whether proliferation gives rise to giant parenchyma cells, 60 to 90 μ in diameter, or remains restricted to isolated spots, it is invariably confined to the early-formed part of the growth rings. When, sometimes, rays are involved in the proliferation, they are seen to be widened.

Regarding interspecific similarities and discrepancies in the genus *Picea*, the likeness in tissue structure is of such magnitude as to render separation on xylotomical grounds in most cases almost impossible. The similarities are most conspicuous on the transverse surface, where only doubtful differences can be established lacking diagnostic value. The resin ducts are on the whole scattered throughout the growth rings, yet in their majority they occur in the latewood and the transitional zone. They differ in size, sometimes quite considerably, as can be seen in the attached Table VII.

Sometimes they pursue a course fairly equidistant from the outer edge of the growth ring and seem to arrange themselves, as it were, to a regular row of resin ducts. Occasionally, two or more longitudinal resin ducts intercommunicate by anastomosis.

The tangential surface reveals the cross-sectional differences of ray cells in height and width. Ray-cell height and width, and the ratio between them, form a basis on which to divide the species into separate groups of spp. having narrow, medium, and wide ray cells, respectively. On the other hand, by the pitting in the tangential ray-cell walls two groups can be established : one for the spp. with these pits less than 10 μ in diam., and one for those in which this diameter exceeds 10 μ. It should be noted that the height of rays is of no diagnostic worth, the number of ray cells depending on age. Rays are variable in height, ranging from 1 to 20—30 or even 40 cells.

In the tangential section the species show great likeness in other respects as well. Bordered pits in the walls are commonly seen to occur in the transitional and latewood zones and aligned in a row. Biseriate pitting could be observed by the writer but seldom. Shape and orientation of the pits in the tangential walls, and even the orientation of their apertures, may offer some additional aid in specific separation.

Undoubtedly, the radial section is best suited for specific separation since it shows the largest number of characteristic features of diagnostic value. Let us first mention one that is of problematic value. The pits in the radial walls of the longitudinal tracheids have differing average diameters, yet these are of little avail in identification, because the extremes that yield the averages have a far too great scatter, and overlap. Diagnostically most reliable are the transverse tracheids. In *Picea* they are more or less a distinctive feature, although in the quite young tree they are few in number and may be lacking in the very first growth rings. In the annual increments of adult trees, however, the rays are always terminated by them ; moreover, they frequently form continuous rows between the ray parenchyma cells.

The transverse tracheid walls are generally thin, about 0,8—1 μ, but the wall structure is not the same in all the species. The inner wall surface is smooth on rare instances ; as a rule it is minutely dentate from very moderately to most markedly ; occasionally there are even spiral thickenings in it like, for instance, in *Picea likiangensis*.

The tangential walls of the ray parenchyma cells are generally 2—4 μ thick, but occasionally quite thin. Their pits, too, provide a diagnostic feature, being circular in some species, whereby the walls become sievelike ; and elongate elliptical in others, giving the walls a scalariform appearance.

In the radial walls the pits vary in shape and size almost from species to species. Number of cross-field pits 1—2 in the latewood, 4—6, occasionally 8, in the earlywood, regularly or irregularly arranged.

The external walls of marginal parenchyma cells in rays without transverse tracheids, are wavy in all species of the *Picea ;* frequently, they are variably thick with pits in the hollows in them.

Indentures are common to almost all the species in *Picea*. The tracheids have rounded ends, but in the latewood they are nearer to pointed.

KEY

I. In the cross field 2—4 (5) smaller to larger pits, 4—6 μ in diam. ; when 2, they are commonly side by side ; when 4, they are mostly disposed irregularly. Orientation of pit apertures vertical or oblique *(Picea albertiana, P. mariana, P. morinda, P. glauca, P. orientalis, P. smithiana, P. sitchensis).*

A. Commonly 2—3 pits, arranged *side by side*, with oblique pit apertures.

a. Rays 1—16, those with resin ducts 30—40, cells high. Height of ray cells 13—18 μ, width 4—5 μ. Bordered pits in tangential walls of tracheids 6—9 μ, in radial walls 16—18 μ. Cross field with 1—2 (3—6) pits, 4—6 μ in diam. Indentures clearly visible. (*Y.*, *M.*, 59a)

Picea orientalis CARR.
Pl. 263, p. 208

b. Rays 1—10, those with resin ducts 10—15, exceptionally 28, cells high. Height of ray cells 10—16 μ, width 4—8 μ. Bordered pits in tangential walls of tracheids 6—8 μ, in radial walls 10—13 μ. Tangential walls of ray cells commonly pitted, sometimes scalariform. External walls of transverse tracheids delicately dentate. Cross field with 1+2—4 pits, 4—5 μ in diam. (*M.*, 59a)

Picea glauca (Moench) VOSS
Pl. 251, p. 203

B. Commonly 2—3 pits in the cross field, *side by side* or scattered, never diagonally arranged, not even in earlywood. Pit apertures generally vertical.

a. Height of ray cells 13—21 μ, in marginal and single-row ray cells up to 29 μ; width 5—8 μ. Resin ducts more common in latewood. Bordered pits in tangential walls of tracheids 6—8 μ, in radial walls 13—21 μ. Indentures present. Cross field with 2—3 pits, 4—5 μ in diam. (*M.*, 59a)

Picea albertiana STEWARDSON—BROWN
Pl. 245

b. Resin ducts pursue their course more in the earlywood and the transitional zone; they are 27—45 μ in diam. Rays 1—20 cells, those with resin ducts 20—25, cells high. Height of ray cells 10—16 μ, width 4—5 μ, i. e. from twice to two and a half times higher than wide. Bordered pits in tangential walls of tracheids 5—10 μ, in radial walls 15—18 μ. Pit apertures generally vertical. Tangential walls of ray parenchyma sievelike. Inner face of transverse tracheid walls spinous, coarse. In transverse tracheids apertures of bordered pits almost vertical. Cross field with 1—4—6 pits, 3—6 μ in diam. (*M.*, 59a)

Picea mariana BRITTON
Pl. 258, p. 206

c. Ray cells in cross section elliptic. Resin ducts 30—60 μ in diam. Rays generally low, only 1—10, those with resin ducts up to 20, cells high. Ray cells 13—21 μ in height, in single-row rays up to 27 μ; width of ray cells 5—13 μ. Diameter of pits in tangential walls of tracheids 6—8 μ, in radial walls 13—18 μ. Cross field with 2—4, occasionally 6, pits, 4—6 μ in diam. Tangential walls of ray cells sometimes with scalariform pitting. (*M.*, 59a)

Picea smithiana (WALLICH) BOISS.
Pl. 268, p. 212

d. Ray cells in cross section more elongate ellipses. Rays 1—8 (12), those with resin ducts 10—16, cells high. Height of ray cells 13—18 μ, in some marginal rays up to 32 μ. Width of rays 4—13 μ. Bordered pits in tangential walls of tracheids 5—8 μ, in radial walls 13—16 μ. Pit apertures nearly vertical. Tangential walls of ray cells with sievelike or scalariform pitting. In the cross field 2—3 (5) pits with vertical apertures; pit diameter 4—6 μ. Walls of trasverse tracheids very delicately dentate. (*Y.*, *M.*, 59a)

Picea sitchensis CARR.
Pl. 267, p. 211

e. Rays 1—6—12, those with resin ducts up to 32, cells high. Height of ray cells 8—16 μ, width 5—8 μ. Bordered pits in tangential walls of tracheids 5—6 μ, in radial walls 18—21 μ. Pit apertures nearly vertical. Cross field with 1—4 pits in the internal and 6—7 pits in the marginal cells; pits are 4—6 μ in diam. and have vertical apertures even in the earlywood. Transverse tracheids with spiral thickenings in early- as well as latewood; spirals at intervals of 2—4 μ, and with bordered pits with vertical apertures. (*M.*, 70, 170)

Picea neoveitchii MAST.
Pl. 260a

II. Number of pits in cross field (2—3) 4 (6); when 2, they are side by side or superposed; when 3, they form a triangle; when 4, each takes a corner of the field. Upper and lower parts of rays with resin ducts either equally developed or one part somewhat longer than the other.

A. Rays generally regular in form, upper and lower parts equally developed.

a. Rays 1—10, those with resin ducts 12—18, cells high, occasionally partly biseriate. Height of ray cells 13—18 μ, sometimes up to 22—27 μ; width 8—18 μ; rays accordingly subcircular or short-elliptic. In longitudinal and transverse tracheids very delicate spiral thickenings. Bordered pits in tangential walls of tracheids 6—8 μ, in radial walls 12—14 μ. In the cross field 3—4 (7) pits, 4—8 μ in diam. (*M.*, *Y.*, 59a, 171)

Picea likiangensis PRITZEL
Pl. 256, p. 205

b. Rays commonly 1—10, those with resin ducts up to 26, cells high. Height of ray cells 13—18 μ, exceptionally 27 μ, width 6—8 μ, slightly elongate ellipses in cross section. Bordered pits in tangential walls of tracheids 5—6 μ, in radial walls 10—13 μ. In earlywood tracheids very exceptionally paired pits, connected by bars indicating the margins of primordial pits. Walls of transverse tracheids with delicate spikelets, very exceptionally showing traces of spiral thickenings. Cross field with 2—3 (5) pits, 4—6 μ in diam. Tracheids of latewood spirally thickened. (*Y.*, *M.*, 59a, 74)

Picea abies KARST
Pl. 244, p. 198

c. Rays 1—8, those with resin ducts 16—18, cells high. Height of ray cells 13—18 μ, in some marginal and single-row rays up to 30 μ; width 4—13 μ, rather elongate ellipses. Bordered pits in tangential walls of tracheids 5—8 μ, in radial walls 10—13 μ. Walls of transverse tracheids dentate, sometimes with very delicate spiral thickening. Cross field with 4—6 pits, 3—6 μ in diam. (*Y.*, 59a)

Picea maximoviczii REGEL
Pl. 259

B. In tangential section the two portions of rays above and below the resin ducts often *more or less unequally developed.*

a. Rays 4—12, those with resin ducts up to 16, cells high. Height of ray cells 13—18 μ, sometimes up to 40 μ, width 4—8 μ, resulting in more elongate ellipses. Bordered pits in tangential walls of tracheids 6—8 μ, in radial walls 8—16 μ. Pit apertures almost vertical. Walls of transverse tracheids sparsely delicately dentate. Cross field with 2—4 (6) pits, 4—6 μ in diam. (*Y.*, *M.*, 59a)

Picea glehnii MAST.
Pl. 252, p. 203

C. Rays with resin ducts for the major part fusiform.

a. Rays 3—7, those with resin ducts 8—12, cells high. Height of ray cells 16—18 μ, in marginal and single-row rays up to 30 μ, width 6—9 μ, resulting in more elongate ellipses. Bordered pits in tangential walls of tracheids 6—8 μ, in radial walls 9—14 μ. In contrast with the other *Picea* spp., walls of transverse tracheids smooth, with no spikelets visible. Cross field with 2—3—6 pits, 3—6 μ in diam. (*Y.*, *M.*, 59a)

Picea engelmanni ENGELMANN
Pl. 250, p. 202

b. Rays normally 5—10, those with resin ducts up to 20, cells high. Height of ray cells 15—20 (27) μ, width 4—6 μ. Bordered pits in tangential walls 6—8 μ, in radial walls 13—17 μ. Walls of transverse tracheids conspicuously spinous, spikelets 1—2 μ high. In transverse tracheids pit apertures of bordered pits generally slitlike and vertical. Indentures clearly visible. Early- and latewood tracheids with spiral thickenings. In the cross field 2—4 pits, 4—5 μ in diam. (*Y.*, 59a, 170)

Picea asperata MAST.
Pl. 246, p. 199

III. Cross field with (1) 2—3 (4), very exceptionally 6, pits; when 2, they are generally superposed; when 3, they form a triangle; when 4, each occupies a corner of the field. Commonly 2—4 pits in the cross field of marginal parenchyma cells.

A. Ray cells in cross section subcircular or short-elliptic. Rays with resin ducts commonly low, 8—10—14 cells in height; rays without resin ducts 5—8 cells high. Ray cells 14—20 μ, in single-row rays up to 27 μ high; width 7—13 μ. Diameter of pits in tangential walls of tracheids 8—9 μ; pit apertures oblique. Tangential walls of ray parenchyma sievelike, occasionally scalariform. Bordered pits in radial walls of ray parenchyma in earlywood 14—16 μ, in latewood 8—10 μ. Walls of transverse tracheids delicately dentate. Spiral thickenings in late- and earlywood. In the cross field 2—3—4 pits, 4—5 μ in diam. (*M.*, 59a)

Picea schrenkiana FISCHER
Pl. 266, p. 211

B. Ray cells in cross section more elongate upright ellipses.

a. Rays 3—10, those with resin ducts 10—18, cells high. Height of ray cells 15—20 μ, attaining exceptionally 30 μ; width 7—10 μ. Tangential walls of ray cells with sievelike or scalariform thickenings. Walls of transverse tracheids spinulose, dentate. In latewood definite spiral striation. Cross field with 1—2 (6) pits, 4—6 μ in diam. (*Y.*, 59a)

Picea polita CARR.*
Pl. 264, p. 209

b. Rays 1—6 (8), those with resin ducts 10—12, cells high. Height of ray cells 15—20 μ, width 5—10 μ. Bordered pits in tangential walls of tracheids 6—8 μ, in radial walls 10—16 μ. Pit apertures slightly oblique. Walls of transverse tracheids

* Owing to a regrettabble mistake in the compilation the drawing pertaining to this species appears on Plate 120 with the photographs of *Cupressus whitleyana* Carr., while those belonging to that species appear on Plate 264.

spinulose. Latewood with spiral thickenings. In the cross field 2—4—6 pits, 4—6 μ in diam. (*M.*, 59a)

Picea omorika BOLLE
Pl. 262, p. 208

IV. Cross field with 2—3 (4) pits diagonally or irregularly disposed. In case of 2 pits, they are superposed, or in diagonal position, or irregularly arranged. In marginal cells occasionally 6 pits, provided transverse tracheids are lacking.

A. The two portions of the rays below and above the resin ducts not always equally developed. Rays 1—10, those with resin ducts 12—20, cells high. Height of ray cells 13—18 μ, in marginal and single-row rays 30 μ; width 6—9 μ. Bordered pits in tangential walls of tracheids 6—8 μ, in radial walls 10—13 μ. Walls of tracheids distinctly spinulose. In late- and earlywood spiral thickenings. Cross field with 2—4 (6) pits, 4—6 μ in diam. (*Y.*)

Picea yunnanensis HORT.
Pl. 254

B. Rays with resin ducts generally irregular in shape.

a. Horizontal walls of ray cells markedly pitted even in earlywood. Rays 1—8, those with resin ducts 16—20, cells high. Height of ray cells 14—18 (25) μ, width 5—8 μ. Bordered pits in tangential walls of transverse tracheids 6—8 μ, in radial walls in the earlywood 10—14 μ. Spiral thickenings in early- and latewood tracheids. Occasionally *wood parenchyma* near the outer edge of the growth rings, with smooth or pitted horizontal walls. Walls of transverse tracheids spinulose. (*M.*, 59a)

Picea wilsoni MAST.
Pl. 269, p. 213

b. Exceptional occurrence of aggregate rays. Rays 1—10, those with resin ducts 10—12, cells high. Ray cells in cross section more elongate ellipses, 14—20 μ in height, 5—8 μ in width. Walls of transverse tracheids apparently smooth : a feature virtually singular among *Picea* spp. Bordered pits in tangential walls of tracheids 6—8 μ and with nearly vertical apertures ; those in radial walls 10—13 μ. In the cross field 1—2—3—4 pits, 3—6 μ in diam. (*M.*, 59a)

Picea jezoensis CARR.
Pl. 253, p. 204

V. In the cross field 2—4—6—8 pits ; in the marginal parenchyma cells commonly 6—8, in the internal cells 2 or 4. Two pits in the field are superposed, 3 form a triangle, while 4 are diagonally disposed. Certain species occasionally with two kinds of ray parenchyma.

A. Two kinds of ray parenchyma cells : thin- and thick-walled. Rays 3—8, those with resin ducts 8—14, cells high. Height of ray cells 13—20 (40) μ, width 7—12 μ. Walls of transverse tracheids slightly spinulose, bordered pits in them 6—8 μ in diam. Diameter of bordered pits in radial walls of tracheids 10—15 μ in the earlywood and 6—9 μ in the latewood ; in tangential walls 6—9 μ. In the cross field 2—3, in the marginal cells up to 7—8, pits, mostly in two vertical rows and 4—5 μ in diam. (*M.*, 59a)

Picea obovata LEDEB.
Pl. 261, p. 207

B. Rays consisting solely of thick-walled parenchyma cells. Rays 1—10, those with resin ducts 10—14, cells high. Ray cells 14—20 (25) μ high and 8—10 μ wide ; width in radial walls 10—14 μ. Walls of transverse tracheids covered with sporadic delicate spines. Paired pits in radial walls of tracheids uncommon. Cross field with 2—4 (6) pits in two vertical rows and 3—6 μ in diam. (*Y.*, 59a)

Picea pungens ENGELMANN
Pl. 265, p. 210

C. Rays 1—8, those with resin ducts 14, cells high. Height of ray cells 15—18 (27) μ, width 8—10 μ. Bordered pits in tangential walls of tracheids 6—10 μ, in radial walls 10—13 μ. Transverse tracheids with delicate spiral reticulation. Tangential walls of ray cells with sievelike thickenings. In the cross field 3—4, in the marginal cells 6 pits, 4—6 μ in diam. (*Y.*, 59a)

Picea likiangensis var. purpurea DALIMORE et JACKSON
Pl. 257

D. Cross field with large pits, 5—7 μ in diam.

a. Rays with resin ducts elongate and 10—16 cells high, those without resin ducts 6—8 cells in height. Rays 13—18 μ, in single-row rays 35—40 μ high ; ray-cell width 8—13 μ. Bordered pits in tangential walls of tracheids 8—10 μ, in radial walls 10—13 μ. In the cross field 2—4, in the marginal cells 6, pits, 5—7 μ in diam. Walls of

transverse tracheids definitely spinous. Walls of late- and earlywood tracheids with spiral thickenings. (*Y.*)

Picea morissonicola HAYATA
Pl. 260

b. Rays 4—8, those with resin ducts 6—10, cells high. Height of ray cells 15—18 (27) μ, width 6—8 μ. Bordered pits in tangential walls of tracheids 6—8 μ, in radial walls 10—13 μ. Walls of transverse tracheids definitely spinous. Tracheids of early- and latewood with spiral thickenings. In the cross field 2—3, in the marginal cells 6—8, pits, 5—7 μ in diam. (*Y.*, 59a)

Picea koyamai SHIRAS
Pl. 255, p. 205

E. Pits in cross field generally fairly small, 4—5 μ in diam.

a. Rays 1—10, those with resin ducts 12—16, cells high. Height of ray cells 14—18 μ, in single-row rays 25—27 μ; width 8—13 μ. Pit diameter in tangential walls of tracheids 6—8 μ, in radial walls 9—10 μ. Early- and latewood tracheids with spiral thickenings. Walls of transverse tracheids delicately spinous. In the cross field 2—3 (6—8) pits, 4—5 μ in diam. (*Y.*, *M.*, 59a)

Picea bicolor MAYR
Pl. 247, p. 200

b. Rays 4—6 (10), those with resin ducts 10—16, cells high. Height of ray cells 14—18 μ, in single-row rays up to 25 μ; width 8—10 μ. Transverse tracheids with delicate spiral thickenings. Spiral thickenings in walls of early- and latewood tracheids. Occasionally two resin ducts in a ray. Tangential walls of ray parenchyma with sievelike thickenings. In the cross field 2—4 (6—8) pits, 4—5 in diam. (*Y.*, 59a, 171)

Picea brachytyla PRITZEL
Pl. 248, p. 200

c. Rays relatively low, mostly 1—3, less frequently 6, very few of them more than 8—10, cells high. Ray parenchyma cells short-elliptic in cross section. Transverse tracheids few, with smooth or very delicately dentate walls. Walls of early tracheids with spiral thickening. (*Y.*, 59a)

Picea breweriana WATSON
Pl. 249, p. 201

Pinus species

The *Pinus* are readily distinguished from the other conifers by their resin ducts. The parenchyma cells lining the latter do not lignify, but remain thin-walled throughout, with here and there an occasional slight thickening. This makes it easy to keep *Pinus* apart from *Pseudotsuga*, *Larix*, and *Picea*. Because thin-walled epithelial cells in resin ducts do not occur outside the *Pinus*, this type may be called the *Pinus* type.

Apart from being pitted, the longitudinal walls of the tracheids in this genus are always smooth, never with any spiral thickenings, except perhaps in the first growth ring. On this basis the *Pinus* are easily separated from *Torreya*, *Taxus*, *Cephalotaxus*, *Pseudotsuga* and in certain cases from *Larix* and *Picea* as well. In the radial walls of the longitudinal tracheids the bordered pits are aligned in one longitudinal row. In the wider tracheids paired pits are occasionally encountered. An additional characteristic of the *Pinus* is the absence of wood parenchyma, although it may occur quite exceptionally, e. g. in *Pinus cembroides var. monophylla* and *P. massoniana*. The rays in *Pinus* are overwhelmingly heterogeneous. The transverse tracheids chiefly fringe the rays on two sides, as if terminating them, but are not uncommon in the body among the parenchyma cells. In rare instances, rays consist solely of transverse tracheids and are then slightly lower, as a rule, than those composed only of parenchyma cells. The inner face of the transverse tracheid walls is smooth in the *Pinus* species belonging to the *Haploxylon* group; in those of the *Diploxylon* group, teeth different in size penetrate the cell lumen and ramify in it. The presence or absence, and the size of these teeth serve as an important diagnostic feature in the identification of these woods. Ray parenchyma cells are either quite thin-walled or thickened. Both kinds of parenchyma may occur in one and the same ray. While the thin-walled rays are devoid of pitting, at most with insignificant indentations in them, those with thick walls show relatively numerous simple pits. The very variable cross-field pitting, the size, number, and arrangement of pits, the presence or absence of thin- and thick-walled parenchyma cells and the ratio between them, are all features of outstanding diagnostic worth. Particularly great importance attaches in specific separation to the ray structure: less to the numerical data it yields, and more to the distinctive features its internal

morphology reveals. With a view to facilitating identification work, these details have been tabulated and are presented in Table VIII.

On the evidence of their more important anatomical features, the species of *Pinus* can be divided into 9 larger groups.

I. Walls of ray tracheids perfectly smooth *(Haploxylon)*. Pitting pinoid.

A. In the cross field 1 (2—3) pinoid pits of fairly uniform size, occupying almost the entire area, squarish with rounded corners, rhomboidal, circular, or elliptic. Tangential walls of tracheids generally pitted.

a. Cross field with 1 pit, occasionally with 2, mostly superposed; pits practically equal in size. This type of structure is found in *P. armandi*, *P. ayacahuite*, *P. cembra*, *P. flexilis*, *P. monticola*, *P. peuce*, *P. pumila*, *P. wallichiana*.

I. *Cembra group*
p. 214

b. Cross field with 1, frequently with 2, pinoid pits of the same size, commonly side by side. This type of structure is found in *P. albicaulis*, *P. koraiensis*, *P. lambertiana*, *P. parviflora*, *P. strobus*.

II. *Strobus group*
p. 218

B. Walls of ray cells thick. In the cross field 1—4 (5—6) minute, round, fairly equal-sized, *Picea*-type, but really pinoid, pits. This type of structure is found in *P. aristata*, *P. cembroides*, *P. cembroides var. edulis*, *P. cembroides var. monophylla*, *P. cembroides var. parryana*. On the other hand, delicately dentate ray-tracheid walls suggest *P. bungeana*, *P. balfouriana*, or *P. gerardiana*.

III. *Aristata (parryana) group*
p. 221

II. Walls of ray tracheids with slight and rare dentation.

1. Pitting pinoid.

A. Cross field with 1 (2—4) pinoid pits agreeing or differing in size and occupying the entire area. Walls of ray parenchyma cells thin and thick. This type of structure is found in *P. massoniana* and *P. merkusii*.

IV. Massoniana group
p. 224

B. Cross field with 1—8 (2—15) pinoid pits variable in shape and size. Tangential walls of longitudinal tracheids commonly smooth. Walls of ray parenchyma cells thin *(P. patula)*, or thin and thick. This type of structure is found in *P. leiophylla var. chihuahuana*, *P. ponderosa var. jeffreyi*, *P. radiata*, *P. sabiniana*.

V. Radiata group
p. 226

2. In the cross field 1—3 (5—10) minute piceoid pits of fairly uniform size, with diameters from 1/4th to 1/3rd the cell height. Rays with thin- and thick-walled parenchyma cells. This type of structure is found in *P. canariensis*, *P. halepensis*, *P. halepensis var. brutia*, *P. laricio*, *P. leucodermis*, *P. longifolia*, *P. pinea*.

VI. Pinea group
p. 229

III. Walls of ray tracheids moderately dentate, with the teeth not projecting beyond the centre of the lumen. Reticulate thickening rare. Pitting pinoid.

A. Cross field area occupied by 1 (2—3) fairly equal-sized pinoid pits. Rays with thin- and thick-walled cells. This kind of structure is found in *P. densiflora*, *P. funebris*, *P. laricio var. nigricans*, *P. laricio var. pallasiana*, *P. montana var. mughus*, *P. resinosa*, *P. sinensis*, *P. silvestris*, *P. thunbergii*.

VII. Silvestris montana group
p. 233

B. In the cross field 1—6 pinoid pits, variable in size and shape. Walls of ray parenchyma thick or thin. Tangential walls of longitudinal tracheids commonly sparsely pitted. This type of structure is found in *P. banksiana*, *P. coulteri*, *P. montezumae*, *P. muricata*, *P. maritima*, *P. pseudostrobus*, *P. teocote*, *P. attenuata*.

VIII. Banksiana group
p. 239

IV. Walls of ray tracheids markedly dentate and frequently with reticulate thickening. Pitting pinoid. In the cross field 1—6 pits different in size and shape, and so disposed as to come to fall within the circumference of an imaginary circle or ellipse. Generally two kinds of ray parenchyma. Tangential walls of longitudinal tracheids com-

monly without pits. This type of structure is found in *P. clausa*, *P. contorta*, *P. contorta var. murrayana*, *P. glabra*, *P. mitis*, *P. occidentalis*, *P. palustris*, *P. ponderosa*, *P. pungens*, *P. rigida*, *P. serotina*, *P. taeda*, *P. torreyana*, *P. virginiana*.

IX. Ponderosa group
p. 242

Pseudotsuga species

A. Cross field with 2—4 (6) pits, 4—8 μ in diam. Per sq. mm. 45—50 rays and 220—230 ray cells. Rays 1—5 (16) cells high, uniseriate, occasionally with 2—3 paired cells in the body. Height of ray cells 13—21 (27) μ, width 6—13 μ. Bordered pits in tangential walls of tracheids 6—8 μ, in radial walls 10—16 μ in diam. (*M*., 53, 74)

Pseudotsuga macrocarpa MAYR.
Pl. 339

B. Cross field with 2—4 (7) pits, 2—6 μ in diam. Per sq. mm. 90—100 rays and 320—330 ray cells. Rays 1—4 (10) cells in height, uniseriate, occasionally partly biseriate. Height of ray cells 13—18 μ, width 4—8 μ. Bordered pits in tangential walls of tracheids 6—13 μ, in radial walls 10—16 μ in diam. Indentures present. (*M*., 74.)

Pseudotsuga taxifolia BRITT.
Pl. 340, p. 249

Tsuga species

A. Cross field with 1—2 (4) pits, 4—6 μ in diam. Per sq. mm. 70—75 rays and 380—390 ray cells. Rays 1—12, exceptionally 26, cells high, commonly uniseriate. Height of ray cells 13—18 (27) μ, width 4—8 μ. Bordered pits in tangential walls of tracheids 8—9 μ, in radial walls 13—18 μ in diam.

Tsuga heterophylla SARG.
Pl. 344

B. Cross field with 2—4 (6) pits, 5—6 μ in diam. Per sq. mm. 70—75 rays and 270—280 ray cells. Rays 4—6, exceptionally 14, cells high, biseriate in places. Height of ray cells 13—21 (40) μ, width 5—13 μ. Bordered pits in tangential walls of tracheids 8—10 μ, in radial walls 10—13 μ in diam. (*M*.)

Tsuga dumosa EICH.
Pl. 343

C. Cross field with 2—4 (7) pits, 2—5 μ in diam. Per sq. mm. 35—40 rays and 200—210 ray cells. Rays 1—6 (12) cells high, generally uniseriate. Height of ray cells 13—18 (22) μ, width 5—10 μ. Bordered pits in tangential walls of tracheids 8—10 μ, in radial walls 13—16 μ. Indentures present. (*M*., 53, 74, 129)

Tsuga canadensis CARR.
Pl. 341, p. 249

D. Cross field with 3—4 (8) pits, 2—6 μ in diam. Per sq. mm. 65—70 rays and 400—410 ray cells. Rays 1—6 (18) cells high, occasionally partly biseriate. Height of ray cells 10—18 (27) μ, width 4—8 μ. Bordered pits in tangential walls of tracheids 9—10 μ, in radial walls 13—17 μ in diam. Indentures present. (*M*., 129)

Tsuga diversifolia MAST.
Pl. 342

E. Cross field with 2—4 (6) piceoid pits, 4—5 μ in diam. Per sq. mm. 1600 tracheids, 50—55 rays, and 370—375 ray cells. Rays uniseriate, exceptionally partly biseriate. Ray cells 13—24 μ high, 8—16 μ wide. Bordered pits in radial walls 13——18 μ in diam. Horizontal walls of longitudinal parenchyma with beadlike or dentate thickenings, occasionally with 4—5 nodes; in tangential walls minute round pits scattered. Resin cysts uncommon. Wood parenchyma resinous. (*M*., 129, 170)

Tsuga chinensis PRITZEL
Pl. 341a

APPENDIX

KEY FOR THE IDENTIFICATION OF THE FAMILIES OF THE CHLAMYDOSPERMAE (GNETALES)

A. Sharp delimitation between growth rings with vessels more or less uniformly scattered in them. Between the vessels narrow rays of 1—2, and very wide rays of 8—10 cell layers.

a. Perforation plates always simple or scalariform. Sometimes 8—12 bordered pits with large apertures clustered in the end walls and acting as perforations. Rays uni-biseriate and 8—10-seriate, fusiform in tangential section; wide rays occasionally 40—100 cells in height. In ray cells marked abundance of prismatic crystals of calcium oxalate. (60) (p. 251)

Gnetaceae
Pl. 349

b. Vessel perforations originate from 2—3 rows of alternate crowded pits, 18—26 in number. At the apices of vessel segments commonly 2—3 normal bordered pits. Vessels in cross section generally angular, solitary, and gradually diminishing in size in approaching the latewood. Rays 1 (4—5) cells in width, commonly of irregular shape in cross section. Wide rays 30—40 cells in height. (60) (p. 250)

Ephedraceae
Pls. 346—348

B. No sharp delimitation between growth rings. On transverse surface, individual vascular bundles mostly scattered. Definite rays only in outer parts of wood. Wood elements of individual vascular bundles spread abroad from a centre, almost radiating as spokes from a hub, yet they form aliform groups. In ground tissue frequent occurrence of markedly thick-walled spicular cells. Vessel perforations simple and more or less circular. Bordered pits in vessel walls alternate and of araucaroid arrangement. Apertures procumbent ellipses or horizontal slits. (60) (p. 252)

Welwitschiaceae
Pl. 350

B. XILOTOMICAL DESCRIPTIONS OF GYMNOSPERMOUS WOODS BY SPECIES

I. DESCRIPTION OF THE CYCADALES

CYCAS REVOLUTA THUNBERG

Pl. 1.

Distribution: South Japan, Taiwan, China (Yunnan). Sample from a stem about 20 years of age.

C. In relation to the bark xylem very narrow, not more than 5 to 6 mm. wide and divided by primary and secondary rays into several smaller parts. *Rays* 6—8 (10) cells wide, secondary ones uni- to biseriate. *Ray-cell walls* very thin and unpitted. *Ray cells* in cross section commonly squares or radially somewhat elongate rectangles. *Tracheids* in zones 1—3—8—10 cells wide, in cross section angular, generally square or pentagonal, mostly with rounded corners. Horizontal walls of ray parenchyma cells verrucose, the elevations probably representing the sites of plasmodesmata. *Parenchyma cells* comparatively huge: from 40—50 to as much as 130—140 μ. Average diameter of tracheids 40 μ. Pith interwoven with entangled vascular bundles.

T. 4. Rays from 2—3 to 30—40 cells high and 1—3—8—10 cells wide. Uniseriate rays in cross section barrel-shaped, reminiscent in many respects of the ray structure in *Araucaria* and *Agathis*. Along the rays occasionally *longitudinal parenchyma cells* 60—80 μ high and 18—20 μ wide, with all their walls, including the horizontal ones, very thin and quite smooth. This structure of parenchyma likewise reminds one of *Agathis*. *Bordered pits* in tangential walls of tracheids very rare, agreeing in this respect most closely with the *Cordaites*. Border outline of solitary pits elliptical, the conjugate axis measuring 10—11 μ, the transverse one 13—14 μ. The aperture, which is included,

pointed at both ends, and 2,7 μ wide, is in the same direction as the long axis of the pit. This pit structure closely resembles that of *Agathis palmerstonii*. Pits occasionally circular, but apertures always pointed. Some pits reach across the whole width of the tracheids, the apertures are then elongate slits, and several such pits above one another suggest scalariform structure. Though otherwise smooth, the tracheid walls are covered with extremely delicate nodules.

Some tracheids with distinct annular or scalariform thickenings very similar to those in the tracheids of *Pteris*.

R. Bordered pits in the radial walls of the tracheids bi- or triseriate, crowded araucaroid-like. Apertures slitlike and included, greatly resembling the pitting in the tracheids of *Araucaria*, *Agathis* and even in the vessels of *Welwitschia*. Cross fields very seldom distinct, with the bordered pits in the tracheids showing faintly through the very thin walls of the ray cells. Occasionally as many as 8—10—12 pits in one cross field in 3—4 superposed rows, the pit borders abutting so as to give a crowded impression.

All the walls of the *longitudinal parenchyma* cells very thin and quite smooth also in radial sections. These cells are 5 to 6 times as long as wide.

In the ground tissue sporadically *mucilage ducts*, 80—100 μ in diam. and with thin-walled *epithelial cells*. Some tracheids show a scalariform thickening with gradual transition from this to bordered pits. No *spiral thickenings* in the tracheids of the stem, but some in those of the roots. These very interesting spiral thickenings start from a broad base, probably upwards as well as downwards, and while tapering are sometimes divided by nodularly thickened partition walls into 4—6 gradually narrowing cell-shaped parts, whereafter they grow thinner and thinner until, as extremely delicate spirals, they are attached to the walls of the tracheids. Structure and arrangement of the elements in this species greatly resemble *Welwitschia*, since in the tracheal walls of both the bordered pits are crowded, *araucaroid*. In some tracheid walls, especially in those of the roots, there are very delicate spirals and nodular thickenings to be observed in this species, which remind one of the spirals and nodular thickenings in some tracheids in *Ginkgo;* moreover, in their finer structure they are fully identical in the two. The fact that spirals of a similar structure have so far not been detected outside *Cycas* and *Ginkgo* seems to permit concluding the existence of some degree of relationship between the two. (Greguss' thickenings).

Lacking adequate material it was not possible for the writer to examine other genera of the *Cycadaceae*, but he holds that *Cycas revoluta* in itself furnishes sufficient argument in favour of the existence of a relationship with *Ginkgo*.

II. DESCRIPTION OF THE GINKGOALE S

GINKGO BILOBA L.

Maidenhair Tree

Pl. 2

This tree is native to China and Japan, and extensively planted in Europe.

C. 1. Resin ducts absent, on rare occasions present in the pith. *Growth ring delimitations* fairly clear, but by no means conspicuously distinct as stated by HOLLENDONNER (74), nor is there a marked contrast between the earlywood and the latewood as WIESNER points out. There being hardly any difference in wall thickness between early and late tracheids, the outer edges of the growth layers are only marked by some flattened tracheids in the latewood. Walls of tracheids and corners of lumina rounded, particularly in the latewood, where the latter are commonly elliptic or circular. Tracheids of irregular shape and indefinite arrangement : small ones next to or wedged in amongst larger ones deranging the regular course of their radial rows. Intercellular spaces of varying shape and size frequent between tracheids.

Owing to the shortness of their cells and their thin walls, *rays* differ but slightly from tracheids, are always uniseriate and short, passing commonly through but a few (3—4) growth layers, with some just a little longer than the width of a single ring. Their transverse and tangential walls are unpitted, quite smooth or with delicate elevations on them.

Wood parenchyma cells present, but not readily defined. In those of a microtome section cut from adult wood *druses* could be observed in large numbers.

T. 2. Tracheids occasionally with spiral thickenings. These depart from a broad base, probably upwards as well as downwards, and while tapering are sometimes divided by nodularly thickened partition walls into 4 to 6 gradually narrowing cell-shaped parts, whereafter they grow thinner and thinner until, as extremely delicate spirals, they are attached to the tracheid walls. This type of spiral thickening is not to be found in every growth ring. It conforms in every respect to the spiral structure observed in *Cycas revoluta*, and in addition to some other common features affords evidence in favour of a phylogenetical relationship between *Cycas* and *Ginkgo* (Greguss' thickenings).

In the tangential walls of the *tracheids*, predominantly in the latewood, pits fairly abundant, commonly in one, exceptionally in two, rows, or scattered throughout the tracheid, occasionally with two pits side by side. Their borders always regular or almost regular circles, except when in contact with each other, in which case the line of contact between them is a straight. Apertures from mostly circular to less frequently elliptic or eye-shaped, and always included.

Rays consisting wholly of parenchyma cells, uniseriate, 1—5 cells in height. Internal *ray cells* from orbicular to short-elliptic, marginal ones slightly elongate. Tangential walls unpitted but punctate.

R. 3, 4. Pits in radial walls of *tracheids* scattered, or arranged in twos, or in wider tracheids in threes. *Paired pits* possible. Border outline of solitary pits a regular circle ; line of contact between abutting ones a straight. Border outlines sometimes squares with rounded corners. *Araucaria* type! Apertures regular circles or slightly elliptic. Inner aperture occasionally slightly elongate, elliptic or lenticular (eye-shaped), included or just reaching the pit annulus.

Crassulae frequent, particularly in earlywood tracheids. *Partitioned tracheids* as mentioned by NAKAMURA, but challenged by HOLLENDONNER (74), clearly visible ; moreover, there are regular bordered pits in their transverse walls.

Horizontal and tangential walls of *ray cells* unpitted, occasionally punctate. Tangential walls straight or slightly arched, and commonly at right or almost right angles to the horizontal ones. Radial walls unpitted, the bordered pits apparent in them being those of the adjacent tracheids. The border outlines of the pits visible here less distinct than those of the pits elsewhere on the tracheid walls; they are mostly circular or elliptic, occasionally of irregular shape. Not infrequently, two or more adjacent pits abut upon one another with straights as lines of contact between them ; this renders the border outlines irregular in shape. Apertures variable in shape and size : circular, short- or long-elliptic, eye-shaped, rarely slitlike ; sometimes they are visible as small round openings with wide borders around them, sometimes as large openings making the border appear as a narrow ring barely discernible. Only the slitlike apertures reach the pit annulus. Inner apertures relatively often elongated, when they just reach, exceptionally cross, the border outlines.

Arising from the fusion of two pits, some bordered pits are larger than the others, their borders are elliptic, their apertures also elliptic, or eye-shaped, and likewise larger than usual. Different degrees of fusion may be noticed : in some instances, no trace of a fusion is visible even within the borders ; in some others, it appears as a slight strangulation or constriction of them ; yet in others, the two pit borders are apart and only the similarly aligned apertures coalesce end to end ; finally, there are cases in which the outer apertures are independent of one another with only the inner ones coalescing.

Number of pits per *cross field* commonly 2—4, but in ray crossings of marginal cells and in those of large-celled or one cell high rays, there are 6—8, exceptionally 9, araucaroid pits.

Frequently variagated patterns show in the margins of rays. These are due to indentations and projections at the points where longitudinal tracheids butt into the rays.

III. DESCRIPTIONS OF THE ARAUCARIACEAE BY SPECIES

AGATHIS ALBA (RUMPHIUS) WARB.

(Agathis loranthifolia Salisbury)

Amboyna pitch tree

Pl. 3

Tree native to Cambodia and the Malay Peninsula. Sample obtained from Hongkong.

C. 1, 2. Growth ring delimitation almost indiscernible owing to the identical size and wall thickness of the early- and latewood tracheids, which are radially 20—24 μ, tangentially 18—20 μ in diam. Along the outer limits of some growth rings *resin* noted in the tracheids. In cross section, the *tracheids* rounded tetra-, penta- or polygons, some of them tangentially flattened ellipses. In some rows they differ in size considerably from those adjacent to them, having a tangential diameter of 24—28 μ, and a radial one of 16—18 μ. *Rays* commonly with dark contents; their horizontal and tangential walls smooth. Number of tracheids per sq. mm. 3700.

T. 4. Rays comparatively low, only 1—5—7, generally 1—2, cells high. In the sections cut from our specimen of a limb only 7 to 8 years old, the one cell high rows were the most numerous. *Ray cells* in uniseriate rays 22—24, in multiseriate rays 18—20 μ, high and in both 16 μ wide. All their walls thin and quite smooth. Bordered pits in tangential walls of *tracheids* very rare, mostly solitary, sometimes in series; thus these walls are commonly smooth. *Parenchyma* absent. Per sq. mm. 87—88 rays and 150—160 ray cells.

R. 3. Tracheids in earlywood 22—24, in latewood 16—18 μ wide. Bordered pits in radial walls very rarely solitary, commonly uniseriate, while biseriate alternate pitting is quite exceptional. Apertures always circular or short-elliptic; in the latter case those of complementary pits form an X figure. *Rays* composed only of parenchyma cells. Average height of six ray cells 22—24 μ. In the earlywood, number of pits per *cross field* 4—6—8 in the marginal, and 3—4 in the internal cells. Pits commonly large: 4—8—9 μ in diam., circular or elliptic and with apertures which as a rule assume the same shape as the outline of the pit. Pits commonly isolated; when abutting, the border outlines become angular. Pit borders sometimes divided by the apertures into two crescent-shaped portions, at other times they surround the smaller apertures like rings.

In the latewood, there are only 1—2 pits in the cross field, except at the ray margins, where there are 3 vertically superposed pits. In cross fields of the latewood, surface of contact between pit borders always a straight.

AGATHIS AUSTRALIS SALISB.

(Dammara australis Lambert)

Kauri pine

Pl. 4

Tree native to New Zealand. For the sample the author is indebted to the Division of Forest Products, Melbourne, Australia.

C. 2. Growth rings fairly wide, some attaining 3—4 mm or more in width, with slightly undulating and rather inconspicuous delimitations, marked merely by the difference in the wall thickness of the latewood (5—6 μ) and the earlywood tracheids (3 μ). The tracheids differ in size: tangential diameter of late tracheids 30—45 μ, radial diameter 20—22 μ; the early tracheids measure 35—40 $\times$59—60 μ, occasionally more. All of them are hexagonal with rounded corners and arranged in radial rows. Those near the rays are sometimes somewhat larger, sometimes smaller than the others. *Rays* spaced 2—15 tracheids apart, their horizontal walls quite smooth or with only primary pitting; their radial and tangential walls likewise smooth. *Longitudinal parenchyma* cells were not to be observed on the cross section. Ray cells with dark contents. Between 700 and 800 tracheids per sq. mm.

T. 4. Tangential walls of *tracheids* smooth, but under very strong magnification they display oblique striation giving an uncertain impression of initial spiral thickenings. Tracheid pitting in latewood *araucaroid* and uniseriate; when occasionally biseriate, than the pits are regular hexagons and alternate. *Pit apertures* usually circular; when elongate, then they are commonly crossed. *Rays* 2—20, generally 8—10, cells high. *Ray cells* in cross section squares, upright or horizontal rectangles, the marginal cells more cone-shaped; they are 20—35 μ high and 18—22 μ wide, with the horizontal and radial walls quite smooth. Tangential walls apparently likewise unpitted. All walls only about 1 μ thick. *Wood parenchyma* absent. About 30 rays and 180—190 ray cells per sq. mm.

R. 1, 3. Radial walls of *tracheids* smooth but for the occasional occurence of the above-mentioned striation in the latewood, and for a greater likelihood of initial spiral thickenings appearing on this surface. Some tracheids up to 70—80 μ wide. *Bordered pits*, especially in terminal parts of tracheids, 2—3—4 seriate; they are hexagonal from crowding, or scattered, or in parallel rows. In the walls of some tracheids peculiarly *vestured pits*, not observed so far in any other coniferous wood. These hexagonal pits look as if beads were encircling each of them wreath-like. Pit apertures oblique ellipses, those of complementary pits occasionally forming X figures. *Trabeculae*, variable in thickness, markedly abundant in tracheids, sometimes in a series at the same height across the growth ring; they are not uncommon in rays. All walls of *ray cells* very thin and unpitted. In the *cross field* 3—6—10, exceptionally 12, simple pits, isolated, ovoid in shape. Ray cells resinous. Horizontal walls sometimes with primary pitting.

AGATHIS BECCARII WARB.

Pl. 5

Tree native to Borneo. Sample, a piece of board, obtained from Bogor, Indonesia.

C. 1. Wood of uniform structure, except at *growth ring* deliminations where the late tracheids have slightly smaller lumina. Tracheids in cross section rounded, consequently with intercellulars of variable size between them. *Wood parenchyma* cells lacking. *Rays* spaced 3—10—15 tracheids apart, with their horizontal and tangential walls smooth and devoid of pitting. Ray cells frequently with dark contents. Number of tracheids per sq. mm. 750.

T. 2. Rays 1—10 (12) cells high. Per sq. mm. 12—15 rays and 60—65 ray cells. Height of *ray cells* 21—27 (4) μ, width 8—16 μ; in cross section they are commonly barrel-shaped, the marginal ones more pyramidal; their walls are always smooth and thin. In the walls of *longitudinal tracheids* initial spiral thickenings visible under high magnification. Tangential walls of tracheids occasionally with bordered pits, occurring singly or in twos, or scattered, very seldom arranged tier upon tier; their small apertures are circular, or linear, vertically oriented, and always included. Early tracheids are devoid of pitting. No *wood parenchyma* in tangential section either.

R. 3, 4. In the radial walls of *tracheids* the bordered pits commonly biseriate, occasionally in one row or detached; those in wider tracheids 3—4 seriate, alternate and crowded. Pit diameter 10—13 μ. Apertures minute circles or sturdy rods in shape, invariably included. *Longitudinal parenchyma* was absent in the specimen examined. Longitudinal walls of tracheids delicately verrucose and with almost imperceptible initial spiral thickenings. Height of *ray cells* 21—27 (40) μ. In the cross field 3—6—8 pits, in the marginal cells commonly more; they are 5—8 μ in diam. and cupressoid, sometimes podocarpoid in shape. Their apertures are mostly vertical, not only in the latewood but in the earlywood as well. Not infrequently a thin-walled border is visible above and below some rays giving the impression of thin-walled parenchyma. In some cross fields some of the pits are remarkably large, often twice or three times as large as the others. Some cross-field pits are without apertures and occupying almost the entire area of the field. The walls of longitudinal tracheids are somewhat thicker at the places where they are in contact with the rays.

AGATHIS BORNEENSIS WARB.

Pl. 6

Tree native to Borneo. The sample, a piece of board, obtained from Bogor, Indonesia.

C. 1, 2. Wood of uniform structure. *Growth rings* distinct owing to difference in wall thickness of early- and latewood tracheids. As the late tracheids approach the outer limit of the growth ring, their walls gradually thicken to attain, at the limit, 2—3 times the thickness of the early tracheid walls. In cross section, the lumina of the *tracheids* squarish with rounded corners in the earlywood, and circular or elliptical in the latewood. *Wood parenchyma* very scarce and resinous. *Rays* spaced 6—10—15 tracheids apart, occasionally with dark contents; their horizontal and radial walls perfectly smooth and unpitted. Number of tracheids per sq. mm. 950—1000.

R. 3. Radial walls of *tracheids* occasionally with definite initial spiral thickenings. In course and structure spirals roughly the same as in *Cycas* and *Ginkgo*. Under high-power magnification, radial tracheid walls sometimes delicately verrucose, quite like in *Cycas*. The bordered pits in them are predominantly in one row, occasionally biseriate,

exceptionally triseriate and alternate. *Ray cells* 16—27 μ high. In the *cross field* 1—2, in the marginal cells 4—5, pits of cupressoid or araucaroid type, 5—8 μ in diam. The lines of contact between 3 or 4 abutting pits in the field are always straights. *Rays* fringed above and below by wavy, thin-walled, parenchymatous cells that are devoid of pitting. All walls of *ray cells* smooth and thin. *Wood parenchyma cells* very exceptional.

T. 4. Rays 3—10 cells high. Ray cells in cross section elongate barrel-shaped, marginal cells elongated coniform. Per sq. mm. 12—15 rays and 80—85 ray cells. Tangential walls of *tracheids* in part delicately verrucose, in part with closely spaced spiral bars, probably connected with wall structure. In tangential walls bordered pits uncommon, not more than 1—2 per section, so that they may be regarded as unpitted.

AGATHIS CELEBICA Warb.

Pl. 7

Tree native to Celebes. Sample, a piece of board, obtained from Bogor, Indonesia.

C. 1, 2. Wood of uniform structure. *Growth rings* almost imperceptible, evident only where the lumina of the late tracheids are somewhat narrower than those of the adjacent early tracheids. *Tracheids* and their lumina in cross section usually with rounded corners. Between tracheids intercellular spaces variable in size. *Rays* spaced 10—20 tracheids apart, uniseriate, occasionally partly biseriate; their walls smooth or covered with tiny warts, which are really the seats of former plasmodesmata and indicate that the rays have only primary walls. *Ray cells* frequently with dark verrucose resin contents. *Wood parenchyma* very exceptional, at most 1—2 cells per section. Per sq. mm. 970 tracheids.

R. 3. Tangential walls of *tracheids* smooth or covered with bordered pits in single rows, or biseriate and alternate; tracheids with triseriate pits occur but quite exceptionally. Height of *ray cells* 15—35 μ; all their walls thin and smooth. In the *cross field* 1—2—3 pits commonly in a single row; in the marginal cells 4—5 abutting flattened pits with straight lines of contact between them. Pit diameter 6—8 μ. Apertures short rods in shape, generally vertical, always included, though in rare instances reaching quite near to the annulus. When there are 2 pits in the cross field, they are always side by side; even 3 in juxtaposition are not uncommon. Sometimes 3—4 pits without apertures occupy the cross field, at other times a single large oval pit covers its entire area like in *Phyllocladus* and *Dacrydium*: a feature suggestive of a certain degree of relationship. Above and below, rays are bordered by thin-walled cells without any pitting or septation.

T. 4. Rays 6—10 cells high. Internal cells in cross section barrel-shaped, marginal cells conical. Tangential walls smooth. Tangential walls of *tracheids* usually smooth, exceptionally with bordered pits occurring singly and scattered, or but slightly touching in longitudinal rows, or crowded in 3 rows. The bordered pits in earlywood tracheids are somewhat larger than those in the tangential walls of latewood tracheids. Pit apertures minute circles or vertical slits, always included. Per sq. mm. 25—30 rays and 120—125 ray cells.

AGATHIS HYPOLEUCA C. Moore

Pl. 8

Data concerning the geographical distribution of the tree not available to the writer. Sample, a twig 1 inch in thickness, obtained from Australia.

C. 1, 2. Probably because of twists in the twig, outer edges of *growth rings* wavy and only marked by one or two strongly flattened rows of latewood tracheids. Radial width of early *tracheids* 22—30 μ, of late tracheids 8—10 μ; their tangential diam. ranges between 20—30 μ. Tracheids in cross section tetra-, penta-, or polygonal with rounded corners, arranged generally in radial rows, but sometimes interspersed with other tracheids of a lesser diameter and different in shape. *Wood parenchyma cells* present, rarely with contents. Horizontal and tangential walls of *rays* perfectly smooth, without any pitting. Per sq. mm. 2600 tracheids.

T. 4. Rays conspicuously low, at any rate in the sample from a young limb. Rays 1—4, predominantly 1, less frequently 2, cells high; height of 4—5 cells quite exceptional. For adult wood probably higher figures hold good. Single-row rays 28—30—32 μ in height; average height less; some internal cells only 16—18 μ. Rays commonly with dark contents. Tangential and horizontal walls smooth on this surface as well. Tangential walls of *tracheids* generally smooth, very rarely with rows of bordered pits in them. In the sample studied, it

may have been the twist in the twig that caused these pits to appear on the tangential side. Per sq. mm. 80—90 rays and 120—130 ray cells.

R. 3. Radial walls of *tracheids* usually smooth, occasionally with contiguous bordered pits in a single row or exceptionally biseriate. It may be that in older wood biseriation is the rule. Pit diameter 12—13 μ, never attaining the width of the tracheid. Pit apertures circular or long-elliptic. All the walls or *ray cells* thin and unpitted, 20—22 μ high, internal cells slightly lower. Number of pits in the cross field 3—4, in the internal cells occasionally 1 or 2 only. In the marginal cells 4 pits with straight lines of contact between them. Pit diameter 7—8 μ. Pit apertures obliquely oriented rods or slightly pointed ellipses, always included. *Rays* with dark contents. *Wood parenchyma cells* very rare ; their horizontal and tangential walls smooth, the radial walls showing the outlines of irregularly arranged simple pits, which are really those of the complementary half-bordered pits in the adjoining tracheids. Condensed resinous contents are encountered in these parenchyma cells. The presence of parenchyma in this species appears to be definitely established.

AGATHIS LANCEOLATA (PANCHER) WARB.

Pl. 9

Tree native to New Caledonia. Sample, a piece of board, obtained from the French Governorship of New Caledonia.

C. 2. Growth ring delimitation fairly distinct owing to the last one or two rows of late tracheids being strongly flattened. Tracheids in cross section squares or polygons with slightly rounded corners. *Tracheids* relatively large in diam., at any rate in the sample from wood of major age. Radial width of some tracheids 90—100 μ, their tangential diam. 45—50 μ. Occasionally well-discernible intercellulars between the tracheids. Radial width of the last flattened latewood tracheids 16—18 μ. *Rays* faintly resinous, their horizontal and tangential walls smooth. *Wood parenchyma cells* scarce. Thick-walled parenchyma cells (sclereids) exceptional. Number of tracheids per sq. mm. 550.

T. 4. Rays relatively very high : 2—10 cells, with occurrence of as many as 40—45 cells. Height of *ray cells* 24—28 μ, width 8—18 μ, resulting in markedly elongate ellipses in cross section. Their radial and horizontal walls devoid of pitting. In radial walls of *tracheids* bordered pits fairly large, 17—18 μ in diam., with 4—5 μ circular apertures. They are overwhelmingly uniseriate, now with 3—4, now with 10, but mostly with 15—20, pits in the row ; however, singly occurring pits are also encountered. Tangential walls of tracheids occasionally with definite oblique striation.

R. 1, 3. Radial width of early *tracheids* 60—65—70 μ, that of late tracheids slightly less. Radial walls smooth or covered with bordered pits in one row with interruptions, or in 2—3, quite exceptionally even 5, rows. In the latter case the pits extend across the whole width of the tracheids and are 5 or 6 sided from crowding. Their apertures are circular, or short-elliptic and slightly inclined. Diameter of pits 19—20 μ, that of pit apertures 5—6 μ.

Some of the *ray cells* 35—40 μ in height, slightly lower in higher rays but always more than 22 μ high. Horizontal and tangential walls of *ray parenchyma cells* perfectly smooth. *Cross field* commonly with 12—16, exceptionally 20—22, pits in the marginal cells, and occasionally with not more than 6—8 pits, usually in a single horizontal row, in the internal cells. If the number of cells comes up to 12—20, they are arranged in 2—3 horizontal rows. Pit apertures elliptic or slitlike and oriented obliquely. Pits sometimes contiguous, sometimes touching hardly at all and retaining their shape of a circle 9—10 μ in diam. In the latter case the aperture conforms to the outline of the border. No, or only 1—2, pits in the cross field at the places where *wood parenchyma cells* are in contact with rays. *Parenchyma cells* fairly frequent on radial sections ; their tangential and horizontal walls are smooth, but in their radial walls the contours of one or two superposed pits are traceable. The presence of parenchyma in the sample appears to be definitely established.

AGATHIS MACROPHYLLA MAST.

Pl. 10

Distribution : Solomon Islands, Polynesia. Sample obtained from New Guinea.

C. 1, 2. Growth rings inconspicuous, almost imperceptible. *Tracheids* in cross section commonly rounded, in earlywood nearer to penta- or hexagonal ; 900 per sq. mm.; their lumina 45—50 μ, exceptionally up to 60 μ in diam. Tangential width about the same, but in the latewood commonly somewhat less. Tracheids very rarely interspersed

with *wood parenchyma cells* containing a dark resinous substance. *Rays* spaced 2—15 tracheids apart, frequently resinous. *Thick-walled transverse tracheids* (parenchyma cells?) in some of the rays. These cells are 250—300 μ, exceptionally 700 μ, long.

T. 4. Rays 1—18 cells high, uniseriate. Height of *ray cells* 28—32 μ, width 20—22 μ; all their walls smooth and thin. In some rays *thick-walled parenchyma cells* (transverse tracheids?) in 3—4 tight tiers, sometimes with intermittent *thin-walled parenchyma cells*. The walls of thick-walled ray parenchyma are 4,5—6 μ, while those of the adjacent thin-walled parenchyma hardly attain 1—1,5 μ in thickness. About 25—30 rays and 80—90 ray cells per sq. mm. Horizontal ray-cell walls sometimes incline towards each other at acute angles. Tangential walls are commonly smooth, occasionally with well-discernible punctate pitting. In tangential walls of *tracheids* sporadically clearly defined traces of spiral checks, but very few bordered pits. The latter are occurring singly or aligned in rows of different length; pit diameter 11—12 μ. In rare instances small fields, regular hexagons in shape, are seen almost to fill up the tangential ray-cell walls; they measure 10—11 μ in diam.

R. 3. In the radial walls of *tracheids* bordered pits mostly in 1—2, occasionally in 3—4, exceptionally in 5, rows and 13—14 μ in diam. In the walls of latewood tracheids checks are frequently observable proceeding at about 45° to the longitudinal axis at regular intervals. *Rays* commonly consist of *thin-walled parenchyma cells only*, but at some places they are bordered by 1 or 2 *thick-walled parenchyma cells* or sclereids. When these occur in the body of the ray, they are in sharp contrast with the thin-walled ray cells; their horizontal walls are occasionally as much as 6—8 μ thick and clearly reveal the structure sometimes of simple, sometimes of bordered pits. On the walls, the arrangement in layers, which is parallel with the circumference, is clearly noticeable, together with pits 7—8 μ in diameter and having apertures that are 3—4 μ wide. The height of these thick-walled cells or transverse tracheids, respectively, is 22—28 μ, exceptionally attaining 40 μ. Where the thick walls of these transverse tracheids butt into the thin walls of ray cells, there are sometimes half-bordered, sometimes simple, pits quite definitely perceptible.

In the *cross field* 4—6 pits, 11 μ in diam., with slitlike or rod-shaped, or sometimes short-elliptic apertures that are included. Thin-walled *wood parenchyma* quite exceptional; if present, horizontal walls thin and perfectly smooth. Where wood and ray parenchyma meet, cross field devoid of pitting.

AGATHIS MICROSTACHYA Bailey et White

Pl. 11

Tree native to Queensland, Australia. Sample obtained from there.

C. 1, 2. Growth rings in places fairly well discernible since while, at the limits, the tangential diameter of the early *tracheids* is 70—80 or, exceptionally, 100 μ and the radial diameter 40—50 μ, the last-formed late tracheids measure but 15—18 μ radially. Wall thickness 4—5 μ in both early- and latewood tracheids. Tracheids in cross section circular, elliptic, sometimes 4—5—6 sided with more or less rounded corners. Rarely, they are interspersed with *wood parenchyma cells* with dark contents. *Rays* spaced 1—10—20 tracheids apart; resinous; all their walls smooth, unpitted. Per sq. mm. 500 tracheids.

T. 4. Walls of *tracheids* sometimes with spiral checking. The spirals are spaced at regular intervals or, in some instances, proceed singly, which means the checking is the same as in *Cycas*, *Amentotaxus* and *Torreya*. In tangential walls of tracheids bordered pits frequent, aligned in 1—2, very rarely 3, rows and 12—14 μ, very exceptionally 16 μ, in diam. Apertures circular or moderately long-elliptic; in the latter case those of complementary pits form X figures. *Rays* 1—25 cells high, some attaining a height of 40 cells, uniseriate, quite exceptionally with 1—2 paired cells in the body. Per sq. mm. 18—20 rays and 115—120 ray cells. Height of ray cells 20—30 μ. In cross section they are commonly long-elliptic, from narrow to wide.

R. 3. Radial width of *tracheids* 50—60—70 μ, exceptionally 80 μ. Bordered pits 1—2, frequently 4, exceptionally 5 seriate, 12—14 μ high, with apertures round, or short-elliptic and slightly inclined. *Wood parenchyma* fairly common and with dark contents. *Rays* consist only of parenchyma cells; all their walls smooth and thin. In the cross field 4—6, seldom 12, pits detached or contiguous; in the latter case the lines of contact between them are straights. Pit diameter 8—9 μ. Apertures rod- or eye-shaped, slightly canted from the vertical. Ray cells resinous. Minute pits in the radial walls of the scarce *wood parenchyma*. Where wood and ray

parenchyma meet, cross field devoid of pitting. Horizontal walls of ray parenchyma thin (0,5 μ) and smooth.

AGATHIS MOOREI (LINDLEY) MAST.

Pl. 12

Tree native to New Caledonia. For the sample, a twig 10—15 years old, author is indebted to the French Governorship of New Caledonia.

C. 1, 2. Growth rings not very evident, delimitation marked only by a few rows of slightly flattened latewood tracheids. *Tracheids* in cross section squarish with but softly rounded corners. Radial width of early tracheids, 28—32 μ; that of late tracheids, 11—12 μ; their width, 18—30 μ; slight deviations from these figures possible in both directions. Walls of late tracheids with 2,5 μ relatively thick; those of early tracheids sometimes 0,5 μ or thinner. Sporadic occurrence of resinous *wood parenchyma cells;* their walls thinner than those of tracheids, about 1—1,5 μ. Horizontal and tangential walls of *rays* smooth; the cells usually with dark contents. Structure on transverse surface slightly different from that of the other *Agathis* spp. Per sq. mm. 2100 tracheids.

T. 4. The one cell high rays are in cross section long-ovoid, the higher rays have rather barrel-shaped internal cells. Height of one cell high rays, 22—30 μ; that of internal cells, 22—23 μ. Ray cells mostly with dark contents. Tangential and radial walls smooth. Tangential walls of *tracheids* seldom with one or two pits, and only very rarely with a short row of them. They may have come to fall to the tangential section from the radial side. In the walls of some tracheids, spiral checks 20—30 μ apart giving the impression of initial spiral thickenings. True spiral thickenings not observable. Per sq. mm. 52—55 rays and 125—130 ray cells.

R. 3. Bordered pits in radial walls of tracheids commonly uniseriate, for short stretches, and mostly at the ends of early tracheids, exceptionally biseriate. Pit diameter 12—14 μ; pit apertures circular, 4,5—5 μ in diam.; those of alternate pits the same size. Average height of *ray cells* 22—30 μ marginal cells slightly higher. Walls of ray cells smooth and thin, with no pitting at all. In the cross field 1—6 pits (or none), 11—12 μ in diam., detached or abutting with straight lines of contact between them. Apertures elliptic or almost subcircular, slightly inclined, included, rarely reaching the annulus. Their long axis commonly coincides with that of the border. In stretches within the rays tracheid walls slightly thicker. *Wood parenchyma cells* could be observed by the writer on a single occasion in this section.

AGATHIS OVATA WARB.

Pl. 13

Tree native to New Caledonia. For the sample, a piece of branch about 8—10 years old, author is indebted to the French Governorship of New Caledonia.

C. 1, 2. Growth rings indistinct, almost imperceptible, marked but sporadically by a difference in the width of the lumina of adjoining latewood and earlywood tracheids. Occasionally a few *false rings* exhibited. Radial width of late tracheids, 12—13 μ; that of early ones, 16—18 μ; their tangential diam. 25—28 (30) μ. Tracheids 4—5—6 sided with rounded corners. *Rays* 18—30 μ in width; their horizontal and tangential walls smooth. Proliferation of parenchyma occasional. Occurrence of single *parenchyma cells* rare; when present, they are usually with light-coloured contents. Per sq. mm. 1800 tracheids.

T. 4. Rays generally low, the taller ones only 6—8 cells in height. Cells of single-row rays 22—28 μ high and 16—17 μ wide. Average height of ray cells 20—22 μ; all their walls perfectly smooth. In tangential walls of tracheids bordered pits solitary or in groups of 4 or 5. Continuous pit rows rare. Pit diameter 8,5—10 μ. Apertures slightly inclined. Per sq. mm. 70—75 rays and 180—190 ray cells.

R. 3. Bordered pits 10—12 μ in diam., commonly uniseriate, in earlywood sometimes biseriate, quite exceptionally triseriate. Apertures circular or long-elliptic, included, coming rarely near to the annulus. Height of *ray cells* 24—28 μ. Cross field with 8—10—12 pits in the marginal cells, with 4—6 (usually twice 3) pits in the internal ones; pit diameter 6—7 μ; pits crowded, with straight lines of contact between them. Apertures mostly circular or inclined elliptic and included. No *wood parenchyma cells* have been observed in this section despite the definite presence of a few of them on the transverse surface.

AGATHIS PALMERSTONII F. v. Muell.

Northern Kauri Pine

Pl. 14

Tree native to Queensland, Australia. Sample obtained from Melbourne.

C. 2. Growth rings usually 25—30 tracheids in width, fairly distinct owing to contrast between wide-lumened early and narrow-lumened late *tracheids*. Tangential diam. of tracheids 50—80 μ, attaining even 100 μ; radial width of early tracheids 50—60—80 μ; inner radial diam. of late tracheids only 18—20 μ. About 500 tracheids per sq. mm. Of all the *Araucariaceae* dealt with in this work, this species proved to possess the largest tracheids, but it should be noted that the sample examined came from wood of major age. A great number of tracheids with yellowish, the thin-walled *wood parenchyma cells* with dark resinous contents. Contrast between adjoining thin- and thicker-walled tracheids fairly pronounced. Occasionally 2—3 parenchyma cells side by side, arranged radially as a rule. *Tracheids* in cross section generally rounded, in places squarish. Not infrequently, long stretches of tracheids along the rays are filled with resinous contents, but detached tracheids, further away from the rays, are sometimes likewise resinous. Horizontal and radial walls of rays smooth and thin.

T. 4. On the tangential walls of *tracheids* bordered pits in 1—2, sometimes 3, rows and 11—12 μ in diam. Per sq. mm. 20—25 rays and about 100—120 ray cells. *Rays* invariably uniseriate, 1—24 cells high. *Ray cells* 12—18—25 or even 28—32 μ high and 12—18 (30) μ wide; rays are thus not uniform but slightly variable in structure. Ray cells resinous. Tangential walls of *tracheids* with occasional oblique checking giving the impression of initial spiral thickenings, all the more so as the spirals recur at certain intervals. Pits arranged in series in the tangential walls of thin-walled *wood parenchyma* amongst tracheids, but scattered in other places. Horizontal walls of wood parenchyma thin and smooth. The presence of wood parenchyma is quite definite.

R. 1, 3. In radial walls of *tracheids* bordered pits 2—3, sometimes 4—5 seriate. Walls smooth, except for the occasional occurrence of the same regularly intermittent spiral checking, which has been discussed on the tangential surface. Thin-walled resinous *parenchyma cells* amongst tracheids not uncommon. There are pits in their walls, scattered or in series; the half-bordered pits in the tracheids back of them are often well discernible. Pit diameter 6—8—10 μ. *Rays* homogeneous, their horizontal and tangential walls smooth and thin. *Cross field* with 4—10 (12) pits, 7—9 μ in diam. Apertures linear and nearly vertical, occasionally horizontal. Indentures absent. *Trabeculae* and resin plates, respectively, fairly frequent, often across 25—30 tracheids at the same height.

AGATHIS ROBUSTA Mast.

Agathis Brownii L. H. Bailey

Queensland Kauri

Pl. 15

Tree native to Queensland and Fraser Island, Australia. Sample from the Botanic Gardens of Melbourne, Australia.

C. 1, 2. Growth rings not evident, marked only by a slight difference in diameter of the late and early tracheids. *Tracheids*, predominantly those near the outer edges of the rings, filled with dark contents. Tracheids in cross section rounded and variable in size. Wider- and narrower-lumened tracheids very often concomitant. Radial diameter of larger tracheids 24—28 (30) μ, tangential diameter 25 μ, or even 30 μ. Wall thickness of late tracheids 2,3 μ, that of early tracheids only 1,8—2 μ. Thin-walled *parenchyma cells* not infrequent and usually with dark contents. They are mostly solitary, sometimes in groups of 2—3, even 5—6, cells. Walls of parenchyma cells devoid of pitting. Horizontal and tangential walls of *rays* likewise unpitted. *Ray cells* commonly with dark contents. Per sq. mm. 2300 tracheids.

T. 4. Rays comparatively low. Ray cells in cross section roughly barrel-shaped. Per sq. mm. 110—120 rays and 180—190 ray cells. In single-row rays some cells 30—40 μ in height and 16—17 μ in width; smaller ones only 24—25 μ high and 16—17 μ wide. Average height of cells in storied rays 18—20 μ. Tangential and horizontal walls without pitting. In tangential walls of *tracheids* bordered pits few in number, mostly solitary, very rarely in a tight row. Apertures horizontal and included; in this respect *A. robusta* differs from the other *Agathis* spp. Occasionally *wood parenchyma cells* with perfectly smooth and very thin horizontal walls among the tracheids. Radial walls, too, devoid of pitting. Neither is there any pitting observable in the place where parenchyma cells and

ray cells meet, not even at high magnification. Wood parenchyma cells definitely present.

R. 3. Rays homogeneous. Marginal *ray cells* 22—24 μ in height. *Cross field* with 6—8 pits in the marginal cells, and 4—6 in the internal cells ; their apertures horizontal and included. Pitting alternate and crowded.

In radial walls of *tracheids* bordered pits in a tight row with horizontal lines of contact between them, or in 2—3 rows and alternate. Detached pits very rare. Occasionally *trabeculae* in a series at the same height across 10—15 tracheids.

ARACUARIA ANGUSTIFOLIA O. KUNTZE

(Araucaria brasiliana A. RICHARD)

Candelabra Tree

Pl. 16

Tree native to Brasil. For the sample author is indebted to Professor H. ERDTMAN of Stockholm.

C. 1, 2. Growth rings variable in width, yet narrow on the whole. Practically no difference in wall thickness between early and late tracheids. Last rows of late tracheids flattened but slightly, or not at all. Growth ring delimitation accordingly indistinct. Walls of *tracheids* thick. Their lumina, in contrast with those in *Abies* and, generally, the other conifers, are rounded giving thereby rise to intercellulars of varying size. *Trabeculae* discernible across several tracheids. *Rays* in cross section inconspicuous, with horizontal walls thin and unpitted. *Wood parenchyma* wanting.

T. 4. Walls of *tracheids* smooth and without spiral thickenings. Tangential walls, predominantly in latewood (according to HOLLENDONNER (74) exclusively in latewood), provided with bordered pits. They are few in number, mostly detached, or in twos or threes above one another. Their border outlines are rather indistinct. The apertures are circular or short-elliptic, but most frequently long-elliptic or lenticular, reaching near to, or quite to, the annulus. The inner apertures are sometimes slightly extended, and those of complementary pits form X figures. In the sample examined the *rays* were 1 cell wide (HOLLENDONNER states they are, rarely, biseriate). They are commonly 1—8, in rare instances 10, cells high. WIESNER and HOLLENDONNER claim the rare occurrence of 14—16 cells in height. They consist solely of parenchyma cells which are thin and not lignified ; their tangential walls are unpitted.

R. 3. In radial walls of *tracheids* bordered pits in 1—3 rows, interrupted in places. Seldom, they are detached and then regular circles in shape. The line of contact between contiguous pits is straight, with only their free portions arching. Even when in a single row, the majority of the pits is set tight. With several rows of them, the pits are crowded, form a mosaiclike surface, and those in the middle are hexagonal. When, occasionally, the pits are not involved in the crowding with their entire circumference, triangular spaces arise between them. Pit apertures predominantly elliptic, in the widest early tracheids sometimes circular ; they are included, obliquely oriented, and those of complementary pits form X figures.

Tracheid ends are variable in shape from blunt to having more or less sharp points. Sometimes the convex end of one tracheid fits the hollow end of another. Tapering tracheids are often in touch with each other for stretches of various length and then communicate through a few or more pits on the tangential side. Through butting into rays, the end of some tracheids become slightly bent and more or less a beak in shape. This beaklike projection, too, is sometimes provided with bordered pits establishing communication with other tracheids or the horizontal walls of ray cells ; it is quite likely that in such instances the horizontal ray-cell walls develop large simple pits similar to those in the radial walls. This, perhaps, is the phase that gives rise to transverse tracheids.

Owing to their thinness, the walls of *ray parenchyma* are devoid of pitting ; the pits that show through them are those of the tracheids at the back. The pits in the *cross field* are fairly large and varying in number. When few, or occurring singly, they are circular; when more and in touch with one another, they usually occupy the entire area of the field. Their number ranges from 1 to 9 ; when 9, they are disposed in threes side by side and superposed. Their apertures are, as a rule, lenticular or slitlike, in the earlywood sometimes elliptic. They are included, sometimes reaching the annulus, never extended. Usually they are oriented obliquely to the long axis of the tracheid, occasionally they approach its direction or coincide with it. Apertures of horizontal or nearly horizontal orientation are only encountered in pits that have arisen from the fusion of two pits radially next to each other.

ARAUCARIA ARAUCANA (MOLINA) K. KOCH

(Araucaria imbricata PAVON)

Chile Pine or Monkey Puzzle

Pl. 17

Distribution : Chile and Argentine. For the sample from a branch about 25 years old, author is indebted to Professor H. Erdtman of Stockholm.

C. 1, 2. Growth rings fairly distinct due to last rows of latewood tracheids being strongly flattened. Radial diameter of early *tracheids* 22—24 μ, of late tracheids 11—12 μ ; tangential diam. about 22—24 μ or less ; wall thickness in latewood 3—3,5 μ, in earlywood 2,8—3 μ. *Rays* spaced 2—20 tracheids apart. Horizontal and tangential walls of *ray cells* perfectly smooth and thin. No *wood parenchyma*, or at least none on the examined section. Per sq. mm. 2000 tracheids.

T. 4. Rays comparatively closely spaced, 1—8 cells high. Height of *ray cells* in single-row rays 24—30—35 μ, width 14—15 μ, sometimes 18—20 μ, resulting in the shape of a strongly bulging barrel. Height of internal ray cells 18—20 μ, width as much as 20—22 μ. All ray-cell walls thin and smooth. Where tracheids are in contact with ray cells and the half-bordered pits of the former widen towards the cell lumen, these parts of the tracheid walls appear more or less trapezoid. Tangential walls of ray cells devoid of any markings or pitting. In very rare instances, *the walls of the marginal ray cells are markedly thicker than those in the internal cells proving that it is possible for rays to have parenchyma cells with walls of two thicknesses.* Walls of *tracheids* smooth, only in the tangential walls a few pits, solitary or in pairs. Per sq. mm. 72—73 rays and 170—180 ray cells.

R. 3. In the radial walls of *tracheids* bordered pits commonly uniseriate, only in rare instances and for quite short stretches biseriate. While the lack of biseriation in the sample may have been due to its coming from a branch, it is quite possible that uniseriation is a genuine feature in this species. Rows of bordered pits present in comparatively few tracheids. Horizontal diam. of bordered pits 14—18 μ, their hight 8,5—9 μ. Distance between scattered pits variable. Pit apertures circular, 2 μ in diam. Horizontal and tangential walls of *rays* smooth and thin. In the cross field 4—5—6 pits, generally elliptic and inclined, with apertures included and conforming to the outlines of the borders. Sometimes the pits are contiguous with straight lines of contact between them. Cross-field pits 4,5—5 μ, apertures 4—4,5 μ in diam., borders barely visible.

ARAUCARIA BALANSAE BRONGN. et GKIS.

Pl. 18

Tree native to New Caledonia. Sample, a piece of branch 14—15 years old, obtained from there.

C. 1, 2. Growth rings always imperceptible. Outermost *tracheids* in latewood with somewhat thicker walls and slightly narrower lumina than earlywood tracheids following them. Radial diam. of early tracheids 25—30 μ, of late tracheids 20—22 μ. Walls comparatively thick, 6,5—7 μ, those of earlywood tracheids somewhat thinner. Tangential diam. of tracheids about 30 μ. Tracheids in cross section mostly rounded, circular or multiangular. Horizontal walls of *ray cells* unpitted. *Wood parenchyma* absent. Per sq. mm. 1700 tracheids.

T. 4. Rays relatively low and scarce, at any rate in the sample from wood of minor age. Height of *ray cells* in single-row rays 30—40 μ, in cells of higher rays generally less ; width 16—18 μ, their walls all thin and smooth. Walls of *tracheids* with obliquely proceeding checks recurring at certain intervals and suggestive of initial spiral thickenings. They are probably due to other than mechanical causes.

Tangential walls very seldom provided with bordered pits, if present, they are in groups varying in size, or aligned in rows and alternate. Pit diameter 5,5—6 μ ; pit apertures short-elliptic, the minor axis measuring 2,5 μ and always included. Per sq. mm. 27 rays and 52—53 ray cells.

R. 3. In the *tracheids* bordered pits commonly uniseriate, very rarely biseriate, and then only for short stretches. This may not hold good for adult wood. Occasionally there are very thin-walled cells wedged between the tracheids ; probably they are *parenchyma cells* of traumatic origin and usually with dark contents. On one occasion a circular pit was seen in the wall of a traumatic cell. These thin-walled parenchyma cells and the adjacent tracheids contrast not only in wall thickness but in colour as well. In adult wood there may be more of these parenchyma cells.

All walls of *ray cells* thin and unpitted. Average ray-cell height 22—24 μ. In the cross field 6—8 pits, in marginal cells sometimes more, commonly biseriate and superposed. Borders usually in contact, occasionally apart. Pit diameter 6,5—7 μ. Apertures almost vertical, linear, 1,5 μ wide, included.

ARAUCARIA BECCARII WARB.

Pl 19

The sample, a piece of board, obtained from Bogor, Indonesia.

C. 1, 2. Wood of perfectly uniform structure, with the *growth rings* almost imperceptible. *Tracheids*, respectively lumina, in cross section, rounded; walls externally pentagonal due to compression. Where 2—3 cell walls meet, intercellulars of variable size arise between them, but they fail to form if the mutual compression is very severe. *Rays* 10—20—30 tracheids apart. All *ray-cell* walls smooth and thin. *Wood parenchyma* absent. About 1000 tracheids per sq. mm.

T. 4. Per sq. mm. 15—20 rays and 70—80 ray cells. *Rays* 1—6 (18) cells in height. *Ray cells* in cross section usually barrel-shaped, 21—27 (40) μ high, 13—27 μ wide. Tangential walls of *tracheids* commonly smooth, but vestigial spiral thickenings with furcating spirals visible at high magnification. No bordered pits, exceptionally one or two per section. *Wood parenchyma* was not observable in the material.

R. 3. Radial walls of *tracheids* commonly smooth, but sometimes strong magnification reveals concentric circles of spirally wound delicate fibres. These fibres being in places very delicately punctate are apparently true spirals and not cracks; they are reminiscent of the similar spirals in *Ginkgo* and *Cycas*. In the walls of tracheids bordered pits uniseriate, or in two rows and alternate, i. e., typically araucaroid. Pit apertures are minute and circular or short-linear. In the walls of some tracheids only the borders of the pits are visible; they have no apertures. This is a phenomenon particularly frequent on the ends of tracheids and indicative of the primitive stage of tracheid fusion (Cf. *Gnetales*). *Rays* 2—10—12 cells high. Per cross field 2—10 (12) pits, crowded. Pit apertures linear with rounded ends, commonly vertical or slightly oblique, included. Sometimes 3—6—8 pits are disposed so as to come to fall within the area of an imaginary ellipse. Cross-field pits occasionally without apertures. All walls of *ray cells* very thin and smooth, devoid of pitting, then and when with vestiges of plasmodesmata. Where the walls of *longitudinal tracheids* are in contact with rays they are slightly thicker to become thin again beyond the stretches of mutual contact. *Parenchyma* was not observable on the radial section either.

ARAUCARIA BIDWILLII HOOK.

Bunya Bunya

Pl. 20

Distribution: Australia and the Australian archipelago. Sample, a piece of twig about a finger's breadth and 10—12 years old, obtained by courtesy of the French Governorship of New Caledonia.

C. 1, 2. Growth rings quite indistinct, their delimitation marked only by the thicker walls of the latewood tracheids. *Tracheids* in cross section mostly rounded, occasionally tetra- or polygonal. They are frequently arranged in long radial rows traceable sometimes through 2—3 growth rings. Radial diam. of early tracheids 35—40 μ, of late tracheids 12—14 μ; tangential width usually 24—26 μ. Rare occurrence of tracheids with contents; these are sometimes quite thin-walled, similar in some respects to *wood parenchyma cells*. Horizontal walls of *ray cells* smooth, without pitting. About 1100 tracheids per sq. mm.

T. 4. Rays comparatively low: in the sample from the young twig not more than 1—6—8 cells high. *Ray cells* barrel-shaped or short-elliptic, height of those in single-row rays 22—24 (26) μ; average height in taller rays slightly less; ray cells lower than 18—20 μ very rare; cell diameter 15—16 μ. Tangential walls of *tracheids* generally smooth, very seldom with 1—2 solitary bordered pits. In some tracheids a number of bars were observed by the writer 15—20 μ apart and pursuing a spiral course; although they looked very much like spiral thickenings, they probably were but patterns on the cell wall, which have arisen during the mechanical treatment of the section, very likely whilst it was being carbonized. True spiral thickenings were not to be seen, nor were any *wood parenchyma cells* observable on the tangential section. *Ray cells* with dark resinous contents. Per sq. mm. 18—20 rays and 30—40 ray cells.

R. 3. Some *tracheid* walls with very faint spirals in pairs at certain intervals. *Wood parenchyma* seldom encountered; if, then with minute simple pits definitely discernible in tangential walls. Horizontal and tangential walls of *rays* smooth. Average height of *ray cells* 22—24 μ. In the *cross field* 1—4 (5) pits mostly in horizontal rows; in the marginal cells 4—6, arranged irregularly. Pits commonly detached, very rarely touching. Apertures variable in size and assuming the contour of the border. The pits in the walls of tracheids sometimes arranged in longitudinal rows.

ARAUCARIA COLUMNARIS (FORSTER) HOOK.

Pl. 21

Tree native to New Caledonia. Sample obtained from Numea (New Caledonia) by courtesy of the French Governorship of New Caledonia.

C. 1, 2. Growth rings very indistinct, marked solely by the late terminal tracheids being slightly smaller. Radial width of early *tracheids* 35—50 μ, that of last late tracheids sometimes only 20—22 μ; tangential diam. up to 45 and even 50 μ. Wall thickness 5—6 μ. Tracheids in cross section commonly rounded, tetra- or pentagonal, occasionally irregular in shape. *Rays* 3—15—20 tracheids apart; their horizontal walls smooth, but the radial walls occasionally with minute pitlike hollows. *Wood parenchyma cells* absent. Per sq. mm. 600 tracheids.

T. 4. Tracheids 35—45 μ wide. In very rare instances, some of them with spiral checks at distances of 10—12 μ, giving the impression of spiral thickenings. These checks do not appear to have been caused by mechanical action. In the walls of tracheids bordered pits irregularly arranged, sometimes in two rows and alternate, very exceptionally in three. Pit diameter 12—13 μ. Apertures circular or markedly short-elliptic. *Rays* 1—12, typically 7—8, cells high. *Ray cells* in cross section barrel-shaped; some of them up to 40 μ in height. Marginal ray cells of about the same height, while internal ones only 30—35 μ. Ray-cell width 18 μ. Tangential and radial walls perfectly smooth. Per sq. mm. 15 rays and 90—92 ray cells.

R. 3. Walls of *tracheids* smooth, occasionally with uniseriate, more frequently with biseriate alternate pitting. Pit diameter 16—17 μ, that of two conterminous pits 26—27 μ. Apertures circular, 4 μ in diam. Pits in 3 rows quite rare, and occurring only in earlywood tracheids. It merits mentioning that where they pass through rays the walls of tracheids slightly thicken, attaining 4—4,5 μ in diam. *Parenchyma* was not observable on the radial section. *Rays* consist only of *parenchyma cells;* all their walls very thin and unpitted. In the *cross field* 4—12 pits with clearly defined borders and slitlike or short-elliptic, slightly inclined or vertical apertures that do not extend to anywhere near the pit annulus. By mutual contact and compression, the pits in the cross field are rendered polygonal, in the marginal cells in three, in the internal cells in two rows. Pit diameter 9—11 μ.

ARAUCARIA CUNNINGHAMII SWEET

Moreton Baj Pine

Pl. 22

Tree native to New South Wales and Queensland, Australia. Sample, a piece of a branch 8—10 years old, obtained from the Botanic Gardens of Adelaide.

C. 1, 2. Growth rings indistinct, their delimitation marked only by the contrast between the last late *tracheids* of 12—13, and the succeeding early tracheids of 24—26 μ diam.; tangential width of tracheids 20—24 μ. In cross section, they are rounded, tetra- or polygonal, but in the latewood long-elliptic in tangential direction. Sometimes rows of tracheids with walls approaching 4 μ in thickness pass along the rays through several growth rings. Occasionally, rows of narrower-lumened between rows of wider-lumened tracheids. Typical wall thickness of tracheids 3—3,5 μ. *Rays* 2—20—25 tracheids apart; their horizontal and tangential walls smooth and thin, with no pitting at all. *Wood parenchyma* probably absent. Per sq. mm. 2300 tracheids.

T. 4. Walls of *tracheids* normally smooth, but sometimes with transverse or oblique checks, which appear less to be cracks and more to represent primitive initial spiral thickenings. Although these initial spirals follow each other at regular distances, as if proceeding in pairs, they cannot be regarded as true spiral thickenings. In the tangential walls bordered pits few in number, scattered, or in files of 3 to 5, but very seldom touching. Pit diameter 8—9 (10) μ. Apertures oblique slits, 1,5—2 μ in width, always included. *Rays* 1—6—8, fairly frequently 4—6, cells high. Height of *ray cells* in single-row rays up to 40 μ; in the taller rays, on an average, 20—22 μ; in the marginal cells attaining as much as 25—28 μ. They are with red contents, and all their walls are thin and smooth. Where the tracheids meet ray parenchyma, there the canals of their pits do not widen towards the lumen. Per sq. mm. 25—27 rays and 60—65 ray cells.

R. 3. Tracheid walls occasionally with a transverse series of trabeculae at the same height. Bordered pits in tracheids uniseriate; biseriation rather rare, at least in our sample from a young branch. Diameter of pits 13—14 μ horizontally, and 9—11 μ vertically. *Wood parenchyma* quite exceptional and then with reddish-brown contents; walls very thin, hardly discernible, about 0,75 μ thick. Very exceptionally the above-mentioned cellular contents appear as if being not in the parenchyma but in

the tracheid, yet undoubtedly it is the same substance which is generally encountered in ray parenchyma cells. *Ray parenchyma* cells 22—26 μ, occasionally 28 μ, high with all their walls thin and smooth. In the *cross field* 4—6—8, even 12, pits which are 5 or 6 sided, 7—9 μ in diam., and have obliquely, almost vertically oriented linear, slitlike, or short-elliptic apertures, 2 μ wide and included.

ARAUCARIA CUNNINGHAMII var. GLAUCA ANTOINE

Pl. 23

Tree native to New South Wales, Australia. Sample, a branch about 20 years old, obtained from Kirstenbosch, South Africa.

C. 1, 2. Growth rings almost imperceptible, marked only by a few flattened cell rows of the latewood. Radial width of early *tracheids* 25—30—35 μ, that of the last late tracheids 12—13 μ; tangential diameter 20—22 μ. Tracheids in cross section tetra- or polygonal with rounded corners. Walls of tracheids in rows along the *rays* 4 μ, those of other tracheids only 3—3,5 μ thick. The tracheids, which are squares in cross section, sometimes form rows passing through several growth rings interspersed with but a few tracheids irregular in shape or having lumina differing in diameter. They are conspicuous for their regular radial alinement. *Wood parenchyma* absent. Horizontal and radial walls of rays thin and smooth. Per sq. mm. 1900 tracheids.

T. 4. Tracheids 22—25 μ in width. Walls of tracheids with fairly numerous pits, uniseriate, not infrequently biseriate and alternate. Transverse *resin plates* not uncommon; they are at right angles to the long axis, join the radial walls in T form like true trabeculae, but are nonetheless merely resin plates. *Rays* 1—10, typically 2—8, cells high. *Ray cells* in single-row rays 35 μ, or even 40 μ, high; in taller rays, on an average, only 22—24 μ. Horizontal walls smooth. Walls sometimes significantly thicker in marginal than in internal cells; this proves the possibility of a co-occurrence of two types of wall in the *parenchyma cells* of some rays. Thick-walled (2—2,5 μ) parenchyma cells are occasionally also encountered in the body of a ray. Some rays partly biseriate in the middle; a feature common to no other species of the *Araucaria*.

There are well discernible triangular intercellular spaces between tracheids and ray cells. Where the tracheids meet rays, that part of the half-bordered pit which is next to the ray, is but slightly protuberant, like a watch glass, while the other part, the one towards the lumen of the tracheid bulges considerably, like a barrel. This phenomenon was observed to hold throughout the examined section (see drawing). Ray cells with dark resinous contents. Per sq. mm. 60—65 rays and 170—190 ray cells.

R. 3. Average width of *tracheids* 24—36 μ; their walls 3—3,5 μ thick, increasing to 5—5,5 μ where they pass through rays. They are provided with fairly numerous bordered pits, usually uniseriate, not infrequently biseriate, but only for short stretches. These pits measure 11—12 μ horizontally, 8,5—9 μ vertically. Pit apertures circular, 3,5—4 μ in diam. Average height of ray cells 20—24 μ; all their walls thin and smooth. In the *cross field* 3—5, exceptionally 6—7, pits, crowded and with straight lines of contact between them. Diameter of pits 7—7,5 μ; pit apertures 2,5—3 μ wide.

ARAUCARIA EXCELSA R. BROWN

Norfolk Island Pine

Pl. 24

Tree native to Norfolk Island. Sample obtained from Kirstenbosch, South Africa.

C. 1, 2. Growth rings very indistinct, delimitation marked only by 1—2 rows of narrower-lumened latewood tracheids. Radial width of early *tracheids* 25—28 μ, that of latest-formed flattened tracheids 7—8 μ; tangential diam. 26—28 μ. Amongst tracheids of average size there are sometimes considerably larger ones; tangential width of the latter 32—34 μ, that of the former 20—22 μ; radial width of both larger and smaller tracheids 24—25 μ. Tracheids in cross section elliptic, rounded, or multangular. *Wood parenchyma* absent. *Rays* 8—20—30 tracheids apart. Per sq. mm. 3500 tracheids.

T. 4. Rays sparse and relatively low: 1—8 cells high. Ray cells in single-row rays 30—32 μ, in the taller rays the marginal ones 25—28 μ, the internal ones 20—22 μ, in height. Ray-cell width 17—18 μ. At high magnification, in the walls of some tracheids the same oblique checking observable as in *Araucaria rulei* and *A. muelleri*. Tangential walls of tracheids with but one or two sporadic bordered pits, 7—7,5 μ in diam., with their apertures short-elliptic, or nearly vertically oriented slits. In some tracheids there appear transverse

resin plates. Such tracheids then look as if they were rows of parenchyma cells. However, since resin is also deposited on the tracheid walls, the double wall evidences that they actually *are* resin plates and not partitions between parenchyma cells. Besides, there is a discrepancy in colour between the resin and the tracheid walls. Per sq. mm. 80—90 rays and 260—270 ray cells.

R. 3. Relatively few *tracheids* with bordered pits; where pits do occur, they are commonly uniseriate, occasionally biseriate and alternate. They are 11 μ in width and 9—10 μ in height. *Rays* consist solely of parenchyma cells, with all their walls thin and smooth. In the *cross field* 1—2, possibly 4, in the marginal cells exceptionally 5—6, pits with straight lines of junction and triangular or quadrangular spaces developed between them. Pit diameter 8—9 μ. Apertures oblique, nearly vertical, short-elliptic or slitlike, and included. *Resin plate* fairly frequent, mostly assuming the form of a procumbent T extending across the tracheids; presumably, they have a mechanical function to fulfill inside the tracheids. At first sight, they look as if they were horizontal walls of parenchyma cells, but closer inspection reveals them to be merely trabeculae-like resin plates.

ARAUCARIA HUMBOLDTIENSIS Buchh.

Pl. 25

Tree native to New Guinea. Sample by courtesy of the French Governorship of New Caledonia.

C. 1, 2. Growth rings indistinct, marked only by a slight contrast between the last narrower-lumened late *tracheids* with 15 μ, and the succeeding wider-lumened early tracheids with 24—26 μ radial diameter. Tangential width 20—22 μ. Tracheids in cross section tetra- or polygonal with rounded corners. Tangential and horizontal walls of *rays* smooth and thin, with no pitting at all. Per sq. mm. 1400 tracheids.

T. 4. Walls of *tracheids* with occasional oblique checks appearing as if they were initial spiral thickenings. But they are not true spirals; nor can they be regarded as mechanically induced cracks in the wood, since they sometimes proceed in pairs and at regular intervals, and even exhibit anastomosis. Tangential walls with but one or two solitary bordered pits, 6 μ in diam. Apertures always included oblique ellipses, with the major axis 3 μ long. In rare instances, the pits are contiguous and the lines of juncture between them straights. *Rays* 1—7—8, typically 4—6, cells high. Height of *ray cells* in single-row rays 28—30 μ; in the taller ones, on an average, 20—22 μ; ray-cell width 17—18 μ. Where tracheids are in contact with ray parenchyma, that part of the half-bordered pit which is next to the ray is but slightly protuberant, like a watch glass, while the other part, the one towards the lumen of the tracheid, bulges considerably, like a barrel. Although observed in several tracheids in contact with rays, it was not possible to decide whether this structure constituted a specific feature: the less so as in other tracheids that part of the half-bordered pit widens which is next to the ray, whereby the portion of the tracheid falling between two pits takes the shape of a trapezoid. Per sq. mm. 55 rays and 100—110 ray cells.

R. 3. In radial walls of *tracheids* bordered pits generally uniseriate, very exceptionally biseriate and alternate, but only for short stretches. In wood older than that of our sample from a small branch, biseriation is probably more frequent. The bordered pits are contiguous, 11 μ wide and 7 μ high. Apertures circular, or short procumbent ellipses. *Parenchyma cells* were wanting on the section examined. *Rays* composed of parenchyma cells only. Cross field 6,5—7 μ in diam., with straight lines of junction between them. Apertures 4—4,5 μ long, linear, obliquely oriented, 2 μ in width. Two pits are sometimes enveloped in a larger pit, elliptical in shape, as is also observed fairly frequently in *Ginkgo*. Cross field with never more than 7—8 pits in the marginal cells.

ARAUCARIA KLINKII Lauterb.

Pl. 26

Tree native to New Guinea. Sample obtained from there.

C. 1, 2. Growth rings almost imperceptible. *Tracheids* in cross section rounded, elliptic, circular, tetra- or polygonal. Lumina rather varied in width: the wider ones measure 40—45 μ radially and 50—60 μ tangentially. Narrow-lumened late tracheids encountered but occasionally. Some rows of tracheids can be traced through several growth rings, while other tracheids are inserted between these rows. Lumina commonly rounded, but some tracheids are thickened collenchyma-like. About 700 tracheids per sq. mm. *Rays* 3—20 tracheids apart,

with all their walls unpitted. *Ray cells* frequently with dark contents. *Wood parenchyma* absent.

T. 4. Rays generally 1—16 (20) cells high and uniseriate. Per sq. mm. 12—13 rays and about 65—70 ray cells. *Ray cells* comparatively high : in single-row rays up to 35 μ, others commonly 22—25 μ high and 14—18 μ wide. Walls all smooth. Tangential walls of *tracheids* with only one or two occasional bordered pits 7,5—8 μ, exceptionally 9 μ, in diam. Tangential walls sometimes with checks extending in pairs at regular intervals and simulating primitive spiral thickenings. *Wood parenchyma* absent.

R. 3. Walls of *tracheids* commonly smooth, occasionally with bordered pits in two rows and alternate. Triseriate pitting of very rare occurrence. Pits 15—18 μ high ; apertures circular or short-elliptic ; *tori* well discernible. *Rays* consist only of parenchyma cells. All ray-cell walls thin and unpitted. Tangential walls at right angles or slightly oblique to the horizontal walls. In the *cross field* 2—3, in the marginal cells 5—6, pits, 10—12 μ in diam. Pits seldom contiguous ; if so, then predominantly in the latewood where the lines of juncture between them are straights. It is remarkable that the pit apertures, although they are nearly vertically linear or slitlike, do not extend to the annulus.

ARAUCARIA MONTANA Brongn. et Gris.

Pl. 27

Tree native to New Caledonia. Sample, a piece of board, obtained from place of geographical origin.

C. 1, 2. Growth rings markedly indistinct, made perceptible only by the last 2—3 rows of late tracheids having slightly narrower lumina and slightly thicker walls. Tracheids in cross section squares, or polygons, or irregular in shape, but always with corners rounded. Radial width of early tracheids 45—60 μ, that of the adjoining late tracheids about 30 μ. Wall thickness of late tracheids 6—7 μ, sometimes 8—9 μ, of early tracheids 5,5 μ ; tangential width about 40 μ. Lumina almost always rounded. Horizontal and tangential walls of *rays* smooth. *Wood parenchyma* wanting. Per sq. mm. 650 tracheids.

T. 4. Tracheid walls occasionally with an oblique striation. In the walls of some tracheids bordered pits in 1 row, or for very short stretches in 2 rows. Long rows of bordered pits not to be observed at all ; double rows of pits also very rare. *Rays* 1—20—22 cells in height. *Ray cells* barrel-shaped in cross section ; those in single-row rays 40—42 μ high and 13—14 μ wide. Marginal cells of taller rays 32—33 μ, internal cells seldom attaining 22 μ in height. Horizontal and tangential ray-cell walls smooth. In very rare instances, the walls of marginal ray cells attain up to 2 μ, while those of the internal cells hardly 0,5 μ, in thickness. From this it appears to follow that in this species there may be two kinds of parenchyma in the ray cells ; a feature not observed by the author in any other *Araucaria*. Tracheids sometimes with thin *resin plates*. Where two thin-walled ray cells, placed above each other, are in contact with the tracheids, a triangular intercellular arises between them, and the ray cells are octagonal in cross section. Per sq. mm. 25 rays and 90—95 ray cells.

R. 3. No spiral thickenings in the walls of tracheids ; the bordered pits in them very rarely solitary, commonly uniseriate or arranged in 2 or 3 rows. Triseriation is quite frequent offering a modest means of separating this species from *Araucaria columnaris*. Pit apertures from short- to long-elliptic, inner orifices circular. Pit diameter 11—12 μ ; the elliptic pit aperture 4,5—5 μ in height, 2,2 μ in width, and vertical. Between contiguous pits the lines of junction straights, the spaces between 3 pits triangular. Combined width of 3 pits 40 μ. The triseriate and the very exceptional quadriseriate pits are mostly limited to the ends of tracheids in the vicinity of the radial walls. *Rays* consist solely of parenchyma cells with thin and smooth walls. In the *cross field* 2—4—6—8, in the marginal cells 12—14, pits, predominantly but not invariably contiguous, and 10—11 μ in diam. Pit apertures slightly inclined or nearly vertical and elliptic, 3 μ in width and 4 μ in height, never extending to the border. Pits in marginal cells commonly flattened by mutual contact and compression, yet sometimes detached pits occur with circular border outlines and apertures assuming their shape. Owing to thickness of ray walls indentures wanting. *Wood parenchyma* absent.

ARAUCARIA MUELLERI Brongn. et Gris.

Pl. 20

Tree native to New Caledonia. Sample, a piece of a 14—15 year old branch, by courtesy of the French Governorship in Numea, New Caledonia.

C. 1, 2. Growth rings almost imperceptible, marked only by a discrepancy in size between the last row of late and the succeeding early tracheids. Radial diam. of early tracheids 30—35 μ, of late tracheids 22—25 μ; tangential width generally 28—30 μ. Wall thickness 3,5 μ. Tracheids in cross section tetra- or polygonal with rounded corners, or elliptic. Some tracheid rows pass radially through several growth rings and are sometimes interspersed with smaller-lumened tracheids. *Rays* 2—20 tracheids apart, and with smooth horizontal walls. *Ray cells* with dark-brown contents. Some tracheids likewise with dark resinous material. Per sq. mm. 2100 tracheids.

T. 4. In the tangential walls of *tracheids* bordered pits very rare, occurring singly or in a small group of 2 or 3. Diameter of pits 11—12 μ, of circular apertures 2 μ, of short-elliptic inner orifices 5—6 μ. Apertures of complementary pits sometimes form X figures. *Trabeculae* and thin *resin plates* not uncommon in tracheids.

In some tracheids there is an oblique checking suggestive of spiral thickenings; the spirals follow at intervals and occasionally in pairs, reminding one in this respect of the *Torreya*. But they are no true spirals, neither are they cracks; at most, one may regard them as primitive spiral thickenings. *Rays* 1—8—10 cells high. *Ray cells* in single-row rays up to 30—32 μ, in the taller rays the marginal cells 25—26 μ, the internal ones, on an average, 22 μ high; ray-cell width 17—18 μ. Horizontal and tangential walls smooth. Rays sometimes filled with tiny globules of a resinlike substance. Where tracheids communicate with ray parenchyma through half-bordered pits, a peculiar pit structure is sometimes seen: two chambers are observed in the tracheid wall: one on the side of the parenchyma cell, the other towards the lumen of the tracheid; the latter is generally circular in section. (See drawing.) The author has failed to detect vestured pits of this character in any of the other species of *Araucaria*. It would offer an intriguing investigation whether this feature were detectable in individuals of a different geographical origin. Per sq. mm. 50—52 rays and 110—120 ray cells.

R. 3. Tracheid walls with bordered pits commonly uniseriate, occasionally biseriate, particularly on the end of the tracheids. Uniseriate pits 10—12 μ in width, 10—11 μ in height; combined width of two pits 18—19 μ. Pit apertures circular, 3,5 μ in diam., sometimes short-elliptic. *Walls of rays* thin, smooth, and devoid of pitting. Cross field with 4—6—8 pits, 6,5—7 μ in diam. Apertures inclined, short-elliptic, included. Pits sometimes not in contact, but where there are 5—6 (8) of them in the cross field, the lines of junction between them are horizontal straights.

ARAUCARIA RULEI F. VON MUELL.

Pl. 29

Tree native to New Caledonia. Sample, a piece of a branch about 15 years old, obtained from place of origin.

C. 1, 2. Growth rings almost indiscernible, marked solely by a slight difference in the thickness of early and late tracheid walls, the former being 3 μ, the latter 4 μ. *Tracheids* in cross section circular, elliptic, tetra- or polygonal with rounded corners. Radial width of earlywood tracheids 25—30 μ, that of last latewood tracheids 13—14 μ; tangential diam. 30—35—40 μ, or slightly less or more. *Rays* pursue a somewhat meandering course, their horizontal and tangential walls are smooth. *Wood parenchyma* wanting. About 3000 tracheids per sq. mm.

T. 4. Like in *Araucaria muelleri* and a few other *Araucaria* species, in some *tracheids* of this wood there are oblique checks frequently recurring at regular intervals (14—18 μ) and in pairs. Although reminiscent of them, they are by no means true spiral thickenings, nor are they cracks in the walls. They may have arisen during carbonization, yet they differ greatly from the fissures and chinks common to appear during that process. Their occurrence in pairs, on the other hand, gives rise to the view that they may be but primitive spiral thickenings; a possibility not without important phylogenetic bearings. Where tracheids communicate with ray parenchyma, the same peculiar structure of a compound chamber is seen as in *Araucaria muelleri:* one facing the ray parenchyma, the other the lumen of the tracheid. However, in this species the latter is not bulging but open. (See drawing.) In the tangential walls of tracheids there are no bordered pits, but spiral checks are definitely discernible. Per sq. mm. 32—33 rays and 60—62 ray cells.

R. 3. In the radial walls of *tracheids* bordered pits uni- or biseriate, 12—13 μ in width and 9 μ in height. Pit apertures circular, 3 μ in diam. *Rays* contain only parenchyma cells; all their walls

smooth and thin, devoid of pitting. In the *cross field* 2—4, in the marginal cells 8—9, pits. Are there only a few pits in the field, they are commonly isolated or just touching. Are they numerous and contiguous, the lines of contact between them are straights. Pit diameter 5—5,5 μ; pit apertures oblique ellipses and included; sometimes they are oriented horizontally.

IV. DESCRIPTIONS OF THE PODOCARPACEAE BY SPECIES

ACMOPYLE PANCHERI PILGER
Pl. 30

Tree native to New Caledonia. Sample by courtesy of the French Governorship of Noumea.

C. 1, 2. Growth rings vary in width from 6—8 to 40—50 tracheids; their delimitation fairly distinct owing chiefly to contrast between last-formed thick-walled late tracheid rows and succeeding thin-walled and wider-lumened early tracheids. Radial diameter of early *tracheids* 26—30 μ, of late tracheids 9 μ; tangential diameter 22—24μ. Wall thickness of late tracheids 6 μ, of early tracheids only 1,5—2 μ. Tracheids in cross section squares or radially upright rectangles in the earlywood; radially flat rectangles in the latewood; occasionally, polygons in the body of the growth ring. Predominantly in the latewood and sometimes quite near to its outer edge, *parenchyma cells* with usually reddish contents. *Rays* radial and from 2—3 to 15—20 tracheids apart; their horizontal walls smooth except for vestigial pitting. Sometimes rows of tracheids differing in size from the others pass through several growth rings. Number of tracheids per sq. mm. 2300.

T. 4. Apart from pitting, walls of *tracheids* smooth. Bordered pits relatively large; 12—13 μ in diam. reaching from one radial tracheid wall to the other. Apertures long-elliptic, measuring 6 $\times$ 4 μ, sometimes more in length; they are included, but in the earlywood, where they are mostly vertical in position, they are occasionally extended. Bordered pits in the earlywood 10—11 μ in diam. and in fairly tight rows. *Rays* 1—5, typically 1—2, cells high. *Ray cells* 20—28 μ high, 10—12 μ wide; their tangential walls with primary, occasionally with juniperoid pitting; their radial walls smooth. *Parenchyma* fairly abundant and with reddish contents; horizontal walls smooth; radial wall with fairly numerous, tangential wall with considerably fewer, simple pits. Per sq. mm. 100—110 rays and 170—175 ray cells.

R. 3. Radial walls of *tracheids* with vestigial spiral thickenings. In the walls of early tracheids the bordered pits commonly scattered, occasionally slightly crowded, with horizontal lines of junction between some of them. Pit diameter in late tracheids 9 μ and 6 (14) μ. (Bordered pits in tracheid ends sometimes crowded). Horizontal walls of ray cells smooth except for here and there a simple pit. Tangential walls perfectly smooth, slightly arched. Indentures wanting. *Cross field* commonly occupied by a single round or elliptic pit measuring 14—15 $\times$ 9—10 μ. Where ray and longitudinal parenchyma meet, the cross field sometimes pitted. *Longitudinal parenchyma* fairly frequent; horizontal and tangential walls smooth; radial walls with simple pits 6—7 μ in diam. and aligned at varying intervals. Ray cell pitting very similar to that in *Podocarpus*.

This is the sole known species of the genus *Acmopyle*.

AUSTROTAXUS SPICATA COMPT.
Pl. 31

Tree native to New Caledonia. Sample by courtesy of the French Governorship in Noumea.

C. 1, 2. Growth rings vary in width from 20—30 to as many as 60—70 tracheids. *Growth ring delimitation* indistinct because of approximately identical wall thickness of late- and earlywood tracheids (3,5—4 μ). *Tracheids* in cross section circular, or polygonal with rounded corners, and variable in size; those in rows along the rays occasionally wider than the others. Largest tracheids 35—40 μ in width with radial diameters of 25—30 μ. Lumina of some late tracheids quite narrow, not more than 5—6 μ. Among the tracheids sporadically thin-walled *parenchyma cells*, sometimes with resinous contents; their horizontal walls merely suggestive of a pitting. *Ray cells* radially 3—15—20 tracheids apart; their horizontal walls unpitted; nor is any pitting visible in the radial and tangential walls. About 3300 tracheids per sq. mm.

T. 4. Walls of *tracheids* smooth except for here and there an oblique checking. *Rays* 1—6, mostly 1—3, cells high. *Ray cells* in cross section 18—22 (30—34) μ high and 7—12 μ wide, those in single-

row rays occasionally somewhat wider (12—15 μ). Tangential walls smooth or with reticular primary pitting. Horizontal and radial walls thick, the latter without pitting. *Parenchyma cells* fairly numerous among the tracheids, attaining as much as 30—35 μ in width. Horizontal and radial walls smooth; tangential walls occasionally with a few round simple pits. In tangential walls of tracheids bordered pits, scattered, 10—12 μ, or sometimes only 6—7 μ, in diam., with included apertures measuring 3 $\times$ 6 μ. Per sq. mm. 70—80 rays and 100—110 ray cells.

R. 3. Tracheid walls commonly smooth and free from warts. The walls of some late tracheids with oblique bands similar to spiral thickenings, their orientation coinciding with that of the oblique pit apertures. They are suggestive of some primitive bandlike thickenings. Occasionally, these bands are horizontal at distances of 25—30 μ one from the other. Bordered pits scattered, but sometimes, particularly at the ends of the tracheids, more numerous, or even close enough to be almost touching; they are round or slightly flattened elliptic, 10—12 μ in diam. The aperture facing the lumen is slitlike, the other circular. The slit occasionally reaches to the border or is extended. The aperture measures 6—8 $\times$ 2 μ. Paired pits in some tracheids. *Ray-cell* walls thin and devoid of pitting, except for some wartlike primary pits in the tangential walls. Tangential walls somewhat inclined to horizontal ones. Indentures absent. In the *cross field* 1—2, in the marginal cells 2—4, pits of 8—10 μ diam. Apertures measure 6—8 $\times$ 3 μ. All walls of *longitudinal parenchyma* thin and perfectly smooth, even the horizontal walls without any thickenings. The borders and apertures of the small pits in the tracheid walls back of them show through. Cells 15—18 μ wide. Wood parenchyma occasionally with, mostly dark, resinous contents.

In view of the absence of definite spirals in the tracheids, the thinness and perfect smoothness of all ray-cell walls, the smoothness of the parenchyma, and because of the more podocarp affinity of the cross-field pits, this genus should rather be classed with *Podocarpaceae* than the *Taxaceae* as has been suggested by several earlier authors.

DACRYDIUM FRANKLINII HOOK F.

Huon Pine

Pl. 37

Tree native to Tasmania. For the sample we are indebted to the Division of Forest Products, South Melbourne.

C. 1, 2. Growth rings fairly uniform in width. *Growth ring delimitation* markedly wavy. *Tracheid* thin in earlywood, gradually thickening in latewood. Average diameter of late tracheids 10—25 μ, that of early tracheids 25—36 μ. Latewood up to 8—10 cells wide. Walls of tracheids externally squarish or angular, in the latewood with, while in the earlywood without, rounded corners, this discrepancy making the edges of the growth rings fairly discernible. *Wood parenchyma cells* rare, some rings entirely devoid of them. *Rays* from 2—3 to 8—10 tracheids apart; not always uniform in width since in places they bulge tangentially. No pits visible in horizontal walls, not even at high-power magnification, at most a very fine punctation. No pitting discernible in the horizontal walls of the rare *wood parenchyma* cells either. About 2000 tracheids per sq. mm.

T. 4. Rays 1—20, typically 4—6, cells high. HOLLENDONNER, with reference to BURGERSTEIN, claims the occurrence of 30 cells in height. In the rigorously identified wood carefully examined by the present writer no rays of this extraordinary height could be spotted. *Ray cells* 17—20 (22—26) μ high and 7—10 (10—12) μ wide. Walls of *tracheids* smooth except for bordered pits rare in the earlywood and fairly numerous in the latewood. These are small (7—8 μ) in relation to the width of the tracheids. Their eye-shaped apertures for the greater part included, reaching almost to the border, occasionally extended. Those of complementary pits mostly form X figures. Exceptionally two pits across a tracheid. In the tangential walls of some tracheids, particularly in the latewood, oblique bands. In the radial walls a fair number of pits visible in cross section. *Wood parenchyma* very sparse and confined to the latewood; cell walls exceedingly thin with even high magnification failing to reveal pits. Horizontal walls likewise perfectly smooth and very thin. Width of parenchyma 22—24 μ. Tangential walls of ray cells also quite smooth apart from occasional pin-holes. Per sq. mm. 50—55 rays and 190—200 ray cells.

R. 3. Walls of marginal cells in *rays* externally smooth or wavy. Horizontal and tangential *ray-cell* walls perfectly smooth, very thin, slightly verrucose. The large oval pits of the tracheids at the back of them show clearly through the thin radial walls of the rays. Pits in the cross field solitary, seldom in twos, now occupying almost its entire area, now considerably smaller than the pits elsewhere. In shape, they are reminiscent of the large

pits in *Sciadopitys*, being procumbent-elliptic or rhomboid in the earlywood, and more upright-elliptic or ovoid in the latewood. In the earlywood they measure 13 × 25 μ, in the latewood 6 × 12 μ. In the radial walls of the *tracheids* the bordered pits disposed irregularly with two occasionally touching; they are not circles but slightly flattened ellipses, 16—18 μ in diam. Apertures commonly circular or ovate, yet sometimes extended; those of complementary pits sometimes form X figures. Strong magnification sometimes reveals radially arranged delicate dots, designs, in the pit borders. *Wood parenchyma* exceedingly rare on the radial surface.

The *Dacrydium* spp. are generally distinguished by the large circular or elliptic pits in the cross field, which are typical "circospores" (KRÄUSEL). True, the cross-field pitting in the *Phyllocladus* is similar to that in the *Dacrydia*, yet while the former possess no parenchyma, the latter do.

Xylotomically, the *Dacrydium* spp. are similar to one another with but slight differences between them in the number and size of the cross-field pits and the height of ray cells. But *D. colensoi* HOOK. needs to be treated separately since, in view of other authors too (PHILLIPS), it is without parenchyma cells. If it nonetheless possesses such cells, then the differentiation is to be made on the ground of ray height, admitting that this feature is not necessarily a constant and fully reliable one. Relatively low are the rays in *D. araucarioides* BRONGN. et GRIS. (Pl. 32) and *D. taxodioides* BRONGN et GRIS. (Pl. 38), and higher (1—22 cells) in *D. cupressinum* Sol. (Pl. 35), *D. pierrei* Hickel (Pl. 37a), and *D. elatum* (Roxb.) Wall. (Pl. 36). In addition, slight interspecific differences manifest themselves in the number of rays and ray cells per sq. mm.

MICROCACHRYS TETRAGONA HOOK. F.

Pl. 39

Tree native to Tasmania. Sample obtained from Melbourne.

C. 1, 2. Growth rings relatively narrow some 6—8, others 25—30, tracheids in width. Delimitation fairly distinct owing to discrepancies in size and wall thickness of the last-formed late and the succeeding early tracheids. *Tracheids* in cross section commonly squares or polygons, but frequently irregular in shape. Radial diameter of early tracheids 30—40 μ, that of late tracheids 10—15 μ; tangential width 16—20 μ. In some rows tracheids different in size and irregular in shape succeed one another in alternation. *Rays* from 1 or 2 tracheids to relatively wide apart. *Ray cells* sometimes with dark contents; their horizontal walls apparently smooth, exceptionally delicately verrucose. Only a few *parenchyma cells* visible, predominantly next to the rays, some of them with dark resinous contents. About 3700 tracheids per sq. mm.

T. 4. Rays 1—6, quite frequently 1—2, exceptionally 12, cells high. *Ray cells* in cross section circular or elliptic, the marginal cells slightly elongate. Height of ray cells commonly 14—18 μ, width 6—8 μ. Horizontal walls thin and apparently unpitted. Walls of *tracheids* smooth except for an occasional close row of pits in the tangential walls in the earlywood. Pit diameter 6—8 μ, relatively small, about half of, or slightly more than, the width of the tracheid. Apertures round, or moderately long-elliptic, exceptionally extended. Those of complementary pits frequently form X figures. Per sq. mm. 100—110 rays and about 300—310 ray cells.

R. 3. Tracheid walls smooth, except for the relatively abundant pits in the radial walls, where exceptionally two pits take up the width of the tracheid with vertical lines of junction between them. Pits not regular circles or ellipses, but variable in shape from ovate to distorted. They are relatively small, 12—14 μ in diameter, always less than the width of a tracheid. *Rays* consist solely of parenchyma cells with thin walls devoid of pitting. *Cross field* in the earlywood with 2—3 large pits, in the latewood commonly occupied by a single large, circular or upright-elliptic pit, which is really in the wall of the tracheid and shows through the thin ray-cell wall. Only a few *parenchyma cells* could be observed in the section examined which, however, may not have been real parenchyma cells. In favour of their genuineness seems to speak the fact that in the radial walls of some tracheids oval pits were seen that fully corresponded to the simple pits in parenchyma cells. These doubtful parenchyma cells were relatively short and had perfectly smooth horizontal walls. Some tracheids with *trabeculae*, occasionally extending in a series at the same height across 2—3 growth increments. Only a single *Microcachrys* species is known. Its ray structure refers it to the *Podocarpaceae*.

PHYLLOCLADUS TRICHOMANOIDES D. DON

Tanekaha

Pl. 43

Tree native to New Zealand. Sample obtained from the Museum in Melbourne.

C. 1,2. Growth rings commonly 40—60 tracheids in width and fairly distinct due to differences in the width of the lumina, but not in wall thickness, of the last-formed late tracheids and the succeeding early tracheids. Transition from early- to latewood gradual. The early *tracheids* measure 36—40 × 26—28 μ, the late ones 10—12 × 26—28 μ. Growth ring delimitations wavy, in places quite markedly so. *Rays* 4—5 or 20—25 tracheids apart; their horizontal walls apparently unpitted, exceptionally delicately verrucose. *Parenchyma cells* wanting. Number of tracheids per sq. mm. 1700.

T. 4. Rays 1—10, typically 8—10, in very rare instances 22, cells high and invariably uniseriate. *Tracheid* walls smooth, apart from a sparse pitting in the tangential walls. Pit apertures with pointed tapering ends and extended, those of complementary pits forming X figures. The walls of some tracheids with a sparse oblique striation, predominantly in the latewood. *Ray cells* in cross section from moderately- to long-elliptic, marginal cells nearer to triangular, their walls thin, with no pitting observable in them; height commonly 10—16 (20—22) μ, width 7—10 (12) μ.

R. 3. In radial walls of longitudinal *tracheids* pits fairly frequent and relatively small (10—12—18 μ in diam.), never reaching across the cell; they are seldom circular, mostly sligthly flattened procumbent ellipses. Apertures as a rule markedly extended, those of complementary pits forming X figures. Walls of *ray cells* very thin and perfectly smooth. The tangential walls sometimes join the horizontal ones at a sharp acute angle and without giving rise to indentures. *Cross field* commonly occupied by a single ovoid pit, seldom by two pits; the pitting is in this respect similar to that in *Sciadopitys* and *Microcachrys*. Pits measure 20 × 16 μ. However, here the pits in the tracheids have very large borders, while the apertures are oblique ellipses with bluntly pointed ends. The cross-field pits in the latewood are narrow (16 × 20 μ), with apertures nearly oblique. Marginal cells of rays with walls externally wavy and perfectly smooth. Some tracheids with *trabeculae*.

From the other genera in the *Podocarpaceae* the *Phyllocladus* are distinguished in the first line by their lack of longitudinal parenchyma. They are further characterized by having commonly but a single large pit in the cross field and by the slitlike apertures of the bordered pits in the tracheid walls being nearly vertically oriented. There is an intergeneric difference in ray-cell height. Xylotomically, there is relatively little difference between *Ph. alpinus* Hook. f. (Pl. 40), *Ph. rhomboidalis* Rich. (Pl. 42), *Ph. glaucus* Carr. (Pl. 41), and *Ph. trichomanoides* D. Don (Pl. 43).

PODOCARPUS MACROPHYLLUS D. DON

Kusamaki

Pl. 59

Tree native to Japan. Sample, a piece of thick board, obtained from place of geographical origin.

C. 1,2. Growth rings distinct, delimitation brought into prominence by markedly flat and considerably thick-walled latewood tracheids. *Tracheids* in cross section sometimes irregular polygons; those in rows along rays occasionally larger than the others. *Rays* uniseriate, 1—2 or 6—8 tracheids apart. Smooth horizontal walls of scattered *parenchyma cells* well discernible on the transverse surface. There are considerably more of these cells in the latewood than in the earlywood. Longitudinal parenchyma cells with mostly reddish or russet resinous contents appearing on this surface as tiny black dots. About 2500 tracheids per sq. mm.

T. 4. Rays uniseriate, very seldom with 1—2 paired cells in the body, 1—5—12—18, commonly 8—10, exceptionally 24, cells high. Per sq. mm. 160—170 rays and 580—590 ray cells. *Ray cells* in cross section ovoid or elliptic, occasionally circular; 15—18 (22) μ high and 9—10 (12) μ wide; marginal cells roughly as high as internal ones. External surface of marginal-cell wall sometimes wavy. Walls relatively thin. Tangential walls of *wood parenchyma cells* perfectly smooth except for a delicate verrucose surface visible at high magnification. It is characteristic of these warts that from 20 to 25 of them are aligned in a slightly oblique row across a cell. Tangential walls of *tracheids* smooth, entirely devoid of pits. Parenchyma amongst tracheids fairly abundant and conspicuously thin-walled. Horizontal parenchyma walls smooth or with tiny beadlike warts. Some parenchyma cells with resinous, usually russet, contents.

R. 3. In radial walls of *tracheids* bordered pits from dense to sparse or missing for long stretches.

Apertures eye-shaped, obliquely oriented, and for the greatest part extended; in the latewood nearly vertical in position. *Rays* consist solely of parenchyma cells. Marginal cells slightly higher than the others, but their walls thinner. Horizontal walls of internal ray cells perfectly smooth. *Cross field* commonly with 1, in the marginal cells with 2, occasionally 3, pits of 6—10 μ diam. Radial walls probably unpitted, as only the slitlike apertures of the obliquely oriented pits in the adjoining tracheids show through the extremely thin walls. At the points of contact of longitudinal and ray parenchyma commonly one pit in the cross field, exceptionally two pits. Horizontal walls of *wood parenchyma* smooth with then and when a slight protuberation on them; tangential walls likewise smooth, straight or slightly bulging, thin nearly to being imperceptible.

Although thin and smooth ray-cell walls, the presence of parenchyma cells with thin and smooth horizontal walls, and pits of a podocarpoid type even in the cross fields, are generally characteristics of the *Podocarpaceae*, it is quite understandable that in a family of this size some of these features undergo modifications in the individual genera or species, or are missing altogether. E. g., *Podocarpus spicatus* R. Br. (Pl. 67) is devoid of parenchyma. Further differentiation is based upon the cross-field pitting, by which groups can be formed. In the first group belong the species with dacrydioid, i. e. more circular, pits. Such are *Podocarpus wallichianus* C. Presl. (Pl. 70), *P. elatus* R. Br. (Pl.47), and *P. blumei* Endl. (Pl. 44).* In the second group are included the spp. with 2—3 or 6 podocarpoid pits, or pits reminiscent of the taxodioid type. But even within this group distinctions can be made according to the prevailing arrangement of the pits or dependent on the differences in ray-cell height. Separation on the evidence of these features is fairly reassuring in *P. coriaceus* A. Rich. (Pl. 45), *P. dacrydioides* A. Rich. (Pl. 46), *P. falcatus* R. Br. (Pl. 49), *P. ferrugineus* D. Don (Pl. 50), *P. ferruginoides* Compt. (Pl. 51), *P. gracilior* Pilger (Pl. 53), *P. henckelii* Stapf (Pl. 54), *P. javanicus* Bl. (Pl. 55), *P. latifolius* R. Br. (Pl. 56), *P. longifoliatus* Pilger (Pl. 57), *P. lycopodioides* (Pl. 58), *P. manii* Hook (Pl. 61), *P. minor* Parl. (Pl. 63), *P. neriifolius* D. Don (Pl. 65), *P. totara* D. Don. (Pl. 68), *P. usambarensis* Pilger (Pl. 69).

* Magnification of Fig. 1 is not 100 x, as stated in this Plate, but 30 x.

PRUMNOPITYS ELEGANS Philip

(Podocarpus andinus Poepp.)

Pl. 71

Tree native to Chile. Sample by courtesy of Professor Jessep of Melbourne.

C. 1,2. Growth rings indistinct, delimitation marked solely by an increased closeness of the late tracheids and their thicker walls; they vary in width from 8—10 to as much as 25—50 cells. *Tracheids* variable in size: in earlywood 32 $\times$ 20 μ, in latewood 12 $\times$ 20 μ. Next to the wide-lumened, occasionally narrow-lumened tracheids in irregular arrangement. Tracheids disposed in rows along the rays have not infrequently wider lumina than the others. *Rays* commonly 6—8 tracheids apart. *Parenchyma cells* markedly abundant, in some growth rings with a predilection for the latewood where there are sometimes 4—5 in a group, while at other times they are detached and scattered. Occasionally they are present in significant numbers in the earlywood as well, while some growth increments are practically without any of them. In the horizontal walls of wood parenchyma cells as well as ray cells, delicate punctations apparent, at times more abundant near the radial walls. True pits definitely wanting. About 4600—4800 tracheids per sq. mm.

T. 4. Tracheid walls smooth, apart from a very few pits and perhaps slightly more in the latewood. Pits relatively small (6 μ), apertures likewise minute, and invariably included. *Rays* 2—6, typically 2—3, very rarely 10, cells high. *Ray cells* in cross section elongate ellipses 16—20 μ high and 8—10 μ wide; some of those in single-row rays twice as high as the internal cells in higher rays. Radial walls sporadically pitted, tangential walls commonly smooth with then and when a slight protuberation. *Parenchyma cells* fairly frequent, 14—16 μ wide; their horizontal walls perfectly smooth; no pitting visible in the radial walls; tangential walls sometimes with tiny pits appearing now round, now elliptic and inclined. About 245—250 rays and 520—530 ray cells.

R. 3. In radial walls of *tracheids* bordered pits relatively numerous, sometimes pressed tightly to one another, 9—13 μ in diam. Apertures commonly round or eye-shaped, yet occasionally extended in the latewood. Extended apertures of complementary pits form X figures. Spiral thickenings absent. *Parenchyma cells* rather frequent, 9—10 μ wide, their horizontal walls perfectly smooth, tangential

walls with exceptional indentations ; the tracheidal pits show through the radial walls, so they themselves must be unpitted, the more so as there are never any pits in the cross field at the points of contact of ray and parenchyma cells. *Rays* consist solely of parenchyma cells with thin and perfectly smooth horizontal and tangential walls. The tangential walls join the horizontal ones at a slight inclination. Indentures absent. *Cross field* mostly with but one comparatively small elliptic pit. In the single-row rays predominantly two superposed pits. In the marginal cells of rays the pits slightly larger. Pit diameter a half or a third of the cross field. Pits measure 6—8 × 11 μ. Cross-field pits elongate oblique ellipses.

Xylotomically, *Prumnopitys* agrees particularly with *Podocarpus*, differing from it only in pitting.

SCIADOPITYS VERTICILLATA SIEB. ET ZUCC.
Japanese umbella pine
Pl. 72

Native to South Japan. Sample from a wood collection in Japan.

C. 1,2. Resin ducts wanting. *Growth rings* vary in width, some are 4—6 mm wide. Transition from early- to latewood gradual. Last-formed rows of late *tracheids* flattened, their tangential diameter sometimes twice or thrice the radial ones. Growth ring delimitation accordingly sharp. Walls of tracheids in the earlywood grow thicker as the latter approach the latewood. *Rays* uniseriate, 4—10—12 tracheids apart. Horizontal walls unpitted. About 2000 tracheids per sq. mm.

T. 4. Rays uniseriate, quite exceptionally biseriate and even then restricted to a single cell ; they are 1—7, in very rare instances 9—10, cells high. *Ray cells* in cross section slightly elongate ellipses measuring 14—20 × 12—18 μ ; internal cells predominantly squares ; marginal cells slightly conical. Tangential walls of early tracheids smooth, in the latewood with bordered pits, which are slightly smaller (8—9 μ) than those in the radial walls (9—13 μ). Pit apertures slitlike, oblique, those of complementary pits crossed. *Wood parenchyma cells* were not seen, not even exceptionally, though some investigators claim their occurrence. Per sq. mm. 32—35 rays and 110—115 ray cells.

R. 3. In walls of *tracheids* bordered pits scattered, slightly inclined ellipses or round, 13—15 μ in diam., occasionally stretching across the tracheid but only in the latewood. Apertures round, but inner orifices slightly slitlike. Two pits at the same height very rare and then only in the largest tracheids of the earlywood. All walls of *ray cells* smooth and thin, 1/2—3/4 μ ; this is one of the reasons for which this species does not quite fit the *Taxodiaceae*. In the *cross field* a single large pit, occasionally 2 pits, mostly ovoid or rhomboid, 15—22 μ in diam. In the latewood the pits are upright ellipses and this is another feature by which *Sciadopitys* is rendered unfit for the *Taxodiaceae*. *Rays* consist solely of parenchyma cells. *Transverse tracheids* absent. Tangential walls of ray cells bulging, oblique, or vertical.

From the *Pinus* this species is readily distinguished by the absence of transverse tracheids and by the smoothness of all its ray-cell walls. On xylotomical evidence *Sciadopitys verticillata* should be referred to the *Podocarpaceae* in spite of not fitting this family in every respect.

V. DESCRIPTIONS OF THE TAXALES BY SPECIES

AMENTOTAXUS ARGOTAENIA PILGER
Pl. 73

Distribution : Western China and Taiwan. Sample from Taiwan, by courtesy of the High School for Forestry in Tarandt.

C. 1,2. Growth rings varying from 40—50 to 70—80 tracheids in width with delimitation inconspicuous for lack of a significant difference in the wall-thickness of early- and latewood tracheids. Radial diameter of last-formed late tracheids 10—12 μ, tangential diameter 25—30 μ. Early tracheids measure radially 30—32 μ or slightly more. *Tracheids* in cross section predominantly squares or polygons with rounded corners. Latewood portion of the growth increment considerably larger than the earlywood portion, the latter conspicuous for the presence among the tracheids of numerous wide-lumened *parenchyma cells*, not infrequently in whole rows or groups ; rows of them occasionally ramify or produce peculiar patterns. This disposition of the parenchyma cells and their difference in size from the tracheids are

features so very characteristic as to permit of an immediate separation of this species from all the other conifers on the basis of only the transverse surface. Parenchyma cells 40—50 μ in diam.; their horizontal walls with 4—6 simple pits arranged regularly or irregularly, almost sievelike. *Rays* uniseriate, very exceptionally biseriate, with fairly well defined simple pitting in their horizontal walls. The tangential walls commonly join the horizontal ones at an oblique angle. The rays sometimes 20—25 tracheids apart. Per sq. mm. about 1900—2000 tracheids.

T. 4. Tracheids with spiral thickenings, the spirals pursuing a course at 45°, or nearly horizontal, always in pairs, threes, or fours. In the tangential walls bordered pits rarely present. *Rays* 1—10 cells high; higher rays did not occur in the section examined. *Ray cells* in cross section slightly ovate, 18—20 μ in height, 10—18 μ in width, the marginal cells and those of the single-row rays sometimes slightly higher; their tangential walls with primary pitting, the horizontal ones with fairly distinct simple pits. *Wood parenchyma cells* up to 40—50 μ in width, with smooth or nodularly thickened horizontal walls; their tangential walls with simple pits. About 50—55 rays and 155—160 ray cells per sq. mm.

R. 3. In radial walls of *tracheids* bordered pits scattered, uniseriate; biseriation is very rare and limited to the earlywood. Pit diameter 12—15 μ. Apertures circular or slitlike, the slits following the direction of the spirals; apertures not infrequently bounded by two spirals. In some tracheids where the spirals are horizontally oriented the latter bound the pits in the same manner as in some *Callitris* species. *Rays* consist solely of parenchyma cells. *Ray tracheids* absent. Horizontal walls of *ray cells* commonly smooth or with primary pits; tangential walls always perfectly smooth, but radial walls provided with round simple pits and the apertures of the bordered pits in the tracheids can clearly be seen. At the points of contact of the tangential and radial walls indentures fairly frequent. In the *cross field* commonly 1—2 pits, in some marginal cells and in the cells of single-row rays sometimes 3—4; for 2 pits a diagonal arrangement is the rule. Where wood and ray parenchyma meet, cross field with 3—10 simple pits variable in shape, size, and arrangement. Where the tracheids terminate at the rays there the ray parenchyma is provided with simple pits. *Longitudinal parenchyma cells* abundant on this surface, too; their radial walls display numerous round or procumbent-elliptic simple pits; their horizontal walls are mostly with simple thickenings, occasionally smooth. Parenchyma cells up to 40—50 μ in width. Simple pits of rays 6—8 μ; apertures 3—4 μ wide. Aperture of bordered pits in tracheids inclined at 45°. Pits of parenchyma nearly regular circles, 6—8 μ in diam. Radial walls of longitudinal parenchyma with scattered simple pits.

CEPHALOTAXUS DRUPACEA Sieb. et Zucc.

(C. drupacea Koidz.)

Cow's-tail pine

Pl. 74

Distribution: China and Japan. Sample from a wood collection originating from Japan.

C. 1,2. Growth rings almost indistinct, indicated by a few rows of flattened latewood tracheids. Between tracheids with large lumina occasionally rows of tracheids with narrow lumina. Radial diameter of early tracheids 25—30 μ, of late tracheids 8—10 μ; tangential width 22—25 μ. Tracheids in cross section tetra- or pentagonal with rounded corners, latewood tracheids radially flattened ellipses. Wall thickness 2—2,5 μ. *Wood parenchyma* abundant, but scattered, with reddish contents. Horizontal walls with simple pits from abundant to rather sparse. Parenchyma cells along the rays sometimes aligned in fairly long rows. Per sq. mm. 2400 tracheids.

T. 4. Rays 1—12—14 cells in height, 1 cell in width. *Ray cells* circular or short-elliptic in cross section; in single-row rays 18—20 μ, internal ones 11—13 μ high and 8—10 μ wide. Horizontal walls 2,5 μ thick; radial walls thin and unpitted. Tangential walls likewise devoid of markings. Ray cells with dark contents; even their walls look as if they were impregnated with a reddish substance, for there is a marked colour contrast between them and the much lighter tracheid walls. All *tracheids* with spiral thickenings. Spirals relatively closely spaced, 6—7 μ or less apart, mostly occurring singly. In very rare instances, two spirals come close to each other and continue in pairs on parallel courses. The spirals are at high angles to the vertical axis, never at less than 45°. In tangential walls bordered pits very rare. *Wood parenchyma* relatively abundant and with resinous substance. Transverse walls smooth, or slightly nodular, or thickened in the middle; radial walls

pitted; tangential walls likewise pitted, but sparsely. Per sq. mm. 110—120 rays and 250—260 ray cells.

R. 3. When extending in pairs in the *tracheids*, the spirals generally border the pit aperture, but sometimes they are further apart. In radial walls bordered pits rather small, 4,5 μ in diam.; apertures mostly oblique slits or ellipses extending to the border, 2,5 μ in width, scattered, or 15—20 μ apart. All walls of *parenchyma cells* thin. Horizontal walls smooth or very slightly thickened. Large circular pits scattered in radial walls. Pit diameter 4,5—5 μ. At points of contact of parenchyma and rays 2—3 simple pits in the cross field. *Rays* consist only of parenchyma cells. Horizontal walls with simple pits, uniformly thick, unlike those in *Taxus*. Horizontal walls sometimes with so many pits as to give it the appearance of a string of beads, but at other times with not a pit for quite long stretches. Tangential walls smooth and unpitted. Indentures present and fairly discernible. In the *cross field* 1 or 2 pits, in the marginal cells the same number; where two appear, they are superposed. Pits commonly small, 3,5—7 μ in diam. Apertures oblique slits 1,5 μ wide. Borders not clearly distinct. By its pitting, this species is readily differentiated from the *Taxus*.

CEPHALOTAXUS FORTUNEI Hook.

Pl. 75

Native to North China. Xylotomically, similar to *Taxus baccata* except for the presence in it of longitudinal parenchyma.

C. 1,2. Growth rings rather variable in width. Latewood a narrow dark strip well defined from the earlywood. Growth ring delimitation fairly evident and slightly undulating. *Longitudinal parenchyma cells* scattered throughout the growth ring, or aligned in radial rows, or disposed in groups; their walls thinner than those of the adjacent tracheids; their horizontal walls mostly unpitted and with dense tiny protuberances (warts), but not uncommonly with 1—4 round or elliptic simple pits having slitlike apertures with rounded ends. In the horizontal walls of the *ray parenchyma cells* there also occur tiny round pits in larger numbers, but wall portions free from pits are observable as well. Number of tracheids per sq. mm. 4000.

T. 4. Barring the longitudinal parenchyma, the tangential surface of this wood shows the same structure as that of *Taxus baccata*. The spirals in the tracheids pursue a fairly even course at equal distances from one another, mostly occurring singly or in pairs. (In some tracheids, particularly in the inner parts of the latewood, there seem to be annular thickenings.) Tangential pits 4—8 μ in diam.; their apertures from short- to long-elliptic, occasionally circular, or eye-shaped and of oblique orientation, sometimes reaching the pit annulus but never extended. Exceptionally two pits across the width of a tracheid. *Rays* uniseriate, rarely with 2 paired cells in the body; they are typically 1—3 cells high, with even the tallest not extending 6—8 cells. They consist solely of parenchyma cells, and in cross section are nearer to long-elliptic (16—18 μ); their tangential and horizontal walls are unpitted. *Wood parenchyma cells* correspond in width to the tracheids, and their tangential walls have round simple pits. Per sq. mm. 150—160 rays and 250—260 ray cells.

R. 3. In radial walls of *tracheids* round pits, 12—13 μ in diam., reaching, or almost reaching, from wall to wall. Inner orifices circular in the earlywood, but nearer to eye-shaped in the latewood. Outer orifices eye-shaped in both seasonal increments. Apertures oblique. Horizontal walls of *ray parenchyma cells* with well-defined outer pit orifices. In their radial walls circular simple pits correspond to the half-bordered pits in the tracheids, which latter are round or elliptic and have apertures that are wider in the earlywood and narrower in the latewood, eye-shaped, in most cases markedly extended; if not then at least reaching the pit annulus. In the earlywood the border is sometimes reduced to crescents to the right and left of the aperture. *Cross field* with 1—2, marginal cells with 2, occasionally 4, pits (5—6 μ).

CEPHALOTAXUS OLIVERI Mast.

Pl. 76

Distribution: Western Hupeh and Szechwan in China. Sample, a piece of board, obtained from Nanking.

C. 1. Growth rings distinct. *Tracheids* in cross section angular with rounded corners. *Wood parenchyma* absent.

T. 2,4. Rays 1—12 (18) cells high, uniseriate, taller ones partly biseriate.

R. 3. In the *cross field* commonly 1—2, in the marginal cells 2, occasionally 4, pits of a nearly

cupressoid type, 4—5 μ in diam. Horizontal walls of *ray cells* variably thickened and unpitted ; tangential walls smooth. Indentures frequent.

CEPHALOTAXUS PEDUNCULATA SIEB. ET ZUCC,
Cephalotaxus drupacea var. harringtonia (Forb.) Pilger
(C. harringtonia K. Koch)

Pl. 77

Distribution : Japan. Sample, a piece of a branch 5—6 years old, obtained from Nanking.

C. 1,2. Growth rings indistinct, in places hardly discernible, indicated by a few flattened rows of latewood. Radial width of early tracheids 16—18 μ, of flattened late tracheids 6—8 μ. Lumina of the latter narrowed to nearly a slit. Wall thickness of both early- and latewood tracheids 2—2,5 μ. *Tracheids* in cross section tetra- or polygonal with rounded corners, in latewood flattened ellipses. Some rows of tracheids form continuous chains through 3—4 growth rings. *Wood parenchyma cells* with dark contents scattered throughout the growth rings in relatively large numbers, but those along the rays sometimes aligned in rows of 8—10 cells. Horizontal walls of *ray cells* with pits closely set in some places, but wider apart in others. Tangential walls smooth. About 4300 tracheids per sq. mm.

T. 4. All *tracheids* with spiral thickenings. Spirals closely spaced, 3—4—6 μ apart, practically at right angles to the long axis, therefore appearing horizontal on the tangential section or at a low angle to the horizontal axis. They are more widely spaced in the early tracheids and often looking as if they were annular thickenings. They occur singly, exceptionally in pairs at 3—4 μ from each other. In tracheid walls bordered pits very scarce, hardly a few per section, 5—6 μ in diam. *Wood parenchyma cells* 18—19 μ in width, their walls thin, transverse walls generally inclined, entirely smooth or thickened in the middle, occasionally with 2—3 nodules. Tangential and radial walls sparsely provided with simple pits. *Ray cells* in single-row rays 34—35 μ, in the internal cells of taller rays typically 16—18 μ, exceptionally 30—33 μ, high and commonly 8—9 μ wide, yet in some instances they are short-elliptic or subcircular in cross section. Their horizontal walls are thick, the radial and tangential walls thin. Per sq. mm. 170—180 rays and 370—380 ray cells.

R. 3. All *tracheids* with clearly discernible spiral thickenings ; those in the earlywood 24—26 μ wide. Bordered pits not more than 4—5 μ in diam. ; apertures elliptical, 2,5—3 μ wide, extending to the border. *Wood parenchyma* provided with simple pits, 10—15 μ apart ; their horizontal walls smooth, or thickened in the middle, or nodular ; tangential walls smooth. *Rays* homogeneous. *Ray cells* on an average 16—18 μ high : their horizontal walls 2 μ thick, with from sparse to relatively numerous simple pits, always less in number in the earlywood, while in other places the walls are variably thickened. Tangential walls smooth, mostly at acute angles to the horizontal walls ; indentures well discernible. *Cross field* in the single- and double-row rays usually with 2 superposed pits, in the internal cells of taller rays mostly with 1, less frequently with 2, pits 4,5—5 μ in diam. Apertures oblique ellipses with the minor axis 2,5—3 μ long ; they extend to the border. Between the horizontal walls of *ray cells* sometimes significant negative intercellular spaces ; these walls have conspicuously drifted apart. No pits in the cross field at the points of contact of ray parenchyma with wood parenchyma. Marginal ray cells somewhat higher than internal cells, and the external surface of their walls slightly wavy.

The xylotomical findings in no way support the view that *Cephalotaxus pedunculata* should be regarded as a hybrid of *C. drupacea* and *C. fortunei*, for while the horizontal walls of ray cells in the supposed parents are generally smooth and provided with but a few pits, those in *C. pedunculata* are abundantly pitted. On xylotomical evidence *C. pedunculata (harringtonia)* deserves the rank of a species, the more so as it greatly differs from *C. drupacea* as well.

NOTHOTAXUS CHIENII (CHANG) FLORIN

Pl. 78

Tree native to the Province of Chekiang in China, where it has been discovered but some years ago (1934). For the sample the author is indebted to Professor FLORIN, who in turn received the material from Professor CHANG, directly from China. Unfortunately, it comes from a branch not more than 4—5 years old, wherefore the features established on its strength may not be regarded as characteristics of absolute value, the least so those concerning ray height.

C. 1,2. Growth rings indistinct, marked only by some rows of flattened late tracheids. *Tracheids* in cross section generally angular with rounded

corners and variable in diam. The widest early tracheids measure 22—24 μ tangentially, and only 14—16 μ radially. *Wood parenchyma* absent on the transverse surface.

T. 4. All *tracheids* with distinct spiral thickenings, the spirals occurring singly, or in pairs or groups; when single, they can be traced for considerable stretches. Those at right or oblique angles to the vertical walls follow each other at distances of 2—3 μ, while single ones are 8—10 μ apart. Walls with bordered pits 8—10 μ in diam. and aligned at intervals the width of 1—2 pits. Pit apertures circular. *Rays* in the specimen from a young branch 2—3 cells in height, probably attaining the height of 8—10 cells in the adult wood. *Ray cells* 20—24—26 μ in height, 12 μ in width, in cross section somewhat long-elliptic. No *wood parenchyma* observable in this section either.

R. 3. Tracheids with distinct spiral thickening like on the tangential surface and 20—22—24 μ in width. Apertures of bordered pits occasionally oblique with a tendency to the perpendicular. *Rays* consist only of parenchyma cells 22—26 μ in height; their horizontal walls smooth, sporadically with slight thinnings. *Cross field* with 2—3 cupressoid pits 4—5 μ in diam. Tangential walls of *ray-parenchyma cells* smooth, without any pitting at all, and arched towards the latewood. Indentures could not be observed. In the marginal cells pits generally superposed in twos, exceptionally in threes. *Wood parenchyma* absent.

TAXUS BACCATA L.

Common yew

Pl. 79

Distribution: Europe, the Caucasus, North Africa, the Himalayas, Japan, North America.

C. 1. Walls of *tracheids* thick. No noteable differences between early and late tracheids. In cross section, they are squares with rounded corners or radially oriented ellipses in the earlywood, but radially flattened cells in the last-formed 2 or 3 rows of the latewood. Apart from those in these few rows, early and late tracheids are of approximately the same radial diameter. Between two rays the outer edge of the growth ring is sometimes slightly bent outwards. *Rays* uniseriate, quite exceptionally biseriate, from 2 to 15—20 tracheids apart. About 2700 tracheids per sq. mm.

T. 2,4. Rays 1—30, typically 1—15 (20—22), cells high, uniseriate, in rare instances with a few paired cells in the body. *Ray cells* in cross section upright ellipses. Walls of tracheids with spiral thickening in both the early- and latewood. The spirals ascend counterclockwise, are commonly 2, seldom 3 or 4, in number; their angles vary, are sometimes so low as to make the spirals appear almost horizontal annular thickenings. The spacing of the coil is more or less uniform. In the tangential walls, particularly in those of the tracheids in from the first to the fourth rows at the outer edge of the growth ring, the pitting is abundant and uni- or biseriate, but pits can be found elsewhere as well. They are round, their apertures slitlike and nearly reaching the pit annulus. Generally, they agree with the pits in the radial walls of the latewood. *Wood parenchyma* absent or very sparse. Per sq. mm. 80—85 rays and 195—200 ray cells.

R. 3. In the walls of *tracheids* bordered pits aligned singly or in pairs. Apertures circular in the earlywood, with gradual transition to slitlike in the latewood, where they are obliquely oriented and nearly reach the border. Pits invariably round. *Rays* consist solely of parenchyma cells with walls of variable thickness. In their horizontal walls simple pits with blunt edges. The tangential walls, which are perpendicular or slightly canting from it, are devoid of pitting, perfectly smooth. Indentures definable. The simple pits in the radial walls circular and smaller than the others in the tracheids, matching perhaps those in the most narrow-lumened late tracheids. Outer apertures oblique ellipses or slits, somewhat narrower in the late- than in the earlywood. *Cross field* with 1—2 pits in the internal ray cells, and 3—4 in the marginal cells, mostly in quadratic arrangement; not more than 2 pits superposed.

TAXUS BREVIFOLIA NUTTAL

Pl, 80

Distribution: British Columbia, the states of Oregon and California in the U. S. A. Sample, a piece of a thick board, received from California.

C. 1,2. Growth rings distinct due to the great difference between the flattened and thick-walled latewood tracheids and the thinner-walled early tracheids of larger lumina. Radial width of outermost late *tracheids* only 10—12 μ, of early tracheids 28—30 (38) μ; tangential diam. 20—22 μ.

Transition from early- to latewood gradual. Tracheids in cross section tetra- or pentagonal, in the latewood with rounded corners or flattened ellipses. Walls of late tracheids markedly thickened, attaining 2,5—3 μ, of early tracheids only 1,5—2 μ. *Rays* 4—10—20 tracheids apart, their horizontal walls with occasional simple pits. About 3100 tracheids per sq. mm.

T. 4. In all *tracheids* spiral thickenings, the spirals occurring singly or in pairs as seen in *Torreya*, and they are generally 15—20 μ apart. Sometimes they are nearly horizontal, at other times assuming angles of 25—30°, or rarely 45—60°, to the horizontal axis. They are more closely spaced in the latewood. In places three spirals extend side by side. Bordered pits 5—6 μ in diam., apertures circular or slitlike, the slits oblique or nearly vertical. *Rays* 1—12—14, typically 3—6, cells high. Height of *ray cells* in single-row rays 20—26—27 μ, of marginal cells about the same or slightly less, of internal cells only 12—14 μ; width of ray cells 4,5—5 μ. Horizontal walls thick, tangential walls devoid of pitting or any kind or markings. Per sq. mm. 90—95 rays and 260—270 ray cells.

R. 3. Spirals in pairs or in threes, in the earlywood nearly horizontal or at low angles to the horizontal axis, in the latewood at angles of 45—50°. Two spirals run as a rule in opposite directions. In radial walls of *tracheids* bordered pits 12—14 μ, and circular apertures 3—3,5 μ in diam. *Rays* only of parenchyma cells. Horizontal walls unevenly thickened, quite thin in places, markedly thickened in others. Horizontal walls with occasional simple pits. Frequently negative intercellular spaces between horizontal walls. Tangential walls very thin and smooth. Indentures definite. *Cross field* occasionally without, commonly with, 1—2 pits side by side, in the marginal cells with 2, sometimes 4, pits disposed diagonally and 4,5—5 μ in diam. Apertures oblique and elliptic or circular, extending to the border. In some instances major axis of pit aperture at right angles to that of the elliptic pit, i. e. cupressoid.

TAXUS CANADENSIS MARSH.

Canada yew

Pl. 81

Distribution: North America, from Newfoundland to Virginia, U. S. A. Sample, a piece of board, received from California.

C. 1. Growth rings distinct due to great contrast between the flattened late tracheids and the wider-lumened early tracheids with thin walls. Tracheids in latewood radially 8—9 μ, some of them in earlywood 25—32 μ in diam. Tangential width 20—22 μ. Early tracheids in cross section tetra-, penta-, or polygonal; late tracheids tangentially elongate ellipses. *Rays* 2—12—20—25 tracheids apart. Tangential walls smooth, horizontal walls very rarely with a simple pit. Per sq. mm. 3000 tracheids.

T. 2,4. In all *tracheids* spiral thickenings, the spirals occurring singly or in pairs, occasionally in threes or fours, at angles of 15—20° to the horizontal. While they very seldom assume higher angles they not infrequently pursue a nearly horizontal course. *Rays* 1—12, in quite rare instances 12—13, cells high. *Ray cells* in single-row rays 22—24 μ, in internal rays 16—18 μ, high and 5,5—6 μ wide. Horizontal walls much thinner than in the other *Taxus* species. At least in the early tracheids tangential walls without, or very rarely with, 1—2 bordered pits 6—7 μ in diam. Apertures circular, 2,5 μ in diam. Per sq. mm. 90—100 rays and 400—420 ray cells.

R. 3. All *tracheids* with spiral thickenings, the spirals rather wide apart, usually at 16—18 μ, or in pairs, nearly perpendicular to the vertical axis, or at angles of not more than 45—50°. Bordered pits, scarce in number, occur amongst the spirals at intervals of from 8—10 to as much as 50—60 μ. Pit diameter 13—14 μ. Apertures circular, 2—2,5 μ in diam. *Wood parenchyma* not observed. *Rays* consist only of parenchyma cells. Height of *ray cells* 15—16 μ, that of marginal cells slightly more, 19—20 μ. Horizontal walls unevenly thickened, at places quite thick, about 2,5 μ, at others thin throughout. Simple pits fairly frequent in thicker walls. Horizontal walls sparsely pitted. Tangential walls very thin, smooth, with sporadic indentures, but occasionally attached with a broad base to the horizontal walls. *Cross field* with 1—2—3, in the marginal cells exceptionally 4, relatively large pits. A single pit sometimes occupies almost the entire area of the field, is mostly procumbent-elliptic, with a major axis of 16—18 μ and a minor axis of 6—8 μ. At other times the cross field is filled up by two large pits. Pits of this size are not seen in any other *Taxus* species. The pits are circular, the apertures elliptic and included. Oblique pit apertures distinct from borders, while around large apertures the border shows only as a

narrow ring. This feature is fairly frequent. Large pitting is characteristic of this species and therefore a feature of considerable diagnostic value.

TAXUS CHINENSIS REHDER

Chinese yew

Pl. 82

Distribution : the provinces of West-Hupeh and Szechwan in China. Sample received from the Research Institute of Forestry in Nanking.

C. 1. Growth rings rather distinct. Late *tracheids* thick-walled, radially flattened, and followed abruptly by early tracheids with wide lumina. Radial width of outermost late tracheids 12—14 μ, that of adjacent early tracheids up to 30—45 μ ; tangential diam. 28—30 μ or less. Wall thickness in latewood 4,5—5 μ, in earlywood slightly less, 3,8—4 μ. Tracheids in cross section tetra- or polygonal, usually with rounded corners, sometimes almost circular. *Rays* 5—8—15—20 tracheids apart. Horizontal walls of *ray cells* with sparse circular or elliptical simple pits ; tangential walls smooth. *Wood parenchyma cells* missing.

T. 2,4. All *tracheids* with spiral thickenings, the spirals generally 15—20 μ apart and, as a rule, at an angle of 45° to the vertical axis. Quite close and nearly horizontal spirals not observable. Tangential walls of tracheids without pits ; those sporadically encountered probably came to fall on the tangential side as a consequence of twists in the tracheids. *Rays* 1—12 cells high. The sample examined having been taken from wood about 50 years old, higher rays are improbable in this species ; none have been seen by the writer exceeding 14 cells. *Ray cells* in cross section circular or upright-elliptic ; those in single-row rays 16—20 μ, those in internal cells 13—14 μ high ; ray-cell width 7—9 μ. Tangential ray walls devoid of pitting and any kind of markings. Some rays with dark contents. Horizontal ray walls 2,5—3 μ thick. Per sq. mm. 70—75 rays and 240—250 ray cells.

R. 3. Tracheids with spirals occurring singly, 12—18 μ apart. Bordered pits in their walls at intervals of 20—30—40 μ. Apertures circular and 6—7 μ in diam., or slitlike and 2 μ in width and about 10 μ long, reaching the pit border or crossing it. When extended, they usually continue in one of the spirals. *Rays* consist only of parenchyma cells. Horizontal walls relatively thick, 2,5—3,5 μ, but thickened unevenly and in some places with definite simple pits. Between them there are longitudinal hollows (negative intercellular spaces). Tangential walls smooth, mostly arching, indentures clearly visible.

Per *cross field* 2—3 pits mostly in horizontal rows, in marginal cells 4 pits in 2 rows with 2 pits each. Pit diam. 4—5 μ. Apertures slitlike, from included to extended. External surface of marginal-cell walls thin and slightly undulating.

TAXUS CUSPIDATA SIEB. ET ZUCC.

Japanese yew

Pl. 83

Native to Japan. Sample comes from a Japanese wood collection.

C. 1. Growth ring delimitation strongly undulating and rendered conspicuous by flattened late tracheids being followed by wide-lumened early ones. Radial width of *tracheids* in the latewood 10—12 μ, that of the adjacent early tracheids 34—36 (40) μ ; tangential width 24—26 μ. Wall thickness in latewood 3—4 μ, in earlywood 1,5—2 μ. Tracheids in cross section squares or radially elongate rectangles, in the first rows of the latewood sporadically with rounded corners. Latewood restricted to from a sixth to a quarter of the growth increment. About 1600 tracheids per sq. mm.

T. 2,4. All *tracheids* with spiral thickenings, the spirals occurring at intervals of 16—20—30 μ, and assuming angles of 15—20° to the horizontal ; spirals at a 45° angle are rare exceptions. In the latewood some pursue a nearly horizontal course. In this respect the species definitely differs from *Taxus chinensis*. In the latewood bordered pits rather frequent and 30—40 μ apart. Pit diameter 8—10 μ. Apertures narrow and vertical. *Ray cells* in cross section elongate ellipses, those in single-row rays 24—26 μ, those in internal cells only 16—17 μ high ; ray-cell width 5,5—6 μ. Horizontal walls thick, radial walls thin, tangential walls without any markings, perfectly smooth. *Rays* 1—18 (32), frequently 14—16, cells high. This wood can be quickly and easily distinguished from that of *T. brevifolia* by the height of rays. Per sq. mm. 50—55 rays and 270—280 ray cells.

R. 3. Spirals in the *tracheids* usually extend at angles of 15- 25° to the horizontal, or are nearly horizontal. Bordered pits large, with diameters

of 16—18 μ and circular apertures 4,5—5 μ in diam. *Rays* consist only of parenchyma cells. Horizontal walls vary in thickness and display sporadic simple pits. Tangential walls perfectly smooth, indentures well discernible. Internal *ray cells* on an average 16—17 μ high, marginal cells 24—26 μ. *Cross field* mostly with 2 pits commonly side by side, sometimes with 1 or none ; in the marginal cells 2 or 4 ; when 4, each takes a corner of the field. Pit diameter 5—6 μ. Apertures 2—3 μ in width, obliquely oriented, extending to the border. Between horizontal walls negative intercellular spaces fairly frequent.

TAXUS SPECIOSA Florin

Pl. 84

Distribution : the provinces of Szechwan, Chekiang, and Yunnan in China. For the sample, a piece from a branch 8 years old, author is indebted to Professor Florin, who collected it in China and was the first to describe the species.

C. 1. In view of the minor age of the specimen careful conclusions only can be drawn regarding the structure of the adult wood. Yet, on the evidence available from the transverse surface it is safe to make a few statements. *Growth rings* are distinct due to the contrast between the wider-lumened early, and the narrower-lumened late *tracheids*. Radial diameter of early tracheids 22—24 μ, of late tracheids only 8—9 μ. Walls of tracheids thinner in early- than in latewood. Transition from the early- to the latewood gradual. Tracheids in cross section generally tetra- or pentagonal, corners not rounded, not even in the latewood. Horizontal walls of *ray cells* with sporadic pits, but tangential walls definitely smooth. About 4600 tracheids per sq. mm.

T. 2,4. Rays comparatively low in the sample from a young branch : 1—6, exceptionally 8—10, cells high. Tracheids spirally thickened. Spirals nearly horizontal, spaced mostly 7—8 μ apart, occurring singly as a rule, quite exceptionally in pairs. In tangential walls very few bordered pits, and only in the latewood. Pit diameter 6—7 μ. Apertures circular. *Ray cells* in single-row rays 22—24 μ high and 6—7 μ wide ; those in taller rays generally less in height, 17—18 μ. Horizontal walls thick, radial walls thin, tangential walls without any pitting or markings. Radial walls with pits, but those in the earlywood barely perceptible. Per sq. mm. 120—130 rays and 270—280 ray cells.

R. 3. In all the *tracheids* on this surface spiral thickenings well defined. Spirals nearly horizontal, but more stretched in the earlywood and 10—15 μ apart. Bordered pits in the earlywood 13—14 μ in diam. Apertures usually circular or short-elliptic ; the circular apertures 3 μ in diam. *Rays* homogeneous. Horizontal walls variably thickened, relatively thin, only 1—1,5 μ. Negative intercellular spaces fairly frequent between horizontal walls. At places simple pits in the walls, except the tangential walls which are perfectly smooth. Indentures absent owing to the thinness of the walls. Tangential walls from straight to bent. In single- and double-row rays *cross field* with 3 superposed pits, in internal cells overwhelmingly with 2, and only exceptionally with 3, pits one above the other. On this basis this species is readily separated from *Taxus cuspidata*, *T. brevifolia*, and *T. chinensis*, but it should be borne in mind that in the adult wood these conditions may be different, no matter how constant they proved to be in the specimen studied.

TAXUS WALLICHIANA Zucc.

Pl. 85

Distribution : the provinces Szechwan, Kansu and Hupeh in China. For the sample, a piece from a branch 7 years old, the writer is indebted to Professor Florin, who collected it in China in 1934. Xylotomically, this species differs from *Taxus speciosa*, although the two do have characters in common.

C. 1. Transverse surface very similar to that in *T. speciosa*. *Growth rings* distinct, marked chiefly by the apposition of the width of the lumina in the early and late tracheids. Radial width of early *tracheids* 18—20 μ, of late tracheids 8—9 μ ; tangential diameter 17—18 μ. Practically no difference in wall thickness, which is 2,5 μ in the late and 2 μ in the early tracheids. In cross section tracheids usually tetra-, penta-, or polygonal, but in the latewood radially elongate rectangles. *Ray cells* with pink resinous contents ; their horizontal walls with but quite sporadic pits ; tangential walls smooth.

T. 2,4. Rays 1—8 cells high, very rarely attaining a height of 9—10 cells, but in adult wood they may be slightly higher. *Ray cells* in single-row rays 22—24 μ, in the internal cells of taller rays

17—18 μ in height ; ray-cell width 8—9 μ. Horizontal walls comparatively thick and pitted in some rays. Triangular intercellular spaces between ray and tracheids always well discernible. Tangential walls perfectly smooth. Radial walls without any pitting. All *tracheids* with spiral thickenings, the spirals generally horizontal or at very low angles to the horizontal, and 7—8 μ apart. They mostly occur singly, occasionally in pairs or threes. Tangential walls of tracheids with no, or just one or two, pits probably transposed to this side from the radial side. Per sq. mm. 280—290 rays and 680—690 ray cells.

R. 3. All *tracheids* with spiral thickenings, the spirals occurring singly or, not infrequently, in pairs. The members of a pair are 6—7 μ apart, while the interval between pairs is 16—18 μ. To the vertical the spirals assume an oblique angle. Bordered pits sometimes closely spaced, scattered at other times, 12—13 μ in diam. Apertures circular or elongate ellipses, 2—3 μ in width. *Rays* have only parenchyma cells. The horizontal walls commonly smooth, in places coarse or markedly thickened, and very rarely with simple pits in them. Tangential walls smooth and arched towards the horizontal walls. Indentures well discernible. Commonly 2 pits per *cross field* in single- and double-row rays, 3 pits infrequent. Pit diameter 5,5—6 μ. Apertures oblique ellipses, the border appearing as crescents to the right and left of them. In the cross field of the internal cells a single pit is the rule, and this is a feature which permits the conclusion of a close affinity to *T. baccata*. Apertures of solitary pits about 4,5—5 μ, the pits themselves about 6—6,5 μ in diam. The fact that in the cross field of the internal cells there is predominantly a single pit reminds one in a degree of *T. canadensis*, however in *T. wallichiana* this pit is much smaller and never occupies the entire cross field. In the latewood there is a single elliptic pit in the cross field and that is of vertical orientation.

TORREYA CALIFORNICA Torrey

California nutmeg

Pl. 86

Native to California, U. S. A. For the sample the writer is indebted to Professor Erdtman of Stockholm.

C. 1. Growth rings variable in width, occasionally excentric. Walls of *tracheids* thick. In size and wall thickness no essential difference between early and late tracheids. Seasonal contrast inconspicuous. Growth ring delimitation definite but not sharp. In cross section the tracheids and their lumina have rounded corners, consequently there arise intercellular spaces of different size between them. *Rays* differently spaced ; in their horizontal walls circular or elliptic pits present or frequently absent. *Wood parenchyma cells* sparse and mostly restricted to earlywood ; their walls substantially thinner than those of the tracheids ; horizontal walls at most with vestigial pits. (Some authors claim the total absence, some the presence of but little parenchyma.) About 3600 tracheids per sq. mm.

T. 2,4. Tracheids with spiral thickenings. However, in contrast with *Taxus* and *Cephalotaxus*, the individual spirals do not proceed at equal distances ; instead, from 2 to 4 extend near to one another with a fair stretch of entire wall between them and the next group of 2—4 such spirals. True, there are exceptions to this rule, particularly in the earlywood, where the spirals are at fairly the same distance from one another. Moreover, in very rare instances, there occur tracheids with smooth walls. The angle of the spirals varies from nearly horizontal in the earlywood to higher inclinations elsewhere. They ascend in counter-clockwise direction. In tangential walls pits restricted to the last-formed late tracheids ; they are 6—7 μ in diam., circular, have eye-shaped apertures oriented perpendicular to the spirals and included. Occasionally their direction conforms to that of the spirals. *Rays* composed of parenchymatous elements, low, even the highest attaining but 6—7 cells in height. Typical height 1—4 cells. They are invariably uniseriate. Horizontal walls the thickest, tangential ones the thinnest. Horizontal and radial walls with pits, tangential ones devoid of them, but occasionally with minute protuberances. *Ray cells* in cross section short-elliptic or circular, sporadically long-elliptic but only in marginal cells and single-row rays, these may be pointed at both ends. Between the ray parenchyma cells and the tracheids there are triangular or differently shaped intercellular spaces, in some instances with ramifications. In the tangential and radial walls of the *wood parenchyma cells* round simple pits of the same size as the half-bordered pits in the adjoining tracheids. Their horizontal walls smooth, or slightly thickened, or pitted. Per sq. mm. 70—75 rays and 130—140 ray cells.

R. 3. In the radial walls of *tracheids* the spiral thickening the same as in the tangential walls. The bordered pits uniseriate, circular or short-elliptic, their size contingent on the width of the tracheids, 9—11 μ. The apertures, always fairly wide, are circular, elliptic, or eye-shaped, and included in the earlywood ; they are circular, but occasionally slightly narrowed, in the latewood. They are obliquely oriented and at right angles to the spirals, or they come to lie in the direction of the spirals, usually between two of them. Some tracheids with trabeculae. Where longitudinal tracheids butt into rays there sometimes arise various patterns on the external surface of the marginal cell walls. Among the walls of *ray parenchyma cells* the horizontal walls are the thickest with variable thickenings, especially at their points of contact with tracheids. Radial walls with clearly defined round simple pits that are visible in cross section on the tangential surface. They communicate with the half-bordered pits in the walls of the adjoining tracheids. Half-bordered and simple pits agree in size and shape. Their apertures are obliquely oriented, elliptic or eye-shaped, in the earlywood slightly wider, and the border around them appears as a narrow band. In the earlywood they are somewhat narrowed and occasionally linear or slitlike. Border and aperture always clearly separable. Apertures normally reaching the pit annulus, but sometimes included, at other times extended. These features of the apertures can likewise be observed on the tangential surface. *Cross field* with 1—2—4 pits. Because the tracheids are narrow, wherever there are 4 of them, they are mostly in quadratic arrangement and seldom in juxtaposition.

TORREYA GRANDIS Fortune

Pl. 87

Distribution : the provinces of Chekiang, Hupeh, and Szechwan in China. Sample received from Taiwan.

C. 1. Growth rings distinct. *Tracheids* thin-walled in early- and thick-walled in latewood. Transition gradual. Tracheids in cross section rather angular in earlywood, elongate flattened elliptical but occasionally angular, hexagonal in latewood. Radial width of early tracheids 18—20 μ, tangential diam. 14—16 μ. Radial width of late tracheids 7—9 μ. In the horizontal walls of rays a few scattered pits, but tangential walls smooth. *Wood parenchyma* very scarce, only one or two cells in one section. About 3600 tracheids per sq. mm.

T. 2,4. Ray structure as seen on the tangential surface definitely different from that in the other three *Torreya* species. *Ray cells* 14—16 μ in height and about the same (15—18 μ) in width ; in cross section, accordingly, subcircular or short-elliptic. In this species, too, there are spirals in pairs, predominantly in the latewood, but mostly they occur singly, from 10—12 to 22—26 μ apart. *Wood parenchyma cells* were seen by the writer on two occasions only on this section ; their horizontal walls were found to be smooth or slightly coarse ; in the tangential walls no bordered pits could be observed, but they are probably present in the late tracheids. Rays usually low, 1—8 (10) cells in height, very likely higher in the adult wood. Per sq. mm. 90—100 rays and 255—260 ray cells.

R. 3. Average height of *ray cells* 22 μ ; their horizontal walls smooth or with a fair number of pits side by side ; tangential walls smooth ; indentures not uncommon, but mostly poorly defined. Per *cross field* 1—2—3 (5) minute pits, as many in the marginal cells. Pit diameter 4—4,5 μ. Apertures 2—3 μ in width, always included. In the radial walls of *tracheids* bordered pits scarce, 9—11 μ in diam. Spiral thickenings in latewood definitely in pairs, the two members usually flanking the pit apertures. *Wood parenchyma cells* were seen in a single instance by the writer ; their horizontal walls were smooth or somewhat uneven ; in the radial walls there were a few simple pits relatively widely spaced in vertical rows. *Ray cells* occasionally with dark contents.

TORREYA NUCIFERA Sieb. et Zucc.

Kaya

Pl. 88

Native to Japan. Sample recevied from Hongkong.

C. 1. Growth rings distinct, their contour slightly wavy. Radial width of last *tracheids* in latewood 18—20 μ, that of early tracheids 25—30 μ ; tangential diameter about 20 μ. *Ray parenchyma* with rather scarce pits in the horizontal walls ; tangential walls smooth. *Wood parenchyma cells* sparse, scattered, and commonly with dark contents. Tracheids in cross section in the earlywood generally squares or polygons, in the latewood with rounded corners and much thicker walls. About 1200 tracheids per sq. mm.

T. 2,4. Spiral thickenings in *tracheids* delicate, in pairs with 5 μ space between the members and 22 μ between the individual spiral pairs. Singly occurring spirals more numerous in the latewood. Height of *ray cells* in single-row rays 22—26 μ, width 7—8 μ, therefore in cross section markedly elongate ellipses. Their tangential walls perfectly smooth, radial walls unpitted. *Wood parenchyma cells* rare, their horizontal walls, mostly at an acute angle to the radial walls, are smooth or with minute projections. In the tangential walls sporadic simple pits, fairly large, 3,5—4,5 μ in diam. Per sq. mm. 60—65 rays and 115—120 ray cells.

R. 3. Ray cells 22—26 μ high ; their horizontal walls generally smooth, pits or thinnings very rare in them. Per *cross field* 3—4 or even 5 minute pits, 4,5—5 μ in diam. Apertures 2,5—3 μ in width, mostly oblique or almost horizontal. Tangential walls smooth ; indentures obscure. In radial walls of *tracheids* pits scattered, 11—14 μ in width, with slitlike included apertures ; those of complementary pits crossed. Spiral thickenings, though sometimes occurring singly, definitely proceed pairwise, the members quite frequently flanking the apertures of bordered pits. Occasionally three bars parallel their course.

TORREYA TAXIFOLIA ARNOTT

Slinking cedar

Pl. 89

Native to Florida, U. S. A. The sample comes from a wood collection of Mr. Houg. B. Romeyn (Lowville, N. Y., U. S. A.)

C. 1. Growth rings distinct, on the margins not wavy. Last 1—2 cell rows of latewood flattened. *Tracheids* in cross section rectangular, square, or multangular ; their radial diameter 45—50 μ, tangential diameter 28—30 μ. Since the available specimen was a thin, one millimeter panel, it was not possible to prepare a sufficiently fine section. *Wood parenchyma cells* could not be observed. About 1150 tracheids per sq. mm.

T. 2,4. Rays comparatively high, commonly 15—18, occasionally up to 30—36 cells. Spiral thickenings well discernible in all *tracheids*. Spirals in pairs rare and only occur in late tracheids, 9—10 μ apart. Single spirals are at 20—25 μ from one another, but somewhat closer in the latewood. *Ray cells* in single-row rays 20—25 μ, and about as high in internal cells, they are 9—12 μ wide, i. e. in cross section elongate ellipses. Tangential walls perfectly smooth. In tangential walls of tracheids, especially in the latewood, bordered pits. Pit apertures occasionally flanked by two parallel spirals. Per sq. mm. 20—22 rays and 210—220 ray cells.

R. 3. In radial walls of early *tracheids* commonly two bordered pits side by side at the same height. Only in the last few rows of the latewood are the pits uniseriate, tightly aligned or at larger intervals. Spirals sparse like on the tangential section, pairs spaced 6—8 μ apart. *Rays* consist only of parenchyma cells. Height of *ray cells* 22—30 μ. Horizontal walls partly smooth, partly with definite simple pits. Tangential walls smooth ; indentures well discernible in some cells. Per *cross field* 3—4—5 (6) pits in earlywood tracheids, 4,5 μ in diam. Apertures 2,2 μ wide, linear, and included. Pits minute in relation to cross field area.

VI. DESCRIPTIONS OF THE CUPRESSACEAE BY SPECIES

ACTINOSTROBUS ACUMINATUS PARL.

Pl. 90

Distribution : the southwestern regions of Australia. For the sample the author is indebted to Professor GOTHAN of Berlin. The specimen coming from a branch 6 years old and no material having been available for comparative purposes, the present description apparently requires to be supplemented.

C. 1. Growth rings barely discernible, marked by a few rows of narrow-lumened late tracheids. Walls of early and late *tracheids* of about the same thickness ; lumina in the former 2—3 times as wide as in the latter ; those in the early tracheids narrow gradually in approaching the latewood. Growth rings varying in width, some 10, some 30 cells wide. Tracheids in cross section 4—5—6 sided or polygonal. Latewood tracheids tangentially elongate rectangles. Transverse walls of *wood parenchyma cells* devoid of pitting. *Rays* uniseriate. Some cells barrel-shaped in cross section. Horizontal walls unpitted. Rays and wood parenchyma resinous.

T. 2,4. Ray 1—8—10 cells high. A height of 24 cells is mentioned by PIERCE. For the discrepancy in our findings the fact is probably answerable that the writer's sections were cut from a thinner branch. In cross section the *ray cells* are barrel-shaped, resembling largely those in the *Araucaria* and *Callitris*. All walls perfectly smooth. *Wood parenchyma cells* sporadic; their transverse walls perfectly smooth. In the walls of tracheids the bordered pits few in number, predominantly isolated, very exceptionally biseriate and alternate. Pit apertures oblique, occasionally horizontal, included, from linear to nearly slitlike. Walls of ray cells smooth except for, frequently, a minute glistening dot at the point of contact of the radial walls of ray cells with tracheids.

R. 3. In the walls of *tracheids* pits sporadic, in some early tracheids exceptionally biseriate and alternate. Apertures from oblique to occasionally horizontal. *Rays* 1—6 cells high; all their walls smooth but for an exceptional primary pitting. Per *cross field* 3—4—6 pits, or 12 pits in two vertical rows as seen in the *Ginkgo* and *Araucaria*, respectively. Apertures short-elliptic or linear and always included. When crowded, the pits are polygonal, i. e. quite araucaroid in type. The cells of single-row rays are much taller than those of rays of 2 or 3 rows, and this explains how in the cross field as many as 12 to 14 pits find room in an approximately (but not invariably) alternate arrangement. *Wood parenchyma cells* scarce with transverse walls completely smooth. In the walls of some tracheids very delicate striations of oblique orientation.

ACTINOSTROBUS PYRAMIDALIS MIQUEL

Pl. 91

This species is readily differentiated from *A. acuminatus* by its higher rays and the delicately verrucose surface of its tracheids. Only these two species of *Actinostrobus* are known.

ARCEUTHOS DRUPACEA ANT. et KOTSCHY

Juniperus drupacea Labill

Syrian juniper

Pl. 92

Distribution: Asia Minor and Greece. Sample, a piece from a branch about 10 years old, originates from the Olympus.

C. 1. Growth rings from 20 to 40 tracheids wide, their contour fairly sharp and slightly wavy. Early *tracheids* measure 16 × 18 μ. Radial diameter of late tracheids 6—8 μ, their lumina appear as narrow bands, their walls are 3—4 μ thick. Walls of early tracheids slightly thinner. In cross section tracheids 4—5—6 sided with their corners not rounded, or of irregular shape. *Wood parenchyma cells* occasional, quite thin-walled, with dotlike or elongate pits in the horizontal walls. *Rays* 1—10—15 tracheids apart, following a a radial but slightly winding course; several simple pits in their horizontal walls, and one or two beadlike thickenings in the tangential ones. About 7600 tracheids per sq. mm.

T. 2,4. Tangential walls of *tracheids* commonly smooth, those in the early tracheids sometimes with a few bordered pits, those in the late ones with more. Pit diameter 10—12 μ. Apertures circular or slightly oblique ellipses. *Rays* 4—8 (18) cells high, in cross section round or slightly long-elliptic. *Ray cells* occasionally differ in height within the same ray, the lowest being 10—12 μ, the tallest 22—27 μ high. On the other hand, the cells in single-row rays are 30—37 μ high and 5—13 μ wide. Tangential walls commonly smooth but not infrequently with horizontal and reticular thickenings. *Wood parenchyma cells* present, 10—15 μ in width; their horizontal walls smooth or with 2—3 beadlike thickenings; their radial walls pitted. Per sq. mm. 220—230 rays and 510—520 ray cells.

R. 3. Walls of *tracheids* smooth, apart from sporadic but marked striations in the latewood. Bordered pits in tracheidal walls uniseriate and scattered, 12—15 μ in diameter, with circular apertures. These pits are almost as wide as the tracheids. *Rays* built up exclusively of parenchyma cells with relatively thick horizontal walls displaying a fair number of simple pits and alternately thickened and thinned. Tangential walls at right or slightly acute angles to horizontal ones and smooth or with thickenings appearing as strings of 1—4 beads. Radial walls provided with pits, the oblique apertures of the bordered pits in the tracheids underneath showing clearly through them. Pit diameter 5—6 μ. *Cross field* with 2—3 simple pits, in some taller marginal cells sometimes 4 pits in quadratic arrangement. At the points of contact of tangential with horizontal walls indentures clearly defined. *Wood parenchyma cell* elongate, their horizontal walls with simple pits or thickened to appear as a string of beads. Tangential and radial walls likewise provided with several

simple pits. Where rays and wood parenchyma meet, cross field with 5—7 minute, circular or elliptic, simple pits.

This is the only known species of the genus.

BIOTA ORIENTALIS Endl.

(Thuja orientalis L.)

Chinese arbor vitae

Pl. 93

Distribution : North China, Turkestan. It has been planted since 1752 everywhere in Japan, the whole of Asia, and Europe.

C. 1. By the evidence on the transverse surface the species is not readily differentiated from *Thuja occidentalis*, nor do the longitudinal sections offer a reassuring means of separation. In the specimen examined the latewood was found to be rather narrow consisting of but a few rows of tracheids, with the last of them markedly flattened. *Tracheids* in cross section angular with more or less rounded corners and some intercellular spaces between them. *Wood parenchyma cells* occur predominantly in the latewood, but also appear in the earlywood, where they are often encountered directly on the inner edge of the growth rings. Their walls are thinner than those of tracheids, and in their horizontal walls there already appear definite circular or elliptic pits. About 3200 tracheids per sq. mm.

T. 2,4. In tangential walls of *tracheids* pits fairly frequent and similar to those in *Thuja occidentalis*. *Ray cells* consist only of lignified parenchyma cells, are uniseriate, rarely biseriate, in cross section mostly short-elliptic or circular, occasionally long-elliptic, moreover, in some low rays, quite narrow. The horizontal *ray-cell* walls are the thickest, the tangential walls much thinner and smooth apart from occasional minute projections. Height of rays commonly below 10, exceptionally up to 14—15, cells. Ray cells 10—20 (22) μ in height, 4—9 μ in width. The commonly triangular or quadrangular intercellular spaces between *ray parenchyma* and *tracheids* occasionally with ramifications. The latter are bifurcations next to single-row rays, and branchings in diamond shape next the double-row rays. Since these conditions do not prevail in the *Thuja* ssp., they can to some extent be regarded as differentiating features. Per sq. mm. 120—125 rays and about 410—420 ray cells.

R. 3. Radial walls of *tracheids* with bordered pits, uniseriate in the latewood and occasionally biseriate in the earlywood. Their apertures circular in the earlywood and more eye-shaped in the latewood. In horizontal walls of *ray cells* the pits well discernible. Tangential walls very thin and unpitted, mostly arched towards the cambium. Small indentures present on both sides, as seen in the *Thuja*. Per cross field 1—4 pits in the earlywood, and 1—2 (3) pits in the latewood. Pits generally circular or of the cupressoid type ; in this respect the species slightly differs from the *Thuja*, in which the cross-field pitting is occasionally taxodioid.

This is the only known living species in this genus.

CALLITRIS CUPRESSIFORMIS Vent.

Illawarra mountain pine

Pl. 94

Distribution : Queensland and New South Wales, Australia. Sample obtained from the Division of Forest Products, Melbourne, Australia.

C. 1. Growth rings nearly indiscernible, marked but by a few rows of smaller tracheids. Practically no difference in the diameter of early and late tracheids. Larger tracheids measure 50—70 × 40—50 μ, while the radial diameter of the late tracheids is 35—40 μ. The tracheids vary in width from quite narrow ones to quite wide ones next to one another. These tracheids are in cross section rounded squares, multangular or irregular. Walls 3—4 μ thick. *Rays* 1—10—15 tracheids apart and with dark resinous contents. *Wood parenchyma cells* scattered amongst tracheids, or joined to form terminal *plates* variable in length. The walls are thin, 1—1,5 μ ; horizontal walls perfectly smooth. About 900 tracheids per sq. mm.

T. 4. On tangential sides of *tracheids* only a few or no bordered pits ; their presence is probably due to twists in the tracheids. *Rays* 1—35, commonly 8—10, cells high. Height of *ray cells* 8—22 μ, width 4—18 μ, therefore somewhat elongate ellipses in cross section. Marginal cells occasionally slightly higher. Rays generally uniseriate, but some are biseriate ; for instance, a 7 cells high ray may have 5 paired cells in the body. All ray-cell walls perfectly smooth. *Wood parenchyma cells* relatively frequent and resinous, 28—30 μ in width. Horizontal walls smooth, tangential walls with primary pitting, or very rarely with circular pits 3—4 μ wide, corresponding probably to the bordered pits

of the tracheids back of them. About 25—30 rays and about 220—240 ray cells per sq. mm.

R. 3. Tracheids smooth-walled apart from wide-spaced striations in some of them in the latewood. The bordered pits in their walls solitary or scattered; paired pits occur in the walls of wider tracheids with crassulae clearly visible above and below them. Two pits at the same height are often pressed against each other with the line of contact between them resulting in a vertical. Pit apertures circular or blunt elliptical, occasionally extended. The outlines of the *tori* are well discernible. Radially arranged dots often fused into lines sometimes give rise to peculiar designs in the pit borders. *Rays* composed exclusively of *parenchyma cells* with smooth walls. In some places primary thinnings on the horizontal walls. Tangential walls generally vertical. No indentures. Per *cross field* 1—2 pits, in marginal cells 4—6 pits. Pit apertures measure 6—7 × 3—4 μ; pit diameter about 6—8 (12) μ. All walls of *wood parenchyma cells* entirely smooth, but through the radial walls show the bordered pits in the tracheids back of them. Those pits are 8—9 μ in diameter. The absence of pits from the points of contact of wood parenchyma with ray cells obviously confirms that the radial walls of both these kinds of cells are also unpitted.

About 18 species of *Callitris* are known. Xylotomically, they can be divided in two groups. In the first group belong those species in which on the radial walls of the tracheids the so-called bars of *Kleeberg* are seen to follow a zigzag path; these are: *C. arenosa* A. Cunn., *C. baileyi* White, *C. calcarata* R. Br., *C. glauca* R. Br., *C. gracilis* Bak., *C. propinqua* R. Br., *C. verrucosa* R. Br. (For their short descriptions refer to key on page 89) The second group includes the species without the bars of KLEEBERG in the walls of tracheids, viz.: — *C. cupressiformis* Vent., *C. intratropica* Benth., *C. macleayana* F. Müll., *C. muelleri* (*Parl.*) Benth., *C. oblonga* Rich., *C. tasmanica* Bak. (Based in part upon KRÄUSEL's data. For short descriptions refer to key on page 89)

CALLITROPSIS ARAUCARIOIDES COMPT.

(Neocallitropsis araucarioides (Compt Florin)

Pl.101

Native to New Caledonia. Sample, a thick piece of board, obtained from the place of geographical origin. The only species known in the genus.

C. 1,2. Growth rings variable in width and difficult to distinguish. Some are 4—5, others 20—30, tracheids wide. Transition from early- to latewood and from the late- to the succeeding early-wood so gradual as to be almost imperceptible. In some exceptional increments, however, the early tracheids are considerably larger (25—30 μ) than the late ones (13—15 μ), and their tangential width is 27—45 μ, i. e., they are rather strongly flattened; in such cases the lumina show as narrow slits. *Tracheids* in cross section squares with rounded corners or circular, those along rays sometimes more spacious than the others. *Rays* radially 4—20—25 tracheids apart. All their walls perfectly smooth. *Wood parenchyma* exceedingly scarce, just one or two per section, the cells with resinous contents. About 1500 tracheids per sq. mm.

T. 4. Rays 1—10—12 cells high. Although a height of 24 cells is mentioned by PIERCE the present writer has been unable to detect rays higher than 12 cells. They are commonly uniseriate, with exceptionally 1—2 paired cells in the body. Their walls are very thin, the horizontal and radial walls unpitted. *Ray cells* on the tangential surface subcircular or procumbent short ellipses, but the marginal cells slightly elongated. They are 16—24 μ, those in single-row rays 35, μ high and 15—20 μ wide. In the *tracheids* bordered pits scattered or in rows, 10—12 μ in diameter, their apertures short-elliptic, the tori slightly scalloped. The apertures are occasionally extended and then a peculiar striation appears on the walls of the tracheids, predominantly in the latewood. In the section examined the writer saw but one *parenchyma cell;* the horizontal and radial walls were found to be perfectly smooth. Per sq. mm. probably 35—40 rays and 110—115 ray cells.

R. 3. In the earlywood, walls of *tracheids* with bordered pits, commonly solitary; paired pits fairly frequent and with vertical lines of juncture between them. In places, well-defined crassulae. In the latewood pits mostly scattered, occasionally in tight rows, 13—18 μ in diameter, i. e., larger than those in the tangential walls. *Wood parenchyma* scarce in the section studied, just one or two cells with resinous contents. All their walls very thin and perfectly smooth. *Rays* built up of parenchyma cells only. Not on the closest inspection did the writer succeed in detecting ray tracheids and is therefore unable to corroborate the findings of PIERCE who claims their presence in the heartwood. The writer does not think their existence here is probable. Marginal cells occasionally up to 32—35 μ high. Tangential walls mostly

at right angles to horizontal ones, perfectly smooth and thin. Horizontal walls likewise thin, and although very thin in places yet without definite pitting. Indentures absent. *Cross-field* pits solitary or double, in the marginal cells sometimes 3—4 per field. The cupressoid pits are elliptic, the major axis 7—13 μ, the minor 3—8 μ long. Pit borders clearly defined, but are really those of the bordered pits in the tracheid walls at the back. Occasionally a single pit takes the place of two pits, which is then procumbent- or upright-elliptic. In some instances, a single large pit fills up almost as much of the cross-field area as in *Pinus silvestris* or *Dacrydium franklini*. Horizontal walls devoid of pitting.

CHAMAECYPARIS LAWSONIANA PARL.

Lawson cypress

Pl. 103

Native to California, U. S. A. Sample obtained from New Haven, Conn., U. S. A.

C. 1. Walls of *tracheids* commonly thin in latewood, considerably thinner in earlywood, the former more angular, the latter not infrequently with rounded corners. Since the primary walls are also with rounded corners, intercellular spaces arise between the tracheids which are variable in size and may also vary in shape in dependence on how many tracheids are in contact with one another and in what manner contact is established. Some tracheids have lumina which are regular circles or ellipses, and occasionally both the early and late increments consist of such tracheids, when there is practically no difference between the two. Even the last-formed one or two cell rows are but slightly flattened causing the contour of the growth ring to be almost imperceptible. In other instances, thin-walled angular tracheids are predominant in the earlywood between which there is no possibility for intercellular spaces to arise. The transition of these early tracheids to thick-walled tracheids in the latewood is gradual. In such instances the growth ring contour is sharp. The thin-walled early tracheids greatly vary in amount; sometimes almost none but they are visible throughout the annual increment. Occasionally, normal growth rings are divided in several (4—5) false growth rings by the intrusion of one or two rows of radially flattened tracheids. The phenomenon being definitely attributable to environmental factors cannot possibly possess diagnostical value.

As stated also by HOLLENDONNER (74), exceptionally there arise giant tracheids along with those of normal size. On the section examined the present writer has failed to discover tracheids as large as HOLLENDONNER had even represented by drawings. The largest seen were about 2 or 3 times the size of the adjacent normal tracheids.

Rays uniseriate following a slightly undulating course at various distances from one another. Their horizontal walls are fairly thick and the presence of pits in them is doubtful. *Wood parenchyma cells* frequent not only in the latewood but throughout the growth ring. They are mostly scattered, yet occasionally 2 or 3 rows of them come to be next to one another. Being considerably thinner their walls are readily distinguished from those of the adjacent tracheids. Tangential walls with simple pits. The cells reveal reddish or russet contents. About 7500 tracheids per sq. mm.

T. 2,4. Apart from pitting, walls of *tracheids* smooth. According to HOLLENDONNER pits are fairly frequent in the tangential walls, but on the section examined by the writer one or two were seen to occur sporadically. Tracheids with tapering ends. *Rays* relatively low; 13 cells was the maximum height seen by the present author; typical height 2—4 cells. This finding differs essentially from the data in the literature. HOLLENDONNER reports the specimen he studied contained rays varying in height from 1 to 25 cells. His specimen came from a tree about 15 years old, the present writer's was a piece of a board of several years. According to WILHELM, in an old resinous trunk the typical height was 2—5 cells and rays higher than 10 cells were rare occurrences. ESSNER states the height to be 1—19, and KLEEBERG fixes it at 1—6 cells. The discrepancies in the relative data show that ray height is not a feature of appreciable diagnostic value. The rays are sometimes partly biseriate. In cross section the cells, particularly the internal cells, are almost regular circles. The marginal ones are elliptic. The cells in single-row rays are nearer to lenticular being more or less pointed at both ends. All cells are parenchymatous cells with lignified walls. The tangential walls are devoid of pits, also according to HOLLENDONNER.

R. 3. Radial walls of *tracheids* with bordered pits aligned in one row. The tracheids having narrow walls the pits practically reach across them even in the earlywood. The pits are regular circles. The apertures likewise mostly round in the earlywood, but nearer to long-elliptic or lenticular in

the latewood. The pits in the earlywood have elliptic outer and circular inner orifices. In the latewood the tangential walls of the tracheids, particularly in the last-formed rows, are also provided with a fair number of pits. Tangential walls of *ray cells* perpendicular to the horizontal or making smaller or larger angles with it ; they are straight or arched. At the points of contact the small indentions in the horizontal walls characteristic of most members of the *Cupressaceae* were, in accordance with HOLLENDONNER's findings, not visible in this wood ; only occasional vestiges of them could be seen. In the tangential walls of some cells narrowish pits appear like pinholes in large numbers. Radial walls provided with minute round simple pits to which are attached the half-bordered pits of the tracheids. The simple pits are circular or elliptic. In the latter case they are mostly obliquely oriented, very seldom horizontally, but their apertures are elliptic or lenticular in both the early- and the latewood. (HOLLENDONNER and KLEEBERG claim the apertures to be subcircular in the latewood.) They are oblique, included, and in both increments clearly distinguishable from the border. In the *ray cells*, particularly in the marginal ones, the pits are near the horizontal walls and sometimes cause them to undulate markedly. *Cross field* commonly with 1—3 superposed pits, in the wider cells and in those of single- or double-row cells occasionally with more. (The present writer has observed 4—5 and even 7.) *Wood parenchyma cells* with small circular simple pits in the tangential and radial walls. The apertures of the corresponding half-bordered pits are predominantly slitlike.

About 8 to 10 *Chamaecyparis* species are known. Xylotomically, they can be divided in two not quite convincing groups. The first includes those spp. in which the horizontal walls of rays, although slightly thickened, are without pitting. To this group belong, a. o., *Ch. lawsoniana* Parl. (Pl. 103), *Ch. thyoides* Britt. (Pl. 108), *Ch. formosensis* Mats. (Pl. 102), *Ch. taiwanensis* Masamune et Sufuki (Pl. 107). In the second group the horizontal ray walls are conspicuously pitted, as in *Ch. pisifera* Endl. (Pl. 106), *Ch. nootkaensis* Spach. (Pl. 104), and *Ch. obtusa* Endl. (Pl. 105).

CUPRESSOCYPARIS LEYLANDII DALLIMORE

Pl. 109

The sample, a piece of a branch about 15 years old, was received from the Arboretum des Barres (France). The species is really a hybrid of *Chamaecyparis lawsoniana* and *Cupressus macrocarpa*. Xylotomically, it appears to stand nearer to *Chamaecyparis*, notwithstanding some *Cupressus* features.

C. 1. Growth rings conspicuously distinct. *Tracheids* in cross section commonly squares in the earlywood. Last-formed tracheids in latewood significantly flattened radially with their lumina appearing as narrow slits. Transition from early- to latewood gradual. Horizontal walls of *ray cells* smooth in some places, scattered with minute simple pits in others. Tangential walls commonly smooth. About 4900 tracheids per sq. mm. In some growth rings rows of tracheids at least twice the size of adjacent ones. *Tracheids* in cross section generally square, not infrequently 5—6 sided or of irregular shape, rendering the inner structure varied in appearance. *Wood parenchyma* fairly abundant.

T. 2,4. Rays usually 1—8, exceptionally up to 12, cells high, and uniseriate. *Ray cells* 10—15 μ, those of single-row rays 20—21, μ high and 10—13 μ wide, i. e. rather low upright ellipses. In tangential walls of tracheids, especially in the latewood, bordered pits 8—10 μ in diam. Tangential walls of ray cells entirely smooth and uniform in thickness. Horizontal walls of *wood parenchyma* slightly nodular. In some tracheids almost imperceptible spiral thickenings, occurring singly. Although they are not the same definite thickenings as those seen, for instance, in the *Taxus*, these spiral bars can sometimes be traced through several coils. They are probably correlated with the finer structure of cellular walls. About 80—85 rays and 225—230 ray cells per sq. mm.

R. 3. In the *cross field* 1—2, in the marginal cells 3—4, cupressoid pits, commonly superposed or in quadratic arrangement, but procumbent elliptic pits with barely visible borders are not uncommon. The apertures of the latter are very wide and short-elliptic. In this respect, too, the species under consideration is more reminiscent of the *Thuja* than the *Cupressus*. Horizontal walls of *ray cells* coarse, in places with simple pits ; tangential walls nearly always smooth, very rarely with 1—2 minute beadlike thickenings. Indentures sometimes quite definite. *Transverse tracheids* could not be seen in the section examined. Radial walls of *wood parenchyma cells* with a few circular pits. Per cross field of wood parenchyma and ray parenchyma 3—5—6 small pits arranged irregularly and different in width. Trabeculae rather frequent.

The inner wood structure as a whole betrays hesitancy and indecision. The number of irregularly shaped, distorted cells is great; a feature attributable perhaps to the hybrid character of the wood. Its being a hybrid may also be responsible for the fact that a few rare longitudinal tracheids of irregular shape link up with horizontal ray cells in the same manner as transverse tracheids do.

CUPRESSUS SEMPERVIRENS L.

Mediterranean cypress

Pl. 118

Distribution: Greece, Asia Minor, Cyprus, Iran, Iraq, and Syria. Naturalized to the western Mediterranean.

C. 1. Growth rings indistinct, contours marked only by the flatness of the last formed few rows of late tracheids. Early and latewood not conspicuously differentiated. Walls of tracheids thick, lumina rounded; intercellular spaces few in number. *Rays* fairly close to one another, slightly undulating, commonly uniseriate, sometimes biseriate, their horizontal walls sparsely provided with round simple pits. *Wood parenchyma cells* occur along, or quite near to, the outer edges of the growth rings, predominantly in the latewood, and sometimes in rows. Occasionally, some of these rows adjoin radially to form tangential plates varying in size. Having thin walls, the wood parenchyma cells are clearly distinct from the thin-walled tracheids. About 5200 tracheids per sq. mm.

T. 4. Tracheids without spiral thickenings. Their tangential walls abundantly pitted, especially in the latewood. Pits barely visible, circular or short-elliptic, 6—8 μ in diam. Apertures lenticular (eye-shaped) or slitlike, included, obliquely oriented, and those of complementary pits crossed. *Rays* composed entirely of parenchyma cells, uniseriate, occasionally with one or two paired cells in the body.

Ray cells, in cross section, commonly elliptic with the major axis from 1½ to 2½ the minor axis, seldom short-elliptic or circular. Marginal cells slightly more elongate than the other and pointed. (According to HOLLENDONNER (74) the ray cells are in cross section more often circular and less frequently elliptic). Height of ray cells 13—25 μ, occasionally 35 μ; width 6—15 μ. Intercellular spaces between ray and wood parenchyma cells triangular. Tangential ray-cell walls smooth or with minute, sometimes larger, nodules on them. The height of rays varies from specimen to specimen; hence the divergence of the data in the literature (cf. HOLLENDONNER p. 148). In one specimen the writer found 1—5, in others 1—20, and seldom even 24, cells high rays. About 100—110 rays and 170—175 ray cells per sq. mm. *Wood parenchyma cells* thin-walled, especially the horizontal walls, which are commonly at an oblique angle to the radial walls. On the horizontal walls delicate indentations which on the tangential surface appear as strings of beads. Radial walls provided with round simple pits agreeing in size with the bordered pits in the adjacent tracheids. Cells sometimes with russet resinous contents.

R. 3. In radial walls of *tracheids* bordered pits in one row, 8—13 μ in diam., their borders regular circles or ellipses differing but slightly from circles. Apertures lenticular, oblique, and included. Except for narrower and slightly longer apertures, the pits in the early tracheids are the same as those in the late ones. In the *ray cells* the horizontal walls are the thickest, the tangential walls the thinnest, the latter being perpendicular or at oblique angles to the former and commonly arched; indentures present. Tangential walls smooth or with the small beadlike protuberances mentioned in discussing the tangential surface. In radial walls large round simple pits. The borders of the half-bordered pits in the adjacent tracheids are distinct from the apertures in both the early- and the latewood. The apertures are oblique slits, linear, or eye-shaped, and commonly included, occasionally reaching the pit annulus, but never extended. In the *cross field* commonly 1—2, infrequently 3—4, pits. In the marginal cells and in the fields in the earlywood the pits are as a rule more numerous than in the internal cells and the latewood fields; in the marginal cells their number is 5—6.

About 18—20 *Cupressus* species are known. On the basis of xylotomical evidence it is difficult and doubtful to separate them from one another. Some support for differentiation is afforded in the height of rays. Species with relatively high rays are *Cupressus arizonica* Greene, *C. lusitanica var. Benthami* Carriere (25 μ), and *C. torulosa* (45 μ). Lower are the rays in *C. sempervirens* L. (20 μ), *C. ludley* (15 μ), and *C. duclouxiana* Hickel (14 μ). They are the lowest in *C. funebris* Endl. (10 μ), *C. goveniana* Gord. (10 μ), *C. macrocarpa* Hart. (10 μ), and *C. whitleyana* Carr. (12 μ). (Cf. Pls 110 — 120)

DISELMA ARCHERI HOOK. f.

(Fitzroya archeri *Benth. et Hook.)*

Pl. 121

Native to Tasmania. Sample from the Division of Forest Products, Melbourne, Australia.

C. 1. Growth rings relatively narrow: some only 4—5, the majority 8—10, tracheids wide; even the widest seldom exceed 10—12 tracheids. In this specimen from wood about 50 years old the writer was unable to detect wider growth rings. Contours of growth increments sligthly undulating, indistinct, marked only by the flatness of the two last-formed rows of late *tracheids* (6—8×18—20 μ); in wall thickness there is no difference between them and the succeeding rows of early tracheids. Tracheids in cross section 4—5—6 sided or of irregular shape; in some rows considerably wider than in adjacent ones. Rows occasionally traceable through several growth rings. *Wood parenchyma cells* sparse, their horizontal walls unpitted, sometimes delicately verrucose. Some *rays* traverse 20—25—30 growth increments. They are relatively closely spaced, at from 3—4 to 10—14 tracheid rows from one another. Horizontal walls of *ray cells* with but a few simple pits. The latter relatively short, the length of some not more than the width of 4—5 tracheids. About 5500—5700 tracheids per sq. mm.

T. 2,4. Rays 1—6—8 (10), very many of them only 1—2, cells high. PIERCE mentions the height of 12 cells. *Ray cells* in cross section mostly elliptic or ovoid, marginal ones tending to conical. Ray-cell height 10—24 (27) μ, width 8—17 (20) μ. Lower and higher cells alternate in the same ray. Per sq. mm. 160—170 rays and 330—340 ray cells. *Wood parenchyma* abundant; tangential walls commonly smooth, very rarely with tiny circular or elliptic simple pits which sometimes occur in groups; horizontal walls very seldom smooth, mostly with thickenings showing as strings of beads. Radial walls with fairly clearly definable simple pits. In the late tracheids oblique striae which, however, are not true spiral thickenings. The tangential walls of ray cells are spanned by transverse barlike thickenings reminiscent of the pitting of the *Juniperus* (juniperoid pitting).

R. 3. Apart from the bordered pits in them, radial walls of *tracheids* smooth. Shape of pit dependent upon width of tracheids; in the wider ones the pits are commonly circular, very seldom slightly elliptic, tending to be upright ellipses in the late-wood; yet sometimes they are irregular in shape. Apertures conform to the outlines of the border. Contours of tori well discernible. Pit diameter 6—11 μ. In the tangential walls of the *wood parenchyma cells* circular or procumbent-elliptic simple pits, scattered or in groups of 3—4. Number of pits in radial walls moderate. Horizontal walls smooth or occasionally with 1 or 2 pits. *Rays* composed entirely of parenchyma cells and 3—5 cells high. *Ray cells* rectangular or markedly flat hexagons. Tangential walls nearly perpendicular to horizontal walls, occasionally with beadlike thickenings in them which remind one of the *Juniperus;* indentures not readily discernible. Horizontal walls sparsely pitted or covered with warts varying in size. Number of cupressoid pits in cross field variable: in the earlywood 1—3—5 overwhelmingly irregular in arrangement, in the marginal cells sometimes 5—6 in two superposed rows; pit diameter 5—6 μ. Radial ray walls sometimes appear definitely pitted, at other times one gains the impression it is the pits in the tracheids at the back of them that show through these walls. Apertures occasionally flanked by crescent-shaped borders. At the points of contact of ray and wood parenchyma cells the simple pits are smaller, but more numerous. The closest inspection failed to exhibit *ray tracheids*, though their presence is claimed by PIERCE. This is the only known species in the genus.

FITZROYA CUPRESSOIDES JOHNSTON

Pl. 122

Native to Chile. Sample of Chilean origin, obtained by courtesy of Forstbotanisches Institut of Tarandt, Germany.

C. 1. Growth rings from 8—10 to 18—20 tracheids wide; delineations slighty undulating and fairly distinct due to contrast in size and wall thickness of the few last-formed late tracheids and the succeeding early rows of early tracheids. *Tracheids* in cross section commonly angular, in the earlywood squarish. Radial diameter of early tracheids 40—50 μ, of last-formed late tracheids 12—15 μ; tangential width 35—40 μ. Wall thickness in latewood 5—6 μ, in earlywood 1,5—2μ; the lumina of the outermost late tracheids reduced to narrow slits. Tracheids sporadically interspersed with *wood parenchyma cells* much smaller than the other cells in their environment. Their horizontal

walls provided with tiny pits. *Rays* pursue a slightly undulating radial course lightly interrupted at the outer edges of the growth rings. In all their walls several simple pits. About 1200 tracheids per sq. mm.

*T. 2,4.** In walls of *tracheids* pits very rare, in latewood slightly more in number, scattered, 10—13 μ in diameter, apertures measure 3×5 μ, outlines of tori fairly distinct. On the bordered pits in the tangential walls radially aligned dots. Rays 1—19 cells high. Although the material he tested came from an adult stem higher rays were not seen by the writer. *Ray cells* in cross section circular or upright-elliptic, marginal cells elongate ovoid. They range in height from 20 to 24 μ, some cells in single-row rays attaining 35 μ; width 14—16 (17) μ. Per sq. mm. 40—45 rays and 120—130 ray cells. Tangential ray-cell walls smooth, or with primary pitting, or occasionally with clearly definable simple pits. Radial walls thin and without definite pitting. *Wood parenchyma cells* fairly abundant, up to 32—34 μ in width; their horizontal walls smooth or unevenly nodular; tangential and radial walls occasionally provided with simple pits.

R. 3. In radial walls of late *tracheids* bordered pits scattered, very exceptionally in tight rows, with the lines of contact between them not straights. Pits in early tracheids elliptic, 13×16 μ, in the latewood more circular. Apertures circular. Tori with visible margins. Pit borders present most diverse designs (some of them shown in the drawing on the table); these patterns appear as radial lines or punctations. In no other conifers has the writer seen a similar ornamentation. *Rays* composed entirely of parenchyma cells with simple pits in their horizontal and tangential walls; tangential walls, in cross section, with beadlike thickenings. In the *cross field* 1—2—3 pits, in the marginal cells sometimes 4—8, situated mostly in the corners and measuring 4×5 (8) μ. *Ray cells* occasionally resinous. *Wood parenchyma cells* fairly abundant, 13—14 μ in width; their horizontal walls smooth or with one or two pits; the tangential and radial walls with relatively small simple pits, 4—5 μ in diam. This is the only species known in the genus.

* Magnification of Fig. 4. is not 100 ×, as stated in this Plate, but 300 ×

FOKIENIA HODGINSII HENRY et THOMAS

Pl. 123

Native to East China. Sample obtained from Hong Kong.

C. 1. Growth rings from 10—15 to 30—35 tracheids in width, contours not wavy and rendered fairly conspicuous by from 3—4 to 6—8 rows of radially flattened *tracheids* on the outer face of the latewood. These last-formed tracheids measure $18—20\times6—8$ μ, while those in the succeeding earlywood are $26—30\times20—22$ μ. Wall thickness the same in early- and latewood. Tracheids in cross section rectangular. Wider rows of tracheids sometimes alternate with smaller ones. *Rays* in radial arrangement and from 8—10 to 20—30 tracheids apart. Horizontal walls very seldom pitted. *Parenchyma cells* scattered in the older wood; all their walls smooth or verrucose in different degrees. About 4100 tracheids per sq. mm.

T. 2,4. Rays commonly 1—6, less frequently 6—8 (9), cells high. PIERCE states the rays to be 1—24 cells high, but the present writer has seen none that were higher than 9 rays. *Ray cells* in cross section slightly elongate ellipses, in the marginal cells somewhat taller than in the internal ones: they measure $13—21\times6—13$ μ; their tangential walls smooth or slightly verrucose with the warts sometimes aligned in horizontal rows. Tangential walls of *tracheids* sparsely pitted in the earlywood, but abundantly and densely in the latewood; sometimes 2, exceptionally 3, pits at the same height, but commonly only one; pit diameter 6—10 μ. The lines of contact between 2 or 3 pits at the same height are straights. In some late tracheids the bordered pits are crowded like in the *Araucaria*. *Wood parenchyma cells* conspicuously abundant; their tangential walls very sparingly pitted; the simple pits circular. Horizontal walls smooth or with beadlike thickenings. Radial walls also pitted. At the places where parenchyma cells meet ray cells the former only are pitted, and the latter not, which confirms the absence of a pitting in the radial ray-cell walls. About 60—65 rays and 150—160 ray cells per sq. mm.

R. 3. Rays composed of parenchyma cells only; in cross section, rectangles varying in length, the shorter sides sometimes bulging. Horizontal walls commonly, tangential and radial walls invariably, smooth. In the *cross field* 1—2 (3), in the marginal cells mostly 3—6, pits of 5—6 μ diameter. The apertures in the bordered pits in the tracheids

at the back are commonly long-elliptic and slightly pointed at both ends (6×3 μ). In the cross field of single-row rays commonly 6, occasionally 8, exceptionally 10, pits arranged in two superposed rows. *Tracheid* pitting uni- or biseriate ; pits commonly scarce yet in some places so closely packed that the lines of juncture between superposed pits result in horizontal straights ; pit diameter 8—10 μ. Borders and apertures mostly circular. Fine striae in some parts of late tracheids ; striations intersecting. In such striated tracheids the pit apertures predominantly extended. *Wood parenchyma cells* relatively long and narrow, 6—8—10 μ in width ; their tangential walls smooth or with beadlike thickenings ; tangential and radial walls with sparse simple pitting. In some tracheids *trabeculae*, as a rule at the same height.

Another species in this genus is *Fokienia kawaii* Hayata known from Yunnan. (For its short description cf. key on p. 93)

JUNIPERUS COMMUNIS L.

Common juniper

Pl. 130

Distribution : Europe, North Asia, North China, North America, and North Africa.

C. 1. Resin ducts absent. *Growth rings* variable in width, with contours slightly wavy and conspicuous. Band of latewood darker than that of earlywood. Walls of tracheids thicker in the former than in the latter. Last few rows of late tracheids strongly flattened radially. *Tracheids* in cross section squares or polygonal in the earlywood, with a tendency to rectangular in the latewood. About 4500 tracheids per sq. mm.

T. 2,4. Tangential walls of *tracheids*, particularly those in the latewood near the growth ring limits, provided with several pits, 4—5 μ in diam. *Wood parenchyma cells* scattered in the latewood ; with russet contents ; their walls thin ; they communicate through simple pits with each other, and through half-bordered pits with the adjacent tracheids. *Rays* uniseriate, occasionally biseriate and 1—15, most frequently 3—6, cells high. These figures may vary in dependence on the age and the growth conditions of the tree. Per sq. mm. 90—95 rays and 350—360 ray cells. In cross section *ray cells* short- or long-elliptic ; marginal cells slightly higher than internal cells and triangles with rounded corners. Ray cells 13—22 μ high, 4—6 μ wide : ratio about 3 to 1.

R. 3. In radial walls of *tracheids* pits uniseriate and large, 11—13 μ in diameter, reaching practically across the tracheid ; their borders are distinct even in the earlywood where the apertures are circular, while they are oblique slits in the latewood. *Rays* composed of parenchyma cells only ; their horizontal walls thicker than the others and sparsely pitted unlike, for instance, in the *Abies* spp., where pits are conspicuously abundant. Tangential walls thin with simple pits less in number than in the *Abies* and not round, like in them, but elongated, they display a tendency to being scalariform. Some of these walls are so thin as to render the pits barely perceptible ; in some instances no pits are to be seen at all. Indentures as a rule clearly defined. In the radial walls in contact with tracheids there are pits with very distinct borders. The apertures differ in width in the early- and latewood. In the latter, they are obliquely oriented, linear or lenticular, reaching nearly to the annulus. *Cross field* with 1—4 pits, in the latewood commonly with only 1 or 2, in the taller marginal cells occasionally 4 ; the usually single pit in the internal cells is 6—8 μ in diam.

Interspecific distinction of the *Juniperus* on the basis of xylotomy is a very problematic if not altogether impossible task rendered more difficult by the dependence of some of the features on age, environmental conditions, on whether the specimen comes from a stem or a limb, and so on and so forth. While in some spp. the cross-field pits are remarkably large, they are tiny in others. A feature manifesting itself repeatedly is that the cross-field pits occur singly or in pairs ; if in pairs, then they are side by side or superposed. In distinguishing the species the writer took into account *the height of rays, the shape of the ray cells in cross section, the smoothness or coarseness of the horizontal walls of the longitudinal parenchyma, the size of the bordered pits in the tracheids, the presence or absence of resinous contents in the wood parenchyma cells, etc.* In addition, consideration was given, though somewhat hesitatingly, to such even less reliable features as *the number of tracheids per sq. mm., in the tangential section the number of rays and ray cells per sq. mm. or the ratio of the one to the other, the presence or absence of indentures, the quality of the tangential ray-cell walls, whether they were smooth or displayed dentate or beadlike thickenings, etc.* The tissue structure of about 40 *Juniperus* spp. has been carefully examined, but definite transverse tracheids, or true spiral thickenings in

the walls of longitudinal tracheids have not once been encountered. This permits the conclusion that they do not occur at all in the *Juniperus*, and most probably in the *Cupressaceae* either.

Only *Juniperus communis* is described here as a type, while of the others short descriptions are given in the key. Some of the species studied allow of satisfactory separation on gross inspection, while others have so many macroscopic characters in common that a study of their minute structure, based on well-prepared sections and photomicrographs, cannot be dispensed with. (Cf. p. 97)

LIBOCEDRUS DECURRENS Torrey

(Heyderia decurrens K. Koch)

Incense cedar

Pl. 166

Distribution: California and Oregon, U. S. A.

C. 1. Resin ducts absent. *Growth rings* vary in width, are slightly wavy and distinct with lens but not conspicuously so, for in wall thickness there is no pronounced difference between early and late tracheids, although the last-formed rows of the latter are of a darker colour and flattened. *Tracheids* of medium wall thickness, commonly angular, irregular, seldom with rounded lumina. In cross section, variable from minute to nearly twice the average. In arrangement, irregular; the radial rows which are confluent in some places and ramifying in others, are frequently interspersed with differently sized single tracheids or tracheid rows varying in length. In or near the latewood band, but sometimes in the earlywood as well, the radial rows break up entirely in places and the tracheids re-form to from smaller multiples to fair-sized groups. The *rays* are uniseriate, and while sometimes they end short or are interrupted to traverse less than half the growth ring, at other times they extend across 3 to 4 annual increments. They are spaced at various intervals, the short rays being 2—3, the long ones up to 30—35, tracheids apart. They pursue a slightly undulating, occasionally zigzag course. Their horizontal walls are fairly thick, sparsely provided with round or ovoid simple pits variable in size. *Wood parenchyma cells* abundant throughout the growth ring, mostly solitary with walls thinner than those of the adjacent tracheids; in the tangential walls radially aligned elliptic, less frequently round, pits which give them a scalariform appearance. The parenchyma cells generally agree in size with the tracheids, though sometimes there occur amongst them tubular ones which are larger. About 5500 tracheids per sq. mm.

T. 2,4. In the tangential walls of *tracheids* bordered pits abundant in the latewood, less numerous or wanting in the earlywood; pits in a single vertical row, but sometimes two side by side at the same height; their borders are regular circles and distinct; apertures mostly elliptic or eye-shaped, seldom round, obliquely oriented, and included; pit diameter 6—10 μ. *Rays* composed entirely of parenchyma cells, uniseriate, commonly 1—10, exceptionally up to 18, cells high; rays exceeding 7 cells in height are rare, those between 2 and 4 cells are the most frequent, while one cell high rays are not infrequent. (Hollendonner (74) reports heights ranging from 1 to 6 in limbs, and from 1 to 20 in stems). *Ray cells* 10—22 μ high and 4—13 μ wide, in cross section ovoid, rarely circular. The outer end of the marginal cells is pointed. Tangential walls often appear scalariform because the simple pits, which are procumbent ellipses in shape, are so large as to reduce the wall portions visible between them to narrow bars connecting the radial walls (juniperoid pitting). These bars sometimes deviate from the horizontal, or branch out. Tangential walls of *wood parenchyma cells* provided with medium-sized, round, simple pits, more numerous in the latewood than the earlywood; they communicate with the half-bordered pits in the adjoining tracheids and, accordingly, are larger than the other tangential pits. Per sq. mm. 115—120 rays and 330—340 ray cells.

R. 3. In the radial walls of *tracheids* the bordered pits uniseriate; they touch but exceptionally. For size they depend on the width of the tracheids and usually reach, or nearly reach, across even the wider earlywood tracheids, being correspondingly smaller in the latewood; pit diameter 8—10 (14) μ. Borders commonly round and fairly defined, occasionally flattened and difficult to distinguish. The circular apertures in the pits of the early tracheids pass gradually into the obliquely oriented, elliptic or eye-shaped and included pits of the late tracheids. No essential difference in size between internal and marginal ray cells. Outer edge of ray cells wavy. Tangential walls at right angles to horizontal walls or slightly bent. Indentures present. Radial walls covered with simple pits. These and their complementary half-bordered pits indistinct. Apertures circular, obliquely elliptic, or eye-shaped; in the earlywood wider and more approach-

ing the horizontal, with the borders around them narrow. In the latewood the apertures are narrower, inclined at 45°, and the border is more distinct. The apertures are mostly included, but come fairly near to the pit annulus. In the *cross field* of the internal cells commonly 2—4, of the marginal cells 5—6, pits, mostly arranged irregularly. Pits in the radial walls of wood parenchyma similar to those in tangential walls but more in number. With ray cells the radial walls communicate through simple pits irregular in shape. Late tracheids occasionally striated.

About 10 species are known in this genus. Interspecific differentiation on xylotomical evidence is cumbersome and dubious. Some differences prevail in ray structure. One group can be formed of the spp. in which the horizontal walls of the ray cells are perceptibly pitted ; such are *Libocedrus macrolepis* Benth. et Hook. f. *(-Heyderia macrolepis (Kurz) Li* (Pl. 168), *L. decurrens* Torrey-*Heyderia decurrens (Torr.) K. Koch* (Pl. 166), *L. formosana* Florin *(-Heyderia formosana (Florin) Li* (Pl. 167). To the same group should be counted *Pilgerodendron uviferum* Florin *(Libocedrus uvifera Pilg.)* which, xylotomically, has very much in common with the *Libocedrus* and cannot be separated from them unless by its commonly smooth or slightly nodular tangential walls in the longitudinal parenchyma which walls are more distinctly nodular in the said 3 species. (Cf. key on p. 95) A second group would include the spp. in which smooth horizontal walls in the rays and wood parenchyma cells are the rule ; such are : *L. austrocaledonica* Brongn. (Pl. 163), *L. bidwillii* Hook. (Pl. 164), *L. chilensis* Endl. *(-Austrocedrus chilensis (D. Don) Florin et Boutelje* (Pl. 165), and *L. plumosa* Druce *(-L. doniana Endl.)* (Pl. 169). As regards specific differentiation within each of the two groups, some guidance may be obtained from a study of the photomicrographs.

MICROBIOTA DECUSSATA KOMAROV

Pl. 170

This is the only species in this interesting genus, and there is very little known about it. It was first observed by J. K. SHISHKIN in the region of Vladivostok in 1921. From nowhere else has it so far been reported. KOMAROV, who was the first to describe the genus and the species, respectively, wrote about it as follows :

„Crescit in montibus altioribus provinciae Primorskaja, districti Olginensis a Vladivostok orientem versus in valle fluvii Sutschan magna in copia fruticeta densa in solo lapidoso efformans. Legit J. K. Schischkin 6. jun. et 5. aug. 1921. in monte Chualadsa et 12. jul. 1921. in monte Zamo-diszsa non procul a fossis Sutschanensibus."

To the present writer's knowledge, the genus has not yet been described from the point of view of xylotomy.

The sample, a piece of a branch 7 or 8 years old and about one inch long, was received from the Herbarium of the National Museum of Sweden, by courtesy of Professor FLORIN. It is still being studied. The results of the xylotomical investigations that have been carried out so far on this not wholly ideal specimen, are presented in the following.

On the strength of its external morphology KOMAROV classes *Microbiota* in the subfamily *Thujopsideae*, while PILGER holds it should be referred to the genus *Juniperus*. On xylotomical evidence it appears to stand nearer to *Thuja* than to *Juniperus*, although in some respects it differs from the latter as well.

C. 1,2. Growth rings relatively narrow, probably wider in older wood ; contours slightly wavy, and rendered conspicuous by the 3 to 4 μ thick walls, the radial flatness and, consequently, narrow lumina of the last-formed latewood tracheids contrasting with the but 2 μ thick walls and wider lumina of the succeeding tracheids in the earlywood. Radial diameter of early *tracheids* 13—16 μ ; tangential diameter 16—20 μ. Tracheids in cross section from commonly square or rectangular to not infrequently penta- or hexagonal. They are not always conterminous being occasionally interspersed with tracheids irregular in shape. Radial diameter of late tracheids not more than 5—8 μ. The latewood tracheids are tangentially elongated rectangles with rounded corners. About 9800 tracheids per sq. mm. *Wood parenchyma cells* in the latewood few in number and with walls somewhat thinner than those of the adjacent tracheids, mostly solitary, very rarely in groups of 2 or 3 ; cells with dark contents ; transverse walls devoid of pitting. *Rays* 2—8—10 tracheids apart ; their horizontal walls unpitted or, very rarely, with one or two dotlike pits.

T. 4. Rays 1—7—8 (10), typically 3—4, cells high, in the adult wood probably slightly higher. About 90—100 rays and 300—320 ray cells per

sq. mm.; these figures, of course, offer little of diagnostic value. Rays uniseriate; higher rays occasionally with one paired cell in the body. *Ray cells* in cross section long-elliptic, reminding one of the ray structure in *Thuja occidentalis*. Height of ray cells 13—21 (35) μ, width 7—8 μ; ratio 1 to 2, or slightly higher. Ray cells in single-row rays being 24—26 μ high and only 8 μ wide, the ratio for them is 1 to 3, and this is in conformity with that in *Th. occidentalis*. In *Biota orientalis* this ratio is 1 : 1,5, i. e., the ray cells are almost circular in cross section. Tangential walls smooth, but quite exceptionally with 1—2 very delicate scalariform transverse bars.

Tangential walls of *tracheids* sparingly pitted in the earlywood, much more liberally in the latewood. Pits relatively minute, 7—8 μ in diam.; apertures circular or oblique short-elliptical, commonly included, infrequently reaching the pit annulus. *Wood parenchyma cells* of the same width as tracheids, about 20 μ wide; occurring singly; wall thickness only 1—2 μ; transverse walls smooth or slightly nodular, without conspicuous thickenings. In this latter respect the species under consideration shows greater similarity to *Biota*, in which the transverse walls of the wood parenchyma cells are likewise smooth or rarely bear 1 or 2 small nodules. In the radial and tangential walls, on the other hand, there are several simple pits. The bordered pits, 4—5 μ in diam., which are in the walls of the tracheids at the back of wood parenchyma cells, show through the tangential walls, in which sometimes there appear only simple pits of the same diameter. Parenchyma cells are different in length (80—100—150 μ), and filled with a granulous substance.

R. 3. Rays composed only of parenchyma cells. Transverse tracheids absent. Horizontal ray-cell walls 2—2,5 μ in thickness, delicately uneven in some places, significantly thinning in others, occasionally with a fair number of simple pits. In respect of these features the species is in conformity with *Biota* and *Thuja occidentalis*, and *Thujopsis* as well. Tangential walls perfectly smooth, free even from beadlike projections, in the rarest instances with some local coarseness. In this the said three genera apparently agree. Tangential walls slightly bent towards the latewood. Indentures absent, at least none were observed by the writer, whereas they are present in *Biota*, *Thujopsis*, and *Thuja*. Another point common to this species and the three genera is that in places the horizontal walls part and thereby give rise to intercellular spaces. In the radial walls of rays the pitting, too, differs from that in *Biota*, for while in the latter the cross fields of the internal ray cells commonly contain but one pit, in *Microbiota* they are usually occupied by two superposed pits. Marginal cells present 2 pits in general in *Biota*, but in *Microbiota* there are 3 of them, or even 4 pits superposed in twos; moreover, twice 3 superposed pits can also occur. In this regard the species resembles *Thuja occidentalis*, where the arrangement of pits is more or less the same. Pits cupressoid. Borders visible as two narrow crescents flanking the aperture. Pits are 4—6 μ in diam.; apertures 3—4 μ in width.

In summing up, it may perhaps be stated, that distinctive features affording the separation of *Microbiota* are the following, viz.: that the horizontal ray-cell walls are generally, and the tangential walls invariably, smooth; that the radial walls are devoid of pitting; that the horizontal walls of wood parenchyma cells are also always smooth.

These xylotomical features seem to justify the segregation of *Microbiota*, which on xylotomical evidence has the least in common with the *Juniperus*, wherefore the present writer cannot, at least not on the basis of xylotomy, share PILGER's conclusion, that the *Microbiota* should be referred to the genus *Juniperus* and there assigned a place somewhere near to *J. pseudosabina*, although he of course understands that in the *Microbiota* there are many *Juniperus* traits.

PILGERODENDRON UVIFERUM (Don) FLORIN

(Libocedrus uvifera (Don) PILGER)

Alerce

Pl. 171

Tree native to Chile. Sample, from wood 80—100 years old, obtained through the kindness of Professor ERDTMAN of Stockholm from place of geographical origin.

C. 1,2. Growth rings wavy and distinct, delineated by some rows of flattened thick-walled late tracheids contrasting with the thin-walled and wide-lumened early tracheids of the succeeding increment. Radial diam. of early tracheids, 40—60 μ; tangential diam., 24—28 μ. Radial diam. of late tracheids, 10—12 μ; tangential diam. 20—30 μ. Thin-walled *parenchyma cells* with, commonly dark, contents. *Ray cells* also resinous; their tangential walls with simple pits.

T. 4. Rays 1—20 cells high, uniseriate; the taller ones very rarely with 1 or 2 paired cells in the body. Moderately high rays fairly frequent. *Rays cells* in cross section, from short- to long-elliptic; 16—22 μ in height, 16 μ in width. *Parenchyma cells* clustered in places; their horizontal walls commonly smooth or slightly verrucose, sometimes with 2 or 3 minute nodules. Tangential walls of *tracheids* without spiral thickenings, but with numerous bordered pits in a row. Pits rather minute, 5—6 μ wide; apertures 2—3 μ in diam., commonly included oblique ellipses, but slitlike and almost vertical in the latewood. Occasionally, two pits, not contiguous, at the same height across the tracheids. On the cross section of ray cells, i. e., on the tangential walls, sometimes 5—6 transverse bars visible indicating the presence of minute elevations on the tangential ray walls.

R. 3. In walls of tracheids bordered pits scarce, scattered, and never touching; 14—16 μ in diam.; apertures circular, included; in the latewood vertical ellipses. *Rays* consist entirely of parenchyma cells; marginal cells slightly higher than the others, up to 28—30 μ. Walls of parenchyma cells in rays commonly smooth, exceedingly seldom with sporadic simple pits or locally thinned areas. Tangential wells usually smooth, sometimes with 2—3 beadlike thickenings, which is a *Libocedrus* or cupressoid character, respectively. *Cross field* commonly with 1—2, exceptionally with 3, pits: marginal cells with 3—4 pits as a rule. Pits in the internal cells mostly in a row. *Parenchyma cells* encountered on this surface, too; their transverse walls here again smooth or verrucose, with but very exceptional thickenings. Parenchyma pits 5—6 μ in diam.; apertures oblique, mostly assuming angles of 60—70°. Indentures absent.

TETRACLINIS ARTICULATA Mast.

(Callitris quadrivalvis Vent.)

Alerce

Pl. 172

Distribution: North Africa, Atlas Mountains, the southern regions of Spain and Malta. Only one living species known.

C. 1. Resin ducts absent. *Growth ring delineation* slightly wavy. Latewood darker and denser than earlywood, but restricted to only a few rows of *tracheids*. Late tracheids radially flattened, their walls not much thicker than those of the early tracheids. Earlywood portion of the growth increment excessive. Tracheids in cross section of great variability, from commonly squarish or rectangular with or without rounded corners, to occasionally oval or irregular in shape. They also vary in size and arrangement: rows of larger tracheids alternate with rows of smaller ones; tracheids of different size alternate within the same row; radial rows of uniform tracheids are disarranged by others pervading them occurring singly or also in rows. Occasional intercellular spaces triangular or quadratic. About 1500 tracheids per sq. mm. *Wood parenchyma cells* fairly abundant, distributed chiefly in or near the latewood band but also present in the middle or outer portions of the earlywood; they are missing in the innermost part of the growth rings. Their walls are thinner than those of the tracheids. Horizontal walls without pits, but with many minute elevations (warts) arranged in single rows. *Rays* generally uniseriate, occasionally biseriate, rather closely spaced but, being short and thin-walled, not readily distinguished. At most, they traverse two growth rings and are somewhat wavy. Horizontal walls devoid of pitting and perfectly smooth, occasionally verrucose.

T. 2,4. Tangential walls of *tracheids* provided with numerous bordered pits in the latewood, with less in the early- and transitional wood. Pits fairly variable in size and form; those in the last-formed tracheids which communicate with the first-formed early tracheids are large and round. Apertures from occasionally circular or short-elliptic to more frequently long-elliptic or eye-shaped. The outer orifices normally retain the circular shape, while the inner ones are elongated; the rims of the latter are rounded. Apertures always included. This is best observed on radial sections, on which also the *tori* are well visible in cross section. Pits of the same type are encountered in the inner walls of the first early tracheids; they may even be limited to the earlywood, and only much smaller ones may occur in the latewood. This supposition seems to find support in the fact that occasionally two borders are visible: an inner one which is distinct, and an outer one less readily discernible. These are probably the borders of pits immediately at the growth ring limit, the inner border being that of the latewood pit, the outer that of the half-bordered pit in the early tracheid. Another

type of pit in the tangential walls is much smaller, but the borders are more readily discernible. The apertures are obliquely oriented, elliptical, slitlike, linear, or eye-shaped, frequently reaching the annulus or extended. An abundance of intermediate types between these two types of bordered pits are encountered. *Rays* composed entirely of parenchyma cells, commonly uniseriate, occasionally with a few paired cells in the body; they vary in height between 1 and 17 cells; those higher than 10 cells are rare, while those 1—2 cells in height are frequent. Internal cells of higher rays short-elliptic, subcircular, but marginal cells and cells of single- or double-row rays more elliptic. Tangential walls of ray cells unpitted, but with numerous minute projections, which occasionally fuse to form transverse bars. Intercellular spaces between ray cells and tracheids triangular, but not always present. *Wood parenchyma cells* and tracheids agree in width on the tangential section, but the walls of the former are much thinner. Apart from rare exceptions, the tangential walls in the earlywood are perfectly smooth; in the latewood they are unpitted occasionally, but more frequently provided with circular or elliptical simple pits much smaller than the adjacent bordered pits. Horizontal walls as described in the cross section. Parenchyma cells with a reddish-brown substance.

R. 3. In radial walls of *tracheids* bordered pits usually uniseriate, biseriation frequent in the wider early tracheids, where the pits are more in number and where, exceptionally, two pits and a half are set side by side, in which case the third comes to be placed somewhat higher or lower. Pits regular circles, except for those compressed; the lines of juncture between the latter are straights. Borders as a rule well discernible. Apertures similar to those of the larger pits seen on the tangential section, included, and only three quarters of the border in length; those of complementary pits are often crossed. Along with the larger ones, smaller pits occur in rare instances in the latewood, similar to the smaller pits observed on the tangential section; they are clearly defined, round, 13—18 μ in diam., with slitlike or eye-shaped apertures, reaching the border, occasionally extended. Horizontal walls of *ray cells* somewhat thicker than the tangential walls; the latter mostly at right angles to, or slightly bent towards, the former. Marginal cells always higher than internal cells; the pits always uniseriate in the radial walls of the latter, but biseriate in the marginal cells. (Exceptions very rare.) External surface of walls of marginal cells slightly wavy. In radial walls of ray cells large round simple pits, agreeing in size with the half-bordered pits in the adjacent tracheids. The latter are circular or subcircular, with a tendency to the elliptic in the flattened latewood tracheids; they show faintly, yet are discernible. According to HOLLENDONNER (74), the borders are not visible, the apertures only can be seen. Pit apertures in the earlywood elliptical or eye-shaped, in the latewood similar but somewhat narrower, nearer to linear or slitlike; they are oblique, mostly at an angle of about 45°, canting to the horizontal in the earlywood, and to the vertical in the latewood. Apertures mostly three quarters of the border diameter in length, occasionally reaching the pit annulus in the latewood, but never extended. In the internal ray cells the pits uniseriate, the cross field therefore with one pit in the latewood, and two pits in the earlywood; in the marginal cells 2, occasionally 3, pits in the latewood and 4 to 5 in the earlywood. Horizontal walls of *wood parenchyma* perfectly smooth or with slight beadlike thickenings. Wood parenchyma and ray cells communicate through horizontally elongated simple pits placed close to one another.

THUJA OCCIDENTALIS L.

American arbor-vitae

Pl. 174

Distribution: the eastern regions of the U. S. A. Planted throughout Europe.

C. 1. Resin ducts absent. *Growth rings* slightly wavy and distinct, delineated by a narrow darker band of thick-walled latewood tracheids. Distinction between early- and latewood within the annual increment fairly conspicuous. Last-formed late tracheid rows radially strongly flattened. Both late and early tracheids angular, commonly with but a few intercellular spaces between them, yet in some growth rings the walls are thick already in the first-formed early tracheids with a fair number of large intercellular spaces between them. *Tracheids* in cross section overwhelmingly circular or elliptic. Horizontal walls of *ray cells* provided with circular or elliptic pits. *Wood parenchyma cells* commonly restricted to latewood and few in number; their walls are thinner than those of the adjacent tracheids. About 4600 tracheids per sq. mm.

T. 2,4. Tangential pitting present in the last few rows of late *tracheids*. Bordered pits predominantly scattered, frequently in one row or very rarely paired; pits circular; apertures obliquely oriented, elliptic or eye-shaped, included; those of complementary pits crossed; pit diameter 8—11 μ. *Rays* consist entirely of parenchyma cells; uniseriate, seldom biseriate; commonly 2—6, exceptionally 12, cells high; one-cell high rays rather rare. *Ray cells* in cross section long- or short-elliptic, marginal cells slightly longer and with pointed ends. Circular cells never occur. The tangential walls are the thinnest of the ray parenchyma walls, with no pitting in them, only occasional indentations and elevations; intercellular spaces present and triangular. Per sq. mm. 70—75 rays and 230—240 ray cells.

R. 3. In radial walls of *tracheids* bordered pits in one row, in the widest tracheids occasionally paired. Depending for size on the width of the tracheids, the pits in the narrowest late tracheids are hardly larger than the tangential pits. Pit diameter 10—13 μ. Apertures circular in the earlywood, and circular, or short- or long-elliptic, or eye-shaped, in the latewood; the latter are obliquely oriented and included. Inner and outer orifices practically agree in width. The thickest of the *ray-cell* walls are the horizontal walls in which the pits are clearly defined. Outer pit apertures more rounded. The thinnest are the tangential walls with no definite pitting in them, only very minute protuberances which in cross section make the walls appear as strings of tiny delicate beads. Tangential walls inclined, less frequently at right angles to the horizontal walls. Indentures present. Radial walls also provided with round simple pits. Apertures in the earlywood commonly horizontal, or nearly so, rather wide, eye-shaped or elliptic, with the border around them a narrow ring, to which they sometimes extend. Apertures in the latewood narrow, eye-shaped or linear, sharply distinct from the border, obliquely oriented, commonly included. *Cross field* with 2—5 taxodioid pits in the earlywood, and 1—3 cupressoid pits in the latewood. Tangential walls of *wood parenchyma* smooth or slightly coarse.

Xylotomically, this species greatly resembles *Thuja plicata* D. Don (Pl. 175), which has a range of distribution from Alaska to California. The differences between the two consist chiefly in that the rays in *Th. plicata* are higher, viz.: 5—10 (15) cells; that the ray cells are more long-elliptic in cross section and occasionally 3 to 4 times as high as wide; that in the cross field of the internal cells there are 2 taxodioid pits mostly side by side, whereas in the species under consideration there are 3 to 4 and usually irregular in disposition.

THUJOPSIS DOLABRATA Sieb. et Zucc.

Hiba arbor-vitae

Pl. 176

Native to Japan.

C. 1. Resin ducts absent. *Growth rings* variable in width, some 70 to 75 tracheids wide, fairly conspicuous, delineated by a band of slightly thicker-walled and flattened late tracheids. *Tracheids* in cross section circular or, particularly in the early-wood, elliptic; transition from early- to latewood gradual; walls rather thick; radial rows fairly symmetrical, often traceable through the entire growth ring; some tracheids, even whole rows of them, occasionally remarkably large. Tracheids along ray cells sometimes strikingly large and with somewhat thicker walls than the others. In some instances peculiar groupings of thinner-walled tracheids observable before the commencement of the latewood. *Rays* uniseriate, 3—5—10, sometimes as many as 20—25, tracheids apart. *Parenchyma* fairly abundant in latewood, scattered, conspicuous for orange-red contents; horizontal walls sporadically with minute round simple pits. Wood parenchyma cells rare in the earlywood and barely perceptible. About 5000 tracheids per sq. mm.

T. 2,4. In tangential walls of *tracheids* bordered pits few and scattered. *Rays* uniseriate, very exceptionally biseriate but only in the so-called „large" rays, i. e. those with cells from 2 to 3 times the size of the normal ray cells. Such differing vast-sized rays have not been observed by the writer in any other conifers. Height of *ray cells* commonly 3—5, very rarely 6, cells; tangential walls perfectly smooth, but with delicate striations in opposite directions; radial walls fairly thick and contrasting the tracheid walls in colour. Per sq. mm. 55—60 rays and 130—140 ray cells. Ray cells more or less elongate ovoid. No appreciable difference in the shape of marginal and internal cells. Horizontal walls of *longitudinal parenchyma cells* commonly smooth, occasionally locally thickened and verrucose; tangential walls with bordered pits few in number and 6—8 μ in diam.

R. 3. Bordered pits in radial walls of *tracheids* uniseriate, practically never contiguous, circular,

6—10 μ in diam.; apertures circular or slightly oblique ellipses, included, occasionally extended. Horizontal *ray-cell* walls pitted, tangential walls perfectly smooth and very thin. Indentures well defined. *Cross field* with 4—6, or even 8, pits in the marginal cells of the earlywood, and 2—3 superposed pits in the latewood; pit diameter 5—8 μ. Horizontal walls of *wood parenchyma* perfectly smooth. Radial walls of ray cells in all probability devoid of pits; the pits with oblique apertures appearing on them are those of the adjoining tracheids.

Xylotomically, the species under consideration bears resemblance to *Thuja standishii* (Gord.) Carr. *(-Thuja standishii* Carrière) (Pl. 177). An appreciable difference between the two is the occurrence in the latter of rays with transverse tracheids displaying delicate spirals. Another aid in differentiation is that while in *Th. standishii* the 2 or 3 pits in the ray-cell cross field are usually side by side, in *Th. dolabrata* they are commonly detached or superposed.

WIDDRINGTONIA JUNIPEROIDES (L.) ENDL.
Clanwilliam cedar
Pl. 180

Native to South Africa. Sample from Kirstenbosch.

C. 1. *Growth rings* from 10—15 to 50 tracheids in width, sometimes wavy, in places very markedly so. Transition from early- to latewood gradual. Early *tracheids* 16—18 μ in radial width. Latewood tracheids flattened near growth ring limits and have narrow lumina (10 μ). Tracheids in cross section variable, from squarish to polygonal. Some tracheidal rows markedly wider (20—24 μ) than others, especially those near to, or directly along, rays. *Rays* occasionally pursue a winding course. *Ray cells* relatively short, sometimes bulging bilaterally; tangential walls commonly at oblique angles to radial walls; horizontal walls smooth. *Parenchyma cells* absent from some growth rings, but fairly abundant in others, forming more or less continuous terminal parenchyma chains; horizontal walls perfectly smooth. Number of tracheids per sq. mm. 4500.

T. 2,4. *Rays* 1—6—(30), commonly 6—10, cells high, but 1 cell high rays are no rare occurrence. PEIRCE, in his paper on the „Systematic Anatom of the Woods of the Cupressaceae", reports 1—24 cells high rays whereas the present writer was unable to detect rays higher than 16 cells. In cross section, *ray cells* squarish, rectangular, or elliptic, but marginal cells more often triangular. Height of ray cells 16—24 (44) μ, width 13—21 μ. Some rays with small cells amongst the larger ones. Tangential ray-cell walls smooth or rarely punctate, the tiny warts scattered or aligned along the radial walls or, sometimes, arranged in horizontal rows and giving rise to a reticulate pattern on the tangential walls. Radial walls very thin and unpitted. *Wood parenchyma* fairly abundant in places; cells relatively long-stretched; horizontal walls smooth or slightly verrucose; tangential walls with minute pits occasionally aggregated into groups of varying size or aligned in a double row along the radial walls. In walls of tracheids pits restricted to latewood; pit diameter 12—14 μ; apertures small and round. Per sq. mm. 30—35 rays and 210—220 ray cells.

R. 3. *Rays* consist entirely of parenchyma cells; horizontal walls thin and smooth or sligthly coarse owing to tiny warts on them; tangential walls perfectly smooth; indentures absent. Some tangential walls slightly arched towards the cambium. Radial walls also perfectly smooth. *Cross field* with 2 superposed pits; if with 3 or 4, each one takes a corner as a rule; cross field in marginal cells with 3 to 4 superposed pits or with up to 6—8 pits mostly arranged in twos. *Wood parenchyma cells* fairly abundant: horizontal walls smooth; tangential and radial walls with round or long-elliptic pits. Walls of late tracheids with clearly defined striations.

Six living *Widdringtonia* species are known. Xylotomically, they are best separated by the height of rays in them. The rays are high in *W. schwarzii* Marl. (Pl. 181) with 33 cells, and considerably lower in *W. juniperoides* Endl. (Pl. 180), and *W. cupressoides* Endl. (Pl. 178) each with 16 cells, and *W. dracomontana* Stapf (Pl. 179) with 15 cells. The last-mentioned species and *W. whytei* Rendle (Pl. 182) are characterized in addition by a very delicately verrucose surface of their tracheids. (For further differentiation cf. key on p. 88)

ATHROTAXIS SELAGINOIDES D. DON

King William pine

Pl. 183

Native to Tasmania. Sample, a thick piece from a stem, obtained from Melbourne, Australia.

C. 1. Growth rings from 40 to 70 tracheids, sometimes 2 to 2,5 mm. wide, sharply delineated by radially flattened late tracheids with 4—5 μ thick walls and narrow lumina (10—15 μ). Walls of early tracheids only 1—3 μ in thickness. *Tracheids* in cross section penta- or polygons reminiscent of those in *Abies alba*. Radial diameter of early tracheids up to 60—70 μ, of late tracheids not more than 10—15 μ. *Rays* 2—20 tracheids apart. Horizontal walls of *ray cells* commonly smooth. *Wood parenchyma* fairly abundant, scattered, with a predilection for the earlywood; pits in the horizontal walls absent or very rare, slight local thickenings less rare. Number of tracheids per sq. mm. about 1600.

T. 2,4. Walls of *tracheids* commonly smooth, but most of those in the latewood seem to betray primitive spiral thickenings at varying distances from one another; bordered pits few in the early tracheids, rather more numerous in the latewood; pits relatively small, about one third the width of a tracheid (10—12 μ), predominantly not perfect circles but suborbical; apertures frequently extended, those of complementary pits crossed. *Rays* uniseriate, rarely with 1 or 2 paired cells in the body; height 1—14 cells. *Ray cells* in cross section mostly circular or slightly elliptic, marginal cells occasionally somewhat taller and triangular; tangential walls devoid of pitting. *Wood parenchyma cells* fairly abundant, 25—30 μ wide, with resinous contents; tangential walls occasionally scattered with minute elliptic pits; radial walls unpitted. About 50—60 rays and 230—240 ray cells per sq. mm.

R. 3. In radial walls of *tracheids* bordered pits in single rows in the latewood, in twos or alternating, and close to one another, in the earlywood; pit diameter 11—15 μ; apertures circular or slits, in the latter case from commonly included to occasionally extended. Trabeculae extend sometimes at the same height across as many as 10 to 15 tracheids. *Rays* composed entirely of parenchyma cells; horizontal walls smooth or delicately verrucose, unpitted or with local thin areas; tangential walls at right or oblique angles to horizontal walls; indentures apparently absent. Cross field with 1—2—3 relatively small simple pits side by side, occasionally with 4—6 in quadratic arrangement; pits procumbent or slightly oblique ellipses measuring $5^1/_2 \times 8$ μ. *Parenchyma cells* fairly numerous, 25—35 μ in width, their horizontal walls smooth or slightly verrucose, without definite pitting. Radial walls scattered with minute circular pits.

CRYPTOMERIA JAPONICA D. DON

Japanese cedar

Pl. 184

Native to the south of Japan. Sample, a piece of a board, from the place of geographical origin.

C. 1. Growth rings variable in width, slightly wavy and distinct. Early- and latewood clearly differentiated. Latewood portion of the growth increment for the greater part moderate. *Tracheids* in cross section predominantly squares. Smaller tracheids inserted sporadically among larger ones. Wall thickness in earlywood 1,5—3 μ, in latewood 4—6 μ. Lumina in latewood slightly rounded. About 3600 tracheids per sq. mm. *Rays* difficult to recognize on transverse surface, relatively few in number and as a rule fairly wide apart; some of them traverse several growth rings; their horizontal walls very sparingly pitted. *Wood parenchyma* fairly abundant chiefly in the latewood at various distances from the growth ring limits. Parenchyma cells thin-walled and thereby readily distinguished from the thick-walled late tracheids; scattered or aligned in radial or tangential rows; local thinnings in horizontal walls circular or oval, in the cross section not always visible because of the length of the cells. *Resin ducts* absent. In some growth rings occasional parenchyma proliferation, probably due to adverse conditions during the growing period or some other unfavourable internal or external effect. The cells in them are large and polymorphous have walls thicker than the normal parenchymatous elements with simple pits varying in shape and size, occasionally very large. In the tree these cells are probably resinous.

T. 2,4. Tangential walls of *tracheids* provided with numerous pits, especially abundant in the latewood, 9—11 μ in diameter, commonly in one row, exceptionally in two, circular, with poorly defined borders. Apertures in the earlywood cir-

cular or elliptic, in the latewood eye-shaped or slitlike and included, with many intermediate varieties. Tracheid ends pointed. *Rays* uniseriate. HOLLENDONNER (74) reports the rare occurrence of biseriation. They consist entirely of parenchymatous elements. Height variable, on the whole rather moderate, commonly 3—6, very rarely 8, cells high. In the literature the rare occurrence of 25 cells high rays is mentioned. Tangential ray walls thin, occasionally delicately verrucose. *Ray cells* in cross section short- or long-elliptic, 18—22 μ high, 9—11 μ wide, marginal cells predominantly conical. At the points of contact of tracheids with ray cells, chiefly in the latewood, there are fair-sized intercellular spaces of a triangular or similar shape. In the latewood these are smaller or disappear gradually as the thin-walled tracheids press closer to the ray-cell walls. *Wood parenchyma cells* fairly abundant, aligned to rows occurring singly, or several of them close to one another; horizontal cell walls slightly nodular; the cells communicate with each other through simple, with adjoining tracheids through half-bordered, pits. The latter are smaller than the tangential pits, and their apertures are different in size and shape in the early- and latewood. About 40—45 rays and 150—160 ray cells per sq. mm.

R. 3. Bordered pits in walls of *tracheids* uniseriate, in the earlywood occasionally 2—3 seriate; pits circular, in the narrow-lumened late tracheids lightly flattened; in the earlywood they practically reach across even the widest tracheids; apertures circular, elliptic, linear, or slitlike; when slits, they are obliquely inclined or nearly vertical; pit diameter 13—14 μ. Horizontal walls of *ray cells* relatively thick (1,5—3 μ) and smooth except for sporadic local thinnings; tangential walls perfectly smooth and thin (1—1,5 μ); in the radial walls farily large round simple pits with half-bordered complementary pits in the tracheids. Apertures of variable size and shape; in the earlywood in rare instances nearly as large as the border or the simple pit, respectively, rendering the border itself barely perceptible; normally the apertures are in the earlywood oval or lenticular and divide the border into two crescent-shaped portions. *Cross field* commonly with 1—2 pits in the internal cells, seldom with 3 in the wider marginal cells of the latewood. The tracheids being narrow, the simple pits are usually superposed, and only in the wider cross fields in the earlywood are they rarely side by side. Pit diameter 6,5—8 μ. Indentures occasionally present. Tracheids sometimes with trabeculae, extending in a series at the same height through several growth rings.

CUNNINGHAMIA LANCEOLATA HOOK.

Pl. 185

Native to the southern parts of China.

C. 1. Growth rings variable in width, usually narrow, slightly wavy and distinct. Radial diameter of early *tracheids* 35—80 μ, tangential diameter 30—55 μ, walls only 1,5—5 μ in thickness, lumina angular. Radial diameter of late tracheids 10—20 μ, tangential diameter 30—44 μ, walls 4—7 μ thick, lumina slightly rounded. Intercellular spaces fairly common. Early- and latewood as a rule clearly differentiated, but varying in width; in some growth rings the latewood is restricted to a few rows of tracheids, while others consist almost entirely of thick-walled tracheids with rounded lumina. *Rays* uniseriate, spaced from 1—2 to 40—50 tracheids apart, and following an undulating path. Horizontal walls generally unpitted, very rarely with circular simple pits which are then clearly discernible. *Wood parenchyma cells* fairly abundant in both the early- and latewood. On the transverse surface it is difficult to distinguish them from the tracheids because there is practically no difference in wall thickness, and because the horizontal walls are rarely visible owing to the length of the parenchyma cells. NAKAMURA claims these cells to occur much rather amongst the tracheids in the earlywood than amongst those in the latewood. KLEEBERG reports them to occur frequently, but believes their horizontal walls are smooth. The present writer's findings are to the effect that sometimes there really do occur horizontal walls that are perfectly smooth, but that in their majority they are provided with simple pits smaller in the latewood, quite large and located along the walls in the earlywood. The diameter of the pits is contingent on the width of the cells. Tracheids with trabeculae not uncommon, but resin ducts absent.

T. 2,4. In tangential walls of *tracheids* bordered pits fairly numerous and not confined to the latewood; pit diameter 6,5—9 μ; apertures eye-shaped and included, being only three quarters of the pit diameter in length. On tangential section, tracheids with pointed ends and the radial walls of two adjacent tracheids abundantly pitted. *Rays* consist entirely of parenchyma cells, are uniseriate,

very rarely with one or two paired cells in the body. Rays commonly 8 cells high; the highest seen by the writer comprised 15 cells, although HOLLENDONNER (74) reports 20, and CHANG 30 cells high rays. Internal *ray cells* in cross section circular or subcircular. Marginal cells are at one end, cells of single-row rays at both ends pointed and, having a height from 35 to 40 μ, are from 2 to 2,5 times as high as internal cells, and mostly narrower than the latter. *Wood parenchyma cells* fairly abundant also in the earlywood, occasionally aligned in rows. Walls thin and with rather numerous simple pits. Horizontal walls, which are usually very thin, appear in tangential view as strings of beads. Tangential walls provided with circular simple pits commonly uniseriate, on rare occasions biseriate. Pit rows not straight. To these simple pits half-bordered pits correspond in the tracheids. The bordered pits are larger in the tangential walls of tracheids than the simple pits of wood parenchyma cells and are regular circles in shape. The pit apertures are also circular, but much smaller than the pits of wood parenchyma. Per sq. mm. 100—105 rays and 180—185 ray cells.

R. 3. In radial walls of *tracheids* bordered pits uniseriate. According to HOLLENDONNER, they are occasionally biseriate. Pits circular or tending to be elliptical; pit diameter 9—11 μ, i. e., large enough to nearly reach across even the early tracheids. Apertures mostly slitlike or lenticular and obliquely inclined, rarely from elliptical to circular. These variations more or less obtain in the early- and latewood alike. Occasionally the superposed pits are close enough to touch and form fairly long rows. In relation to their height, *ray cells* short, particularly the marginal cells. Horizontal ray-cell walls thin, 1—2,5 μ. Tangential walls perpendicular or at an oblique angle to the horizontal walls and straight or somewhat arched, commonly smooth occasionally with minute projections or a punctate pitting. In radial walls pits simple, circular or slightly elliptic, 5—7 μ in diameter, i. e., mostly too large for two pits to be side by side in the cross field of even the widest earlywood tracheid. Superposed are commonly two pits, but in the marginal cells three are not infrequent. The simple pits and the half-bordered pits in the adjoining tracheids agree in size. In the earlywood the apertures are large oblique ellipses occasionally extending to the border and dividing it into two distinct crescent-shaped portions. In approaching the latewood, the apertures gradually narrow to become eye-shaped or slitlike (linear) in the last-formed late tracheids; these apertures are always included. In the radial walls of *wood parenchyma* the simple pits are uniseriate and somewhat smaller than the pits in the ray-cell walls.

GLYPTOSTROBUS PENSILIS K. KOCH

Chinese deciduous cypress

Pl. 186

Native to South China. Sample, a fair-sized piece from a stem, obtained from Shanghai.

C. 1. Growth rings vary in width from 5—20—30 to as many as 80 tracheids, and are distinct, though sometimes delineated only by 1 or 2 rows of flattened late tracheids. At other times, the latewood portion of the growth increment is pronouncedly wide. *Tracheids* in cross section squares in the earlywood, rectangles in the latewood. They measure 35—40×25—50 μ in the earlywood, 10—15×25—50 μ in the latewood. In the growth ring the horizontal walls of one or two *wood parenchyma cells* visible occasionally, with 2—8 simple pits in them, commonly biseriate. *Rays* 1—8 or 12 tracheids apart, with a few simple pits in their horizontal walls. Tangential walls mostly at oblique angles to the horizontal walls. About 2200 tracheids per sq. mm.

T. 2,4. In the walls of late *tracheids* numerous relatively small (8—11 μ) bordered pits with linear included apertures vertical in position. *Rays* 1—18 (30) cells high. *Ray cells* in cross section upright ellipses measuring 20—26×9—12 μ. Cells of single-row rays practically fusiform. Marginal cells markedly elongate. Rays uniseriate, rarely with 1—2 paired cells in the body. Horizontal walls relatively thick (1—3,5 μ). *Wood parenchyma cells* fairly abundant, with 3—4 beadlike thickenings in their horizontal walls; some of these thickenings occasionally much larger than the others. In some instances, on the other hand, there are only 1—3 simple pits in the horizontal walls. About 85—90 rays and 300—330 ray cells per sq. mm.

R. 3. Early *tracheids* with frequent paired pits, sometimes aligned in long rows, or with uniseriate bordered pits. Pits procumbent, or nearly procumbent, ellipses with plainly visible crassulae above and below them. Bordered pits 13—16 μ in diam. *Wood parenchyma cells* fairly abundant, long-stretched, narrow (12 μ). Radial walls with several round simple pits. No definite pitting in

the tangential walls. In horizontal walls 1 or 2 occasional pits. *Rays* consist entirely of parenchyma cells. Outward walls of marginal cells very thin and slightly undulating, inward walls thicker, 2—3,5 μ, sometimes only with sporadic local thickenings, at other times with well-visible simple pits. At the points of contact with horizontal walls the tangential walls sometimes widen in the shape of a triangle, wherefore there are no, or only very indistinct, indentures. Radial walls thin. *Cross field* with 1—3—4 simple pits, in the internal fields mostly in twos and side by side, in the marginal cells predominantly 4, which are usually superposed in twos. But occasionally there are 6, and exceptionally even 8, simple pits in the cross field. Pit diameter 6—8 μ. Apertures broad ellipses or full circles (glyptostroboid pitting). Horizontal walls not always smooth, occasionally with warts or elevations variable in size. Tangential walls usually smooth, very seldom with 1 or 2 minute beadlike thickenings. In the cross field of those cells of single-row rays, which are the first cells in the growth ring, there are sometimes 8—10 simple pits (in 5 pairs). Trabeculae fairly frequent, extending sometimes across 8—10 tracheids at the same height.

METASEQUOIA GLYPTOSTROBOIDES Hu et Cheng

Pl. 187

Native to the province of Hupeh in China. This tree has been discovered in 1943. For the sample the writer is indebted to Professor Chang of the University of Nanking. It must have come from a larger stem, for some growth rings were found to be 6—8—10 mm in width.

C. 1,2. Growth rings distinct, delineated by narrow-lumened late *tracheids* being followed by thin-walled early tracheids with larger lumina. Earlywood tracheids in cross section commonly angular, thick-walled latewod tracheids mostly rounded, lumina more elliptic. Radial diameter of early tracheids 65 μ, exceptionally 82—85 μ, tangential diameter 30—40 μ. Radial diameter of late tracheids only 16—18 μ. Wall thickness in earlywood only 1,5—2 μ, in latewood 4—6 μ. Resin ducts absent, but cysts occasionally present. *Wood parenchyma cells* few in number, at any rate in the specimen studied. Horizontal walls of *ray cells* appear to be sparsely pitted. Number of tracheids per sq. mm. 1300.

T. 2,4. Rays commonly 8—10, exceptionally 16—18, cells high, uniseriate, occasionally partly biseriate. *Ray cells* in cross section circular or long-elliptic, marginal cells somewhat longer; height 20—22, exceptionally 24 μ, width 8—12 μ. Tangential walls of *trachsids* with several minute pits, especially in the latewood. Pits scattered and never arranged in straight rows, sometimes clustered into groups, at other times apart from one another. Occasionally 2, exceptionally even 3, pits at the same height in one tracheid. Pit diameter 8—9 (13) μ. Apertures 3—5 μ in diameter, oblique, nearly vertical, always included, with slightly rounded ends. *Wood parenchyma cells* 30—32 μ wide on the tangential side and varying in height, 40—80 μ. Contrary to the findings of Professor Chang, horizontal walls perfectly smooth, except for an occasional primary pitting. In tangential walls of wood parenchyma cells simple pits arranged in two parallel rows, 6—8 μ in diam. Parenchyma resinous. Per sq. mm. 45—50 rays and 260—280 ray cells.

R. 3. In radial walls of *tracheids* bordered pits uniseriate, exceptionally biseriate, in the latter case crassulae well discernible. Pits 20—22 μ in diam. Apertures circular, always included. *Wood parenchyma* about 20 μ in width; horizontal walls apparently smooth also on this section; cells frequently with dark resinous contents. *Rays* composed entirely of parenchyma cells. In the cross field generally 2 taxodioid pits, 7—8 (11—13) μ in diam., the borders divided by the apertures into 2 crescent-shaped parts. Pits in ray parenchyma always in longitudinal rows. Tangential walls entirely smooth, even with no, or rarely a few, indentures. Horizontal walls usually smooth, occasionally with a definite simple pitting. Tangential walls perpendicular or at a somewhat oblique angle to the horizontal walls. The external walls of marginal cells entirely smooth. Some tracheids with trabeculae. *Smooth-walled transverse tracheids* very exceptional (Chang).

SEQUOIA GIGANTEA S. G. Decne

(Sequoiadendron giganteum Buchh.; Sequoia Willingtonia Seemann)

Big tree

Pl. 188

Native to the Sierra Nevada in California. Sample from the University of Syracuse, U. S. A.

C. 1. Growth rings uniform in width; contours markedly undulating, fairly distinct, marked

by darker colour and thicker walls of latewood tracheids. Band of latewood narrow in proportion to that of earlywood. *Tracheids* and their lumina in cross section squarish, last-formed late tracheids flattened. Radial diameter of early tracheids 30—90 μ, tangential diameter 20—60 μ; radial diameter of late tracheids 7—20 μ, tangential diameter 20—60 μ. *Wood parenchyma cells* in the earlywood scattered, their walls thinner than those of the adjacent tracheids, their horizontal walls largely unpitted but not without shallow round indentations and minute wartlike elevations. Horizontal walls of *ray cells* smooth or with minute circular simple pits, in some places numerous, in others scarce. Number of tracheids per sq. mm. 2200.

T. 2,4. Tangential walls of *tracheids* pitted; of the smaller pits occasionally 2 at the same height; they are circular or elliptic; apertures variable in width, obliquely oriented, eye-shaped, commonly reaching the pit annulus, occasionally extended. *Rays* usually uniseriate, sometimes with a few paired cells in the body, exceptionally biseriate. Height of rays 1—20, most frequently 1—10—15, cells. (The data in the literature differ on this point; this fact is also commented upon by HOLLENDONNER; PEIRCE reports heights of 30 cells). Rays consist entirely of parenchyma cells with horizontal walls 2—4 μ, and tangential and radial walls only 0,5—2 μ, in thickness. *Ray cells* 20—24 (28) μ high and 13—15 (18) μ wide. Tangential walls smooth except for occasional shallow indentations or a delicate punctation. Marginal cells sometimes slightly stretched and pointed. Intercellular spaces between the ray cells and longitudinal tracheids triangular or diamond-shaped. Tangential walls of *wood parenchyma cells* provided with round simple pits to which are attached the half-bordered pits of the adjoining tracheids. About 40—45 rays and 200—210 ray cells per sq. mm.

R. 3. In radial walls of *tracheids* pits in one row, 14—17 μ in diameter, regular circles, with apertures circular in the earlywood, eye-shaped and included in the latewood. The *rays*, as has already been mentioned, consist entirely of thin-walled parenchyma cells. It has been noted, when discussing the transverse surface, that some of the thicker horizontal walls are provided with pits. The outer orifices of these pits are commonly widened or rounded off. The radial walls are unpitted or display a primary pitting in the form of shallow indentations. Pit border seldom conspicuous. The pits of the tracheids attaching to the rays are small, roughly corresponding in size to the smaller or medium tangential pits; they are circular or elliptic with narrow eye-shaped apertures in the latewood, which are barely visible because of the but faint outlines of the border. These apertures are invariably obliquely oriented, reach the border but do not extend beyond it. *Cross field* with 1—2 pits in the internal and, very rarely, 4—6 pits in the marginal cells, superposed in the latewood, mostly in two rows one above the other in the earlywood. Radial and tangential walls thickened to the same extent.

SEQUOIA SEMPERVIRENS ENDL.

Californian redwood

Pl. 189

Native to California, U. S. A. Sample comes from the wood collection of the University of Syracuse, U. S. A.

C. 1. Growth rings 8—12 cells wide in some trees, attaining more than 10 mm width in others; contours distinct, delineated by a band of late tracheids with markedly thickened walls. Radial diam. of early tracheids 60—70 or even 80 μ, tangential diam. 40—50 μ. Radial diam. of adjacent thick-walled late tracheids only 12—14 μ. Wall thickness of late tracheids 7—8 μ, early tracheids only 1—1,5 μ. Tracheids in cross section angular or polygonal, only in the last-formed few rows in the latewood with rounded corners. *Wood parenchyma cells* restricted to the latewood and its closest proximity. Cells with dark resinous contents. *Rays* 4—10—15 tracheids apart. About 1150 tracheids per sq. mm.

T. 2,4. Rays 1—35, mostly 14—20, cells in height, uniseriate, sometimes with paired cells in the body; this biseriation in some instances repeats itself 3 or 4 times in taller rays. Simple pits being occasionally visible in the tangential walls of rays, it is evident that these walls *are not invariably smooth. Ray cells* 24—26 μ, internal cells only 14—16 μ, high. Horizontal walls thick, with occasional pitting. Width of ray cells 16—17 μ, that of lumina 11—12 μ. Tangential walls of *tracheids* very abundantly pitted, especially in the latewood; pits generally scattered, exceptionally two pits side by side. Pit diameter 14—16 μ. Apertures short-elliptic, oblique in position. *Wood parenchyma cells* with dark resinous contents, 24—26 μ in

width. The horizontal walls, being commonly smooth or coarse, bear great resemblance to those in *Metasequoia*, which too are smooth or but slightly coarse, only occasionally nodular, and only quite exceptionally display inconspicuous beadlike thickenings. There are, however, no definite thickenings like those in *Taxodium*. Per sq. mm. 30—40 rays and 240—300 ray cells.

R. 3. Bordered pits in radial walls of *tracheids* scattered, two pits side by side a rare occurrence. Pit diameter 16—18 μ. Apertures circular and well discernible. *Ray cells* 22—24 μ, marginal cells up to 40 μ high. *Transverse tracheids* scarce, their inner walls smooth. Horizontal walls of *ray cells* smooth and fairly even or with occasional simple pitting: the double walls are 2,5—4 μ thick. Where they butt into horizontal walls there the tangential walls fan out slightly; they are generlly smooth, in places somewhat thickened. Indentures occasional. In the *cross field* usually 1—2 (3), in the marginal cells 3—6, pits, 6—12 μ in diam. Apertures oblique elliptical, with a minor axis of 6—7 μ, attaining the border, but not extended. Pitting taxodioid. Radial width of *wood parenchyma* 22—24 μ. Pits in the cross fields of wood parenchyma and ray cells absent or only very few in number. Sporadically circular pits, 5—6 μ in diameter in radial walls of wood parenchyma.

TAIWANIA CRYPTOMERIOIDES HAYATA

Pl. 190

Tree native to Taiwan. Samples, pieces from branches 8 to 12 years old, obtained from Hong Kong.

C. 1. Resin ducts absent. *Growth rings* varying in width; contours fairly distinct, marked by 4 or 5 rows of flattened late tracheids. Walls of late *tracheids* relatively thick, 5—9 μ. Some rows of tracheids conspicuous for their size, particularly some of those parallelling rays; tangential walls in these sometimes twice as wide as in the tracheidal rows proceeding along them. *Wood parenchyma cells* encountered occasionally between the last rows of late tracheids. *Rays* 4—5—8, occasionally 12—14, tracheids apart; their horizontal walls unpitted. About 5000 tracheids per sq. mm.

T. 2,3. Rays relatively low: commonly 2—5—8, very rarely above 10, cells high; PEIRCE reports ray heights up to 24 cells; invariably uniseriate; according to PEIRCE, occasionally biseriate. *Ray cells* in cross section short- to moderately long-elliptic; 15—18 (24) μ high; marginal cells sometimes slightly higher; ray-cell width 7—8 μ; tangential walls perfectly smooth. In the *tracheids* of the so-called compression wood, obliquely proceeding and intersecting striations, apparently restricted to the latewood. *Wood parenchyma cells* sparse; as wide as the tracheids; their walls very thin and unpitted; on the horizontal walls occasionally minute elevations. Through the longitudinal walls show the half-bordered pits of the tracheids back of them. In the tangential walls of late tracheids very minute bordered pits, with their apertures occasionally crossed or located inside of, and in the same direction as, the spiral striations. Pit diameter 8 μ. Per sq. mm. 85—90 rays and 200—210 ray cells.

R. 3. Apart from being pitted, *tracheid* walls smooth except for marked striations in the latewood, which appear as continuations of the extended apertures of bordered pits. Pits from sparse to so very abundant that straight lines of juncture result between them. Horizontal as well as tangential *ray-cell* walls only 1—2 μ in thickness and smooth; radial walls probably of the same character. Number of pits in the *cross field*, 1—2; in the internal field, commonly 1; in the marginal cells, 2; if they are wider, then 2—3 or 6. Pit diameter, 6—7,5 μ. In shape, pits elliptic; obliquely inclined. Borders divided by apertures into two crescents. All walls of *wood parenchyma cells* smooth on this surface, too, except for occasional insignificantly thickened areas; cells with commonly reddish resinous contents. In radial walls of late tracheids, pit apertures nearly vertical, conspicuously extended, particularly in the late tracheids, where the orifices sometimes reach across the entire cross field. Pit diameter, 7—8 μ. PEIRCE and some other investigators report indentures; in the sections studied by the present writer none were encountered; the smoothness and thinness of the walls seems to preclude their presence.

TAXODIUM ASCENDENS BRONGN.

Pond cypress

Pl. 191

Distribution the same as that of *T. distichum*. Sample by courtesy of the University of Syracuse, U. S. A.

Basing himself upon the results of his extensive morphological and phytogeographical studies, HARPER concludes that *T. ascendens* is by no means a

variety of *T. distichum*, but an independent species. The xylotomical evidence appears to afford support for this view. The sample the present writer has studied, although it came from a branch about 25 years old, distinctly showed morphological differences from *T. distichum*.

C. 1. Growth rings relatively narrow, contours barely perceptible, delineated by a narrow band of late tracheids. *Tracheids* in cross section more definitely angular than in *T. distichum* or *T. mucronatum*. Radial diameter of early tracheids 22—40 μ, tangential diameter 20—22 μ. Radial diameter of late tracheids only 8—10 μ. As a rule no appreciable difference in wall thickness of early and late tracheids; significantly thicker walls are an exception restricted to late tracheids and accompanied by a rounding off of the lumina. *Rays* 2—8—10 tracheids apart, with relatively numerous simple pits in the horizontal walls; tangential walls smooth. The transverse surface reveals but a moderate number of parenchyma cells and the thickenings on their horizontal walls display a tendency more to the scalariform than to the annular. Per sq. mm. 2300 tracheids.

The tangential surface shows greater similarity to *T. mucronatum* than to *T. distichum*. Walls of *tracheids* abundantly pitted, pits commonly arranged in loose rows. Pit diameter 8—9 μ. Apertures usually circular, or slitlike and obliquely oriented. *Rays* 1—8, exceptionally 9—10, cells high, definitely differing in height from the rays of *T. distichum* and *T. mucronatum*. In places minute simple pits in the tangential walls. *Ray cells* 14—22 μ in height, internal cells 14—16 μ and marginal ones 20—22 μ; width 11—12 μ. *Wood parenchyma cells* few in number; 22—24 μ in tangential width; their radial and tangential walls with simple pits; horizontal walls very seldom smooth, generally pitted or nodular, or covered with projections measuring 2—2,5 μ. *Rays* commonly uniseriate, taller ones sometimes with paired cells in the middle. Per sq. mm. 75—80 rays and 315—320 ray cells.

R. 3. Bordered pits in radial walls of *tracheids* commonly uniseriate, in the earlywood mostly in a loose row, in the latewood sometimes contiguous with horizontal lines of contact between them. Pits 10—12 μ in diam. *Rays* consist entirely of parenchyma cells; transverse tracheids wanting; horizontal walls usually smooth. Rays radially comparatively short, some reaching only across 2—3 (5) tracheids. Tangential walls smooth except for the very rare occurrence of 1—2 minute nodules. At the point of contact of tangential with horizontal walls the former is triangularly thickened, but without indentures. *Cross field* commonly with 1—2 superposed, or 3—4 diagonally arranged pits, 6—7 μ in diam. Pit apertures often difficult to distinguish from the border, but in most instances plainly elliptic, obliquely oriented, and dividing the border into two parts. In cross field between wood parenchyma and ray parenchyma 4—5 elliptical pits in horizontal position. Between the horizontal walls of *ray cells* negative intercellular spaces fairly frequent, also in the line of contact of tangential and horizontal walls. In this respect the species under consideration differs definitely from the two other species mentioned above. The funnel-shaped attachment of the tangential walls to the horizontal walls is particularly characteristic of this species. *Wood parenchyma cells* 8—10 μ in radial width; horizontal walls pitted; radial walls with simple pits 2,5—3 μ in diam. and generally scattered. Horizontal walls comparatively thick, double walls up to 4 μ in thickness.

TAXODIUM DISTICHUM Rich.

Deciduous cypress

Pl. 192

Native to the swamps in southeastern North America. In Europe since 1640 in culture. Sample, a sizeable piece of board, obtained from New Haven, Conn., U. S. A.

C. 1. Resin ducts absent. *Growth rings* conspicuous; contours wavy or taking a zigzag path. *Tracheid* walls thicker in the late- than in the earlywood. Major part of ring width occupied by earlywood with larger tracheids. Late tracheids in cross section squares or radially strongly flattened, that is, tangentially positioned, rectangles. *Rays* uniseriate, rather evenly spaced. Sometimes they are not at right angles to the growth ring demarcations but slightly canting from the perpendicular. *Wood parenchyma cells* occur throughout the growth ring and are easily distinguished from the tracheids by their pitted horizontal walls. In cells located along the ring boundary, the pits, which are fairly large, are commonly aligned in rows, oblong or elliptic, and nearly as wide as the cell, the walls left free between them showing like the steps of a ladder. In the walls of cells situated further inward in the growth ring, these

pits are biseriate or scattered, mostly large, and thus differ considerably from the usual minute pits in the wood parenchyma walls. About 1000 tracheids per sq. mm.

T. 2,4. In the tangential walls of the late *tracheids* near the outer face of the growth rings, numerous bordered pits, with obliquely oriented slitlike apertures. *Wood parenchyma cells* abundant throughout the growth ring, with russet or reddish contents, aligned in 1 or 2 longitudinal rows, different in length, some hardly twice as long as wide, others 5 to 6 times their width in length. Walls thin. Horizontal walls perpendicular to the tangential and radial walls. In their tangential walls, depressionlike simple pits complement the half-bordered pits in the adjoining tracheid walls. *Rays* composed entirely of parenchyma cells, commonly uniseriate, occasionally with 1 or 2, rarely with 4 or 5, paired cells in the body; they are generally 1—20, occasionally up to 30—40, or even more (60), cells high. *Ray cells*, in cross section, circular or short-elliptic; in height, 18—20 μ; in width, 10—12 μ. Cells markedly flattened where ray biseriate; the two cells together very slightly wider than the one cell in the uniseriate ray. Marginal cells conical. Per sq. mm. 50—60 rays and 350—360 ray cells.

R. 3. Early *tracheid* pitting 2 to 3, occasionally 4, seriate; pit diameter, 12—14 μ. Paired pits not uncommon. Pit apertures round or short-elliptic, with pointed ends, obliquely oriented. Radial walls of *wood parenchyma* narrower than the tangential walls and likewise with depressionlike pits. Adjoining wood parenchyma and ray cells communicate through radially extended large simple pits. *Ray parenchyma cells* radially much elongated. Thickest of their walls are the horizontal walls (3—4 μ) equipped with simple pits. Tangential walls smooth, and abutting perpendicularly, obliquely, or in an arch, on the horizontal walls. Indentures absent or barely perceptible. Radial walls with circular simple pits, about the size of those in the wood parenchyma and somewhat larger in the early- than the latewood. Apertures of half-bordered pits in the adjacent tracheids distinct from the border throughout the growth ring; they reach the pit annulus. Number of pits in the cross field, 2 to 6; in the marginal cells, occasionally 8. Pit diameter, 5,5—8 μ.

Marginal ray cells taller than internal cells; cross fields, according by larger, with, sometimes as massy as 8 pits in them.

TAXODIUM MUCRONATUM Tenore

Mexican cypress

Pl. 193

Distribution: the mountains of Mexico at levels ranging from 1400 to 2300 metres, predominantly on the shores of rivers. The sections examined were prepared from a stem, 4 cm. in diameter.

C. 1. Growth rings distinct. Latewood only a few tracheids wide. Radial width of early *tracheids* 35—40 μ, of late tracheids only 8—10 μ. Tangential diam. 30—35 μ. Tracheids in cross section rounded tetra- or polygons, in the earlywood mostly angular. Occasionally one or two growth rings are traversed by several parallel rows of tracheids with differently sized tracheids inserted amongst them. Rays 8—10—25 tracheids apart, some of them conspicuously wide (16—18 μ). In horizontal walls of *ray cells* simple pits relatively frequent; tangential walls completely smooth. Rays frequently resinous. *Wood parenchyma cells* scattered; their transverse walls mostly with scalariform, exceptionally with sievelike, thickenings. In this latter respect the species under review slightly differs from *Taxodium distichum* in which the transverse walls are predominantly sievelike. Per sq. mm. 1800 tracheids.

T. 2. 4. Rays lower than in *T. distichum*, height 1—12, commonly 8—10, exceptionally 20—22—26, cells. Per sq. mm. 65—70 rays and 280 ray cells; these figures do not necessarily hold good for the adult wood. Rays uniseriate, taller rays with 1 or 2 paired cells in the body. *Ray cells* 20—22 μ, those in single-row rays up to 30—36 μ high. Internal ray cells 18—20 μ in height. Hardly any ray cells less than 16 μ in height. Ray cells 16—18 μ in width, sometimes resinous. Horizontal walls of rays thick (2—4 μ) with 1—2 pits in them. Tangential walls always smooth. Tangential walls of *tracheids* with numerous bordered pits. Pits scattered, only one, exceptionally two, pits at the same height, and never connected. Pits 9—11 μ in diam. Apertures either circular or very short elliptical and oblique in position, about 2 μ in diam. *Wood parenchyma cells* resinous; their horizontal walls, which are smooth in the rarest instances only, commonly display 2—3, occasionally up to 5, nodules or pits; the radial and tangential walls are provided with round simple pits up to 2—3 μ in height.

R. 3. In radial walls of *tracheids* bordered pits scattered or very seldom contiguous. Commonly

only one pit at the same level of height in the tracheid, in some earlywood tracheids exceptionally two. Pits 13—15 μ in diam. Apertures circular or markedly short-elliptic. *Rays* composed entirely of parenchyma cells ; *transverse tracheids* wanting. Horizontal walls of *ray cells* commonly smooth, somewhat coarse, occasionally with a few simple pits. Tangential walls perpendicular or at an oblique angle to the horizontal walls. Indentures absent or very obscure. In the *cross field* 1—2—3—4 taxodioid pits, generally in a horizontal row, in the marginal cells 3—4 pits commonly clustered. Pit diameter 8—10—11 μ. Apertures elliptic, oblique or horizontal, 6—7 μ long and 2,5—3 μ wide. Radial diameter of *wood parenchyma cells* 10—12 μ, their horizontal walls nodular. Radial walls with simple pits, 6—7 μ in diam. Several simple pits in the cross field of wood parenchyma cells and rays.

APPENDIX

PHEROSPHAERA HOOKERIANA ARCHER

Pl. 194

Tree native to Tasmania. Sample, a 6 to 8 cm piece from a trunk, by courtesy of the Division of Forest Products, Melbourne, Australia.

C. 1,2. Growth rings relatively narrow : from 18—20 to at most 30 tracheids apart ; delineations rendered conspicuous through 5 to 6 rows of flattened late *tracheids* which, however, agree in wall thickness with the succeeding rows of early tracheids. Radial diam. of early tracheids, 14—16 μ ; tangential diam. 16—18 μ. Radial diam. of late tracheids, 6—8 μ. Tracheids, in cross section, procumbent rectangles, squares, occasionally polygonal. *Wood parenchyma cells* sparse and scattered ; horizontal walls unpitted, except for 1 or 2 occasional simple pits. *Rays*, in their radial course, sometimes considerably widened, almost barrel-shaped ; from 2—3 to 7—8—10 tracheids apart. Tangential walls not always perpendicular to the radial walls, sometimes abutting on them at acute angles of 30° to 40°. Horizontal walls commonly smooth, very rarely with 1 or 2 minute pits. In tangential walls, 2 or 3 beadlike thickenings, especially when assuming acute angles to the horizontal walls.

T. 4. Rays 1—6, very rarely 8—9, most frequently 1—2, cells high. *Ray cells*, in cross section, subcircular ; marginal cells more ovoid. Height of ray cells, 12—14 μ ; width, 10—12 μ. In the tangential walls commonly 5—8 simple pits, usually aligned in a row near the radial walls. Occasionally, the pits in these walls elliptic, as wide as the ray cells, displaying an almost scalariform pitting. Walls of longitudinal tracheids smooth, apart from oblique striations confined to the latewood. *Parenchyma cells* among the tracheids fairly abundant, 10—12 μ wide. Horizontal walls smooth or verrucose, but occasionally with beadlike thickenings. Tangential walls sometimes provided with fairly numerous simple pits in a row. Radial walls with pits much less in number.

R. 3. In the *tracheid* walls, the bordered pits scattered and 6—8 μ in diam. ; border outlines nearly procumbent ellipses ; apertures conforming to the border outlines, commonly obliquely inclined, and reaching the pit annulus. *Parenchyma cells* fairly abundant. Radial walls with rather numerous round or elliptic simple pits, scattered or in clusters of 3 or 4. Tangential walls commonly smooth, occasionally with 1 or 2 pits or nodules. *Cross field* with 5—6 simple pits. Horizontal walls of ray cells usually smooth, occasionally with simple pits at different distances to one another. Tangential walls perpendicular to the horizontal walls or abutting on them obliquely. In the *cross field*, 2—3 subcircular simple pits, measuring 6—8 $\times$ 2—4 μ ; in the internal cells, mostly 2 superposed simple pits short-elliptic in outline in the earlywood, and upright, slightly pointed ellipses in the latewood. Some late tracheids with dense spiral striation.

In conclusion, the xylotomical features of *Pherosphaera* are in various respects similar to those in the *Cupressaceae*, yet at the same time they include many of the characters of the *Taxodiaceae*. Since *Pherosphaera* in its external appearance, flower structure, and alternate leaf arrangement, shows a greater likeness to the *Taxodiaceae* than to the *Cuppressaceae* with their verticillate leaves and whorled cones, the writer has for the time being referred this species, in an appendix, to the first-mentioned family.

SAXEGOTHAEA CONSPICUA LINDL.*

Prince Albert's yew

Pl. 195

Distribution: Patagonia and South Chile. For the sample, a piece of a branch 8 years old, the writer is indebted to Professor GOTHAN of Berlin.

C. 1,2. Growth rings relatively narrow, from 6—8 to 30—40 tracheids in width, probably different in the adult wood; contours distinct, marked by the contrast of the thicker-walled and narrower-lumened late tracheids, on the one hand, and the early tracheids with a considerably greater diameter, on the other hand. Transition from early- to latewood commonly gradual but there occur growth rings in which the seasonal increments are barely differentiated, the growth rings consisting almost entirely of thick-walled tracheids. *Tracheids* in cross section tetragonal. *Rays* from 3—4 to 15—20 tracheids apart, uniseriate; horizontal walls with numerous circular pits; tangential walls unpitted or very sparsely pitted. Tangential walls of parenchyma cells with minute pitting in some places.

T. 4. Rays 1—7 cells high in the young wood studied; height of 1—2 cells were found to be the rule and 6—7 cells rare exceptions. *Ray cells* in cross section long-elliptic; radial walls very thin; horizontal walls markedly thicker and occasionally with simple pits. In tangential walls of *tracheids* pits commonly in interspaced vertical rows, occasionally two pits side by side. *Wood parenchyma cells* conspicuously numerous, with minute, circular pits in their tangential walls arranged in vertical rows. Pits also distinct on radial walls. Horizontal walls with 1—2 nodular thickenings, or perfectly smooth.

R. 3. In radial walls of *tracheids* pits normally in single longitudinal rows, exceptionally in two rows and alternate, producing an araucaroid type of pitting. *Rays* 1—7 cells in height. Horizontal walls of taller rays markedly pitted; sometimes there are irregular spinulose or nodular thickenings to be observed on them; external walls entirely smooth; tangential walls commonly likewise smooth, very rarely with 1—2—5 beadlike thickenings. Cross field with 1—2 superposed pits, marginal cells sometimes contain 3, possibly 4, pits. The pits being circular and the apertures obliquely oriented the pitting is typically *cupressoid*. Pits relatively large. In the cross field of ray parenchyma and wood parenchyma up to 6—7 simple pits. Indentures occasional.

VIII. DESCRIPTIONS OF THE PINACEAE BY SPECIES

Abies species

ABIES ALBA MILLER

[A. pectinata LOUD]

European silver fir

Pl. 196

Distribution: Central and South Europe.

C. 1. Resin ducts absent. Growth rings wide; contours distinct, marked, on the one hand, by a difference in the radial diameter of the early and late tracheids, on the other hand, by the conspicuous thickness of the walls of the last-formed late tracheids. The secondary walls of the late *tracheids* are strongly thickened, contrasting sharply with the thin-walled early tracheids. Due to the thick walls the lumina of the late tracheids are rounded, elliptic or circular, while those in the early tracheids are more definitely angular. The latewood is restricted to a small portion of the growth increment. Transition from early- to latewood gradual. About 1200 tracheids per sq. mm. *Rays* uniseriate, from 1—2 to 14—15, or more, tracheids apart. Horizontal walls of *ray cells* abundant with round simple pits, more so in the latewood where, however, they are larger. Pits commonly scattered, occasionally aligned in regular rows of a different length. In narrower cells there is usually but one row at about equal distances from the radial walls. In wider cells occasionally two rows which are then nearer to the radial walls. *Wood parenchyma cells* located in the latewood near to, or exactly on, the border between the early and late

* This genus is commonly referred to the *Podocarpaceae*, but the xylotomical evidence in no way confirms its position in that family. There are departures of diagnostic significance: the horizontal walls of rays are markedly pitted, while the tangential walls are not invariably smooth. For this very reason, *Podocarpus nubigenus* Lindley- *Saxegothea gracilis* Hort. (Pl, 195a) should be refered to this group. Although its systematic position still awaits clarification, it is perhaps safe to assume in anticipation that the genus belongs to the family of the *Taxodiaceae*.

tracheids. They vary in number from tree to tree and from growth ring to growth ring. Their walls are thinner than those of the adjacent late tracheids, but roughly agree in thickness with the early tracheidal walls. Abutting horizontal and end walls scattered with simple pits, i. e., these walls are more or less sievelike. The pits are circular, elliptic, or lachrymiform and larger than the ray-cell pits.

T. 4. Pits commonly restricted to the walls of the late *tracheids;* according to HOLLENDONNER, exclusively to those along the growth ring limits. The present writer, on the other hand, found them in fair numbers scattered in the earlywood, or aligned in rows varying in length. Depending on the width of the tracheids, sometimes two pits at the same height. Pits here generally smaller than on the radial walls (6—8 μ) ; the borders circular and indistinct. Apertures slitlike or eye-shaped, about 3/4 the length of the pit diameter, obliquely or nearly vertically oriented, sometimes almost parallelling the long axis of the border ; those of complementary pits frequently crossed. *Rays* uniseriate and consisting entirely of parenchyma cells ; 1—30, typically 10—12, cells in height. (WIESNER and HOLLENDONNER claim the height of 1—40 cells). *Ray-cell* walls thick, the tangential walls sievelike. Pits numerous and scattered, occasionally less in number but larger in circumference. In cross section ray cells circular or elliptic, marginal cells conical, sometimes with a blunt end, both commonly 10—21 (27) μ high, but occasionally attaining twice this height. Intercellular spaces occasional. Tangential walls of *wood parenchyma cells* with round simple pits agreeing in size with the borders of the corresponding half-bordered pits in the tracheids. The pits are of the same size as, or slightly smaller than, the pits in the tangential walls of the longitudinal tracheids. Their apertures are slitlike or eye-shaped and included. Per sq. mm. 50—55 rays and 370—380 ray cells.

R. 3. In radial walls of *tracheids* the bordered pits commonly occur singly, paired pits are rare occurrences. Pit size and width of tracheids are proportionate ; with the narrow late tracheids go smaller pits than with the wider tracheids in the earlywood. Pits regular circles, 13—16 μ in diam. The bordered pits which in the early tracheids form close longitudinal rows varying in length are more or less flattened and, consequently, become ellipses with their major axis at right angles to the long axis of the tracheids, i. e., procumbent ellipses. In rare instances, two pits at the same height are contiguous. The apertures of the early pits conform to the border outlines and the rings around them are caused by the tori. In the early wood the apertures are only 3/4 the length of the border diameter ; in approaching the outer face of the earlywood they lengthen until they reach the pit annulus or are extended. Apertures of complementary pits form X figures. In some tracheids trabeculae present. In radial walls of *wood parenchyma* simple pits with corresponding half-bordered pits in the adjoining tracheids. Borders as large as the simple pits. Apertures, in dependence on whether the pits are located in the early- or the latewood, nearly vertical slits, or ellipses or circles almost equal in size to the borders. In the former case the borders distinct, in the latter almost imperceptible. *Ray cells* thick-walled and with contents that are sometimes reddish-brown. Some cells with rectangular crystals, predominantly in the marginal cells. Rarely, the outward horizontal walls of the marginal cells slightly undulating. Tangential walls perpendicular to the horizontal walls or inclined to them at various angles ; in both cases they can be straight or arched. Inner orifices of the simple pits in the horizontal walls commonly angular, occasionally from slightly to markedly rounded. The pits in the radial walls are compounds of the simple pits in the ray-cell walls and the half-bordered pits of the adjoining tracheids ; their borders, circles corresponding in size to the simple pits ; the apertures of those in the earlywood, almost as large as the borders, elliptic or lenticular ; the apertures of those in the latewood, narrow, slitlike, vertical or nearly so, usually extending to the border, not infrequently beyond it. In the earlywood, the borders distinct ; in the latewood, appearing as a narrow ring around the apertures. In the *cross field* 1, in the wider marginal cells of the latewood exceptionally 2, pits; in the earlywood, occasionally 2—3—4 pits. Pits mostly in twos at the same height but at intervals of at least 2—3 pit diameters; this is a feature which to some extent is an aid in identification.

A similar ray structure can be seen in the following spp., viz. : *Abies balsamea* Mill. (Pl. 198), *A. concolor* Lindl. et Gord. (Pl. 202), *A. cephalonica* Loud (Pl. 199), *A. grandis* Lindl. (Pl. 206), *A. homolepis var. umbellata* (Mayr) Wilson (Pl. 208), further *A. lasiocarpa* Nutt. (Pl. 211), *A. procera* Rehder (Pl. 220), *A. spectabilis* (D. Don) Spach (Pl. 223), *A. venusta* K. Koch

(Pl. 226). It needs to be mentioned that with the last-mentioned 4 species *A. alba* agrees not only in ray structure but also in the mean height of rays which in the 4 species commonly is 35 to 45 cells as against 15 cells or slightly more in the first-mentioned 5 species. On the other hand, it must be borne in mind that being subject to variations in dependence on the age of the tree or on whether the wood is from a stem or a limb, ray height cannot be regarded as a constant specific character.

ABIES BALSAMEA Miller

Balsam fir

Pl. 198

Distribution: the northern regions of North America, ranging from the Atlantic to the Pacific Ocean; identical with the distribution of *Picea alba*.

C. 1. The transverse surface shows this wood to be considerably denser than that of *A. Alba* and *A. grandis*, owing to the smaller size of its tracheids, the number of which per sq. mm. is much larger in this species (5000) than in the other two (2100 and 2800, respectively). *Wood parenchyma cells* are located along the growth ring limits, where they sometimes form a continuous band. In this region there also occur large-sized distorted parenchyma cells, some of them with brownish contents, some others bearing rectangular or quadratic crystals. The cells of rays which traverse such a band usually change their normal shape, become disfigured and expand in width; not infrequently they grow wider than long. When this is the case the rays may become biseriate. Such bands of parenchyma probably still belong to the latewood; frequently thick-walled tracheids can be observed amongst them. They probably have bearings on the *resin cysts* described by Hollendonner in the latewood. However, cysts as represented by Hollendonner by his resolute drawings, the present writer has failed to detect.

T. 2,4. Rays commonly 5—7, even the tallest only 10, cells high. Per sq. mm. 45—50 rays, considerably more than in *A. alba* (50—55) and *A. grandis* (40—45), and 180—210 ray cells. In tangential walls of *tracheids* pits less in number than in *A. alba*, but of the same shape although smaller because of the smaller tracheids.

R. 3. The species under review differs from the two aforementioned spp. in the pitting of the radial ray-cell walls. In the latter the apertures in the latewood are extended, in the former not invariably, and if so, in a lesser degree. The pit apertures in *A. balsamea* are not as wide as in *A. amabilis*, and considerably narrower than in *A. arizonica*. *Wood parenchyma cells* variable in shape, more abundant than in most of the other *Abies* species. Those in the surrounding resin cysts commonly differ from the others in shape and wall thickness; they are mostly irregular polygons with walls thicker than those in the other parenchyma cells and the simple pits in them are elliptical or biconvex, occasionally circular. Normal parenchyma cells rectangular and generally shorter than those in the *Abies* spp. described in the foregoing, though occasionally equally long and narrow. Walls as thin as those of the ray parenchyma cells. The scattered simple pits mostly circular and roughly of the same distribution in all the walls. Cells resinous. Some parenchyma cells crystalliferous; these are usually very long, with both ends tapering, thin-walled, and unpitted.

Approximately similar xylotomical features prevail in *A. concolor* Lindl. et Gord. (Pl. 202), *A. grandis* Lindl. (Pl. 206), *A. homolepis var. umbellata (Mayr)* Wilson (Pl. 208), and *A. cephalonica* Loud. (Pl. 199), with which *A. balsamea* agrees primarily in the structure and height of rays, while from *A. venusta* K. Koch (Pl. 226), *A. spectabilis* Spach (Pl. 223), and *A. procera* Rehder (Pl. 220) it differs mainly in ray height.

ABIES CEPHALONICA Loudon

Grecian fir

Pl. 199

Distribution: Greece and the Ionian islands, especially the island of Cephalonia.

C. 1. Transverse section roughly the same as in most *Abies* spp. *Growth rings* and the latewood band within them variable in width; contours slightly wavy. About 6500 tracheids per sq. mm.

T. 2,4. In tangential walls of *tracheids* apertures of pits commonly elliptical or eye-shaped, occasionally circular, 6—8 μ long, included, very rarely reaching the pit annulus. They are obliquely inclined, occasionally horizontal as in *A. amabilis*. *Rays* 1—13 cells in height. Internal cells circular or short-elliptical in cross section, marginal cells more elongate. According to Hollendonner, there occur biseriate rays. Per sq. mm. 115—120 rays and 370—380 ray cells. *Ray cells* 13—21 μ, some of those in single-row rays up to 54 μ in height; width 8—13 μ.

R. 3. In radial walls of *tracheids* bordered pits uniseriate, 9—15 μ in diam., occurring singly, occasionally two or three continguous, usually circular, in the narrow late tracheids flattened. Apertures normally round, in the latewood sometimes elliptical or eye-shaped, always fairly wide and included. Pit borders frequently with radial striation, especially in the earlywood. Some *ray cells* short, but amongst marginal cells upright forms not uncommon. Indentures present. Per cross field 3, occasionally 5, pits. External walls of marginal cells mostly wavy, due to the proximity of pits. Horizontal walls of *wood parenchyma* pitted.

ABIES CONCOLOR LINDLEY et GORD.

Colorado white fir

Pl. 202

Distribution : the Highlands of California, U. S. A.

C. 1. Transverse surface the same as in *A. cephalonica*, and largely similar to that in the other *Abies*. HOLLENDONNER reports the frequent occurrence of resin cysts near growth ring limits identical with those in *A. balsamea*. In the material available to the present writer, longitudinal parenchyma cells were not encountered. About 4500 tracheids per sq. mm.

T. 2,4. In tangential walls of late *tracheids* pits in fair numbers, 6—8 μ in diam. Pits regular circles, occurring singly, arranged in one row. Apertures narrow, eye-shaped, their length about 3/4 of the pit diameter, obliquely inclined ; those of complementary pits occasionally crossed. In some instances, the inner aperture is elongated, reaches the pit annulus, or is extended. In others, particularly in striated tracheids, lines in X form and shining with reflected light under the microscope are visible in the apertures ; these lustrous lines agree in direction with the apertures and, because they extend considerably beyond the borders, make the latter appear as slits vastly extended in length. In reality, they are but anomalous cracks and related to the striae in the tracheids ; this must be so, for they can also be seen in the unpitted areas of the tracheids; obviously, the phenomenon is one connected with the finer structure of the walls of tracheids. On these grounds, *A. concolor* is to be referred to that group of the *Abies*, in which the pit apertures in the tangential walls of tracheids are included.

Rays 1—12 cells high in the material examined. (The section was prepared from a fairly thick branch.) *Ray cells* elliptical in cross section. Biseriate rays very rare. In every other respect the tangential surface agrees with that in the other *Abies* species. Per sq. mm. 65 rays and 280—290 ray cells. Height of ray cells 8—13, exceptionally 27 μ, width 4—8 μ.

R. 3. In the radial walls of early *tracheids* pit apertures regularly circular, 6—8 μ in diam. ; in the latewood circular, elliptical, or eye-shaped. Inner apertures, including those in striated tracheids, of the same structure as discussed in connection with the tangential surface. Margins of tori well discernible. Marginal *ray cells* very variable in shape from upright to distorted. Outer walls follow a zigzag line or are slightly wavy with sporadic locally thickened areas. In the earlywood pit apertures remarkably wide, the faint borders commonly showing as quite thin crescents. Not infrequently the pits are elliptical or wide and eye-shaped, while the apertures are circular, looking as if capped by the borders on both sides. Pit apertures occasionally extended. Some larger elliptical pits with two smaller elliptical or circular pit apertures. In the latewood pit borders and apertures commonly resemble those in the earlywood, but narrow elliptical or eye-shaped apertures are more frequent and are generally extended. On the basis of these pits *A. concolor* could be included in those species of *Abies*, in which the pit apertures in the radial walls of rays are extended. Yet, these apertures do not resemble those observed in *A. alba* or *A. grandis*, since in the latewood they are not as narrow, nor do the tangential pits agree with the tangential pits in *A. alba* and *A. grandis*. *Cross field* with 1—3 simple pits, 3—8 μ in diam. ; they do not always come to lie near the outward walls of marginal cells. Those located near to the walls and those in contact with them, cause the walls to undulate in a limited degree. Calcium oxalate crystals in some of the last-formed latewood tracheids, as well as in marginal cells. No *wood parenchyma* in the section examined.

ABIES FIRMA SIEB. et ZUCC.

(A. momi SIEB., A bifida SIEB et ZUCC.)

Japanese fir

Pl. 204

Distribution : Japan, East China, and Korea.

C. 1. The transverse surface largely agrees with that in the other *Abies*. *Wood parenchyma*

was absent in the specimen examined. Per sq. mm. 1000 tracheids.

T. 2,4. In the tangential walls of *tracheids* pits abundant in the latewood, circular, 8—9 μ in diam., seldom contiguous, and variable in size, even within the same tracheid. Margins of *tori* well discernible within the borders. Pit apertures small, circular, short-elliptic or eye-shaped, always included. *Rays* 2—10 (12) cells in height. *Ray cells* in cross section elliptical, the internal cells of taller rays sometimes nearly circular. Ray cells 10—21 (30) μ high and 7—10 μ wide.

R. 3. Pit apertures in radial walls of *tracheids* circular in the earlywood, circular or elliptical in the latewood, but occasionally there occur eye-shaped apertures. In radial walls of *ray cells* pits circular or elliptical. Pit apertures large and conforming to the outlines of the border, reaching the latter, but never crossing it. Narrow, eye-shaped or slitlike apertures are not seen on this surface. The border appears as a narrow ring around the aperture or is divided by it into two crescent-shaped portions ; it is in either case difficult to discern. In the *cross field* 1—2 simple pits, in the very high marginal cells generally 3—4 pits, 4—5 μ in diam. Last-formed late tracheids as also marginal cells occasionally crystalliferous like in *A. concolor.*

The group of *A. firma* primarily includes the species, in which in the earlywood there are commonly 1—2, rarely 4, pits in the cross field and mostly superposed. Such spp. are : *A. nephrolepis* Maxim. (Pl. 215). *A. numidica* De Lannoy (Pl. 217), *A. pinsapo* Boiss (Pl. 219), *A. veitchii* Lindl. (Pl. 225), *A. koreana* Wils. (Pl. 210).

ABIES FRASERI Poir.

Fraser's balsam fir

Pl. 205

Distribution : Allegheny Mountains in North America.

C. 1. The transverse surface agrees with that in the preceding *Abies* species.

T. 2,4. In tangential walls of *tracheids* pits less in number than in *A. firma.* Borders very faint, barely discernible, 6—9 μ in diam. Pit apertures narrow, eye-shaped or linear, about 3/4 the pit diameter in length, occasionally extending quite near to the border or reaching it, obliquely inclined at angles less than 45°. *Rays* 1—11 cells in height. *Ray cells* in cross section lenticular, with both ends slightly pointed, and of only three quarters or half the width of those in the *Abies* species discussed in the foregoing. The same conditions prevail even in the internal cells of the tallest rays, and wider ray cells or cells with blunt ends are very rare occurences. Marginal cells slightly taller than internal ones. Ray cells 10—16 μ in height, 5—8 μ in width. Per sq. mm. 60—70 rays and 180—200 ray cells.

R. 3. In radial walls of *tracheids* pits and apertures circular in the latewood. Where, as a very rare departure, the pits are subcircular there the apertures are elliptical or, occasionally, wide and eye-shaped. The pits in the radial *ray-cell* walls are similar to those in *A. firma*, i. e., circular or elliptical, with apertures large both in the early- and the latewood and the borders barely discernible around them. In the *cross field* 1—4 pits, occasionally more in the marginal cells. *Wood parenchyma* was not detectable in the material examined.

The group of *A. fraseri* includes the following species : *A. holophylla* Maxim. (Pl. 207), *A. nordmanniana* Spach (Pl. 216), *A. sachaliensis* Mast. (Pl. 221), in which there are generally 2, occasionally 4—6, smaller pits in the cross field, mostly superposed. Superposition may be a trait peculiar in many cases to young wood. To this group may also be referred *A. chensiensis* Van Tieghem (Pl. 200), *A. pindrow* Spach (Pl. 218), *A. squamata* Mast. (Pl. 224), and *A. vilmorini* Mast. (Pl. 227).

ABIES GRANDIS Lindley

(A. exelsior Franco)

Giant fir

Pl. 206

Distribution : from Vancouver Island and British Columbia to Northern California.

C. 1. It is exceedingly difficult, if not impossible, to distinguish this species from *A. alba* by the structures visible on the transverse surface, not even by the number of tracheids per sq. mm. The material studied by the writer only permits the statement that while the latewood zone occupies about two thirds of the growth increment in *A. grandis*, it is only one third or one quarter, or even less, in *A. alba* and that while early- and latewood are fairly conspicuously differentiated in the former, the transition is very gradual in the latter. Unfortunately, these are features known to be without diagnostic value. Number of tracheids per sq. mm. 2800.

T. 2,4. The tangential surface brings out some differences in the height of rays, the maxima being 14 cells in *A. grandis* and 40 cells in *A. alba.* The typical ray height in *A. grandis* is 5—10 cells. Additional slight differences manifest themselves in the number of rays per sq. mm. which is 40—45 for *A. grandis* against 50—55 for *A. alba*, and in that of ray cells which is 250—260 in the former against 370—380 in the latter. These numbers appear to be specific constants.

R. 3. This species and *A. alba* also agree in respect of the radial section. *Wood parenchyma* sparse.

ABIES HOLOPHYLLA v. UMBELLATA Wils.

Manchurian fir

Pl. 208

Distribution : Southeastern Manchuria.

C. 1. Transverse surface the same as in the *Abies* spp. discussed previously. True, the walls of the *tracheids* are slightly thicker, but this is probably the effect of environmental conditions, since this wall thickness changes from tree to tree and even within the same individual. Tracheids with more than usually wide lumina encountered sporadically. Number of tracheids per sq. mm. 6200.

T. 2,4. Tangential pits confined to the last-formed rows of late *tracheids*, and there more numerous on the walls facing the succeeding early-wood tracheids. Tangential walls of other latewood tracheids very rarely pitted. Pits circular, sometimes nearly imperceptible. Pit apertures rarely circular, mostly eye-shaped or slitlike and then obliquely inclined or, not infrequently, nearly or actually horizontal ; alway included. *Rays* 1—10 (12) cells high. *Ray cells* in cross section slightly wider than in *A. fraseri*, yet not attaining the width and shape general in the other *Abies* species. Marginal cells not infrequently elliptic, occasionally with pointed ends. Height of ray cells 13—18 (27) μ, width 4—6 μ. Per sq. mm. 110—120 rays and 280—290 ray cells.

R. 3. In radial walls of *tracheids* bordered pits mostly ellipses variable in shape and size, only in the earlywood sometimes circular. Pit apertures rather large in the earlywood and assuming the same shape as the pits, the borders therefore faintly show as narrow rings around them. Sometimes the apertures are elongated, reach the pit annulus and divide the border into two thin crescents. Occasionally there occur elliptical pits with circular apertures, the latter looking as if capped by the border on two sides. In the latewood pit apertures smaller than in earlywood, mostly elliptic or eye-shaped, occasionally linear, but still narrower forms also frequent. Some apertures extended. Radial structure of *tori* occasionally well discernible. In marginal cells the pits are so very near the outward walls as to cause deep hollows and high crests in them. *Cross field* commonly with 1—3, rarely with 4, pits, 4—6 μ in diam. *Wood parenchyma* restricted to the growth rings near the central pith, but there fairly abundant.

ABIES LASIOCARPA Nutt.

(A. subalpina Engelm.)

Alpine fir

Pl. 211

Distribution : from 49° N. L. to Alaska.

C. 1. Growth rings varying in width ; contours fairly wavy. Early- and latewood conspicuously differentiated, primarily through discrepancy in wall thickness. About 2000 tracheids per sq. mm.

T. 2,4. In tangential walls of *tracheids* apertures of bordered pits circular, elliptical, or eye-shaped, included, and mostly small. *Rays* 1—12 (30) cells high. *Ray cells* in cross section narrow elliptic or lenticular, some markedly elongate ; short-elliptic or circular cells very rare. Marginal, and even some internal, cells with tapering ends. About 35—40 rays and 450—460 ray cells per sq. mm. Height of ray cells 12—20 μ, exceptionally 40 μ.

R. 3. In radial walls of *tracheids* apertures circular in the earlywood. In the latewood outer apertures mostly circular, inner ones elliptic or eye-shaped and included. In radial walls of *ray cells* apertures large in the earlywood and assuming the shape of the circular or elliptic pits with the borders as barely perceptible narrow rings around them. In the transition zone and in the latewood these apertures gradually narrow until they are eye-shaped or slitlike and well differentiated from the border which is rather indistinct in these zones. These apertures reach the borders, and not infrequently extend beyond them, when they appear as lustrous spots or tiny sticks on both sides of the borders. Pit apertures obliquely inclined, nearer to the vertical than to the horizontal. In some instances, the pit apertures are not slitlike in the latewood, but wider and eye-shaped like in

the earlywood. Close proximity of the pits to the external walls of marginal ray cells often causes hollows and corresponding crests in these walls. *Cross field* with 1—3 pits, 4—6 μ in diam.

ABIES MAGNIFICA A. MURRAY

(-A. nobilis magnifica MAST.)

Californian red fir

Pl. 214

Native to California, U. S. A.

C. 1. Transverse surface largely the same as in the other *Abies* spp. In the latewood zone of one of the *growth rings* in the material examined hollow spaces very similar to resin ducts were encountered in one row at the same height. Presumably they were but resin cysts such as are common in some other *Abies*. For the most part they were found to be circular in cross section and lined with thin-walled parenchyma cells bearing simple pits different in shape and size. *Wood parenchyma cells* fairly numerous around the resin cysts and amongst the tracheids. Per sq. mm. 5000 tracheids.

T. 2,4. Tangential pitting confined to last-formed late *tracheids*. Pits fairly numerous, circular, 8—10 μ in diam. Inner apertures commonly circular, outer apertures occasionally elliptic or lenticular, up to three quarters the pit diameter in length, slightly oblique, but not infrequently nearly or actually horizontal. *Rays* 1—15 (27), mostly 3—6, cells in height. *Ray cells* 10—18 (27) μ high and 5—12 μ wide ; in some instances 2—3 times as high as wide. Although ray cells lenticular or eye-shaped in cross section are not uncommon, elliptic cells are more frequent than, for instance, in *A. fraseri* or *A. holophylla*. Per sq. mm. 90—100 rays 390—400 ray cells.

R. 3. In radial walls of *tracheids* pits uniseriate, occasionally contiguous, 8—13 μ in diam. Apertures from circular in the earlywood to elliptic or eye-shaped in the latewood, mostly oblique, included. Marginal *ray cells* from procumbent to upright, occasionally deformed. Bordered pits in radial walls circular or short-elliptic. Apertures in the earlywood larger and wider ellipses, commonly included, sometimes extended ; borders indistinct. Apertures in the latewood narrower, eye-shaped or linear ; borders distinct. In the *cross field* 1—3 pits, in that of the taller upright or deformed marginal cells sometimes 4—5 ; pit diameter 4—5 μ. Outward walls of marginal cells wavy due to proximity of pits. Some of the last-formed late tracheids bear calcium oxalate crystals.

Having commonly 1—2 pits in the earlywood cross fields, and mostly 2 superposed pits in the fields of the marginal cells, the following spp. can be included in the *A. magnifica* group : *A. amabilis* Forb. (Pl. 197), *A. cilicica* Carr. (Pr. 201), *A. fabri* Craib. (- *A fargesii* Franch.) (Pl. 203), and *A. lowiana* A. Murr. (- *A. cencolor v, lowiana* Lemm.) (Pl. 213).

ABIES NEPHROLEPIS MAXIMOVICZ

(- A sibirica nephrolepis TRAUTV.)

Pl. 215

Distribution : Manchuria and the region of the Amur.

C. 1. This surface the same as in the other *Abies* spp. Per sq. mm. 5000 tracheids.

T. 2,4. Tangential pitting sparse and restricted to the last latewood *tracheids*. Pits circular, 5—8 μ in diam. Apertures circular, or from elliptical to eye-shaped and then obliquely or sometimes horizontally oriented and included. *Rays* 1—12, typically 2—5, cells in height. *Ray cells* in cross section wider than those in *A. fraseri* or *A. holophylla*, attaining roughly the width normal to the *Abies*. Short-elliptic or circular cells frequent, long-elliptic cells and cells with pointed ends less so, apart from marginal cells and cells of single- or double-row rays. Height of ray cells 13—20 μ, width 4—8 μ.

R. 3. Bordered pits in radial walls of *tracheids* circular or procumbent elliptic, with the apertures conforming to the outline of the border. Inner apertures markedly elongated, particularly in the latewood, but always included. *Ray-cell* pittings similar to that in *A. holophylla* and *A. magnifica*. Bordered pits generally elliptical or circular in shape. Pit apertures rather large and wide in latewood, and frequently extended. Despite the proximity of pits external walls of marginal cells not perceptibly wavy. Commonly 1—3 (4) simple pits in the cross field in the wider marginal cells, occasionally more (5). Pit diam. 4—6 μ.

ABIES NORDMANNIANA SPACH

Caucasian fir

Pl. 216

Distribution : Western Caucasus and the Armenian Plateau.

C. 1. Wood fairly dense ; about 5000 tracheids per sq. mm. In the specimen examined *wood paren-*

chyma was found to be very sparse, and in some growth rings to be missing altogether. This, however, is not a constant criterion for differentiating.

T. 2,4. Rays 3—8, typically 3—6, occasionally 1—2, exceptionally 15, cells high. *Ray cells* 10—18 (27) μ in height, 5—8 μ in width.

R. 3. Rays generally short. Pit apertures in radial walls of *ray cells* much wider than those in *A. alba*, but always included. By this feature the species is readily distinguished from *A. grandis* and *A. alba*. The cells being taller, the number of pits per *cross field* is greater than in the *A. alba* group. In internal cells there are commonly 2, in marginal cells 2—3, superposed pits, accordingly in all 4—6 pits to the cross field, but normally not more than 1—3 ; pit diameter 2—5 μ.

In addition, this species differs from the *A. alba* group by the presence in it of radially vestured bordered pits with apertures circular or occasionally short-elliptic, even in the latewood, but never linear or slitlike as in *A. alba*. Also, they are invariably included, whereas in *A. alba* they extend to the pit borders and occasionally beyond them. In this respect *A. nordmanniana* is similar to *A. lasiocarpa var. arizonica*.

ABIES NUMIDICA De Lannoy

Algerian fir

Pl. 217

Native to Algeria.

C. 1. Growth rings, and within them the seasonal increments, variable in width. Growth ring limits slightly wavy and distinct. Early and late *tracheids* conspicuously differentiated through discrepancy in wall thickness. *Rays* comparatively closely spaced, but of rather uneven distribution and varying in length ; some traverse but a few cells, others several growth rings. As a rule, they are fairly wide, occasionally attain the width of tracheids. Their walls are thick and provided with numerous simple pits. These commonly circular or subcircular and relatively large simple pits align in a row along each radial wall. In some cells they are larger and mostly transversely elliptic ; they are then scattered or disposed in a row in the middle of the horizontal walls. Occasionally lachrymiform, lenticular, or eye-shaped pits are encountered. *Wood parenchyma* present, distributed along the growth ring demarcation in both the early- and latewood. Number of tracheids per sq. mm. approximately 6000.

T. 2,4. Tangential walls more liberally pitted in the last latewood *tracheids*. Pits uniseriate, but in the wider tracheids occasionally two pits occur at the same height. Pit apertures circular, long- or short-elliptic, or eye-shaped, oblique or horizontal, and the longest of them extending to the borders. Pits 10—15 μ in diam. In the tangential walls of *wood parenchyma* the half-bordered pits similar to the pits in the tangential walls of tracheids, the pit apertures may however be extended. *Rays* relatively numerous, 1—15 cells high, but heights above 10 cells very rare. *Ray cells* wide and answering to the general *Abies* type. In cross section they are circular or short-elliptic. Lengthwise elongate cells very rare even amongst the marginal cells, and cells with pointed ends occur only amongst marginal cells and in single-row rays. Tangential walls fairly pitted ; pits commonly circular, occasionally procumbent elliptical or of irregular shape. *Ray cells* 10—18 (32) μ high and 5—13 μ wide.

R. 3. In radial walls of *tracheids* bordered pits circular or elliptical and then commonly horizontal in position ; 10—15 μ in diam. Pit apertures rarely circular, generally elliptical or eye-shaped. Not infrequently the inner apertures are substantially increased both in length and width, they are then eye-shaped or elliptic, and reach the border or cross it. The latter feature particularly characterizes inner apertures dissymetrical in relation to the border, i. e., with one end extended, the other remaining included. Such apertures occur both in the early- and the latewood. *Ray cells* elongate or quite short, or even higher than long. Marginal cells slightly larger than internal cells, some of them irregular in shape ; their outward walls slightly wavy. Bordered pits in radial walls circular or elliptical. Pit apertures in the earlywood wide and fairly large, elliptical or eye-shaped, the narrow borders around them show faintly. Pit apertures in latewood somewhat narrower and usually extended ; borders more distinct. Despite the close proximity of pits, outward walls of marginal cells not wavy. In the *cross field* generally 1—3 pits ; in the upright marginal cells sometimes more (4—6). Pit diameter 4—6 μ. Pitting in the radial walls of *wood parenchyma* similar to that of the rays.

ABIES PINSAPO Boiss.

Spanish fir

Pl. 219

Distribution : Spain, the province of Malaga.

C. 1. Transverse section eminently of the *Abies* type without any appreciable departures. Per sq. mm. about 8000 tracheids.

T. 2,4. In tangential walls of last *tracheids* in the latewood, pits 6—8 μ in diam. and uniseriate with exceptionally two pits in the body. Apertures rarely circular, mostly elliptical or eye-shaped ; the latter forms are peculiar to the inner apertures, the former to the outer apertures. Apertures oblique in position and included. *Rays* 1—10 cells high. *Ray cells* circular or short-elliptic in cross section (*Abies*-type). Some marginal cells, as well as cells of 1—2 row rays markedly elongated, occasionally 2—3 times the height of internal cells. Ray cells 13—18 (27) μ high and 6—13 μ wide.

R. 3. In radial walls of *tracheids* outer pit apertures circular, inner apertures, predominantly in the latewood, from occasionally elliptic to commonly eye-shaped and mostly included. Pit diameter 13—18 μ. Apertures of pits in *ray-cell* walls in the earlywood nearly as large as, sometimes larger than, the border ; circular or elliptic, the border around them showing but faintly. In the latewood they are narrower, occasionally slitlike and extended. External walls of marginal cells slightly wavy due to the closeness of pits. In the *cross field* 1—3 (5) pits, 4—8 μ in diam.

ABIES SACHALIENSIS Mast.

Pl. 221

Distribution : Sakhalin Island and Japan.

C. 1. On the transverse surface walls of *tracheids* fairly thick. Earlywood zone commonly very narrow. Number of tracheids per sq. mm. 10 000, probably varying with the age of the wood. Undoubtedly the species is one of the *Abies* of the densest structure.

T. 2,4. Like in other *Abies* spp., pits commonly confined to the tangential walls of the last latewood *tracheids*. Pit diameter 5—6 μ. Pit apertures variable in length, obliquely inclined, elliptical or eye-shaped, and included. About 210—220 rays and 340—350 ray cels per sq. mm. *Ray cells* 13—18 (27) μ in height, 4—8 μ in width.

R. 3. In radial walls of *tracheids* pits 10—12 μ in diam. Occasional trabeculae, extending across one or two tracheids only. A modest number of cells in some tracheids on the growth ring limits crystalliferous. In the *cross field* 2—3 pits of relatively small size, 3—4 μ in diam.

ABIES SIBIRICA Ledeb.

Siberian fir

Pl. 222

Distribution : the central and northern parts of Asia, the Ural mountains, and the region of Lake Baikal.

C. 1. Growth rings variable in width ; in some rings alternating zones of narrow and broad increments are visible. The latewood zone, too, varies in width ; the contours of the growth rings are wavy. *Rays* relatively closely spaced. About 7500 tracheids per sq. mm.

T. 2,4. Tangential walls of last-formed late *tracheids* sparsely pitted ; pits 5—6 μ in diam., borders rather indistinct. Apertures short-elliptic or eye-shaped and included, rarely circular. The *rays* differ in height from those in most of the *Abies* spp. discussed in the foregoing. While in the latter they are at most 10—15 cells high, in *A. sibirica* the maximum height frequently exceeds 15, and occasionally 20, cells. All these data refer to samples of young wood. In very rare instances 1 or 2 paired cells in the body of the ray. About 100—110 rays and 860—870 ray cells per sq. mm. *Ray cells* in cross section long- or short-elliptic, occasionally to some extent angular or acuminate ; they are not quite as short and broad as, for instance, in *A. pinsapo*. Ray-cell height 13—18 (40) μ, width 5—10 μ. The tangential pitting is that typical of the *Abies*. In rare instances there occur transverse elliptic pits lending the walls an almost scalariform appearance.

R. 3. In radial walls of *tracheids* pit apertures in the earlywood predominantly circular, occasionally elliptical or eye-shaped and included. Pit diameter 10—13 μ. Radial structure of tori sometimes well defined. Pits in radial walls of *rays* circular or elliptical both in the early- and the latewood. Pit apertures usually assume the same shape as the outlines of the pits and in the earlywood are nearly as large as the pits themselves, with the borders faintly showing as narrow rings around them. Apertures reaching the pit annulus are rare occurrences. Some connected pits have

common apertures. In the latewood the apertures are smaller and narrower and therefore the borders more readily discernible. They are elliptic or eye-shaped, commonly included, occasionally extending to the border but not beyond it. In the *cross field* 1—3, occasionally 4, pits. In the marginal cells they are close to the external walls, which in consequence are slightly wavy. Pits 4—5 μ in diam.

To this *Abies sibirica* group belongs *A. koreana* Wils. (Pl. 210) having 3—4 pits in the cross field in irregular arrangement or one in each corner of the field.

ABIES VEITCHII LINDL.

Veitch's silver fir

Pl. 225

Distribution : the mountains of Central Japan.

C. 1. On the transverse surface no departure from the other *Abies* species. *Growth rings* varying in width, frequently very narrow, contours slightly undulated. About 7000 tracheids per sq. mm.

T. 2,4. In tangential walls of *tracheids* pits 5—8 μ in diam. Pit apertures circular or short-elliptic, not infrequently eye-shaped, usually less than half the pit diameter in length. *Rays* 1—10 (11) cells in height. *Ray cells* in cross section elliptical, rarely circular, occasionally narrow and eye-shaped throughout the ray. Marginal cells frequently much longer than internal cells.

R. 3. Structure of bordered pits in radial walls of *tracheids* usually the same as in the other *Abies* species. Pit diameter 10—13 μ. Marginal *ray cells* variable in shape, with upright forms amongst them ; their external walls are markedly wavy. Pits in rays of the earlywood sometimes very large. Pit apertures also large, nearly the size of the pits, rendering the borders almost imperceptible. In the latewood they are likewise large in relation to the pits, and seldom narrow and elliptic or eye-shaped. In the early- and latewood alike, they reach the borders, but even very slightly extended apertures are exceedingly rare occurrences.

The arrangement of the pits in the marginal cells is rather varied. *Cross field* commonly with 1—3—4 pits ; in the larger, sometimes upright, marginal cells of the earlywood occasionally with 5—6 pits. Pit diameter 4—7 μ. *Wood parenchyma* near the limits of some growth rings. Crystalliferous tracheids occasional.

Cedrus species

CEDRUS ATLANTICA MANETTI

Atlas cedar

Pl. 228

Distribution : Atlas Mountains in North Africa.

C. 1. Growth rings variable in width and distinct ; their limits slightly undulated. Transition from early- to latewood gradual. Only the last few rows of late *tracheids* conspicuously flattened. Tracheids in cross section angular, in the latewood more or less rounded. Rather small tracheids inserted amongst larger ones, scattered, or in fairly long rows. Per sq. mm. 3000 tracheids. *Rays* relatively closely spaced, 2—15 tracheids apart ; uniseriate, very rarely biseriate ; longer ones traverse several growth rings and follow a slightly winding path. *Ray cells* from short to long, sometimes squares. Horizontal walls abundantly covered with small round simple pits, scattered, or in rows near the two radial walls. Larger elliptic or circular pits occur but occasionally. *Wood parenchyma cells* in continuous tangential rows of varying length along the growth ring limits, but rare in the body of the seasonal increments. Abundant simple pits lend their horizontal walls an almost sievelike appearance. Pits circular, elliptic, lachrymiform, or irregular, and generally larger than the pits of rays. In the earlywood of some growth rings the wood parenchyma cells are united to a more or less contiguous expanse with spaces of varying size amongst them ; on the transverse surface these spaces look like resin ducts aligned in rows of various length parallelling the growth ring demarcations ; they are different in shape and lined with parenchyma provided with simple pits. In fact, these spaces are not resin ducts, merely resin cysts, as is evidenced by radial and tangential sections. Cells with resinous, usually reddish-brown, contents. About 3000 tracheids per sq. mm.

T. 2,4. While particularly abundant in the tangential walls of the last-formed late *tracheids*, pits sporadically occur elsewhere as well ; pit diameter 10—13 μ. *Rays* commonly uniseriate, occasionally with 1 or 2 paired cells in the body. Lowest rays 1—2, the tallest 25—30, cells high ; the former far more frequent than the latter ; typical height 6—12 cells. They consist predominantly of parenchyma cells with occasional thin-walled *transverse tracheids* on the margins. Tangential walls of *ray cells* very frequently cribriform. About 65—70 rays and 390—400 ray cells

per sq. mm. Ray cells 13—16 μ in height, 8—13 μ in width, i. e., nearly circular.

R. 3. In radial walls of *tracheids* bordered pits uniseriate, in the widest early tracheids occasionally biseriate; predominantly solitary, very rarely in rows of 2 or 3 pits; commonly regular circles, occasionally short procumbent ellipses in the wider tracheids. The lines of contact between contiguous pits roughly straights. Pit apertures circular in the earlywood, elliptic or eye-shaped in the latewood. Margins of tori scalloped, especially well discernible in the bordered pits of early tracheids. Scalloped tori are a feature characteristic of the cedars. *Wood parenchyma cells* in 1 or 2 rows along practically each growth ring limit; in width these cells agree with the last latewood tracheids; in length they vary. In their radial and tangential walls simple pits of different size, and circular or elliptical in shape. Sometimes two or more (4—5—6) smaller pits cluster, with only narrow stripes of the wall visible between them. To the larger simple pits in the parenchyma cells half-bordered pits correspond in the contiguous tracheids. *Ray parenchyma* consists of thin-walled elongate cells; tangential walls commonly vertical, occasionally oblique or arched; the simple pits in the radial walls circular or elliptic in dependence on the minute complementary bordered pits in the tracheids. This structure is difficult to recognise in the earlywood, where only narrow stripes are visible on both sides of the large, oval pit apertures. In the latewood, the apertures are narrow, linear or slitlike, reaching or nearly reaching the border, which is here more clearly definable than in the earlywood. Commonly 1—4, exceptionally 5, pits per *cross field*, 4—6 μ in diam. The marginal ray cells are commonly thin-walled transverse tracheids, which markedly differ in shape from the parenchyma cells; their external walls are slightly undulated and mostly rather thickened, the inner surface is accordingly uneven and wavy. The bordered pits in their walls are of the same size and arrangement as the pits of parenchyma.

CEDRUS DEODARA Loudon

The Deodar

Pl. 230

Distribution: Northwest India, Afghanistan, Baluchistan.

C. 1. Exhibiting no marked departures of diagnostic significance, it is an intricate task to differentiate this species from *C. atlantica*. In the material studied, the *growth rings* were slightly wider and the delineations less wavy. Number of tracheids, about 3200.

T. 4. Rays commonly about 20, occasionally up to 30, exceptionally more (34), cells high. Thin-walled *transverse tracheids* developed predominantly in the inner, not infrequently in the marginal rays. Number of rays per sq. mm. 35—40, that of ray cells 270—280; in these respects the species differs from *C. atlantica*. Height of *ray cells*, 13—24 μ; width, 5—18 μ. Tangential ray-cell walls with sieve pitting.

R. 3. Hollendonner's finding, that in *C. deodara* the apertures of the pits in the radial walls of rays are smaller, and therefore the borders more distinct, than in *C. atlantica*, the present writer has failed to verify. The material available to him showed the apertures to be as wide as to leave but two narrow crescents of the border, moreover, to be extended. In fact, in no other cedar is this phenomenon as pronounced as in the species under discussion.

Tangential walls of *ray parenchyma cells*, in cross section, display local thickenings beadlike or dentate; number of dents sometimes as much as 6 or 8. *Cross field* usually with 2 or 3, less frequently with 1 or 4 pits, 5—6 μ in diam. *Wood parenchyma* sparse and restricted to the growth ring edges. Transverse tracheids relatively low, smooth-walled, frequently with minute prismatic crystals of calcium oxalate.

CEDRUS LIBANI Loudon

Cedar of Lebanon

Pl. 231

Distribution: the mountains of Lebanon, Taurus, and Anti-Taurus.

C. 1. It is difficult to establish in this species marked departures from the other two cedars. The *tracheids* being small in cross section, there are about 5000 to the square millimeter, i. e., the wood is denser than that of *C. atlantica* or *C. deodara*. *Wood parenchyma cells* are more numerous than in *C. deodara*, but not as abundant as in *C. atlantica*.

T. 2,4. Tangential walls of *tracheids* more abundantly pitted than in the other two *Cedrus* species. Pit diameter 9—10 μ. *Rays* typically 4—8, occasionally 10—15, maximally 20, cells high. *Ray cells* in cross section commonly short-elliptic,

but sometimes, particularly in marginal cells, so very long-elliptic as to remind one of wood parenchyma cells. But the walls of cells of this type are provided with simple pits, i. e., pitted sievelike, as is evidenced on the radial surface. Undoubtedly, these cells are parenchymatous elements, for there are only simple pits in their walls. Per sq. mm. 110—150 rays and 390—400 ray cells. Ray cells 10—27 μ, exceptionally 40 μ, high and 8—16 μ wide. Indentures discernible.

Of a fourth cedar, *C. brevifolia* Henry, a brief xylotomical description is presented in the key on page 114.

Keteleeria species

KETELEERIA DAVIDIANA Beiss.

Pl. 232

Tree native to China. Sample obtained from Hong Kong.

C. 1. On the transverse surface, slight departures from the other *Coniferae*. *Growth rings* conspicuous, marked by the contrast between the very thick-walled last late tracheids and the succeeding thin-walled and wide-lumened early tracheids. Late *tracheids*, in cross section, squarish to rounded, with lumina occasionally reduced to slits or pinholes. Transition from early- to latewood gradual, although the thick-walled tracheids occupy about three quarters of the width of the growth ring. Tracheids variable in size (25—40 μ); the large ones sometimes with exceedingly narrow lumina. The tracheids along the rays are mostly bulkier than the others. *Rays* closely spaced: 1 to 10 tracheids apart; resinous, with commonly black or dark-coloured contents. Horizontal walls equipped with minute pits, scattered, or in rows along the tangential walls. *Wood parenchyma* sparse, mostly confined to the earlywood, frequently to near the inner face of the growth ring. About 2000 tracheids per sq. mm.

T. 2,3. *Rays* uni- or biseriate and 1—12 (34) cells high. *Ray cells*, in cross section, circular or slightly elliptic, 13—18 (43) μ high and 5—18 μ wide. Ray-cell walls thick. Tangential walls variedly pitted, displaying multifarious patterns, sometimes cribriform. Pits visible in radial walls, too. Walls of *tracheids* smooth, except for at most 1 or 2 exceptional pits 8—9 μ in diam. Tracheid walls with obliquely oriented thickenings or bars. In the horizontal walls of *wood parenchyma cells*, 2—3 fairly large pits; in the radial walls, round simple pits, few in number; tangential walls also pitted; pits invariably small and circular or elliptic. Per sq. mm. 32—35 rays and 270—280 ray cells.

R. 4. Like the tangential surface, the radial surface is largely similar to that in *Abies* and *Cedrus*. In the walls of early *tracheids*, commonly two pits at the same height with a vertical line of contact between them, occasionally scattered; pit diameter, 8—9 μ; pit aperture circular. *Rays* consist entirely of thick-walled parenchyma cells. Outward walls of marginal cells wavy, with the ridges raised very high; this is a feature slightly reminiscent of *Larix* and *Cedrus*. Internal ray cells flattened hexagons or rectangles. The tangential walls abutt at various angles upon the horizontal ones. In the horizontal ray walls many, in the tangential walls 3—5, small and round simple pits 4—6—9 μ in diam., about a quarter the width of the cell. Occasionally 2—3 pit rows in a ray cell, in the marginal cells sometimes 4—5 superposed pits. *Parenchyma cells* confined to, or close to, the growth ring limits. Radial walls scattered with procumbent simple pits. Horizontal and tangential walls also pitted. A mostly broad and commonly triangular plate arises at the place where the tangential walls butt into the horizontal walls, while in the cross field of the two kinds of parenchyma 4 to 6 pits are encountered.

In broad outlines, the species agrees structurally with *Keteleeria fortunei* Carr. (Pl. 233), yet the two can readily be differentiated by the height of rays, which is up to 30 cells in *K. davidiana* against a mean height of 15 cells in *K. fortunei*. In addition, there is a difference in the cross-field pits.

Larix species

LARIX DECIDUA Mill.

Common larch

Pl. 234

Distribution: the Alps and the Carpathian Mountains in Central Europe.

C. 1. *Growth rings* variable in width; contours distinct and slightly wavy. *Tracheid* walls different in thickness in early- and latewood. Latewood of darker colour, seasonal transition nonetheless gradual. About 3000 tracheids per sq. mm. *Rays* uniseriate, following a somewhat winding path, 2—15—20 tracheids apart; a few

simple pits scattered in their walls. *Wood parenchyma cells* scattered on the outer face of the growth ring, solitary, or in twos ; in number they vary from abundant to very scarce in dependence on the age of the tree and from ring to ring. Their walls being of about the same thickness, they are not readily distinguished on the transverse surface from the tracheids, except when their horizontal walls are included in the cut and distinction is made easy by the round or elliptic simple pits in them. *Longitudinal resin ducts* scattered throughout the growth ring, but primarily developed along the limits ; they are round or radially elongate ellipses ; sometimes occurring singly, at other times in twos with only one ray between them ; the ducts are 40 to 60 μ in diameter, rather large in relation to those in the other *Larix*.

T. 2,4. Walls of *tracheids* commonly smooth ; only the tertiary layers of the secondary walls and the walls of the late tracheids in the first 10 to 20 growth rings display spiral thickenings (BURGERSTEIN). In addition, the tracheids in the compression wood show sometimes striations. Along with these closely spaced and rather indistinct striae, there proceed in the same direction and at regular intervals others, which are more clearly discernible. These are really cracks in the walls and, as such, destitute of diagnostic worth. Only the tangential walls of the late tracheids with the thickest walls and narrowest lumina are equipped with pits. Pit diameter, 5—8 μ ; borders indistinct ; apertures oblique slits considerably extended, or circular, or elliptic, depending on whether they open into a narrow- or a wide-lumened tracheid.

Processes which are like *trabeculae* and connect the radial walls are visible in large numbers on the tangential surface ; they are mostly straight, sometimes arched, bars with their ends somewhat enlarged where they join the sides of the cell.

Rays uniseriate and 1—15, commonly 1—10, cells high. (According to HOLLENDONNER, ray height 1—22 cells.) They are composed of parenchyma cells and thin-walled transverse tracheids. Rays 1 to 3 cells consist entirely of either parenchyma or tracheids. *Ray cells*, in cross section, circular or elliptic, occasionally of a shape in transition to the angular. Intercellular spaces large and triangular. Tangential walls of *wood parenchyma cells* provided with small compound pits having circular, obliquely elliptic, or slitlike apertures in dependence on whether they lead to early or late tracheids. Per sq. mm. 90—100 rays and about 320—330 ray cells. Height of ray cells, 13—18 (40) μ ; width, 6—10 μ.

R. 3. In radial walls of *tracheids* pits large, 10—21 μ in diam., and uniseriate, but paired pits are not uncommon. If they are in a tight row, the pits assume the form of ellipses at right angles to the long axis of the tracheid. In the early tracheids the apertures conform to the border outlines, are more elliptic or lenticular, the outer orifice attains the width of the border or is, occasionally, extended. The striation in the radial walls of the compression wood is the same as that observable on the tangential surface. Tracheids with *trabeculae* frequent ; also the trabeculae-like processes mentioned in connection with the tangential cut. Trabeculae usually formed at the same height in a number of adjacent tracheids, but occasionally several trabeculae above one another in the same tracheid. Practically all rays contain *transverse tracheids*, commonly aligned in 1—2, or 3, rows on the margins, occasionally in 1 or 2 rows between rows of parenchyma. Their walls are smooth, except for sporadical tiny teeth. Cell shape, particularly in the outermost rows, very varied ; the external walls are consequently more or less wavy. The cells in the inner rows are rectangular or trapezoid. With each other and with tracheids the transverse tracheids communicate through bilateral, and with parenchyma cells through unilateral bordered pits. Pit borders small and indistinct ; apertures seldom circular, mostly elliptic or eye-shaped and included. All walls of *ray parenchyma cells* thick and with simple pits ; horizontal walls with minute elevations, teeth, warts. The apertures of the compound pits in the radial walls clearly distinct from the borders, narrow and slit-like, reaching the pit annulus or extended. In the earlywood, the apertures are eye-shaped or elliptic, reaching the pit annulus or beyond it, but are barely distinguishable from the borders. *Cross field* with 2—4, occasionally 6, pits. Radial walls of *wood parenchyma* densely provided with pits ; they are smaller than those in the tangential walls and their apertures narrow, slitlike. In the young wood, the resin ducts are lined with very thin-walled and barely pitted parenchyma cells, which in the mature wood are lignified and display pits in greater numbers.

By the evidence of resin-duct diameter and ray height, the species appears to stand nearest to *L. leptolepis*. To separate it from the other *Larix*

is an intricate task which involves resin-duct dimensions (although they do not furnish a reassuring basis), and an examination of whether the walls of transverse tracheids are smooth on the inside, or provided with teeth, and whether they are sparsely or densely interwoven with spirals. In these respects, the species seems to show affinity primarily with the *Pseudotsuga* and the *Picea*. Besides the spp. described in detail in this work, the following additional spp. had been studied : *L. gmelini var. japonica* Pilger (Pl. 236), *L. laricina* K. Koch (Pl. 237), *L. lyallii* Parl. (Pl. 238), *L. pendula* Salisb. (Pl. 241), *L. potanini* Batalin (Pl. 242), and *L. sibirica* Ledeb. (Pl. 243).

LARIX GMELINI Litvinov

(L. dahurica Turcz., L. cajanderi Mayr.)

Dahurian larch

Pl. 235

Native to the regions of the Amur.

C. 1. As regards the structure on the transverse surface and the size of resin ducts, this species seems to stand nearest to *L. decidua*. *Wood parenchyma cells* sparse and confined to near the growth ring limits. Like in *L. decidua*, resin ducts scattered throughout the growth rings. Being 70—80 μ in diam., they are wider than those in the said species. About 1300 tracheids per sq. mm.

T. 2,4. Tangential pitting restricted to the last-formed rows of late *tracheids :* pit diameter 8—10 μ. *Rays* similar to those of the other *Larix* except for height which is only 1—12 cells, although those containing resin ducts sometimes attain 26 cells. Of course, ray height depends on whether the wood examined comes from a branch or a stem. Per sq. mm. 35—40 rays and 270—280 ray cells. Height of ray cells 13—24 μ, width 4—6 μ.

R. 3. The tangential surface reveals structures fairly similar to those in *L. leptolepis :* spirally thickened *tracheids* fairly frequent in the latewood; bordered pits uniseriate; paired pits very rare; pit diameter 18—27 μ. The two species also resemble in *ray* structure ; the walls of their parenchyma cells are thinner than in *L. decidua*.

Pitting of tracheids slightly different from that of the other *Larix* species. Pit apertures slit-like or eye-shaped, commonly included, sometimes slightly extended. In the earlywood they are sometimes wider, like in *L. decidua*, and the borders show but faintly on both sides. In the cross field 3—4, exceptionally 6, pits like in *L. decidua* and *L. leptolepis*, but 6—8 μ in diam. Walls of transverse tracheids smooth or delicately dentate. Horizontal walls of *wood parenchyma* smooth or pitted.

LARIX LEPTOLEPIS (Sieb. et Zucc.) Murray

Japanese larch

Pl. 238

Native to Japan.

C. 1,2. Growth rings very wide as compared with those in the other *Larix* species ; growth ring boundaries fairly even. The last few rows of late tracheids and the first-formed early tracheids of the succeeding increment fairly conspicuously differentiated, but within the growth ring the transition from early- to latewood gradual. *Tracheids* in cross section generally multangular, occasionally rounded. Radial rows sometimes interrupted by single cells or rows of them. *Rays* somewhat wider (4—8 μ) than in *L. occidentalis* (4—6 μ) and therefore more readily discernible. Pits biseriate in wider rays. In contrast with *L. occidentalis*, *wood parenchyma* abundant but restricted to growth ring limits ; cells single, or in radial or tangential rows of twos or threes ; their horizontal walls, like those of the rays, pitted but while the pits in the latter are mostly circular, in the former they are frequently elliptical. The number of longitudinal *resin ducts* varies with the growth rings ; they measure about 54 $\times$ 54 μ in cross section. They are generally arranged in series in the central parts of the growth rings. In shape they agree with those in the other *Larix*. About 3000 tracheids per sq. mm.

T. 4. In the latewood of even the outermost growth rings, *tracheids* with sporadic spiral thickenings. In tangential walls of tracheids pits restricted to the last rows in the latewood, and 9—10 μ in diameter. They are particularly numerous in the walls contiguous with the walls of the first-formed early tracheids of the succeeding increment. *Rays* generally uniseriate, but exceptionally even those without resin ducts biseriate ; 1—30 cells in height, but very few higher than 25 cells. *Ray cells* 13—20 (32) μ in height, 4—8 μ in width. Ray cells in cross section commonly wider than those in *L. occidentalis*, yet exceptionally quite narrow and acuminate, seldom even circular. Occasionally cells differing in shape occur within

one and the same ray. Ray-cell pitting the same as in the species previously dealt with. Intercellular spaces triangular and fairly large. Per sq. mm. 50—60 rays and 190—200 ray cells.

R. 3. In radial walls of *tracheids* bordered pits uniseriate. Paired pits less frequent than even in *L. decidua*, if very rarely contiguous, then the lines of contact between them are straights. Superposed pits flattened by mutual contact and the lines of juncture between them likewise straights, the borders therefore procumbent ellipses. Pit apertures regular circles in the earlywood; in the latewood the inner apertures elongated, eye-shaped, obliquely oriented, and included. These pits are much smaller than those in the earlywood.

Ray structure, arrangement, shape, and pitting of transverse tracheids and parenchyma cells the same as in the *Larix* discussed in the foregoing. The greatest is the resemblance of this species and *L. decidua*, although the parenchyma cells of this species are somewhat thinner-walled. *Cross field* with 2—4 (5) pits, not infrequently distributed in the corners. Pit diameter 4—6 μ.

Wood parenchyma scattered on growth ring boundaries. Numerous simple pits in the radial walls.

LARIX OCCIDENTALIS Nutt.

Western larch

Pl. 240

Distribution: the mountains of northwestern North America.

C. 1,2. Growth rings relatively narrow, contours distinct and delicately wavy. Latewood narrow and markedly differing from earlywood. Early- and latewood *tracheids* conspicuously differentiated through discrepancy in size and wall thickness, but colour contrast not as pronounced as in *L. decidua*. *Rays* very narrow and therefore difficult to distinguish on the transverse surface. Minute circular pits scattered in the horizontal walls. Longitudinal *resin ducts* largely confined to the latewood near the outer margin of growth rings, they occur but rarely in the earlywood. In shape, structure, and arrangement they resemble those in *L. decidua*, but are much larger, being 70—80 μ in diam. Apart from those surrounding resin ducts, *wood parenchyma cells* were not encountered in the material examined. There are none at all, in Hollendonner's view. About 800 tracheids per sq. mm.

T. 4. Tangential walls of last-formed late *tracheids* with pits few in number; occasionally sporadic pitting in the transitional and earlywood. In some tracheids they are closely spaced, in others sparse, yet in others missing. Pits small, regularly circular, with eye-shaped apertures varying in length; quite short ones rather elliptic, elongate ones nearly reaching the borders. Like in all *Larix* species, there are transverse tracheids and parenchyma cells in the rays. *Rays* uniseriate, like in *L. decidua*, and only rays containing resin ducts bi- or triseriate above and below the ducts. Their height exceeds that in *L. decidua*, being 1—26 cells. Rays which are only 1—2, or more than 20, cells high, are rare. *Ray cells* 10—13 (18) μ in height, 6—7 μ in width; in cross section long-elliptic, occasionally with pointed ends. Shorter forms occur only above and below transverse resin ducts. In accordance with the general *Larix* character, rays very narrow, narrower than in *L. decidua* or the other *Larix* spp.; a feature by which they are readily distinguished from other conifers, and particularly from the *Abies* and the *Juniperus*. The simple pits in the tangential walls circular or short-elliptic, generally somewhat larger than the corresponding pits in the *Abies*, and commonly arranged as if in rings near the horizontal and radial walls. Apart from 1 or 2 exceptional pits, commonly no pits in the middle of the tangential walls. The intercellular spaces between the tracheids and rays triangular like in *L. decidua*, but in dependence on the cut, occasionally elliptical. The number of rays per sq. mm. is 25—30, and that of ray cells 150—160; by this it seems easy to diferentiate this wood from that of all the other *Larix* spp. However, it is not impossible that the figures quoted only hold for wood from such strongly dimensioned stems as the one from which our sample was taken.

R. 3. Bordered pits in tracheids uni- or biseriate, in the earlywood sporadically triseriate. Pits 16—18 μ in diam. Paired pits relatively numerous in the early tracheids, far more so than in *L. decidua*. In the thick-walled late tracheids they are exclusively uniseriate and smaller than in the earlywood. The apertures are wider, eye-shaped, and included. In the earlywood they are circular, with the tori around them well discernible. In arrangement, shape, and structure, transverse tracheids the same as in *L. decidua*. Dentations or similar initial structures very rare in their walls and quite insignificant, but spiral thickenings

and bars often definitely recognizable. The difference in wall thickness of transverse tracheids and parenchyma cells is not as pronounced as in *L. decidua*. In radial walls of transverse tracheids bordered pits regular circles with apertures usually eye-shaped or slitlike, very rarely short-elliptic or circular, included or reaching the pit annulus but never extended, obliquely oriented at angles more than 45°. The widest *cross fields* in the early-wood contain 4—8 (10) pits, commonly in two horizontal rows with 4, exceptionally 5, pits to the row. In the transitional and the latewood zones their number is sometimes reduced to one. Pit diameter 5—6. μ. On the evidence of the cross field pitting and by the frequency of paired pits, which also is a feature with bearings on tracheidal width, this species is relatively easy to distinguish from *L. decidua* and the other *Larix* spp. examined. The cross fields in the transitional and latewood zones are with 3—4 pits. The borders of the compound pits in the radial walls of *parenchyma cells* are also circular, but somewhat smaller and less distinct than those of the pits in the transverse tracheids ; their apertures are the same throughout the growth rings ; being eye-shaped or slitlike, there is little variation in their width ; they are obliquely oriented, commonly nearer to the vertical, sometimes approaching the horizontal ; as a rule, they are considerably extended or at least reach the pit annulus. Apertures in most cases extended, but always reaching the borders.

The anatomical structure of resin ducts usually resembles that of the *L. decidua*, but ducts are commonly larger in that species.

Picea species *

PICEA ABIES (L.) KARST.
(P. excelsa LINK)
Common spruce

Pl. 244

Distribution : Central and Northern Europa, Northern Asia. Tree grows to heights of 30 to 50 m.

C. 1. Longitudinal tracheids in cross section squares, commonly uniform, but sometimes, particularly in the transition zone and the latewood, smaller cells are encountered, likewise aligned in radial rows. Walls of early tracheids thin and angular, those of late tracheids slightly thicker and with corners lightly rounded. Last rows of late tracheids markedly flattened in radial direction. *Growth ring delineation* conspicuous, frequently somewhat undulating. *Growth rings* variable in width, their greater part occupied by the transition and latewood zones. Transition from early- to latewood gradual. *Longitudinal resin ducts* located primarily in the transition and latewood zones ; in cross section circular or long-elliptic, and 30—40 μ in diam. ; the walls of the epithelial cells lining them, relatively thin, only about 2 μ. Ducts commonly solitary, yet sometimes coming to lie so near to each other that there is but a single uniseriate ray between them. Radial diameter of early tracheids 16—20 μ, tangential diameter 15—18 μ. Radial diameter of late tracheids 8—12 μ, tangential diameter 14—16 μ. Wall thickness of early tracheids 0,8 μ, of late tracheids 2,5—3 μ.

T. 2,4. Bordered pits chiefly encountered in the last-formed rows of late *tracheids*, aligned in rows of more or less sizable groups ; they are circular or long-elliptic, 6—8 μ in diam., have elliptic or slitlike apertures of nearly vertical orientation, commonly just reaching the pit annulus, occasionally extending beyond it. In the walls of the last-formed late tracheids which are contiguous with the walls of the first early tracheids, the pits are larger than in the opposite walls. Tangential walls of late tracheids provided with slight spiral striations. *Rays* commonly uniseriate and 1—12 cells high ; most frequent are the 3—7 cells high rays, but lower ones are not uncommon. The rays of resin ducts are slightly taller, up to 12—18 cells. Resin ducts commonly disposed symmetrically in the middle. Occasionally 2 resin ducts in 1 ray. In the adult wood the rays are taller. HOLLENDONNER reports the occurrence of 24 cells high rays. *Ray parenchyma cells* in cross section short- or long-elliptic ; accordingly, *Picea abies* (L.) Karst belongs to the group of spp. possessing medium ray parenchyma cells. The marginal cells, which are most frequently tracheids, are somewhat lower and triangular. The intercellular spaces between ray cells and tracheids are plainly defined. Tangential walls of ray parenchyma sievelike.

R. 3. Transverse tracheids located commonly at the margins of the rays in 1 or 2 rows. Occasionally, they form rows amongst the *ray parenchyma cells*. Exceptionally, rays a few cells in height are encountered which consist entirely of tracheids.

* Elaborated with the assistance of Imre Horváth, pupil of the writer.

On the other hand, rays composed solely of parenchyma are sometimes found in the outer growth rings where tracheids are well-known to be less in number. Walls of ray tracheids thin, only 0,8 μ, and for the greater part wavy; smooth except for occasional minute dentations. Pits circular, their borders indistinct, about 8 μ in diam. throughout the annual increment. Apertures circular, obliquely elliptic, or slitlike and then sometimes extended. Ray parenchyma cells elongated and uniformly wide. Tangential walls 1—1,5 μ in thickness and provided with simple pits, the secondary cell walls therefore appear as tiny angular nodules on the primary walls. Horizontal walls 1 μ in thickness and covered with round simple pits frequently aligned in rows. Pit diameter about 1 μ. In rays without transverse tracheids outward walls of parenchyma cells undulated, but less resolutely than in *Picea bicolor* and some other *Picea* species. Radial walls likewise about 1 μ thick; the pits in them are fairly large, about 4 μ in diam., and circular, except in the latewood where they are elliptic. *Cross field* commonly with 4, occasionally with 5—6, pits. In the latewood they are but 2 in number. In the radial walls of *longitudinal tracheids* pits uniseriate. In the wide late tracheids exceptionally 2 pits at the same height. Pits round, borders well-defined, commonly reaching across the whole tracheid. Pit diameter in the earlywood 13—15 μ, in the latewood 10—12 μ. Apertures in the earlywood circular, in the latewood elliptic or slitlike and obliquely inclined; in view from above, those in the earlywood surrounded by a lustrous ring; this ring emanates from the margin of the torus adhering to the aperture. Closely spaced striations occur in the radial walls of some tracheids, particularly in the latewood. The striae assume an angle of about 45° to the long axis of the tracheid. Ends of tracheids blunt in the earlywood, slightly pointed in the latewood.

PICEA ASPERATA Mast.

Pl. 246

Native to Western China.

C. 1. Growth rings variable in width; proportion of early- and latewood differs widely from ring to ring; latewood sometimes not more than one eighth of the width of the annual growth increment. Transition from early- to latewood from gradual to not infrequently abrupt. Last rows of tracheids markedly flattened in radial direction. Very substantial difference in wall thickness between early- and latewood; walls the thickest in the transition zone and at the beginning of the latewood. *Resin ducts* distributed in the transition zone and the latewood, not infrequently near the growth ring limits, hence the waviness of the latter. In cross section, resin ducts circular or elliptical and 50—70 μ in diam. As a rare occurrence, the lumina of two or three resin ducts merge into one another. Walls of epithelial cells lining resin ducts, 2—2,5 μ in thickness. Radial diameter of early tracheids, 20—22 μ; tangential diameter, 18—20 μ. Radial diameter of late tracheids, 8—16 μ. Wall thickness of early tracheids only 0,5 μ; of late tracheids, 2—4 μ.

T. 2,4. Tangential walls of late *tracheids* abound in circular pits with clearly defined borders 8—12 μ in diam. Apertures narrow, slitlike, commonly oblique, not infrequently nearly vertical. Tangential walls, by preference in the latewood, with spiral striations. *Rays* uniseriate, commonly 8—10 cells high, occasionally higher or much lower; rays 2—3 cells in height not infrequent; rays containing resin ducts attain 15—20 cells in height and are widened around the resin ducts. *Resin ducts* symmetrically arranged and circular or frequently elliptical in cross section. *Ray parenchyma cells* in cross section of medium width, yet approaching those in the species having narrow ray cells. Ray cells elongate elliptic in shape, marginal cells triangular. The latter are commonly transverse tracheids. Walls variable in thickness, on the whole rather thin. Tangential pits circular, hence the walls cribriform. Elliptical pits not encountered. Pit diameter 1—2 μ. Intercellular spaces well discernible between ray cells and tracheids.

R. 3. Walls of *transverse tracheids in rays* only 0,8 μ in thickness; their inner surface for the greater part spinulose, with the acicular spinules generally in groups. These minute spines commonly rise from a narrow, occasionally from a broader, base. In the group, they are 2—4 μ apart and 1—2 μ in height. There occur perfectly smooth areas amongst them. Bordered pits in transverse tracheids 6—8 μ in diam., circular, with borders well discernible. Pit apertures narrow and elliptic even in the earlywood, frequently slitlike in the latewood, but not extended. They are almost vertical in position both in the early- and the latewood. Ray tracheids varied in shape, from rec-

tangular to quite irregular. Tangential walls of *ray parenchyma cells* 2—2,5 μ thick. Minute simple pits in the secondary walls, appearing linear in lateral view. Horizontal walls uniformly 1—1,5 μ thick and provided with numerous simple pits. Indentures sporadically present. In the *cross field* 1—6, frequently only 2—4, pits in regular quadratic arrangement. Ray parenchyma cells 15—20 μ in height. Radial walls of tracheids 1—1,5 μ thick; the bordered pits in them 2—2,5 μ in diam., circular or short-elliptic in the earlywood, and long-elliptic or slitlike in the latewood. Elliptical and slitlike pits oblique, nearly vertical. Pits uniseriate in the walls of tracheids. Pit borders well discernible, circular in the earlywood, and elliptical in the latewood. Pit apertures circular in the earlywood, narrow, eye-shaped, or slitlike, and nearly vertical in the latewood. Pit diameter 5—6 μ in the latewood, 10—13 μ in the earlywood. Faint spiral striations in radial walls of latewood tracheids. Earlywood tracheids rounded at both ends, latewood tracheids acute.

PICEA BICOLOR MAYR
(P. alkokiana CARR.
Alcock's spruce

Pl. 247

Distribution: Japan, to the north of 35° N. L.; also encountered on the Fujiyama at altitudes of 2000 to 3000 m. The tree attains a height of 15—18 m, according to NAKAMURA; other authors report heights up to 30—40 m. In NAKAMURA's view, xylotomically this wood has much in common with *P. excelsa*.

C. 1. In cross section, *tracheids* square in the earlywood, rounded in the latewood, and radially flattened in the last-formed latewood rows. Vertical *resin ducts* distributed in the latewood immediately along the growth ring limits. *Growth rings* distinct; limits somewhat wavy because of the resin ducts. *Resin ducts* in cross section very rare in the transition zone; circular or elliptic; 35—50 μ in diameter; the epithelial cells lining them, rather thin-walled (2,5 μ). Transition from early- to latewood gradual. Tangential diameter of early tracheids 14—16 μ, radial width 10—16 μ; walls 1—1,5 μ thick. Latewood tracheids radially 6—10 μ wide; walls 2—3 μ thick.

T. 2,4. Tangential walls of *tracheids*, especially in the transition zone, abundantly pitted. Pit borders barely perceptible; apertures more slitlike, included, and obliquely oriented. Pits 4—6 μ in diam. Walls of tracheids, chiefly in the transition zone and the latewood, frequently striated. *Rays* low, most of them without resin ducts, one cell in width, and 1—12 cells high. Tangential walls of ray cells cribriform. In uniseriate rays some cells higher than the others, occasionally twice as high. Resin ducts located in the centre of the rays.

R. 3. Transverse tracheids relatively few, with thin walls (0,8 μ) and slightly dentate. Bordered pits 6—7 μ in diam. Borders well discernible. Apertures elliptical and oblique throughout the growth ring. Tangential walls of *ray parenchyma cells* angular with beadlike thickenings, 1—1,5 μ in thickness. Horizontal walls uniformly 0,5—1 μ thick, provided with several simple pits. Radial walls likewise 0,5—1 μ in thickness. *Cross field* commonly with 2—6, exceptionally 8, pits, circular or elliptic, 3—4 μ in diameter, largely aligned in 1 or 2 vertical rows. *Ray cells* 16—22 μ in height. Rays of a single-cell row 24—28 μ high. External walls of marginal parenchyma cells slightly wavy. Pits uniseriate in longitudinal *tracheids*, with indistinct borders. Pit apertures circular or wide elliptical, especially in the earlywood, and slitlike, occasionally extended, in the latewood. In this respect the species resembles *P. jezoensis*. Pits 12 μ in diam. in the earlywood, 8 μ in the latewood. Radial walls of late tracheids markedly striated. Tracheids with rounded ends in the earlywood, and ligthly pointed in the latewood.

PICEA BRACHYTYLA (FRANCHET) PRITZEL
(Picea sargentiana RHED et WILS.)

Pl. 248

Native to the province West Szechwan in China.

C. 1. Longitudinal tracheids in cross section commonly angular and arranged in rows parallel with the rays; in the earlywood they are slightly, and in the latewood markedly, rounded, occasionally nearly circular. Major portion of *growth rings* occupied by transition zone and latewood; transition gradual. Last rows of late tracheids markedly flattened. Growth ring limits distinct and slightly wavy. In some growth rings more or less marked parenchyma proliferation, involving occasionally the entire ring area. *Resin ducts* in the transition zone and the latewood scattered; in cross section, circular or somewhat elongate elliptical, 30—40 μ in diam. Walls of epithelial cells 3—3,5 μ in thickness. Two or more resin

ducts sometimes coalesce into a single large duct, elliptical in shape. Resin ducts surrounded by parenchymatous elements varying in number. Tracheids 16—18 μ in tangential diam., 15—18 μ in radial width; walls 1—1,5 μ thick in the earlywood. Late tracheids 6—12 μ in radial width; walls 2,5—3 μ thick.

T. 2,4. In tangential walls of late *tracheids* pits uniseriate; 8 μ in diam.; borders well discernible; apertures narrow and eye-shaped or slitlike, included. Tangential walls of late tracheids with spiral striations. The spiral thickenings characteristic of the inner growth rings in *Picea*, are present both in the early- and the latewood. The barlike projections on the walls of tracheids are serrate, especially in the latewood. *Rays* uniseriate; commonly 8—10, not infrequently 1—3, quite exceptionally 20—22, cells high. Rays containing *resin ducts* always more than 10—12 cells high; resin ducts arranged in the middle, symmetrically or dissymmetrically. Some rays with two resin ducts. Rays containing resin ducts only one cell wide at the ends, but wider around resin ducts. Resin ducts in cross section circular or elliptical. *Ray parenchyma cells* wide, short-elliptic or almost circular; cells of single-row rays eye-shaped; marginal cells, being mostly transverse tracheids, are triangular. Intercellular spaces well discernible. Tangential walls of ray parenchyma cribriform. No elongate elliptical pits on tangential walls.

R. 3. Walls of *transverse tracheids* thin, minutely spinous; spines low and rising from a wide base. Pit borders well discernible, 6—8 μ in diam. Pit apertures circular in the earlywood, and oblique elliptical or eye-shaped in the latewood. *Ray parenchyma cells* commonly rectangular; tangential walls 1,5—2 μ in thickness. Horizontal walls uniformly about 1,5 μ thick, provided with numerous simple pits. The external walls of marginal parenchyma cells wavy, like in the other *Picea* species. Indentures present but not conspicuous. Radial walls 1,5 μ thick. Pits circular in the earlywood, 3—4 μ in diam., somewhat smaller in the latewood, elliptical or eye-shaped and oblique in position. *Cross field* with 1—6 pits, commonly arranged irregularly. Ray parenchyma cells, with the exception of proliferating large cells, 16—18 μ in height. Pits in radial walls of longitudinal *tracheids* uniseriate. Pit borders well discernible. In the earlywood pits 14 μ in diameter, apertures circular. In the latewood, pit diameter 10—12 μ, apertures elliptic or eye-shaped and oblique. In radial walls of late tracheids, spiral striations. Spirals nearly horizontal. Early tracheids with blunt ends, late ones slightly pointed.

PICEA BREWERIANA Watson

Brewer's weeping spruce

Pl. 248

Distribution: the mountains of the Pacific Coast in North America.

C. 1. Longitudinal tracheids in cross section angular; arranged in regular radial rows. Last late tracheids markedly flattened radially. Growth ring limits conspicuous and, in consequence of the adjacent resin ducts, frequently wavy. *Growth rings* vary in width. Early- and latewood variable in proportion; transition from gradual to abrupt. *Resin ducts* scattered in the transitional zone and in the latewood; in cross section circular or somewhat elongate elliptical. Between two resin ducts frequently but one ray. Diameter of resin ducts 25—40 μ. Walls of epithelial cells 2—3 μ thick. Radial as well as tangential diameter of early tracheids 14—16 μ. Radial diameter of late tracheids 6—14 μ. Wall thickness of early tracheids 1,5—2 μ, of late tracheids 2,6—3 μ, yet frequently there is hardly any difference in wall thickness between early- and latewood tracheids.

T. 2,4. Radial walls of *longitudinal tracheids* pitted in the latewood and the transition zone. Pits uniseriate, in smaller or larger groups in the middle line of the walls. Borders well discernible, circular, 8 μ in diam. Apertures eye-shaped, horizontal or somewhat oblique. In tangential walls of late tracheids spiral striations. The spiral thickenings, frequent in the tracheids in the younger wood of the other *Picea* species, here often encountered in the early- as well as the latewood. Radial walls of late tracheids serrate; this serration is most probably related to the marked striation of these walls. *Rays* low, mean height 6 cells; heights of 8—10 or more cells very rare, but of 1—3 cells rather frequent. Even *rays with resin ducts* only up to 12—16 cells high. *Resin ducts* circular or elliptical in cross section and placed generally in the middle, very rarely nearer to one of the edges. Rays uniseriate, sligthly widened where they surround resin ducts. *Ray parenchyma cells* wide; in cross section short-elliptic or nearly regular circles; tangential walls cribriform.

R. 3. Transverse tracheids relatively sparse, located near the edges of the rays; their walls only

about 0,8 μ thick, commonly smooth, rarely covered with minute toothlike projections. Borders of pits well discernible, about 8 μ in diam. Apertures elliptic or eye-shaped and oblique. Tangential walls of *parenchyma* 2 μ in thickness. Secondary walls with simple pits are seen on primary walls as angular or rounded nodules. Horizontal walls uniformly 1 μ thick, and with a few simple pits. Indentures present, but inconspicuous. External walls of marginal parenchyma cells without *transverse tracheids* are wavy, like in the other *Picea* species. Radial walls 1 μ thick. Pits circular in the earlywood and 3—4 μ in diam.; slightly smaller in the latewood, short-elliptic or eye-shaped and oblique. In radial walls of *longitudinal tracheids* pits uniseriate, 14 μ in diam. in the earlywood; borders well discernible; apertures circular. Radial structure of *tori* often clearly visible. Pit diameter in the latewood 8 μ. Outer apertures circular, inner apertures slitlike and frequently extended. Slits parallel with spiral striations in the radial walls of late tracheids. Spiral striations occur also in the transition zone and in the earlywood on radial walls. Spirals nearly horizontal. Tracheids with rounded ends in the earlywood, pointed in the latewood.

PICEA ENGELMANNI (Parry) Engelm.

Engelmann spruce

Pl. 250

Distribution: the mountains of western North America. The tree attains heights of 20—25 m. The wood is soft, reddish, and one of the most valuable timbers. Anatomically it resembles the common spruce.

C. 1. Longitudinal tracheids aligned in radial rows; in cross section squares, in the latewood slightly rounded. Last-formed late tracheids markedly flattened. Transition from early- to latewood gradual. *Resin ducts* distributed chiefly in the latewood and in the transition zone; very rarely in the earlywood; in cross section they are circular, exceptionally long-elliptic; duct diameter 25—30 μ. *Epithelial cells* of medium thickness, 2—2,5 μ. Early tracheids 14—16 μ in tangential, and 15—18 μ in radial diameter. Late tracheids 6—12 μ in radial width. Wall thickness of early tracheids about 1 μ, of late tracheids 2—2,6 μ.

T. 2,4. Tangential walls of *longitudinal tracheids* pitted in the latewood. Pit diameter 6—8 μ. Borders barely perceptible. Apertures inclined, elliptical or slitlike; in the latter case reaching the borders or slightly extended. In tangential walls, chiefly in the latewood, spiral striations forming angles of about 45° to the longitudinal axis of the tracheids. *Rays* low, most frequently 1—6, maximally 8—10, cells high in the writer's sample from a young branch; probably higher in adult wood. *Rays with resin ducts* commonly 10—12 cells high. Rays uniseriate, around resin ducts occasionally 3—4 seriate. *Resin ducts* arranged symmetrically in the middle; in cross section circular or elliptic, frequently very small in diameter and slightly flattened. *Ray parenchyma cells* in cross section long-elliptic; marginal cells, being commonly *transverse tracheids*, somewhat lower and triangular in shape. Tangential walls of ray parenchyma cells provided with circular simple pits, therefore cribriform. Intercellular spaces between ray cells and longitudinal tracheids well discernible.

R. 3. Rays commonly bounded by one or two rows of *transverse tracheids*. The latter occasional also amongst *parenchyma cells*, mainly in the innermost growth rings. Some rays composed entirely of parenchymatous elements. Walls of transverse tracheids thin (about 0,7 μ) and smooth. The toothlike projections characterising many of the *Picea* species are here missing. Pits 6—8 μ in diameter, borders well discernible. Apertures circular or elliptic in the earlywood, frequently slitlike in the latewood, always oblique and included. Tangential walls of ray parenchyma cells about 1,5 μ thick and provided with large simple pits, giving the walls a perforated appearance in radial view. Horizontal walls uniformly 1—1,5 μ thick and with simple pits. Radial walls likewise 1—1,5 μ in thickness; the pits in them wide, nearly circular in the earlywood, and narrow and oblique in the latewood. Pits 2—2,5 μ in diam. The apertures of the complementary half-bordered pits in the radial walls of the longitudinal tracheids show through these walls. These apertures are wider than the pits of the parenchyma and make the latter appear as if they were enframed by them. In the *cross field* 1—6 pits, commonly disposed in rows. *Ray parenchyma cells* 18—22 μ in height. In radial walls of longitudinal tracheids bordered pits uniseriate. Borders well discernible, 12—14 μ in diam. in the earlywood, and 8 μ in the latewood. Pit apertures circular or short-elliptic in the earlywood, and eye-shaped, oblique and included in the

latewood. In the early tracheids the margin of the *torus* adheres to the pit aperture and appears as a lustrous ring around it. The radial structure in the tori is well discernible. In the radial walls of the tracheids, particularly in the latewood, spiral striations. Tracheids with rounded ends, but somewhat pointed in the latewood.

PICEA GLAUCA (Moench) Voss
(P. canadensis B. S. P; P. alba Lk)

White spruce

Pl. 251

Distribution: the eastern parts of North America between 45° and 70° N. L. The tree attains a height of 15, 20, rarely 50, meters. Wood light, pale yellow, used in building construction, as pulpwood, and for musical instruments.

C. 1. Tracheids in regular rows; in cross section generally angular, in the earlywood with slightly, in the latewood with more markedly, rounded corners. Last-formed late tracheids strongly flattened radially. *Resin ducts* distributed in transition zone and latewood; in cross section circular, or radially somewhat elongate elliptical, 30—60 μ in diam. Walls of epithelial cells lining resin ducts about 3 μ in thickness. *Growth rings* distinct, transition from early- to latewood gradual. *Wood parenchyma cells*, although Kleeberg reports them frequent, were none in the writer's specimen. Tangential diameter of early tracheids 12—15 μ, radial diameter 10—12 μ; radial diameter of late tracheids 6—10 μ. Wall thickness of early tracheids 1,5—2 μ, of late tracheids 2—2,5 μ. On transverse surface, wood of fairly uniform structure and dense texture.

T. 2,4. In tangential walls of *longitudinal tracheids* bordered pits in smaller or larger groups; pits 6 μ in diam., borders indistinct; apertures elliptic or eye-shaped and oblique. Tangential walls of tracheids in the transition zone and the latewood frequently with spiral striations. *Rays without resin ducts* uniseriate and, in the specimen, 4—12 cells high. *Rays with resin ducts* 10—14 cells in height. Resin ducts located generally in the middle, with the rays widened to 3—4 cells to include them. *Ray parenchyma cells* in cross section narrow, elongate elliptic; in their tangential walls pits frequently elongate ellipses giving the walls scalariform appearance.

R. 3. Transverse tracheids, in the specimen from a young branch, relatively sparse; their walls only 0,5 μ in thickness; external walls sporadically covered with barely visible spinules or toothlike projections; all three walls provided with bordered pits, 5—6 μ in diam. Pit borders indistinct; apertures elliptic or eye-shaped and oblique. *Ray parenchyma* with tangential walls 2—2,5 μ thick and, because of the large simple pits in them, appearing scalariform like in *P. pungens* and a few other *Picea* species. Horizontal walls uniformly 1,5 μ thick and with several simple pits. Provided there are no transverse tracheids, outward walls of marginal cells serrate, like in the other *Picea* species. Radial walls about 1,5 μ thick with relatively large simple pits, 2—3 μ in diameter, circular or elliptic in the earlywood, and predominantly elliptic in the latewood. *Cross field* with 1—6 pits, commonly in irregular arrangement. Mean height of ray parenchyma cells 18—22 μ. *Longitudinal tracheids* with uniseriate pits in radial walls. In the earlywood, pits 10—12 μ in diam., with circular apertures; in the latewood, 8 μ with obliquely oriented elliptical or lenticular apertures. Borders well discernible. In the walls of late tracheids faint spiral striations. *Trabeculae* not uncommon.

PICEA GLEHNII Mast.

Sakhalin spruce

Pl. 252

Distribution: Sakhalin Island, the southeastern coast of Hokkaido Island, Manchuria, and Taiwan. Trees 30 to 50 m tall. Beissner claims the wood is very valuable.

C. 1. Tracheids in regular rows throughout the growth increment; in cross section angular, in the earlywood with slightly, in the latewood with markedly rounded corners. Last rows of late tracheids radially very much flattened. *Resin ducts* distributed in the transition zone and the latewood, frequently quite near to the growth ring limits, which are then slightly undulated. Resin ducts in cross section circular or radially long-elliptic, 30—50 μ in diam. *Epithelial cells* very thick-walled (3—4 μ). *Growth rings* distinct; transition from early- to latewood gradual. Like in several other *Picea* spp.; in some growth rings marked parenchyma proliferation in the earlywood and the transition zone. Tangential diameter of early tracheids, 15—18 μ; radial diameters, 13—15 μ. Radial diameter of late tracheids, 6—10 μ. Wall

thickness of early tracheids 1 μ, of late tracheids 2,5—3 μ.

T. 2,4. Tangential walls of *longitudinal tracheids* with scattered bordered pits in the transition zone, more frequent in the latewood. Borders well discernible, 8 μ in diam. Pit apertures slitlike, nearly vertical. Faint spiral striations in the tangential walls of the tracheids in the transition zone and the latewood. *Rays*, in the specimen from a young branch, rather low: whether *with or without resin ducts*, commonly 4—12, not infrequently 1—2, cells high. Resin ducts located in the middle of the ray. Rays uniseriate, widened only to include resin ducts. *Ray parenchyma cells* in cross section narrow, markedly long-elliptic. Ray cells in single-row rays eye-shaped. Ray-cell walls very thin.

R. 3. Transverse tracheids present even in the sample from a young branch. Rays commonly bordered by transverse tracheids with thin (0,6—1 μ) and delicately dentate, but occasionally smooth, walls. All walls with fairly numerous pits with borders well discernible and 8 μ in diam. Pits wide-elliptic, the minor diameter about 3 μ. Apertures circular or elliptic. Tangential and horizontal walls of *ray parenchyma cells* not more than about 1 μ in thickness; large circular pits in tangential and radial walls, not infrequently also in horizontal walls; pit diameter about 3 μ. *Cross field* with 2—6, but typically 4, pits distributed in the 4 corners, particularly in the earlywood. Ray parenchyma cells 18—22 μ in height. Radial walls of *longitudinal tracheids* with uniseriate pitting; pit apertures circular in the earlywood, and eye-shaped or slitlike and practically vertical in the latewood; included throughout the growth ring; borders well discernible, 14 μ in diam. in the earlywood, but only 8 μ and somewhat flattened in the latewood. In the radial walls of tracheids faint spiral striations in the latewood and the transition zone. Tracheids with blunt ends in the earlywood, slightly pointed in the latewood.

PICEA JEZOENSIS Carr
(P. ajanensis Fisch.)
Jeso or Hondo spruce

Pl. 253

Distribution: Hokkaido Island, Sakhalin Island, and the eastern coast of Siberia. The tree attains a height of 60 m.

C. 1. On the transverse surface the only departure from *Picea abies* and *P. glauca* is the predominant presence of *resin ducts* in the last-formed portion of the latewood where they are scattered over a small band or almost reduced to a row. The transition zone and the earlywood are practically devoid of resin ducts. In cross section, the latter are circular or moderately long-elliptic, 40—50 μ in diam. Walls of *epithelial cells* well-developed, 3—3,5 μ thick. Tracheids angular, in the latewood slightly rounded; transition from early- to latewood gradual. *Wood parenchyma* was wanting on the section examined. Radial diameter of early tracheids, 15—20 μ; tangential diameter, 18—22 μ. Radial diameter of late tracheids, 6—10 μ. Wall thickness of early tracheids, 0,75—1 μ; of late tracheids, 2—3 μ.

T. 2,4. In tangential walls of last-formed late *tracheids* pits fairly numerous; circular; apertures eye-shaped or slitlike, practically vertical in orientation, included, or reaching the borders, but not crossing them. *Rays* lower than in *P. abies*; at most 8—10 cells high, those with resin ducts usually attaining 25 cells in height. *Ray cells* in cross section long-elliptic. Late tracheids frequently striated.

R. 3. Transverse tracheids not encountered in every ray and, in general, few in number, with walls thin (0,8 μ) and smooth. Bordered pits 8 μ in diam.; apertures circular in the earlywood, but nearly vertical elliptic slits in the latewood. In the radial walls of *ray parenchyma cells* pits wider than in *P. abies* and *P. glauca*, nearly circular. Number of pits per cross field 1—6. Tangential walls of ray parenchyma 1—1,5 μ thick and markedly pitted, cribriform; horizontal walls 0,5—1 μ thick and pitted. Mean height of *ray cells* 16—20 μ. Pit borders in the early longitudinal tracheids barely perceptible, circular or subcircular, and almost as wide as the border; in the late tracheids narrower and eye-shaped but not slitlike, reaching the pit borders or, frequently, crossing them. The very much extended slitlike pit apertures frequently visible on this surface result from cleavings. Striations common in radial walls of late tracheids. In one of the sections he studied, an uninterrupted series of trabeculae extending through 6 growth rings, was observed by the writer. Tracheid ends blunt in the earlywood, and tapering to points in the latewood. Pits uniseriate in the radial walls; diameter 8 μ in the earlywood, and 6 μ in the latewood. The transverse resin ducts in the rays sheathed by thick-walled parenchyma cells, with simple pitting.

PICEA KOYAMAI SHIRASAWA

Koyama's spruce

Pl. 255

Tree native to Japan. For the low rays and the limited number of transverse tracheids the fact is probably responsible that the available material came from a branch only 8 to 10 years old.

C. 1. Longitudinal tracheids disposed in radial rows; angular in cross section, in the latewood with slightly rounded corners and radially flattened. *Resin ducts* occur mostly in the latewood near the growth ring limits, rarely in the transition zone; in cross section they are circular or elliptic, 25—50 μ in diam. Walls of *epithelial cells* 2 μ in thickness. *Growth rings* distinct; transition from early- to latewood abrupt. Tangential diameter of early tracheids, 10—20 μ; radial diameter, 18—22 μ. Radial diameter of late tracheids, 4—6 μ. Wall thickness of early tracheids, 0,8—1 μ; of late tracheids, 2—2,5 μ.

T. 2,4. In tangential walls of *longitudinal tracheids* bordered pits few in number, occurring in groups of varying size, and confined to the latewood. Pit diameter, 6—8 μ. Pit apertures small, eye-shaped, oblique, and included. In the tangential walls of tracheids striations frequent in the latewood and the transition zone. *Rays* low in the specimen: those without resin ducts 1—6, most frequently 2—4, cells high and uniseriate; those with resin ducts 8—10 cells in height, widening only to include the ducts, which are commonly located in the centre. *Ray parenchyma cells* in cross section short- or long-elliptic; walls thick; intercellular spaces angular and well discernible.

R. 3. Radial surface very similar to that in *Picea bicolor*. *Transverse tracheids* few in number in the specimen, and chiefly restricted to the inner growth rings; their walls only about 1 μ in thickness, and delicately dentate; tangential and horizontal walls abound in pits of 6—8 μ diameter, with apertures circular or wide-elliptic and commonly obliquely oriented. Many of the *rays* composed entirely of parenchyma cells. Tangential walls of rays rather thick (2—3 μ) and with large simple pits, which give the secondary wall a dentate appearance. Like in *P. bicolor*, outward walls of marginal parenchyma cells undulated, with pits in the hollows between crests. Radial walls 1—1,5 μ thick. Like in *P. bicolor*, pits relatively large, 2—3 μ in diam., circular or elliptic in shape. *Cross field* with 2—6 pits in 1 or 2 vertical rows. *Ray cells* 18—22 μ in height. In *longitudinal tracheids* pits uniseriate; in the earlywood 12 μ in diam., with well-defined borders and circular or wide-elliptic apertures. In the latewood, pits radially flattened and therefrom elliptic, 8 μ in diam., with elliptic or eye-shaped, obliquely oriented and invariably included apertures. Spiral striations visible in the latewood. Tracheid ends blunt, in the latewood tapering to points.

PICEA LIKIANGENSIS PRITZEL

Pl. 256

Tree native to China.

C. 1. Longitudinal tracheids arranged in regular rows; angular in cross section with the corners but slightly rounded, even in the latewood. Apart from the last-formed one or two rows in the latewood, which render the growth ring demarcation distinct, the tracheids are uniform in size almost throughout the growth increment; consequently early- and latewood differ hardly at all, except for a barely perceptible difference in the thickness of the cell walls. In the material studied, the *resin ducts* were observed to display a certain regularity in arrangement: they were found to be located at about the middle between the inner and outer growth ring limits, i. e., within the transition zone. Resin ducts circular, 40—80 μ in diam., not infrequently 2 or 3 quite close with only parenchyma cells between them or, though very rarely, merging into one another. Walls of *epithelial cells* only 1—2 μ in thickness. Marked parenchyma proliferation was observed in the earlywood of one of the growth rings, with vast cells of 40—50 μ taking part in it, and involving widened rays with more than usually large cells in them. Outside the zone of proliferation, and apart from epithelial parenchyma, no wood parenchyma was detectable in the sections examined. Tangential diameter of early tracheids, 22—26 μ; radial diameter, 25—30 μ. Radial diameter of late tracheids, 8—20 μ. Wall thickness of early tracheids, 0,8 μ; of late tracheids about 1,5 μ.

T. 2,4. In the tangential walls of *longitudinal tracheids* pits in the transition zone and the latewood commonly scattered along the radial walls; pits 10—14 μ in diameter, with borders well defined and elliptic apertures forming an angle of about 45° to the longitudinal axis of the tracheid. Barely perceptible, fine spiral striations visible in the tangential walls of tracheids predominantly in the

transition zone and the latewood, but frequently in the earlywood as well. *Rays* of medium height : those without resin ducts commonly 6—12, not infrequently 1—2, cells high, generally uniseriate, occasionally biseriate ; those with resin ducts attain a height of 12—18 cells and widen in the middle to 3—4 cell rows to include the resin duct. *Ray cells* in cross section wide, short-elliptic or circular, by which feature the species under review belongs in the *Picea morinda* group of wide ray cells. Ray-cell walls thin ; intercellular spaces well defined. Tangential walls of *ray parenchyma cells* covered with circular simple pits, rendering the walls cribriform.

R. 3. Rays commonly bounded by *transverse tracheids*, with the exception of single- or double row rays, which are homogeneous. Tracheid walls only 0,8 μ thick and densely covered with bordered pits, 7—8 μ in diam. ; pit borders well discernible ; apertures elliptical or eye-shaped, obliquely oriented. Horizontal walls of transverse tracheids densely covered with prominent toothlike projections about 1—1,5 μ in height and 0,2—0,4 μ in width. In some tracheids these projections grow longer and meet in the cell lumen to form spiral barlike structures extending across the cell ; being nearly perpendicular to the long axis of the tracheid these spirals are apt to give the impression of rings. These structures can be regarded as spiral thickenings. Similar spiral thickenings are present in the transverse tracheids of the *Pseudotsuga*. Tangential walls of *ray parenchyma cells* from commonly 1,5 μ to frequently 2,5 μ in thickness. When thick, then, in radial view, the portions of the secondary wall that remain free between the simple pits appear as transverse rods, like in several other *Picea* species. When the tangential walls are thin, the free portions of the secondary wall are squares in shape. Horizontal walls uniformly 1—1,5 μ thick, abounding in minute simple pits of 1—1,5 μ diam. Radial walls of the same thickness ; the pits in them circular or moderately long-elliptic ; the pit apertures of bordered pits in adjacent tracheids well discernible within the circular simple pits. Apertures elliptical and oblique. In the *cross field* usually 1—6 scattered pits. *Ray parenchyma cells* 18—22 μ in height. Bordered pits uniseriate in radial walls of *longitudinal tracheids*. Pit borders distinct, 10 μ in diam. in the latewood, 12—16 μ in the earlywood. Inner and outer pit apertures are not alike, one is a circle, the other an ellipse ; the diameter of the circle being equal to the minor axis of the ellipse, the circle comes to lie within the ellipse. Elliptical pit apertures are obliquely inclined. Spiral thickenings more frequent and much more definite than in the transverse tracheids, even in the earlywood. In tangential walls of tracheids small projections visible, looking as if they were the points of departure for the spirals ; they are really the spiral bars in cross section. These spirals are similar to those in the *Pseudotsuga*, but while they extend obliquely in the latter, they are nearly horizontal in this species. Tracheids ends blunt in the earlywood, slightly pointed and frequently bent in the latewood.

PICEA MARIANA (Miller) Britton, Sterns et Poggenberg

(P. nigra Ait.; P. brevifolia Peck)

Black spruce

Pl. 258

Distribution : North America, from the Allegheny Mountains to 65° N. L. Trees attain a height of 20—25 m, and 50 cm in diameter.

C. 1. Longitudinal tracheids arranged in regular rows ; in cross section angular, slightly rounded in the latewood. Elements roughly uniform in size throughout the growth rings, which are uniform in width. Latewood only one fifth the width of the growth ring. Transition between the two zones gradual. *Growth rings* distinct. *Resin ducts* distributed in the transition zone and the latewood ; none were encountered near the outer face of the growth ring in the material examined. They vary in number from one growth ring to the other. In cross section, they are circular or moderately long-elliptic, 60—80 μ in diam., lined with thick-walled (about 4 μ) *epithelial cells*. Early tracheids 20—24 μ in tangential, and 26—30 μ in radial width ; walls 1,5 μ thick. Late tracheids 8—10 μ in radial diameter ; walls 3—4 μ in thickness.

T. 2,4. In tangential walls of *longitudinal tracheids* bordered pits in the earlywood numerous, in multiples, and uniseriate. Pits seldom circles, predominantly ellipses with compressed or crushed sides. Apertures slitlike, vertical, half as long as the pit diameter. Pit diameter 15—16 μ, very large in comparison to those in the other *Picea* species. These large-sized pits of peculiar form can be regarded as definite taxonomic features. Spiral striations absent, even from the latewood. *Rays* high ; *those with resin ducts* mostly 15—20 cells in height ; uniseriate ; multiseriate only in the

places where they include the centrally located resin ducts. Rays without resin ducts attain a height up to 25 cells. *Ray parenchyma cells* in cross section narrow, long-elliptic, or eye-shaped. Ratio of minor and major axes of the ellipses : 1 : 2,5—3. Wall thickness the usual. Intercellular spaces fairly well defined. Tangential walls of *rays* cribriform, owing to simple pitting.

R. 3. Transverse tracheids abundant ; every ray, bordered by them, not infrequently in 1 or 2 rows ; walls alternately thickened ; on the whole, thin (about 1 μ) and commonly smooth ; outer wall with locally thickened areas and serrately dentate inner surface. Teeth generally minute, 1 μ in height. In the walls of transverse tracheids bordered pits numerous, about 8 μ in diam., with apertures elliptical, or eye-shaped, or slitlike, and almost vertical. Tangential walls of *ray parenchyma cells* about 1,5—2 μ in thickness and commonly pitted. Horizontal walls uniformly about 1 μ thick, frequently with simple pits, 0,8—1 μ in diam. Radial walls also 1 μ thick, the bordered pits in the *longitudinal tracheids* show through them. Simple pits narrow and eye-shaped, or ellipses with the major axis 3,5—4 μ long, and nearly vertically oriented. *Cross field* with 2—6 pits, very seldom more, commonly uniseriate. External walls of *marginal parenchyma cells* slightly wavy, like in the other *Picea* species. Radial walls of *longitudinal tracheids* with uniseriate bordered pits. Occasionally smaller contiguous pits at the same height. In the earlywood, pit diameter 18—20 μ, apertures circular. In the latewood, pit diameter 8—12 μ, apertures eye-shaped or slitlike, vertical, included. Pit borders distinct. Spiral striations absent. Tracheid ends in the earlywood rounded, in the latewood slightly pointed.

PICEA OBOVATA LEDEB.

(P. excelsa obovata BLYTT)

Siberian spruce

Pl. 261

Distribution : Scandinavia, the northern and north-eastern parts of the Soviet Union. The tree attains a height of 30 m and is very similar to the European spruce.

C. 1. Longitudinal tracheids in distinct rows, like in the other *Picea ;* in cross section angular in the latewood, rounded and markedly flattened in the last-formed rows. *Growth rings* variable in width ; latewood most frequently three quarters their width. *Resin ducts* distributed in the transition zone and the latewood ; in cross section, circular or moderately long-elliptic, 25—35 μ in diam. Walls of *epithelial cells* relatively thin (1,5—2 μ). Growth rings distinct, frequently with wavy contours due to the nearby resin ducts. Transition from early- to latewood gradual. Tangential diameter of early tracheids, 13—16 μ ; radial diameter, 16—17 μ. Radial diameter of late tracheids, 6—10 μ. Wall thickness of early tracheids, 0,8 μ ; of late tracheids, 2,5—3 μ.

T. 2,4. Tangential walls of *longitudinal tracheids*, particularly in the latewood, provided with bordered pits aligned in one row in multiples varying in number. Pits 8 μ in diam. ; borders distinct ; apertures elliptic or eye-shaped and oblique ; in the earlywood in rare instances circular. In the walls of latewood elements faint spiral striations. *Rays* of rather limited height. In INGRARSON's view this is a feature of diagnostic value, for it is constant, independent of age, and the means whereby to separate this species from *Picea abies*, to which it is very similar in every other respect. While the mean ray height is 5—6 cells in *P. obovata*, it is 10 cells in *P. abies*. The tallest ray in the section examined was 13 cells high. Rays uniseriate, several-seriate only to include the centrally disposed resin ducts ; those containing resin ducts, 10—14 cell rows in height. *Ray parenchyma cells* in cross section frequently pointed ellipses. The species belongs to the group with ray cells of medium width. Some marginal cells, mostly *transverse tracheids*, and some cells in the low rays occasionally attain double the average height. Walls relatively thin ; intercellular spaces well defined. Pits in tangential walls of ray parenchyma cells circular ; in consequence cribriform.

R. 3. Transverse tracheids present, depending in number on the age of the wood ; less of them in the inner, more in the outer growth rings ; they vary in shape and are frequently very high, as mentioned in the description of the tangential section. Walls only 0,8 μ in thickness, occasionally covered with spinules, fairly abundantly pitted. Pits 6—8 μ in diam. ; borders distinct ; apertures circular, or elliptic and oblique. Walls of *ray parenchyma cells* only about 1 μ thick ; horizontal walls with inequalities in thickness and rather large simple pits, 2—3 μ in diam. ; external walls of marginal parenchyma cells dentate ; radial walls with large pits, 3—4 μ, occasionally 5 μ, in diam. *Cross field* with 1—6 pits, mostly arranged in two

vertical rows ; with occasionally 8—9 pits in widened parenchyma cells. Ray parenchyma cells 20—22 μ in height. Pits in radial walls of tracheids uniseriate ; borders distinct ; pit diameter 15—16 μ in the earlywood and 6—9 μ in the latewood ; apertures circular or elliptic in the earlywood, slitlike and oblique in the latewood ; slits included, occasionally reaching the pit annulus. In radial walls of longitudinal tracheids spiral striations in the transition zone and the latewood. Tracheid ends blunt in the earlywood, slightly pointed in the latewood.

PICEA OMORIKA (Pančič) Bolle

Servian spruce

Pl. 262

Tree native to Yugoslavia.

C. 1. Longitudinal tracheids in distinct rows ; in cross section angular, with the corners rounded slightly in the earlywood, and markedly in the latewood. Then and when tracheids of quite small diameters occur, likewise in rows, some of which extend beyond the growth ring limits. Marked radial flattening of last-formed rows of late tracheids. *Growth rings* distinct ; not, or very slightly, wavy ; transition from early- to latewood gradual ; alternating zones of narrow and broad increments. *Resin ducts* confined to the latewood and, in a lesser degree, the transition zone ; in cross section circular or radially long-elliptic of roughly uniform (30—40 μ) diameter. Walls of epithelial cells rather thick, about 4 μ. Tangential diameter of early tracheids, 14—16 μ ; radial diameter, 18—22 μ. Radial diameter of late tracheids, 6—10 μ. Wall thickness of early tracheids, 1 μ ; of late tracheids, 2,5—3 μ.

T. 2,4. In tangential walls of *longitudinal tracheids* bordered pits scarce, occurring singly or in multiples of 2 to 3, with borders barely discernible and about 8 μ in diam. ; with slitlike apertures commonly extended and assuming an angle of about 45° to the long axis of the pit. In the tangential walls intensive spiral striations, predominantly in late tracheids, and likewise at about 45° to the long axis. Tiny cracks are frequently visible within them. *Rays* relatively low ; those without resin ducts very frequently 1—3, never more than 6—8 cells high and uniseriate ; those with resin ducts 10—12 cells high and several-seriate to include the centrally located ducts. *Ray parenchyma cells* in cross section short-elliptic, frequently almost regularly circular. The cells in single-row rays being of the same shape, the species appears to fit the *P. morinda* group of wide ray cells. Cell walls of the usual thickness. Intercellular spaces well discernible.

R. 3. Transverse tracheids not present in every ray, at least not in the writer's material from a young branch ; where present, their walls not more than about 1 μ in thickness. Pit borders distinct, 8 μ in diameter ; apertures circular or obliquely elliptical. Scarce but well-visible spines, about 1—2,5 μ high, project from the tracheid walls. *Ray parenchyma cells* 15—16 μ in height ; their tangential walls thin, about 1,5 μ. Secondary walls interrupted by simple pits appear in the form of small nodules deposited on the primary walls. Horizontal walls uniformly 1,5 μ thick, covered more or less abundantly with simple pits. External walls of marginal ray parenchyma cells wavy, like in the other *Picea* species. Radial walls also 1,5 μ in thickness. Simple pits 3—4 μ in diameter, mostly upright or oblique ellipses. Per *cross field* 2—6 pits. *Longitudinal tracheids* with uniseriate pitting. Pits in the earlywood, 15—16 μ in diam., with distinct borders and large (5—6 μ) circular apertures ; in the latewood, pit diameter only 10—12 μ and apertures elliptic or eye-shaped and obliquely inclined. Faint spiral striations in the radial walls of late tracheids. Tracheid ends blunt in the earlywood, slightly pointed in the latewood.

PICEA ORIENTALIS Carr.

Oriental spruce

Pl. 263

Distribution : the Caucasus and the Taurus Mountains ; frequently in dense stands. The tree attains a height of 30 m, with occasional individuals up to 50—60 m. According to Kleeberg, xylotomically the species is very similar to *Picea nigra*, the only significant departure being a slightly higher mean of cells in the rays.

C. 1. Tracheids in cross section from commonly tetragonal to frequently polygonal, in the latewood with rounded corners ; transition from early- to latewood gradual. *Resin ducts* distributed for their greater part in the transition zone, very scarce in the earlywood, and frequently in rows

parallelling the course of the growth rings; they are 35—60 μ in diam. Walls of *epithelial cells* thick, 3—4 μ, and densely covered with minute pits. Tangential diameter of early tracheids, 16—24 μ; radial diameter, 20—28 μ. Tangential diameter of late tracheids, 12—24 (mostly 18) μ; radial diameter, 8—12 μ. Wall thickness of early tracheids, 0,75—1 μ; of late tracheids, 2—2,5 μ.

T. 2,4. In tangential walls of *tracheids* pits rather few in number in the transition zone, and even less in the latewood; always uniseriate, 5—6 μ in diam., with eye-shaped or slitlike and nearly vertical (75—80°) apertures, almost as long as the pit diameter or, occasionally, extended. Tangential tracheid walls smooth in the earlywood, frequently striated in the latewood. In the material from young branches, spiral thickenings in the tangential walls. *Rays* partly with and partly without resin ducts; those with resin ducts, 20—35 cells in height and uniseriate; 3 or 4 seriate only where they include the ducts. Proportion of uni- to several-seriation from 2 : 1 to 3 : 1. Rays without resin ducts range from 1 to 35 cells in height. KLEEBERG reports a mean height of 14 cells, and this roughly agrees with the present writer's observations. In sections prepared from young branches the maximum ray height is 9—10 cell rows. *Ray parenchyma cells* in cross section more or less elliptic. Marginal tracheids pointed. Walls of parenchyma cells thick. Tangential walls cribriform.

R. 3. Transverse tracheids predominant in the marginal, and rare in the internal, rays; walls rather thin and smooth; the pit apertures in them circular, or elliptic and oblique. Horizontal walls of *ray parenchyma* variable in thickness (1,5—2 μ) and pitted; tangential walls 1—2 μ thick, dentate in radial view. Indentures between horizontal and tangential walls well discernible. Radial walls 1,5—2 μ in thickness. *Cross field* with 2—6 pits, in outline circular, or elliptic and obliquely oriented, commonly arranged in one or two horizontal rows. Bordered pits of *longitudinal tracheids* circular, with apertures that show through; in the earlywood pit diameter 14—16 μ; apertures circular or obliquely elliptical and included. In the latewood, pit diameter 6—8 μ; apertures eye-shaped or slitlike, frequently reaching the borders or crossing them. *Tori* nearly as large as the borders and radially developed. Striations frequent, especially in the latewood. Tracheid ends blunt, in the latewood slightly pointed.

PICEA POLITA CARR.

Tiger-tail spruce

Pl. 264*

Tree native to Central Japan; it attains a height of 20—30 m. In NAKAMURA's view, this wood is xylotomically very similar to that of *Picea bicolor.*

C. 1. Longitudinal tracheids in distinct rows; in cross section angular with slightly rounded corners. The transverse surface differs from that typical for the *Picea* spp. only in that it shows the late tracheid walls are also thick, usually just a shade thinner than the walls of the early tracheids. Last few rows of the late tracheids radially flattened. *Resin ducts* scattered chiefly over the transition zone, encountered in the latewood, but missing in the earlywood; in cross section, circular or widely elliptical with a diameter of 15—40 μ. Walls of *epithelial cells* 3 μ in thickness and covered with simple pits. *Growth rings* distinct; contours often rendered wavy by the adjacent resin ducts. Transition from early- to latewood gradual. Apart from epithelial cells lining resin ducts, parenchymatous elements wanting. Tangential diameter of early tracheids, 12—16 μ. Tangential diameter of late tracheids, 13—18 μ; radial diameter, 6—12 μ. Wall thickness of early tracheids, 2—2,4 μ; of late tracheids, 2,8—3 μ.

T. 2,4. Tangential walls of late *tracheids* sparsely pitted; pits 6—8 μ in diam.; apertures narrow and eye-shaped, variable in length, vertical or nearly so, included, the inner orifices exceptionally extended. Tangential walls of late tracheids faintly striated. *Rays* with centrally located resin ducts up to 15—20 cells high; those without resin ducts most frequently 1—3, maximally 10—15, cells in height. *Ray cells* in cross section those usual in the *Picea* species. *P. polita* is an intermediate between the spp. of wide, and the spp. of narrow ray cells, but it should be noted that there also occur narrow- or wide-elliptic, and even subcircular cells. Ray-cell walls thick; their tangential walls scattered with commonly circular pits, rendering the walls cribriform.

R. 3. Transverse tracheids, in the material from a young branch, few in number and restricted primarily to the inner growth rings; their walls thin, 0,8—1 μ, and delicately dentate; the pits in them, of the usual frequency and 8 μ in di-

* Owing to a regrettable mistake in the compilation the drawing pertaining to this species appears on Plate 120 with the photographs of *Cupressus whitleyana* Carr., while those belonging to that species appear on Plate 264.

ameter; apertures eye-shaped and almost vertical throughout the growth increment; circular outlines most exceptional. Many of the rays composed entirely of parenchyma cells. Tangential walls of *ray parenchyma cells* unevenly thick. Secondary walls interrupted by simple pits deposited on primary walls in the form of nodules or bars of different size. Walls mostly thickest in the middle, thinner on the margins, thus resembling a biconvex lens. Margins of simple pits rounded. Walls 2—2,5 μ thick. Horizontal walls evenly thick (1—15 μ) with simple pits. External walls of rays that consist entirely of parenchyma cells commonly wavy, like in the other *Picea* species, and with pits in the hollows between the crests. Radial walls 1—1,5 μ thick; the pits in them large, 3—3,5 μ in diameter, circular or frequently long-elliptic in the earlywood and eye-shaped in the latewood. Pits mostly in vertical rows. *Cross field* with 1—6 pits. Height of ray cells 16—18 μ. In radial walls of *longitudinal tracheids* pits uniseriate; 13 μ in diam. in the earlywood, and 11 μ in the latewood; apertures eye-shaped or slitlike and vertically oriented. Late tracheids with spiral striations. Tracheid ends blunt, but pointed in the latewood.

PICEA PUNGENS ENGELM.

Blue spruce or Colorado spruce

Pl. 265

Distribution: the part of the Rocky Mountains extending through Colorado and Utah, U. S. A. According to BEISSNER and MAYR, under favourable conditions the tree attains a height of 50 m.

C. 1. Longitudinal tracheids in distinct rows; in cross section, angular with slightly rounded corners in the latewood; last rows of late tracheids markedly flattened. *Growth rings* distinct; transition from early- to latewood gradual. Latewood reduced to 10—15 rows of tracheids. *Resin ducts* variable in number: in some rings many, in others just 1 or 2; as a rule they are scattered, but in some growth rings retain a distinct alignement more or less parallelling the demarcation. In cross section they are circular or radially short-elliptic, 30—40 μ in diam. These, and the many parenchymatous elements surrounding them, modify the *rays* in their vicinity, causing them to widen and to bend or twist. These peculiarities seem to suggest that these structures are not really resin ducts, but resin pockets or cysts. *Resin cysts* thin-walled, 1—1,5 μ in thickness; walls of the surrounding parenchymatous cells much thicker. *Twin cysts* are a frequent occurrence, i. e., two cysts with no longitudinal tracheids but only parenchymatous elements between them. In the earlywood of one of the growth rings in the section examined, parenchyma proliferation, similar to that seen in other species of *Picea*, was observable. The rays passing through this area were found to be involved in the proliferation and to have undergone marked modification. The phenomenon is in all probability of traumatic origin, and on this account is not a criterion for specific differentiation. Apart from the parenchymatous elements in these areas and around resin cysts, *wood paernchyma* wanting. Radial diameter of early tracheids, 20—24 μ; tangential diameter, 18—20 μ. Radial diameter of late tracheids, 6—12 μ. Wall thickness of early tracheids, 1—1,2 μ; of late tracheids, 2—3 μ.

T. 2,4. In tangential walls of *tracheids* pits few and scattered, and largely confined to those walls in the last-formed late row which are contiguous with the walls of the first-formed early tracheids of the succeeding increment. Pit diameter 8 μ; apertures circular, or slitlike and obliquely oriented and included. In the material examined, rays 1—12, most frequently 5—6, cells high; those with resin ducts, not much higher. *Ray cells* in cross section the same as in *P. morinda*, i. e., from short-elliptic to nearly circular, very rarely long-elliptic, and then only in single-row rays. The latter, and the marginal cells, are only a little higher than the internal cells. In tangential walls of *ray parenchyma cells* pits commonly circular, with the walls cribriform; occasionally procumbent elliptic, with the walls scalariform. Sometimes the two types of pits occur in one and the same ray. Pits as a rule larger than the corresponding pits in most of the other *Picea* spp.; pit diameter 2—2,5 μ. Intercellular spaces very small and inconspicuous.

R. 3. Transverse tracheids scarce in the specimen from a young branch; their walls thin (about 1 μ) and smooth; the bordered pits in them 5—6 μ in diam.; apertures circular or wide-elliptic. Many *rays* consist of parenchyma only; their tangential walls 2—2,5 μ thick, interrupted by large simple pits, making the secondary walls appear as transverse rods. Horizontal walls 1,5—2 μ thick, with pits unevenly distributed, abundant, prominently in the latewood. Radial walls of the same thickness, with circular, rarely wide-elliptic pits that are fairly large, 2,5—3 μ in diam., like in a few of the species discussed in the foregoing.

Cross field commonly with 1—6, occasionally with 8—10, pits, mostly in vertical rows. *Ray cells* 20—22 μ high. Indentures present, but not conspicuous. *Longitudinal tracheids* with uniseriate bordered pits in radial walls. Paired pits occasional. Pit apertures as a rule circular, or wide-elliptic and oblique even in the latewood, occasionally eye-shaped and included. Pit diam. 14 μ in the earlywood, 10—12 μ in the latewood. In the last-formed late tracheids pit borders elliptical owing to compression. Spiral striations present in the latewood. Tracheid ends blunt in the earlywood, pointed in the latewood. Walls of parenchyma cells surrounding resin cysts 2—2,5 μ thick and densely covered with simple pits.

PICEA SCHRENKIANA FISCH. ET MEY.

Schrenk's spruce

Pl. 266

Distribution: the Tien Shan and the Altai Mountains, and the Soongar and Kirghiz Steppes. A spruce of great height, the wood of which is rather brittle, according to BEISSNER and MAYR.

C. 1. Longitudinal tracheids in distinct radial alinement; in cross section angular, with the corners rounded slightly in the earlywood, and markedly in the latewood. Last rows of late tracheids strongly flattened. *Resin ducts* distributed in the latewood, encountered in the transition zone; in cross section circular or moderately long-elliptic, 30—40 μ in diam. Walls of *epithelial cells* rather thick, 3—3,5 μ. *Growth rings* distinct; contours frequently wavy. Transition from early- to latewood gradual. Sometimes two or more resin ducts coalesce. Tangential diameter of early tracheids, 13—15 μ; radial diameter, 16—20 μ. Radial diameter of late tracheids, 6—10 μ. Wall thickness of early tracheids, 1—1,2 μ; of late tracheids, 2—3 μ.

T. 2,4. In tangential walls of *tracheids* pits largely in a row in short to long multiples, occurring chiefly in the last-formed rows of the latewood, occasionally in rows further inward. Pit diameter 8 μ; borders distinct; apertures eye-shaped or slitlike, commonly nearly horizontal, and included. Spiral striations absent, even from the walls of the last late tracheids. *Rays* low in the specimen from a young branch: those without resin ducts 4—12, but not infrequently 1—3, cells high and uniseriate; those with resin ducts about the same in height and 2—4 seriate, except at the end. *Resin ducts* located centrally. *Ray parenchyma cells* in cross section short-elliptic, often nearly circular. On the above evidence, rays in structure very similar to those in *P. morinda*. In tangential walls of ray parenchyma cells, pits commonly circular, very rarely elliptical; accordingly, these walls very seldom scalariform, and even then not resolutely so. Ray parenchyma walls quite thick; intercellular spaces well discernible.

R. 3. Transverse tracheids few in the specimen from a young branch; their walls only 0,8 μ thick, commonly smooth, rarely coarse or delicately dentate; the bordered pits well-defined and fairly abundant; 6—7 μ in diam.; apertures circular or elliptic; cells often rather high, sometimes attaining 30—32 μ; they are irregular in shape and frequently bulging into one another. *Ray parenchyma cells* 20—22 μ high; their tangential walls unevenly thick, dentate or nodular, average thickness about 2 μ. Horizontal walls uniformly 1—1,5 μ thick, with comparatively large simple pits, many of them as much as 3 μ in diam. In agreement with most *Picea* species, the external walls of marginal parenchyma cells wavy and with pits in the hollows between crests. Radial walls about 1 μ in thickness; the pits in them large up to 4 μ in diam., generally irregular in arrangement, circular in shape in the earlywood, and elliptical or eye-shaped in the latewood. *Cross field* with 1—6 pits. In radial walls of *longitudinal tracheids* pits uniseriate; apertures circular in the earlywood, eye-shaped or slitlike in the latewood. Pit borders distinct, 14—16 μ in diam. in the early tracheids, 8—10 μ in the late tracheids. Delicate spiral striations on the last elements of the latewood. Tracheid ends blunt in the earlywood, slightly pointed in the latewood.

PICEA SITCHENSIS CARR.

(P. falcata SURING)

Sitka spruce

Pl. 267

Distribution: the northwestern regions of North America. Tree attains a height of 50—60 m. In the view of MEYER and that of HOLLENDONNER, xylotomically this wood agrees almost completely with that of *Picea abies*.

C. 1. Longitudinal tracheids angular in cross section, slightly rounded in latewood. Last rows of late tracheids markedly flattened. *Growth rings* distinct and uniform in width. Latewood reduced

to one fifth of the ring. Transition from early- to latewood abrupt. *Resin ducts* scattered over transition zone and latewood, relatively few in number, not infrequently 2—3 of them quite close to one another and surrounded by numerous parenchymatous elements ; in cross section circular, or moderately long-elliptic, 50—80 μ in diam. Walls of *epithelial cells* very thick, 4—4,5 μ. Tangential diameter of early tracheids, 25—28 μ ; radial diameter, 30—34 μ. Radial diameter of late tracheids, 10—18 μ. Wall thickness of early tracheids, 1—1,5 μ ; of late tracheids, 3,5—4 μ.

T. 2,4. In tangential walls of *longitudinal tracheids* pits limited in number, distributed mainly in the last-formed late tracheids, but encountered also in the early tracheids ; distinctly uniseriate ; 8 μ in diam. ; borders poorly defined ; apertures slitlike, slightly wider in the early- than in the latewood, invariably extending to the border, frequently beyond it. Spiral striations absent, even from the latewood. *Rays* predominantly 10—12 cells in height, higher ones occasional, 2—3 cells high rays exceedingly rare ; those with resin ducts attain a height of 14—16 cells, and many of them are 3—4 seriate to include the centrally placed ducts. *Ray cells* in cross section narrow elongate ellipses ; marginal cells, being mainly transverse tracheids, pointed ; tangential walls rendered cribriform by the circular simple pits.

R. 3. Transverse tracheids abundant, bounding practically all the rays in the specimen from adult wood ; their walls only about 1 μ in thickness, densely dentate and covered with numerous bordered pits. Pits about 8 μ in diam., with inconspicuous borders and nearly vertically inclined eye-shaped or slitlike apertures. Tangential walls of *ray parenchyma cells* fairly thick, about 2—2,5 μ, covered with simple pits, which give the secondary walls a rodlike appearance in radial view. Horizontal walls 2 μ in thickness, covered with simple pits. The waviness of the external walls, commonly characteristic of the *Picea* species, was missing in the material from adult wood ; it is only definite in the young tree. Radial walls also about 2 μ in thickness ; the pits in them circular or elliptic. In the cross field 2—6 pits in irregular arrangement. Elliptical pit apertures are vertical. Ray parenchyma cells and transverse tracheids equally 16—20 μ in height. In radial walls of *longitudinal tracheids* pits uniseriate, borders slightly blurred. In the latewood, pits 16 μ in diam., apertures circular ; in the earlywood, pit diameter 4—5 μ less, apertures slitlike and vertical. Delicate spiral striations in radial walls of late tracheids. Tracheid ends blunt, in the latewood slightly pointed.

PICEA SMITHIANA BOISS.
(- P morinda READ.)
West Himalayan spruce
Pl. 268

Tree native to the western parts of the Himalaya, growing at altitudes of 2000—3600 m, attaining a height of 30—50 m. According to BEISSNER, the wood is white, not durable, reddening and rotting quickly.

C. 1. Growth rings distinct ; limit frequently wavy ; transition from early- to latewood gradual. *Longitudinal tracheids* in cross section more polygonal than squarish in the earlywood and the transition zone ; last rows of markedly flattened late tracheids definitely tetragonal, yet aligned in distinct rows. *Resin ducts* located in the transition zone and the latewood. The material examined appears to show that they develop simultaneously in the growth ring, at about the same distance from the demarcation, and that they vary in number from ring to ring, occasionally with but a single one in the inner growth increments ; in cross section, they are circular or moderately long-elliptic and 25—30 μ in diam. Walls of *epithelial cells* relatively thick (2,5 μ). Parenchymatous elements abundant around resin ducts. Excessive parenchyma proliferation was observable in two of the growth rings, each involving the entire width of the ring, and giving rise to parenchymatous cells occasionally as much as 80—90 μ in diam. *Ray cells* frequently widened in the middle, and as their tangential walls retain their original width, the cells are barrel-shaped. Tangential diameter of early tracheids, 14—15 μ ; radial diameter, 15—18 μ. Radial diameter of late tracheids, 6—12 μ. Wall thickness of early tracheids, 1 μ ; of late tracheids, 1,5—2 μ.

T. 2,4. Tangential walls of *tracheids* with bordered pits chiefly in the latewood ; pits uniseriate ; 6—8 μ in diam. ; borders inconspicuous, often barely perceptible ; apertures elliptic or eye-shaped and almost horizontal. Spiral striations conspicuous, particularly in the latewood. Small to large cracks frequent in the cell walls, parallelling the striations. *Rays* generally very low ; mostly 1—3, less frequently 6—7, cells high ; those with resin ducts attain a height of 10—15 cells. Rays

generally 1 cell in width, those with resin ducts multiseriate. *Ray parenchyma cells* in cross section commonly wider than those in the other *Picea* species ; they are wide-elliptic, frequently circular. In size and shape, the cells of single-row rays agree with the other cells. The wide, almost circular ray cells provide a diagnostic feature. Pits in tangential walls commonly circular, giving the latter a cribriform appearance, but as procumbent-elliptic pits are not infrequent, the tangential walls are often scalariform. The frequency of scalariform tangential walls can also be regarded as a feature of diagnostic value. Intercellular spaces well discernible.

R. 3. Transverse tracheids scarce in the young wood examined, occurring predominantly in the inner growth rings ; their walls only 0,8 μ thick and densely spinulose. Bordered pits 8—9 μ in diam. ; apertures circular, but in the latewood elliptic and nearly horizontal. *Ray parenchyma cells* 20—24 μ high ; their tangential walls frequently quite thin, mean thickness 1,5—2 μ. Because of the very large pits in them, the secondary walls often show only as quite narrow transverse bars. Horizontal walls uniformly 1 μ in thickness, with numerous pits which frequently give the secondary wall the appearance of a string of beads. The horizontal walls often split and give rise to gaps several μ in width. Radial walls, like the horizontal ones, about 1 μ thick, with pits in them up to 5—6 μ in diam., mostly circles in the earlywood. *Cross field* with 1—6 pits irregular in arrangement. In radial walls of *longitudinal tracheids* pits uniseriate, frequently in multiples of 8—10 or more ; 10—12 μ in diameter in the earlywood, and 8 μ in the latewood ; borders distinct ; apertures circular in the earlywood, frequently procumbent-elliptic in the latewood. Nearly horizontal spiral striations observable, chiefly in the latewood. Tracheid ends blunt, slightly pointed in the latewood. Quite short tracheids not uncommon.

PICEA WILSONI MAST.

(P. watsoniana MAST.)

Pl. 269

Tree native to China.

C. 1. Tracheids aligned in distinct rows ; in cross section angular, with corners rounded slightly in the earlywood, but so very markedly in the latewood as to be nearly circular. Last rows of the late tracheids strongly flattened. *Resin ducts* located in the transition zone and the latewood ; not infrequently quite close to the growth ring limits, which then take on a wavy contour. In cross section, resin ducts circular or radially somewhat long-elliptic, 25—35 μ in diam. Walls of *epithelial cells* about 2—2,5 μ thick. *Growth rings* distinct ; transition from early to latewood abrupt. Unlike in the other *Picea* spp., *wood parenchyma cells* present, thus providing a diagnostic feature. They are scarce in number and distributed directly along the growth ring limits. Tangential diameter of early tracheids, 13—15 μ ; radial diameter, 16—20 μ. Radial diameter of late tracheids, 6—12 μ. Wall thickness of early tracheids, 1—1,5 μ, of late tracheids, 2—3 μ.

T. 2,4. Tangential walls of *longitudinal tracheids* with bordered pits eminent in the latewood, less so in the transition zone ; largely uniseriate in short to long multiples ; 8 μ in diam. ; borders distinct ; apertures eye-shaped or slitlike and nearly vertical. Spiral striations very frequent throughout the latewood and the transition zone, a little less so in the earlywood. *Rays* low in the specimen from a young branch : those with resin ducts, 4—12 cells in height ; those without 1—10 cell-rows high, but rays 1—3 cells in height not infrequent. Rays uniseriate ; multiseriate only where they include the, mostly, centrally disposed resin ducts. *Ray parenchyma cells* in cross section narrow, long-elliptic, with thick walls. Intercellular spaces angular and well discernible. Cells of single-row rays eye-shaped. *Wood parenchyma* located along the growth ring limits. Cell walls thin, about 1—1,5 μ. Cells relatively short, at most 30—40 μ in length. Tangential walls rarely with minute simple pits. Horizontal walls smooth, or with simple pits.

R. 3. Transverse tracheids scarce, mostly restricted to the inner growth rings. Walls thin, about 1 μ in thickness and delicately dentate. Radial walls abundantly, transverse walls moderately provided with pits 6—8 μ in diam. and having elliptic or eye-shaped apertures. Many of the *rays* composed entirely of parenchyma cells with rather thick (2—3 μ) tangential walls abounding in simple pits, which leave fragments of the secondary wall to look like transverse rods deposited on the primary wall. However, these rods are not as definite in this species as in some of the other *Picea (P. pungens, P. koyamai)*. Horizontal walls uniformly 1—1,5 μ thick, provided with simple pits. In the young wood, external walls of marginal parenchyma

cells wavy, with pits in the hollows between crests. Radial walls 1—1,5 μ thick, with large circular or elliptical pits of 2—3 μ diameter and irregularly arranged. *Cross field* with 1—6 pits. *Ray parenchyma cells* 14—18 μ in height. Pits of *longitudinal tracheids* uniseriate; apertures circular or elliptic in the earlywood and slitlike and extended in the latewood. Pits 14 μ in diam. in the earlywood, 10 μ in the latewood. Marked spiral striations show in the earlywood and, even more prominently, in the latewood. They seem to bear some relation to the slitlike extended apertures in the bordered pits, for the two run parallel courses and the apertures often come to lie within the spiral striae. Radial walls of *wood parenchyma cells* with simple pits slightly larger than those in the tangential walls. Tracheid ends blunt, slightly pointed in the latewood.

Pinus species*

I. Cembra group

PINUS CEMBRA L.

Arolla pine

Pl. 279

Distribution: northeastern Asia, the Alps, and the Carpathian Mountains. The tree grows at altitudes of 1900—2000 meters and attains a height of 10—25 m.

C. 1,2. Growth rings fairly equal and narrow, commonly 18—25 tracheids in width; contours distinct and wavy, delineated by abruptly flattened 2—3 rows of last late tracheids. No discrepancy in wall thickness between early and late tracheids. Transition gradual, wood therefore of even structure. *Tracheid* walls in the earlywood 2—3 μ; in the latewood 3—4 μ. Tracheids, in cross section, squares, 30—40 μ in diam. *Resin ducts* abundant, located chiefly in the outermost portion of the latewood and giving the growth-ring demarcation a still more pronounced wavy appearance; they are occasional in the inner parts of the ring, and exceptional in the earlywood and measure 80—100 μ, sometimes 120 μ. *Rays* uniseriate, difficult to discern, following one another at fairly regular intervals.

T. 4. In the *rays*, similarly to the other *Pinus* spp., cellulose-walled parenchyma cells and lignified transverse tracheids. The latter are practically always absent from the innermost growth rings. *Parenchyma cells* thin-walled, unlignified. The *transverse tracheids* commonly terminate the rays, occasionally occur in the interior, exceptionally build themselves rays a few cells high. Rays always uniseriate and 1—15 cells high; those with resin ducts attaining a height up to 30—35 cells. *Ray cells* elliptic, 8—10 μ wide, 20—23 μ high. *Resin ducts* as a rule centrally located. In tangential walls of tracheids near growth ring limits, small bordered pits fairly frequent, 8—10 μ in diam., about half the width of the tracheid walls. Pit apertures distinct, elliptic or linear; the outer orifices sometimes lenticular or slitlike, when they extend to the border or occasionally beyond it, and transversely or obliquely oriented; in the latter case they form *X* figures with those in the complementary pits.

R. 3. In some growth rings, the walls of late *tracheids* show obliquely oriented and from short to long cracks, which cross the similar cracks on the other side (compression wood). In radial walls, bordered pits fairly abundant, occurring singly as a rule, but in the first-formed early tracheids sometimes as paired pits. Crassulae between the pits distinct. Pits circular, but when closely one above the other, then procumbent ellipses which not infrequently, are rather flattened. For size, they depend on tracheid width, but never reach quite across a tracheid; the longest diameter is 25 μ. Apertures conform to the border outlines.

Early and late tracheids having equally thick walls, the apertures are circular in the earlywood, except perhaps in a few last-formed narrow tracheids, where they are occasionally oblique or upright ellipses and included; the inner orifices are exceptionally extended to reach the pit annulus.

Walls of *transverse tracheids* in rays thin; thickenings, elevations, or indentations absent or insignificant. Transverse tracheids from short to long rectangles with wavy outer margins. Pits small, 8—10 μ in diam., with faintly showing borders and circular or elliptic apertures; elliptic apertures the more elongate and pointed, the narrower the lumina of the communicating longitudinal tracheids; in such cases, outer orifices extend to the pit annulus or, rarely, beyond it. Tangential walls of *ray parenchyma cells* smooth or equipped with 1—2 small simple pits. The same applies to

* Worked up with the aid of *István Varga*, pupil of the writer.

the horizontal walls, where the pits are very variable in shape and size, sometimes attaining 18—20 μ. In the radial walls, large pits occupy the entire cross field, which are rectangular or squarish with rounded corners in the earlywood, but nearer to slightly pointed ellipses in the latewood. *Cross field* commonly with 1—2, occasionally 3—4, pits; if 2, they are mostly superposed; if 3 or 4 are above one another, they are as a rule triangular, lachrymiform, or of irregular shape; those occurring singly, are sometimes bean- or bone-shaped. Borders and apertures of pits in early tracheids barely distinguishable from each other, often leaving the former to appear only as a narrow band. In the latewood, they are more or less distinct. Longitudinal *resin ducts* lined with thin-walled unlignified short parenchyma cells followed by thicker-walled, elongated and slightly lignified cells. The walls occasionally equipped with simple pits. Then and when short tracheids follow this band of parenchyma and the two communicate through half-bordered pits. Resin ducts of rays likewise surrounded by thin-walled parenchyma occasionally equipped with tiny pits.

In the *tracheids*, trabeculae frequent: they are cylindrical bars with a smooth surface, and ends enlarged where they join the opposite tangential walls. Sometimes there is a longitudinal gap in them. They vary in thickness, the thickest may come to lie next to the thinnest. Not infrequently, a trabecula is formed in each, or practically each, of the tracheids in the growth ring resulting in an unbroken or rarely interrupted transverse series, which sometimes continues beyond the growth ring limits. In some instances, a number of such series are superposed in the radial plane.

This surface plainly shows the double T girders mentioned by SCHULTZ which connect two ray cells, or join the radial walls of the longitudinal tracheids with one end and a ray cell with the other. As they do not occur in tracheids, which are not in contact with rays, and because with one end they always adhere to a ray cell, there is evidence for SCHULTZ's assumption that these girders are to protect the tracheids from the pressure exerted upon them by the rays. On the other hand, since in these girders resin or gum drops occur, support is afforded also for the view of RATZ that they are secondary processes arising only in dead wood and not consisting of lignified cellulose. They are commonly perpendicular to the ray cells. Ramifying forms, such as mentioned by SCHULTZ, were not encountered by the present writer. While SCHULTZ reports no double T girders in *P. cembra*, we have failed to detect them in *P. strobus*, and so have HOLLENDONNER and KLEEBERG. (J- 74)

PINUS FLEXILIS JAMES

Limber pine

Pl. 288

Tree native to the Rocky Mountains in North America. It attains a height of 10—23 m, and is 1—1,5 m in diameter.

C. 1,2. Viewed xylotomically this species belongs to the *P. cembra* group, from which it cannot be distinguished without great difficulties and much uncertainty. *Growth rings* fairly wide and contours but very slightly wavy. Early- and latewood rather conspicuously differentiated inside the growth ring. Apart from above-average local thickenings, *tracheid* walls only 1—1,5 μ thick in the earlywood, but thickened up to 2,5—3 μ in the latewood. Vertical *resin ducts* located chiefly in the latewood. *Ray parenchyma* to some extent lignified, and consequently pitted. Horizontal walls with fairly large circular, elliptical, or lenticular pits.

T. 4. In tangential walls of latewood *tracheids* pits rather numerous, with oblique or horizontal apertures, as seen in *P. cembra*. *Rays* 1—10, typically 3—5, cells high; lower than in *P. cembra*. The limited ray height encountered by the writer may be due to the fact that the material available to him came from a branch. *Rays* with resin ducts low, like in *P. wallichiana;* these too are likely to be higher in mature wood.

R. 3. Walls of *transverse tracheids*, in harmony with the group character, thin and smooth. Pit apertures circular or elliptical, rarely eye-shaped, and included. Walls of *ray parenchyma cells* slightly lignified. The thickest walls are the horizontal walls, yet there are occasional pits in the radial walls, though mostly initial ones. The thickest part of the radial walls is that in contact with the tangential walls of longitudinal tracheids. *Cross field* mostly with 1—2, occasionally with 3—4, pits; if there are 2 or 3, they are commonly superposed, very exceptionally side by side. Pits circular or elliptic, with apertures conforming to their outlines, like in *P. cembra*, and difficult to distinguish, even in the latewood. (J.)

PINUS PEUCE GRISEB.

Macedonian pine

Pl. 316

Distribution: the Balkan Peninsula. The tree thrives at altitudes of 1600—2000 m, attains a height of 10—14 m, with individuals up to 30 m high; trunk up to 1 meter in diameter.

C. 1,2. Resin ducts, unlike in the other *Pinus*, aligned in more or less distinct rows exactly on the border line between the earlywood and the latewood, to which line they are strictly confined. They are slightly larger than is usual in the *Pinus* (120—150 μ). *Tracheid* walls fairly thick (3—5 μ), even in the earlywood, with rather many intercellular spaces between them. Primary walls usually polygonal, secondary walls, and with them the lumina, rounded, frequently elliptical or circular.

T. 4. Xylotomically, the species stands nearest to *P. cembra*, but possesses thicker *ray-parenchyma* walls. In horizontal and tangential walls simple pits abundant. *Rays* up to 10—12, those with resin ducts up to 15—20, cells high. These are multiseriate, except at the ends. In tangential walls of *longitudinal tracheids* pits numerous, circular, nearly as wide as the narrower tracheids. Pit apertures predominantly circular, or short-elliptic and included. Inner apertures exceptionally elongated and oblique. In this respect the species is nearer to *P. cembra* than to *P. strobus*.

R. 3. The radial surface likewise requires this species to be included in the *P. cembra* group, the walls of its *transverse tracheids* being smooth, without dentation. To some extent it can be separated from *P. cembra* by its narrower *cross fields* due to narrower tracheids. In these, two pits side by side are rare occurrences, even in the earlywood, whereas this arrangement is rather common in *P. cembra*. Where there are more pits in the cross field, they are superposed, in some marginal cells even in three rows. True, superposed pits are also encountered in *P. cembra*, but almost exclusively in the latewood and in lesser numbers. Pits from variously elliptic to ovoid and sometimes circular. Pit borders more or less distinct. Walls of *parenchyma cells* from quite thin (unlignified) with barely perceptible pitting to thick or very thick. Thick tangential and horizontal walls abound so very much in large simple pits that the free portions of walls between them appear as a string of beads. In other instances, the walls, especially the horizontal walls, are entirely unpitted for long stretches, occasionally through many cells, in which case the walls are even thicker. *Transverse tracheids* were scarce on the sections, prepared from a branch of the thickness of an arm. Apertures of bordered pits occasionally reach the pit annulus. In the *longitudinal tracheids* pits roughly the same in shape and size as in the spp. previously described. Paired pits wanting. (*M.*)

PINUS MONTICOLA DOUGL. et LAMBERT

Western white pine

Pl. 309

Distribution: the western parts of North America, California, and British Columbia. The tree attains a height of 20—25, sometimes 46, meters with a trunk diameter of 1—1,5 m. Xylotomically, this species is similar to *P. parviflora*.

C. 1,2. The transverse surface differs from that of *P. parviflora* in that in this species the growth rings are wider, more even, and rather suggestive of *P. peuce*, having fairly thick tracheidal walls, even in the earlywood. The latewood with thick-walled cells is much wider than the earlywood, which is frequently restricted to a few rows. In spite of angular primary walls, the lumina are rounded. Like in *P. parviflora*, *resin ducts* occur also in the earlywood.

T. 4. Tangential walls of last-formed late *tracheids* rather abundantly pitted. Pit borders distinct. Apertures lenticular from short to long, occasionally elliptic, invariably included, commonly definitely horizontal, exceptionally just a little inclined. The definitely horizontal position of the apertures offers a further means of separating the species from the rest of the *P. cembra* group. *Rays* low like in *P. parviflora* (1—10 cells in height), but the cells somewhat wider. Tangential walls of *ray parenchyma* commonly cribriform.

R. 3. In radial walls of *tracheids* pit apertures commonly from circular to short-elliptic, in the latewood occasionally lenticular; mostly horizontal in the narrow late tracheids, sometimes obliquely inclined; apertures of complementary pits frequently crossed. *Transverse tracheids* few in number. Walls of *ray parenchyma* thick and lignified and definitely pitted. Pit apertures in radial walls slightly narrower than in *P. parviflora*, readily distinguishable from the borders, occasionally narrow and eye-shaped in the latewood. Because the tracheids are narrow, the apertures are obliquely or vertically oriented. Number of pits

in the *cross field* 1—2, in the wider cells very rarely 3 ; if more than 1, they are invariably superposed. This is natural in view of the the thick walls and the narrowness of the tracheids. *(Y., M.)*

PINUS AYACAHUITE EHRENB.

Mexican white pine

Pl. 274

Tree native to Mexico.

C. 1,2. Tracheids are thick-walled (3—4 μ) in some individual growth rings ; in cross section rounded ; intercellular spaces between them. In other growth rings walls thinner and angular, intercellular spaces missing. Early- and latewood not conspicuously differentiated. *Growth rings* indistinct. *Resin ducts* relatively scarce, irregular in arrangement. Horizontal walls of *ray parenchyma* slightly lignified and thickened, and consequently pitted.

T. 4. Tangential *tracheid* pitting confined to latewood ; pit apertures eye-shaped and oblique. *Rays* commonly 3—6, exceptionally 8—10, cells in height ; composed mainly of parenchyma cells ; transverse tracheids rare. Horizontal walls the thickest of all ray-cell walls. Tangential walls with horizontally oriented elliptic pits, rendering these walls scalariform. Circular pits give the walls a cribriform appearance. Intercellular spaces between parenchyma cells and longitudinal tracheids, triangular. Two such intercellular spaces may coalesce in consequence of the displacement of parenchyma cells. Transverse resin ducts few in number and irregular in arrangement.

R. 3. Radial walls of *tracheids* covered in their entire width by circular bordered pits, 18—20 μ in diam., with large (7—8 μ) apertures that are circular even in the latewood.

By the ray structure this species belongs to the *P. cembra* group, from which it is not easily differentiated.

Transverse tracheids scarce, their walls smooth in harmony with the group type. Apertures of the bordered pits in them eye-shaped and oblique. In the *cross field* 1—2, rarely 3, large pits, occupying the entire area. Two pits generally superposed, occasionally side by side. Pits circular, elliptic, occasionally irregular in shape ; apertures fairly large, even in the latewood, and conforming to the outline of the border, which is barely perceptible. No narrow eye-shaped or slitlike pit apertures. On the above evidence, this species is very similar to *P. cembra* and *P. strobus*, definitely distinguishable from *P. monticola*, less decidedly from *P. flexilis* and *P. peuce*. Tracheids with *trabeculae* not uncommon. *(M.)*

PINUS ARMANDI FRANCHET

Armand's pine

Pl. 272

Distribution : the western regions of China, Taiwan Island.

C. 1,2. Transverse surface similar to that of *P. albicaulis*, but early- and latewood less conspicuously differentiated, walls of late tracheids less thickened, lumina angular.

T. 4. Tangential surface also like that in *P. albicaulis*, but rays still lower : 6—8 cells in rays without, and up to 15 cells in rays with, resin ducts.

R. 3. Radial surface shows no significant departures from that usual in the *P. cembra* group. Rows of marginal transverse *tracheids* occasionally more in number. Transverse tracheids short, sometimes upright, with external walls markedly wavy. Walls thin. Walls of *ray parenchyma cells* slightly thicker. In the *cross field* 1—3 pits, superposed unlike in *P. albicaulis*, thereby furnishing a means of differentiation. Pit apertures not distinguishable from the borders except, to some extent, in thicker-walled latewood tracheids. Tracheids occasionally with *trabeculae*. *(M.* 171)

PINUS PUMILA REGEL

Dwarf Siberian pine

Pl. 321

Distribution : North Asia, Siberia, the regions of the Amur, Kamtchatka, the Kuril Islands, Japan, and Iceland.

C. 1,2. The available material came from a young branch ; *growth rings* accordingly uneven ; contours wavy. *Tracheid* walls vary in thickness not only as between early- and latewood but also within the same seasonal increment. The early-wood elements, for instance, may be quite thin-walled in one portion of the growth ring, while in an other they are so very thick-walled (3—4 μ) as to render the lumina barely perceptible ; in fact, their walls may be thicker than those of the latewood tracheids of the preceding growth ring. This circumstance is probably due to mechanical factors. *Resin ducts* sporadical, confined mostly to the late earlywood and the latewood.

T. 4. Rays low in the young wood studied: mostly 3—4, maximally 6—8, cells in height; those with resin ducts somewhat higher. *Ray cells* in cross section usually short-elliptic or subcircular and commonly wide. No appreciable departure in the pitting: simple pits large; tracheidal pits 8—10 μ in diam. in accordance with the average; apertures slightly oblique ellipses or subcircular.

R. 3. Radial surface present the picture typical for the *P. cembra* group. *Transverse tracheids* few in the sample from young wood. Their walls, and those of the ray parenchyma cells, thin. Pitting of the usual group type. If there are more pits in the cross field they are, as a rule, superposed. Pit apertures indistinct, even in the latewood.

PINUS WALLICHIANA A. B. JACKSON
(P. excelsa WALL., P. griffithii Mc CLELLAND)
Bhutan pine
Pl. 337

C. 1,2. Xylotomically, this species cannot be definitely differentiated from those discussed in the foregoing. *Growth rings* fairly wide and even. No appreciable difference in wall thickness of early and latewood tracheids. Latewood much wider than earlywood.

T. 4. Rays maximum 4—6 cells in height. *Ray* cells fairly wide ellipses in cross section; their tangential walls abundantly pitted. Triangular intercellular spaces distinct between them and the *longitudinal tracheids*. In the tangential walls of tracheids only a few pits were visible on the section examined.

R. 3. Nothing remarkable on radial section. Pit apertures of bordered pits of narrower *tracheids* oblique and lenticular, invariably included. In the rays, which are of the *P. cembra* type, transverse tracheids few in number. In the cross field pits commonly superposed; pit apertures distinct, especially in the latewood. *(Y.)*

II. Strobus group

PINUS STROBUS L.
White pine or Weymouth pine
Pl. 330

Distribution: the northeastern regions of North America, from Virginia to Canada, and to the Mississippi in the west. The tree was imported to Europe in 1755, and because of its good reputation in America, it is planted not only as an ornamental garden-tree, but also in big stands. The wood is xylotomically very similar to that of *P. cembra*.

C. 1,2. Growth rings wider than in *P. cembra*; contours appear less pronouncedly wavy, undulations being restricted to places, where *longitudinal resin ducts* force them to give way. These ducts are somewhat larger (100—140 μ) and slightly less in number than in *P. cembra*, but of the same arrangement.

T. 4. In tangential walls of *longitudinal tracheids* along the growth ring limits, bordered pits numerous on this surface, too. In width and shape they are similar to those in *P. cembra*, but, unlike in that species, the linear or lenticular apertures are almost invariably vertical or slightly oblique. Accordingly, apertures forming *X* figures are rare. Pit apertures are but exceptionally extended. On the evidence of the foregoing, *P. strobus* is to some extent separable from the other members of the group, and also from *P. cembra*, in which the apertures are more horizontally or obliquely oriented.

R. 3. The pitting in the radial walls of *tracheids* slightly differs from that in *P. cembra*. Paired pits are rare occurrences. In SCHRÖDER's view, a relative difference is presented by the *cross fields* rarely containing two pits in the present species, but frequently in *P. cembra*. This, however, is not proved, for 2 pits in the cross field are quite frequent, and perhaps 3 or 4 can be said to be rare. Another difference, according to SCHRÖDER, would be that the rays are lower in *P. strobus* than in *P. cembra*. This contention has already been refuted by KLEEBERG, and the present writer has also found that rays without resin ducts attain a height of 14 cells in this species, i. e., approaching the ray height in *P. cembra*, which is 15 to 16 cells. On the other hand, rays with resin ducts do not exceed 18 cells in height in *P. strobus*, while they do attain 30—35 cells in *P. cembra*, and in this respect exhibit a certain difference between the two species. *(M.*, 74)

PINUS LAMBERTIANA DOUGLAS
Sugar pine
Pl. 296

Distribution: the West of North America, from the Rocky Mountains to the coast and from the Columbia river to Mexico. The erect tree attains a height of 100 m, with a trunk diameter of 3—6 m.

C. 1,2. Transverse surface agrees largely with that in the other members of the group. *Growth*

rings wide, and uniform in width. In relation to earlywood, latewood narrow. In respect of wall thickness, slight discrepancy between the seasonal increments. Walls of early tracheids, 1—1,5 μ; of late tracheids, up to 4—5 μ. Transition from early- to latewood gradual. Growth rings distinct, marked by contrast in wall thickness and colour between the final flattened rows of late tracheids and the succeeding rows of early tracheids; demarcation wavy, probably owing to the nearby resin ducts. *Resin ducts* large (150—220 μ), easily recognizable to the unaided eye; numerous, occasionally scattered also in the earlywood; sometimes in twos side by side.

T. 4. On the tangential surface, the likeness is the greatest to *P. cembra*. *Rays* up to 15, occasionally 20, cells high; those with resin ducts, up to 40—45 cells in height. *Ray cells* in cross section from short- to long-elliptic; intercellular spaces between them and the tracheids well discernible. In tangential walls of last late tracheids bordered pits rather large, 10—12 μ in diam.; apertures oblique, short-elliptic or linear and always included.

R. 3. In radial walls of *tracheids* large (25—30 μ) pits occurring singly; in the wider early tracheids paired pits not uncommon. Pit apertures large, frequently 8—10 μ in diam., assuming the outlines of the borders; outer apertures in the latewood sometimes slitlike. *Ray* structure, the usual in the group: composed of thin-walled parenchyma cells and thin- and smooth-walled transverse tracheids. Having thin walls, parenchyma cells frequently smooth, less frequently with fairly numerous simple pits in horizontal and radial walls. These pits differ in size from the corresponding pits in *P. cembra* and *P. strobus*, for those in the horizontal walls are maximally 5—10 μ in diam.; this feature offers a means of differentiation. In the cross field 1—2, in the earlywood almost always 2, sometimes 3—4, pits side by side; mean diameter of pits 15—20 μ; pit outlines circular, or short-elliptic, or lemon-shaped, apiculate at both ends. Smooth areas between pits fairly large. Pit apertures poorly defined in the earlywood, distinct and occasionally slitlike and extended in the latewood. Number and shape of cross-field pits offer a further means of separating this species from *P. cembra* and *P. strobus*, the latter having commonly 1, rarely 2, pits of a different shape (squares with rounded corners, rectangles, long or short ellipses) and only small portions of the walls unpitted. The same departures have been established by HOLLENDONNER and MAYR. An additional appreciable difference consists in that the elements are of larger dimensions, especially the resin ducts, which are commonly twice as large as those in *P. cembra*. (*M.* 74)

PINUS PARVIFLORA SIEB. et ZUCC.

Japanese white pine

Pl. 314

Distribution: Japan and Taiwan. The tree attains a height of 15—20, rarely 32, meters.

C. 1,2. Xylotomically, this species belongs to the *P. strobus* group, but the greatest likeness it bears to *P. flexilis*, the insignificant departures from which are probably individual and not specific.

Growth rings relatively narrow, but fairly uniform in width; contours very distinct due to the marked contrast in wall thickness between the flattened final rows of late tracheids (5—6 μ) and the succeeding rows of early tracheids (1,5 μ).

Early tracheids angular, late ones rounded, frequently circular. Sometimes even primary walls rounded off, with the intercellular spaces between them well defined. Proportion of early- and latewood variable in the individual growth rings. Latewood commonly predominant, yet occasionally restricted to but a few rows. In horizontal walls of *ray parenchyma* large (4—8 μ) simple pits.

T. 4. Tangential walls of late *tracheids* with relatively numerous pits somewhat larger (10—12 μ) than those in the species discussed in the foregoing; apertures mostly circular, obliquely short-elliptic, or eye-shaped, always included. Pits in general very similar to those in *P. peuce*. *Rays* low: commonly 1—4, maximally 6—8, cells high; those with resin ducts 10—20 cells in height. *Ray parenchyma cells* in cross section from short- to long-elliptic, very rarely circular. Pits on tangential walls large, the walls cribriform or scalariform according to the shape of the pits. All walls thick, especially horizontal ones, distinctly seen on tangential section.

R. 3. Radial surface similar to that in *P. flexilis*, but transverse tracheids less in number. *Cross field* commonly with one large *P. cembra* type pit; if occasionally with more then they are invariably superposed. (Y-, M.)

PINUS KORAIENSIS SIEB. et ZUCC.
Corean pine
Pl. 295

Distribution: Central Japan, Korea, Manchuria, Western China, Taiwan. The trees 3—4, rarely 10, m tall in Korea, but attain a height of 32 m in Manchuria; trunk diameter up to 1 m.

C. 1,2. Walls of *tracheids* thin, even in the latewood (2—2,5 μ) with but slightly thickened local areas; lumina large and angular. No intercellular spaces between the tracheids. *Growth rings* distinct due to the flatness of the tracheids in the last rows (5—10 μ radially); contours slightly wavy. *Resin ducts* large (100—130 μ), numerous, encountered throughout the growth ring. In the horizontal walls on *ray parenchyma cells* numerous large (5—10 μ) circular or elliptic simple pits.

T. 4. Rays up to 10—12 cells in height; those with resin ducts not higher than 15 cells; the uniseriate portions above and below the duct consist only a few cells or are missing (cf. *P. flexilis*). *Ray cells* in cross section narrow-elliptic (lenticular). Due to dense pitting, tangential walls commonly reticular or scalariform. Apertures of pits in tangential walls of tracheids from circular to obliquely lenticular or elliptic, in the latter case, those of complementary pits form X figures.

R. 3. Pits in radial walls of *tracheids* the same as those in *P. cembra*. The tracheids being narrow, paired pits absent. In rays, *parenchyma cells* predominantly *transverse tracheids* few in number. The pitting of the radial walls of ray parenchyma agrees with the group type. In general, the species under discussion stands nearest to *P. cembra* itself, from which it differs only by having thicker parenchyma-cell walls, therefore more distinct pit margins, and more numerous pits in the horizontal and tangential walls. Entire area of radial walls occupied by large pits, 1—3 in number in the cross field, superposed in the narrow tracheids, but side by side in the wider ones of the older wood. Pit apertures even in the last latewood tracheids large and barely distinguishable from the borders.

Parenchyma of *resin ducts* thin-walled; arrangement and pitting the same as in *P. cembra*. *(M., Y.)*

PINUS ALBICAULIS ENGELMANN
White-bark pine
Pl. 270

Distribution: Pacific Coast of North America, at altitudes of 1600—4000 m. The tree is shrubby and attains a height of 7—10, rarely 20, meters. On xylotomical evidence, differentiation from *P. cembra* is difficult, slight departures only being encountered in the height of rays, the wall thickness of ray parenchyma, and the structure of growth rings.

C. 1,2. Growth rings fairly uniform in width; demarcations somewhat wavy, probably because of the resin ducts near them; contours conspicuous, marked not only by flattened tracheids but also by the contrast between the 4—5 μ thick walls of the late tracheids and the thin-walled early tracheids. Latewood not more in width than one third the width of the growth ring, frequently less or restricted to but a few rows, exceptionally altogether missing and thereby obliterating the growth ring boundaries.

Resin ducts moderately numerous and unevenly distributed, occurring mostly in the latewood, sometimes along the growth ring limits, and never encountered in the early wood within the inner half of the growth ring. Walls of *epithelial cells* somewhat thicker than in the spp. previously dealt with. Ducts up to 70—100 μ in width. Horizontal walls of *ray parenchyma* sparsely pitted.

T. 4. Rays not exceeding 8—10 cells in height, but those with *resin ducts*, being uniseriate at both ends, attain a height up to 20 cells. Shape and pitting of ray cells as in the other species. Apertures of pits in tangential walls of *tracheids* circular or elliptical, but outer apertures mostly slitlike and oblique.

R. 3. Pitting in the radial walls of *tracheids* and ray structure answer those in the group and stand nearest to *P. cembra*. Paired pits not encountered. *Transverse tracheids* nor infrequent in marginal as well as internal rays, and often bi- or triseriate; their walls are thin and, apart from the pits, smooth. Pit apertures circular, elliptical, most frequently lenticular, included but reaching near to the pit annulus, obliquely or, sometimes, nearly horizontally oriented. Walls of *parenchyma* thicker than those of transverse tracheids. *Cross field* commonly occupied by a single large-sized pit of the *P. cembra* type, occasionally by 2 or 3 which are more frequently side by side than superposed.

In the latewood, pit apertures clearly distinct from the borders owing to the thicker walls of the tracheids. Parenchyma cells of *resin ducts* like those in *P. strobus. (M.)*

III. Aristata (Parryana) group

PINUS ARISTATA ENGELMANN

Bristle-cone pine

Pl. 271

Distribution : the Rocky Mountains, North America. Trees 13—18 m tall, with a trunk diameter of 0,6—1 meter.

C. 1,2. Growth rings wide, even and distinct, marked primarily by flattened late tracheids, since in wall thickness there is no appreciable difference between the early and late elements. Usually no intercellular spaces between the large (20—30 μ) and thin-walled angular tracheids. In some growth rings, however, or in some places within a growth ring, even the earlywood elements are thick-walled and have more rounded lumina. *Rays* straight and relatively closely spaced. *Resin ducts* few in number, but distributed throughout the growth ring ; 60—120 μ in diam.

T. 4. Tangential surface characterized by the great number of rays, usually 7—9, occasionally up to 12—14, cells in height. *Rays* with resin ducts scarce, and only a little higher than the simple ones. *Ray cells* in cross section narrow, commonly 6—8 μ, occasionally only 4—5 μ, in width ; elliptic or lenticular ; in very narrow cells the pitting barely perceptible. Tangential walls of last-formed late *tracheids* abundantly equipped with bordered pits not more than 6—8 μ in diam.

R. 3. In radial walls of *tracheids* bordered pits uniseriate ; paired pits very exceptional. Pit apertures circular ; inner orifice in the latewood occasionally somewhat elongated. Like in the other *Pinus*, *rays* composed of transverse tracheids and parenchyma. The former are fairly numerous, occasionally encountered in several rows on the ray margins, occurring in the interior of rays ; moreover, sometimes they themselves form rays 3—4 cells in height. Their walls are perfectly smooth, like in the *P. cembra* group ; only exceptionally are there quite negligible elevations seen on them. Yet, the species is easily separated from the group members by its *ray parenchyma cells*. These are fairly thick-walled, rectangular, and their horizontal and tangential walls abound in simple pits, although sometimes there are unpitted areas in them. The pitting of the radial walls differs altogether from that in the *P. cembra* group. In the cross field, there are 2—4 small (4—5 μ), circular or elliptic, pits of the piceoid type. The simple pits of the *parenchyma cells* are complemented by half-bordered pits of the same size and shape in the adjacent tracheids. The pit apertures of the latter are distinct from the borders even in the earlywood ; they are elliptic or lenticular, commonly reaching the pit annulus, occasionally extended, especially in the latewood. In size, these cross-field pits commonly agree with the pits of transverse tracheids, occasionally they are smaller. The walls of *epithelial cells* of longitudinal resin ducts are somewhat thicker than in the other *Pinus* species. (*M.*)

PINUS CEMBROIDES ZUCC.

Mexican nut pine

Pl. 280

Distribution : North Mexico and Arizona. The tree attains a height of 8—10 meters.

C. 1,2. Transverse surface agrees with that in the other members of the group. *Growth rings* distinct, marked by flattened latewood tracheids. Transition between the seasonal increments gradual.

T. 4. Tangential surface conspicuous for the great number of *rays* and the slightly winding path of the *longitudinal tracheids* between them. Rays attain a height up to 20—25 cells. *Ray cells* in cross section sometimes circular, frequently from wider to narrower elliptic or lenticular. From *P. aristata* this species can be distinguished by its wider ray cells. No intercellular spaces between ray parenchyma and longitudinal tracheids, in contrast with *P. cembroides var. monophylla*, where they are conspicuous.

R. 3. On this surface no appreciable departures from *P. aristata* and the other members of the group *(P. cembroides var. monophylla) ;* differentiation appears to be impossible. (*M.*)

PINUS CEMBROIDES var. EDULIS (Engelm.) VOSS

Two-leaved nut pine

Pl. 281

Distribution : from Colorado through New Mexico to the western regions of Texas. Trees typically 3—4, exceptionally up to 10, meters high.

C. 1,2. Growth rings fairly wide and even. Early- and latewood more conspicuously differentiated than in the spp. dealt with so far. Growth ring limits more conspicuous. *Resin ducts* relatively large (100—120 μ), numerous, visible to the unaided eye, developing throughout the growth increment but with preference for the latewood,

in some rings aligned in distinct rows. *Rays* fairly numerous. *Ray-cell* walls relatively thick, lignified in different degrees. Horizontal walls rather abundant with circular or subcircular pits variable in width and disposed commonly in the middle in 1 or 2 rows, or along the radial walls in two rows, or, occasionally, scattered.

T. 4. In tangential walls of latewood *tracheids* bordered pits relatively abundant. Pit apertures eye-shaped, commonly horizontal or nearly horizontal. *Rays* closely spaced, up to 15—20, typically 8—10, not infrequently 1—4, cells high and consisting predominantly of thick-walled parenchyma cells. *Transverse tracheids* scarce. The marginal cells of several rays are parenchyma cells. Tracheids sometimes encountered in the interior of rays. In cross section, *parenchyma cells* rather varied in shape (narrow to wide, elliptic, rectangular, lenticular) ; in their tangential walls circular or elliptical simple pits ; walls cribriform or scalariform in dependence on the shape, size, arrangement, and number of the pits ; though cribriform walls are the rule, occasionally the two types occur simultaneously. Rays with *resin ducts* not uncommon.

R. 3. Transverse tracheids fewer in number than in the species discussed in the foregoing ; their walls, apart from the pits, smooth in accordance with the group character. Pit apertures horizontally oriented. In the cross field 1—4 pits, mostly in rows, sometimes scattered. In the parenchyma cells, circular simple pits complement the half-bordered pits of the tracheids. In the marginal cells, pits so close to the external walls as to have a modifying effect upon their thickness : they develop in the recesses of the walls, consequently the latter can thicken but between them. The apertures of the half-bordered pits conform in the earlywood to the outlines of the borders, but in the latewood they are more frequently eye-shaped or elliptical ; they are obliquely inclined, included or reaching the borders, not infrequently extending beyond them. *(Y.)*

PINUS CEMBROIDES var. MONOPHYLLA (Torr. et Frem.) Voss.
Single-leaved nut pine

Pl. 282

Distribution : from Utah to California and southward to East Arizona. Trees 6—8 m tall.

Xylotomically, the species agrees in every respect with *P. aristata*, and therefore cannot be differentiated from it. It is the typical representative of its group.

C. 1,2. It could perhaps be regarded as a departure from the group that the species possesses numerous *longitudinal resin ducts*, either scattered or aligned in short rows throughout the growth ring. Some growth ring limits were markedly wavy on the section examined. *Longitudinal tracheids* all thin-walled ; thick-walled areas, such as occur in *P. aristata*, were not encountered.

T. 2. Rays somewhat higher than in *P. aristata*. Maximum height 18—20, mean height 8—10, cells. Rays containing resin ducts relatively numerous and of a similar height. *Ray cells* in cross section somewhat wider than in *P. aristata*, regularly elliptical ; the sieve pitting in their tangential walls plainly discernible. Intercellular spaces likewise well defined between ray cells and longitudinal tracheids.

R. 3. On the radial surface, *rays* the same as in *P. aristata* barring two exceptions : the walls of the *parenchyma cells* are slightly thicker ; the apertures of the cross-field pits are already in the earlywood clearly distinguishable from the borders. *(M.)*

PINUS CEMBROIDES var. PARRYANA (Engelm.) Voss.
Four-leaved nut pine

Pl. 283

Distribution : Southern California. The tree or shrub attains a height of 6—9 m, and is 0,3—0,5 m in diameter.

C. 1,2. Xylotomically, this species agrees with *P. cembroides var. monophylla* and *P. aristata*, but the growth rings in it are somewhat narrower.

T. 4. Rays up to 14—16, but commonly only 8—10, cells in height. As regards shape and pitting, *ray cells* the same as in *P. cembroides var. monophylla*. Tangential walls of late tracheids abundantly provided with bordered pits. Pit apertures slitlike, mostly reaching the borders, occasionally extended, obliquely oriented ; apertures of complementary pits crossed.

R. 3. No peculiar features on this section ; ray structure and pitting as in the previously discussed species. *(M.*, 74)

PINUS BALFOURIANA Jeffr. et A. Murr.
Fox-tail pine

Pl. 275

Distribution : California. Trees 15, exceptionally up to 30, m tall, with trunks up to 1,5 meter in diameter.

C. 1,2. Xylotomically, this species is very similar to *P. aristata*, from which it is not readily differentiated. A few departures are nevertheless noteworthy. *Growth rings* narrower than in *P. aristata ;* demarcations marked by the flatness of the last-formed rows of late tracheids. Walls of tracheids equally thin in the early- and the late-wood. Lumina of tracheids angular. *Rays* closely spaced, with numerous, clearly defined simple pits in their horizontal walls. *Resin ducts*, even in the earlywood, encountered quite close to the growth ring limits, sometimes in twos or threes.

T. 4. The tangential surface shows a ray height quite unusual in the *Pinus ;* the *rays*, which are closely spaced, sometimes attain a height of 40—45 cells, although the mean height is only 10—15 cells. Rays with resin ducts are not as high as the highest simple rays. Another feature, likewise rare in the *Pinus*, is the occasional presence of 1 or 2 paired cells in the body of the ray. *Ray cells* wider (7—10 μ) than in *P. aristata ;* in cross section from short- to long-elliptic. Sieve pitting in tangential walls well discernible, as also the intercellular spaces. Owing to the close spacing of rays, course of tracheids slightly wavy.

R. 3. On the radial surface, no essential departures from *P. aristata*, except perhaps that the pit apertures in the *cross fields* of ray parenchyma are more readily distinguishable from the borders, and conspicuous already in the earlywood. In this species, too, these pit apertures reach the borders, or are occasionally extended. The thick walls of ray parenchyma lignified. The external walls of *transverse tracheids* somewhat dentate. *(M.)*

PINUS BUNGEANA Zucc.

Lace-bark pine

Pl. 277

Tree native to North China ; attains a height of 20—25 meters.

C. 1,2 ; T. 4 ; R. 3. The wood of this species largely agrees with that in the other members of the group. Unlike in *P. balfouriana*, the rays are low, only 6—8 cells in height, those with *resin ducts* being occasionally somewhat higher. The material studied originated from a young branch, and these figures may not hold for adult wood. As regards shape and pitting of *ray cells*, the species stands nearest to *P. balfouriana*. Tracheids follow a straight path ; tangential walls of those near the outer face of the growth ring abundantly pitted. Pit apertures eye-shaped and oblique. *Ray* structure similar to that in the spp. already dealt with. True, the *transverse tracheids* are here less in number, and even missing in some rays, yet this, too, may follow from young wood having served as a specimen. *(J., M.)*

PINUS GERARDIANA Wallich

Gerard's pine

Pl. 290

Distribution : the northwestern regions of the Himalaya, Kashmir, Tibet, and Afghanistan. The material originated from a branch 5 or 6 years old, and the features observed may not hold for adult wood.

C. 1,2. Growth rings distinct. Earlywood and latewood about equal in width ; transition gradual. *Tracheids* in cross section squarish or irregular in shape. Circular and elliptical tracheid lumina occur only in the thick-walled tracheids of the latewood. Resin ducts relatively numerous in the young branch, distributed in both seasonal increments.

T. 4. Rays in the young branch 2—10 cells in height ; those with *resin ducts* somewhat higher. *Ray cells* in cross section mostly long-elliptic in the single-row rays, and square or rectangular in the taller rays. Horizontal walls commonly thin, showing that the rays consist mostly of thin-walled parenchyma cells. Thick-walled parenchyma cells very rare. No bordered pits on tangential walls of tracheids. If there are some, they are probably transferred to the tangential side from the radial one in consequence of twisting. In the walls of longitudinal tracheids very fine oblique striations predominantly in the latewood.

R. 3. Thick- and thin-walled *parenchyma cells* in the rays ; the thick horizontal walls well provided with simple pits, the thin ones unpitted. On the evidence of its external morphological characters, this species is generally classed into the *Haploxylon* group characterized xylotomically by the smooth walls of its *transverse tracheids* and the presence of 2 to 4 *piceoid* pits in the cross field. However, in his material the present writer has found clearly defined dentations (teeth) in the walls of each and every of the transverse tracheids. This finding seems to exclude the species from the *Haploxylon* group. But the writer has, in addition, established the presence of 2 to 3 simple pits in the cross field which were commonly superposed, but occasionally, particularly in the

early tracheids, located side by side; moreover, in some instances he observed 3 times 2 pits.

The apertures of the bordered pits in the longitudinal tracheids in contact with thin-walled parenchyma cells and *transverse tracheids*, respectively, are commonly horizontal, and by this the species differs essentially from the other members in the *Aristata* group. The pit apertures are distinct from the borders. The pitting is well discernible in all three walls of the thick-walled parenchyma cells. On a tangential wall, there are sometimes as many as 4 or 5 locally thickened areas observable.

Summing up, it may perhaps be stated that from the point of view of xylotomy there is nothing to justify the retention of *P. gerardiana* in the *Haploxylon* group *(Aristata balfouriana)*. In some aspects it may be included in the *Pinea* group, which also is characterized by piceoid pitting, two kinds of ray parenchyma, and slight dentation of the transverse tracheids; nevertheless, taking due account of the external morphological characters, this species has been referred by us to the *Haploxylon*, that is, the *Aristata* group. Had adult wood been available to us, we might, perhaps, have succeeded in detecting additional traits of diagnostic worth. (*Y.*)

IV. Massoniana group

PINUS MASSONIANA LAMB.
Masson's pine

Pl. 304

Distribution: Southeastern China and the province of Szechwan. Sample by courtesy of the Botanic Gardens in Hong Kong.

C. 1,2. The material studied must have originated from a very old tree, since the growth rings exceeded 10 mm in width, some being 13 mm wide. *Growth ring boundaries* very conspicuous and fairly even. Latewood of an average width about two thirds the width of the growth ring. Transition from early- to latewood gradual, but last row of late tracheids followed abruptly by succeeding row of thin-walled early tracheids. Last late tracheids radially flattened, their lumina appearing as narrow slits in consequence. *Tracheids* in cross section commonly squares aligned in radial rows; their lumina mostly rounded. The thin-walled early tracheids have much larger lumina and are usually squares or radially elongate ellipses, occasionally polygonal. *Rays* uniseriate, extending radially, spaced 1—3, sometimes even 8—10, tracheids apart. *Resin ducts* disposed in almost distinct rows more or less parallel with, and in about the middle of, the growth rings, most frequently nearer to the beginning (inner face) of the latewood. Two resin ducts are sometimes connected, with only a single ray between them. Resin ducts occasionally encountered in the outer portion of the latewood. The wood of this species presents a phenomenon hitherto rarely seen in the *Pinus*: *thin- and thick-walled parenchyma cells*, respectively, (short tracheids?) filled with black resin contents are encountered amongst the tracheids. Their walls differ from those of neighbouring tracheids by their much lighter colour. Their walls are sometimes much thicker and sometimes much thinner than those of the tracheids. This phenomenon is best observed on the transverse surface at high magnification.

T. 4. On tangential section, *rays* conspicuous for their abundance; they are generally uniseriate, occasionally with paired cells in the middle. Rays 8—15, very exceptionally 18, cells in height, especially in case of coalescence of two superposed rays. Rays consist of thin-walled *parenchyma cells* and thick-walled *transverse tracheids*. Parenchyma cells are commonly located in the middle, and transverse tracheids form at the bottom, as well as on the top, 2—3 or 5 tiers. Parenchyma cells elliptical or angular in cross section, always wider than tracheids, thus modifying in places the thickness of the rays. It is also remarkable that several evenly developed rays are arranged at the same height side by side, or diagonally in relation to one another.

R. 3. The radial surface clearly reveals the heterogeneous nature of the *ray* structure. Some rays, especially lower ones, consist exclusively of *transverse tracheids*; others, of *parenchyma cells* alternating with transverse tracheids. There are rays which comprise 8 rows of transverse tracheids and only 2 of parenchyma cells. In some larger rays horizontal *resin ducts*, the epithelial cells of which are relatively thick-walled. Special reference needs to be made to the remarkable *resin cells* mentioned in discussing the transverse surface. Through a discrepancy in colour and in contents these cells differ conspicuously from the cells and the horizontal resin ducts of rays. While the contents of these cells are mostly orange-coloured, those of resin ducts are more pale yellow. The resin cells are not horizontal and even, and show in

some respects divergences. On closer examination they are found to possess a different structure. In the thin-walled cells, all the walls are equipped with simple pits. In the thick-walled cells, bordered-pit-like thickenings occur in the horizontal walls; moreover, sometimes thin-walled parenchyma cells join the ends of thick-walled tracheids, and the two elements communicate with each other through half-bordered pits. The thin-walled parenchyma cells are generally elongate, and terminate in a roundish cystlike growth. Commonly, these resin cells occur singly ; very rarely, two adhere closely to each other, and their contents are apparently in no way connected with the horizontal resin ducts.

The walls of *transverse tracheids* are dentate. The teeth rise from a broad base, but are not long, only 1 or 2 reach exceptionally to the center of the lumen ; hence no reticulations. It is remarkable that not infrequently these teeth surround pits in the walls of transverse tracheids, in which case they extend only to one third of the cell lumen. In the *cross field* mostly 1 large *P. silvestris* type pit ; occasionally, 2 superposed ; exceptionally, 3 side by side ; in rare instances, the 3 arranged in a triangle, like in *P. banksiana*. Where there is a single pit in the field, it is as a rule long-elliptic, but exceptionally so very short-elliptic as to be subcircular. In the latewood pit borders distinct, apertures occasionally extended. In the earlywood, apertures oblique slits and barely distinguishable from the borders. Horizontal and tangential walls of *ray parenchyma cells* smooth, exceptionally with locally thinned areas faintly suggestive of the presence of pits.

According to the data in the literature, NAKAMURA, KLEEBERG, BURGERSTEIN and HOLLENDONNER refer this species anatomically to *P. silvestris*. However, the above-discussed structural features show that the two are readily differentiated. The wood of the present species would seem to be an intermediate in the transition to the *Montana-Silvestris* group. (*M.*)

PINUS MERKUSII JUNGH. et DE VRIESE
Tenasserim pine
Pl. 305

Distribution : the Moluccas (Spice Islands) and the Sunda Isles. Xylotomically, the species is classed by HOLLENDONNER with *P. leucodermis*, because he supposes its transverse tracheids to be dentate, and the cross field to hold 1 to 6 pits. In the sample, which was received from Hong Kong, the present writer found that the teeth in the transverse tracheids were not significantly large and that the number of the pinoid pits in the cross field was 1 (2—3). On this basis, the wood has been included in the *Massoniana* group.

C. 1,2. Transverse section characterized by thick-walled *tracheids*, rounded in cross section, with fairly large intercellular spaces between them. *Growth rings* indistinct, often barely perceptible. *Resin ducts* aligned in a more or less distinct row.

T. 4. Rays low, maximally 10—15 cells high ; composed of thicker-walled transverse tracheids and of commonly thin-walled, infrequently thick-walled, parenchyma. *Longitudinal tracheids* follow a straight path ; their tangential walls occasionally with a few pits, 6—8 μ in width, with lenticular apertures nearly the pit diam. in length.

R. 3. The radial walls of *tracheids* being thick, the apertures of the bordered pits in them show already in the earlywood a marked tendency to being long-elliptic or lenticular and obliquely oriented. On approaching the latewood, this tendency increases, and in it, the apertures reach near the borders or even extend beyond them. In the wider late tracheids paired pits encountered. In the material of the writer, the walls of some *transverse tracheids* were devoid of teeth or insignificantly dentate, while in a relatively few instances they displayed marked dentation and even reticulation. *Ray parenchyma cells* overwhelmingly thin-walled and unpitted. Cross field mostly with 1—2 larger pits, circular, subcircular, or elliptic, and nearly as wide as the walls. In the wider earlywood fields occasionally 3—4 smaller pits with always large apertures, conforming to the border outlines and not readily distinguished from them. In the latewood, on the other hand, the apertures are occasionally narrow, slitlike, clearly distinct, reaching to the pit annulus, sometimes extended. (*M.*)

PINUS TONKINENSIS A. CHEV
(Pinus merkusii ?)
Pl. 334

For the sample the author is indebted to the French investigator, D. NORMAND, who sent it with the following remark : »Que nous considèrons, comme synonyme de Pinus Merkusii«. The material, an officially identified specimen (No. 7712), originates from North Vietnam.

The xylotomy of *P. merkusii* has been extensively dealt with by the present writer in his »Monograph on the Pinus Species«. The sample examined at the time originated from the Sunda Isles. Basing himself on the data in the literature, HOLLENDONNER includes the species in the *P. leucodermis* group, stating the transverse tracheids to be dentate and taking the number of cross-field pits to be 1—6. The writer's fresh sample from Hong Kong presented different features: the teeth in the transverse tracheids were barely perceptible and the number of the pinoid pits in the cross field was but 1 (2—3), wherefore the wood has been referred to the *Massoniana* group.

The newly obtained material shows some departures from the specimen received earlier from Hong Kong under the label *P. merkusii*. The main difference between the two is one in ray structure. Although in composition the rays are largely the same in both samples, i. e., *transverse tracheids* occur in association with *thin-* and *thick-walled parenchyma cells*, in *P. merkusii* from the Sunda Isles, the walls of the transverse tracheids are occasionally smooth (though more frequently teethed), whereas in the *P. tonkinensis (P. merkusii)* from North Vietnam they are commonly smooth, and but very rarely and very delicately dentate. On these grounds, these walls are ultimately to be regarded as smooth. It is not improbable that the discrepancy is the consequence in the growing conditions. Should this assumption prove to hold, then *Pinus tonkinensis* A. Chev. and *Pinus merkusii* Jungh. et de Vriese are synonyms. On the other hand, should the xylotomical departures, which in themselves are not of major significance, be complemented by external morphological characters, then *P. tonkinensis* is to be regarded as a variety of *P. merkusii*. Support seems to be afforded to the latter assumption by the conspicuously frequent occurrence in *P. tonkinensis* of *thick-walled ray parenchyma cells* and the tiered structure of *transverse tracheids*. While the ratio of transverse tracheids to parenchyma cells is about 0,8 for *P. merkusii*, it is substantially different for *P. tonkinensis*. Another departure worth considering is perhaps that in *P. merkusii* the resin ducts are 100—150 μ, whereas in *P. tonkinensis* only 80—90 μ in diam. Finally, it merits mentioning that in the sample of *P. merkusii* wood parenchyma cells were, though very rarely, encountered, while none proved detectable in *P. tonkinensis*. All three walls of *wood aprenchyma* are very thin and perfectly smooth. (*M.*)

V. Radiata group

PINUS RADIATA D. DON

Monterey pine

Pl. 323

Tree native to California, U. S. A., 20 to 30 m tall and up to 2 m in diam.

C. 1,2. Growth rings from moderately distinct to very indistinct, as last rows of late *tracheids* not substantially flattened and their walls not, or only slightly thickened. *Resin ducts* more frequent but narrower, only 100—125 μ, than in the two last-discussed species.

T. 4. Rays mostly 1—2, on an average 5—7, maximally 10, cells high. By this limited number of rays the species is separable from *P. patula*, and even from *P. ponderosa var. jeffreyi*. Another diagnostic feature of value is furnished in that the coefficient of rays is above 1 in this species. *Transverse tracheids* are practically confined, in a few rows, to the margins of rays so that they cannot modify the shape of the latter. *Parenchyma cells*, in cross section, circular, wide-elliptic, or angular.

It is a frequent occurrence even in rays with resin ducts, that two parenchyma cells are located next to each other and further widen the already wide and short rays. The *longitudinal tracheids* follow a winding path among the short rays. In the tangential walls of tracheids pits very rare.

R. 3. No essential departures from the group characters. Paired pits very rare, confined to tracheid ends, not typical in shape. Number of ray parenchyma cells in relation to that of transverse tracheids, strikingly great. In very rare instances, in addition to thin-walled ray parenchyma cells thicker cells inserted between the transverse tracheids; their walls with simple pits or initials of pits. These cells do not, however, constitute typical thick-walled parenchyma cells. The pitting in the radial walls answers the group character. Pit borders and apertures in the *cross fields* plainly distinguishable already in the early-wood.

In the latewood, walls of tracheids thinner and lumina wider, therefore pit apertures less narrow slits than in *P. patula* and in *P. ponderosa var. jeffreyi*.

Walls of transverse tracheids exceedingly thin, with less and shorter teeth than in the members of the group. (*M.*)

PINUS PATULA SCHLECHT. et CHAM.
Spreading-leaved pine
Pl. 315

Native to Mexico. Xylotomically, the same as *P. ponderosa var. jeffreyi* except for the following minor differences.

C. 1,2. Growth rings, and within them the latewood portion, wider than in *P. ponderosa var. jeffreyi. Resin ducts* scarce, in the latewood rare.

T. 4. Mean height of *rays* 10—12, maximal height 25, cells; those with *resin ducts* of about the same. Rays consisting *transverse tracheids* and thin-walled *parenchyma;* thick-walled parenchyma missing. Tracheids more numerous than parenchyma cells, frequently occurring in the interior of rays, interrupting parenchyma rows. Rays, in cross section, narrow in such places owing to the narrowness of transverse tracheids. Because of the great number of transverse tracheids, ray coefficient below 1. Tangential walls of longitudinal tracheids apparently unpitted.

R. 3. The pitting in the radial walls of *tracheids* the same as in *P. ponderosa var. jeffreyi.* Paired pits rare and contiguous, flattened from mutual compression. Dentation (teeth) of transverse tracheids more delicate than even in *P. ponderosa var. jeffreyi;* reticulation missing. Not infrequently teeth surround the pits in the horizontal walls, rendering them vestured; occasionally they branch out. The transverse tracheids themselves are elongate rectangles or trapezoids, the walls are thin, those of marginal cells particularly so, and wavy. Bordered pits like those in *P. ponderosa var. jeffreyi.* In the walls of longitudinal tracheids, in cross fields formed by them and parenchyma, the bordered pits fairly similar to those in *P. ponderosa var. jeffreyi.* In larger fields in the earlywood occasionally 7 to 8 pits. Pit borders and apertures sometimes well distinguishable. The preponderance in our material of thin-walled ray parenchyma may prove to be an aid in differentiating this species from *P. ponderosa var. jeffreyi, P. radiata* and *P. sabiniana.* (*M.*)

PINUS PONDEROSA var. JEFFREYI VASEY
Pl. 319

Distribution: California and the southern part of Oregon, where the tree attains a height of 30—60 m, and a diameter of 1 m.

C. 1, 2. Growth rings wide and uniform in width; latewood band narrow; last-formed rows of late tracheids flattened; thick-walled (5—6 μ) late elements conspicuously distinct from succeeding thin-walled earlywood. *Resin ducts* scattered in the transition zone, occasionally in the latewood.

T. 4. Rays low, not exceeding 10—15 cells in height; those with resin ducts only slightly higher. Rays consist of *transverse tracheids* and thin-walled *parenchyma cells.* Thick-walled parenchyma cells occasional; if present, too scarce to modify rays; commonly occurring in lower rays, wedged between transverse tracheids. Parenchymatous elements superior in number to transverse tracheids. *Ray cells*, in cross section, generally narrow, transverse tracheids elliptic, marginal cells triangular. Thin-walled parenchyma commonly angular and devoid of pits. The few thick-walled parenchyma cells provided with large simple pits. The longitudinal tracheids between rays follow a fairly straight course. Tangential walls unpitted.

R. 3. In radial walls of *tracheids* bordered pits mostly scattered and nearly as wide as the walls. Paired pits not infrequent in the wider early tracheids, always with a narrow gap between them, retaining their original circular shape, at most, longitudinally somewhat elongate. Solitary pits from predominantly circular to rarely long-elliptic. In the narrow-lumened late tracheids, pits occasionally circular; in those with the narrowest lumina, longitudinally elongate ellipses; their apertures from short- to long-elliptic or eye-shaped and almost the length of the pit diameter, or extending to the pit annulus, or beyond it. In the most narrow-lumened late tracheids the apertures are sometimes vertical slits. *Transverse tracheids* with minute teeth rising from fairly broad bases, commonly tapering to points and ramifying but not extending beyond the middle cell lumen. They are mostly encountered near bordered pits. In very rare instances, such projections are interlocked by delicate threads. Outer walls of transverse tracheids in most cases markedly wavy. Bordered pits small and circular; apertures also circular or obliquely elliptical, eye-shaped or, in the latewood, slitlike and included. *Ray parenchyma cells* elongate rectangles; their tangential walls mostly vertical, thin and unpitted. Pits appearing in radial walls belong to the longitudinal tracheids. *Cross field* with 1—3 pits, frequently in one row; wider fields with up to 6 pits, in two rows. They vary widely in shape and size; are circular, procumbent or upright ellipses, ovoid, or some tapering form. Cross fields occupied by a single pit, by several smaller

ones, or by small and large pits together. Pits from 2—3 to 15—18 μ in width. Pit apertures of nearly the same size and shape as the borders, which are often indiscernible or perceptible only as a faint ring around the aperture. In the latewood, on the other hand, the pit apertures are frequently eye-shaped or slitlike, reaching the borders or extended, but still showing faintly. Tracheids with *trabeculae* frequent. (*Y.*, *M.*)

PINUS SABINIANA Dougl.

Digger pine

Pl. 326

Tree native to California; from 30 to 50 m tall. Xylotomically, the wood agrees in essence with that in the other members of the group, from which its distinction is almost impossible. The species stands nearest to *P. radiata* or, on the evidence of paired pits, to *P. ponderosa var. jeffreyi*.

C. 1, 2. Apart from the slightly thicker walls of late tracheids, no departures from *P. radiata*.

T. 4. Departure consists in greater height of *rays*, the mean of which is 8 to 10 cells, while even 20 cells high rays are not infrequent; those with *resin ducts* do not exceed 20 cells. In the rays, parenchymatous elements outnumber the transverse tracheids. The former are, in cross section, circular, short-elliptic, or correspondingly angular, as seen in *P. radiata*. Transverse tracheids barely perceptible in the rays, rendering the tangential surface very similar to that in *P. radiata*. Course of longitudinal tracheids between longer rays fairly straight. In very rare instances, thick-walled *parenchyma cells* encountered; these are probably the thick-walled cells of resin ducts.

R. 3. In radial walls of *tracheids* paired pits frequent; unlike in *P. ponderosa var. jeffreyi*, they are in contact with each other, wherefore they are not flattened. Tracheid and ray pitting largely the same as in *P. radiata*, but the pits are not wider than 12—14 μ, and circular, elliptic, lenticular, or lemon-shaped; in the latewood, they are occasionally of some narrower form. Pit apertures more distinct from borders and definitely oblique. Number of pits per cross field 1—8. Smooth areas between pits fairly extensive. It merits mentioning that like in *P. radiata*, thick-walled parenchyma cells are encountered among the thin-walled cells, occurring singly, more frequently in rows, mostly between rows of transverse tracheids; their walls are sometimes much thicker than those of the other parenchyma, and distinctly pitted. These pits are large and the walls between them project into the cell lumen like the teeth do in the transverse tracheids. This phenomenon is best observed in the horizontal walls. These projections are, of course, not tapered to points, but blunt, rounded, or slightly claviform. (*M.*)

PINUS LEIOPHYLLA VAR. CHIHUAHUANA Shaw

Pl. 300

Distribution: New Mexico, South Arizona, Zacatecas. Sample, a piece from a trunk about 70 years old, obtained from the wood collection of the University of Siracusa, N. Y.

C. 1, 2. Growth rings even and distinct, due to 5—6 rows of markedly thicker-walled and flattened late tracheids. Latewood commonly restricted to the outermost portion of the growth ring; transition from early- to latewood mostly abrupt. Early tracheids, in cross section, usually 4—5—6 sided, late tracheids more rounded or tangentially elliptic. *Resin ducts* fairly numerous and relatively large; located predominantly in the latewood, sporadically in the earlywood or in the middle of the growth ring. *Rays* 3—8—15 tracheids apart. Walls of early tracheids thick in relation to other tracheid walls.

T. 4. Tangential walls of *tracheids* smooth. *Rays* rather closely spaced and 2—15 cells high; those with *resin ducts* elongate fusiform. On tangential surface, uniseriate rays seen plainly to consist combinedly of transverse tracheids and thin- and thick-walled parenchyma cells.

R. 3. In radial walls of longitudinal *tracheids* pits uniseriate; in places very abundant but not touching; in others, paired pits across the width of the tracheids. *Rays* of conspicuously heterogeneous structure. Walls of *transverse tracheids* relatively thick, the toothlike projections on them all the more conspicuous; they rise from broad base and have a blunt end. Commonly, they barely extend to the centre of the lumen; exceptionally, especially in the latewood, they form a network with the aid of thin interlocking threads. Bordered pits comparatively small in transverse tracheids; apertures circular. Walls of *thick-walled parenchyma cells* conspicuously thick; lumina sometimes quite narrow, especially in low parenchyma cells. In the *cross field* of thick-walled ray parenchyma cells 2—3 pits; a single pit is very rare, and does not occupy the entire cross-field area. Two or more pits in the field usually differ in size. Horizontal

and radial walls of *thin-walled parenchyma cells* unpitted ; tangential walls very exceptionally with one or two nodules. In the cross field of early tracheids 3—4 minute pits, oblique in position and mostly pointed, equal or differing in size. In the latewood, cross-field pits less in number ; in the narrowest tracheids only one and obliquely oriented.

Two structural features render this wood very similar to *P. ponderosa var. jeffreyi*, namely : — the toothlike projections in the transverse tracheid walls commonly do not extend to the centre of the cell lumen ; the 2 or 3 cross-field pits are in a horizontal row and not arranged in a circle or in the shape of an ellipse. On this account, the species is referred to the *Radiata* group, although it also has some xylotomical characters in common with *P. banksiana* and *P. ponderosa*. (*M.*)

VI. Pinea group

PINUS PINEA L.

Stone pine or umbrella pine

Pl. 317

Distribution : the Mediterranean coast. Trees grow to a height of 15 to 25 meters.

C. 1, 2. Tracheid walls 2—4 μ thick. Between early and late tracheids no marked discrepancy in wall thickness. *Growth rings* indistinct, delineated only by a few rows of flattened late tracheids. *Resin ducts* encountered primarily in the latewood close to the outer face of the growth increment ; in the ring itself rare. *Rays* short, traversing not more than 2 annual growths.

T. 4. Tracheid walls smooth. In the latewood, tangential walls moderately pitted. Tracheids with trabeculae occasional. *Rays* uniseriate, biseriation very exceptional ; composed of transverse tracheids and parenchyma cells ; 1—9, occasionally 10, cells high. *Transverse tracheids* similar in arrangement to those in the other *Pinus*. Marginal cells, in cross section, commonly triangular. *Parenchyma cells* predominantly thick-walled, occasionally thin-walled, and unlignified. Cells, in cross section, circular, elliptic or rectangular with rounded corners. All walls of thick-walled cells with well-defined round, elliptic or irregularly shaped simple pits. In some cells, thick and abundantly pitted tangential walls associated with quite thin radial walls, in which the pits show only as shallow indentations. In any case, parenchyma cells are exceedingly variable in wall thickness. These conditions equally prevail on the radial surface. Intercellular spaces between ray cells and longitudinal tracheids triangular and frequently branched along the cell boundaries. Rays with *resin ducts* slightly taller than simple ones, ranging commonly from 12 to 18 cells. Biseriation limited to a few cells.

R. 3. In radial walls of *tracheids* pits sparse and occurring singly ; for size they depend on tracheid width ; they are round, with round or eye-shaped apertures in the earlywood ; in the latewood, the apertures are more lenticular and nearly the length of the pit diameter. Walls of *transverse tracheids* smooth except for 1 or 2 small teeth or elevations in the horizontal walls. Cells, in cross section, commonly procumbent rectangles with one end tapering ; outer margins variable in shape. Bordered pits small, 6—8 μ in width. *Ray parenchyma cells* elongate rectangles. Tangential walls abutt perpendicularly or obliquely on the horizontal walls and have the same pits but slightly smaller. Radial pits typical representatives of the group pitting ; 6—8—10 μ wide, round, with faint borders. In the earlywood, the apertures practically conform to the pits in shape and size and are difficult to distinguish from the border ; in the latewood, they are eye-shaped or slitlike, varying in width, obliquely oriented, reaching the pit annulus or extended, and distinct from the border. *Cross field* commonly with 3 to 4 pits in the earlywood, with room for only 1 or 2 pits in the latewood. Longitudinal and ray *resin ducts* correspond to the type common in the *Pinus*. The thin epithelial cells are followed first by thin, then by thicker parenchyma cells communicating with the short tracheids through simple pits. (*M.*, *Y.* 74)

PINUS LEUCODERMIS Antoine

Bosnian pine

Pl. 301

Distribution : Yugoslavia and Italy. Although rarely, the tree attains a height of 33 m.

C. 1, 2. Walls of *tracheids* fairly thick ; of about the same thickness in the early- and latewood. *Growth rings* faintly delineated by slightly flattened last rows of late tracheids. Lumina of tracheids very often, primary walls less frequently, rounded. Intercellular spaces between rounded primary walls. *Resin ducts* rather small (80—100 μ) and evenly scattered throughout the growth ring. *Transverse tracheids* distinct from *thick-walled*, occasionally *thin-walled*, *ray parenchyma cells*.

T. 4. In the tangential walls of *tracheids* pits exceptional. Transverse tracheids located predo-

minantly on the margins of rays, mostly in several rows, but are occasionally encountered in the interior where they divide the taller rays in two or more parts. Rays, even taller ones, are occasionally without transverse tracheids at one or both ends. When this is the case, the marginal cells are thin-walled parenchyma cells and there are no transverse tracheids or thick-walled parenchyma in the rays. Some consist entirely of transverse tracheids. The *lignified thick walls of parenchyma* are always thicker than the walls of transverse tracheids. The pits in the tangential walls of the latter are rather large and circular, scattered, or in rows; these walls are sometimes markedly cribriform. *Thin-walled parenchyma* devoid of pits. Frequent triangular spaces between ray parenchyma and longitudinal tracheids. They are occasionally so large as to render the parenchyma cells polygonal in cross section. Rays without *resin ducts* uniseriate and 1—6 cells high. In the individual rays, leaving out the exceptionally low ones, the thin-walled parenchyma cells invariably outnumber the thick-walled parenchyma cells and transverse tracheids taken together.

R. 3. In radial walls of *tracheids* pits uniseriate; apertures circular in the earlywood and obliquely elliptic or lenticular and included in the latewood. Walls of *transverse tracheids* with very minute teeth, chiefly near the bordered pits. Reticular structures like in *P. silvestris* or *P. ponderosa*, not encountered. As already mentioned, the parenchyma cells are composed of unlignified and unpitted thin walls or of lignified thick walls with simple pits.

Thick- and thin-walled cells occur alternatingly. Intermediates are to some extent recognizable between definitely thin- and definitely thick-walled cells. The pits in parenchyma cells are large, commonly circular, occasionally short-elliptic, their outer apertures rounded. In the horizontal walls, the pits are scattered or, as clearly seen on the transverse surface, aligned in one or two rows. They are varied in size, along with large ones there occur smaller and minute pinhole pits. In the radial walls, the pits are rather large and round with oblique apertures that are in the earlywood elliptic or eye-shaped, rarely circular, and commonly included, in the latewood, on the other hand, narrower and sometimes the length of the pit diameter. The borders around apertures are fairly distinct. In the cross field 1—2, rarely 3, pits generally superposed. (*Y.* 74)

PINUS LARICIO Poiret

Corsican pine

Pl. 297

Distribution: the south of Europe, from Spain to the Crimea, the Caucasus, Asia Minor, and the Taurus Mountains. Sample obtained from Italy. By many investigators this pine is identified with *P. leucodermis* Antoine, but the two species differ xylotomically. While they agree in the slight dentation of their transverse tracheids and in the composition of their rays, containing thin- and thick-walled parenchyma cells, they display minor differences in pitting. True, such differences may be due to differences in the age of the samples examined.

C. 1,2. *Growth rings* distinct and even. Latewood band sometimes restricted to but a few rows of flattened and thick-walled tracheids, at other times of considerable width, occasionally much wider than the earlywood. Some growth rings are composed almost exclusively of *thick-walled tracheids*. *Resin ducts* relatively scarce, located mainly in the latewood near growth ring limits, which they render wavy in places. *Rays* 2—25—30 tracheids apart. Tracheids, in cross section, mostly squares, radially or tangentially elongated rectangles, or irregularly penta- or hexagonal.

T. 4. *Rays* 2—10—12 cells high. Rays with resin ducts somewhat wider than others, and occasionally more elongate. This surface also shows the rays to consist of thick- and thin-walled ray cells and of transverse tracheids inserted between them. *Ray cells*, in cross section, moderately long-elliptic, internal cells more circular or squarish.

R. 3. *Rays* plainly heterogeneous. The teeth projecting from the walls of *transverse tracheids* are less in length than half the lumen width, and from quite blunt to sharply pointed. These walls are relatively thick; occasionally, they are perfectly smooth. *Thin parenchyma* walls unpitted, *thick parenchyma* walls densely covered with minute piceoid pits. This pitting is very similar to that in *P. pinea* and *P. leucodermis*, and it is on this account that the species has been included in the *Pinea* group. It must be noted, however, that both the transverse tracheids and the thick-walled parenchyma cells present a great variety in their pitting. *Cross field* commonly with a single pit which is piceoid or shows a tendency to the pinoid type. Pit apertures distinct from borders and commonly somewhat pointed ellipses slightly inclined. In some cross fields 2 pits side by side. In *P. leucodermis*

he 2 pits are as a rule superposed and thereby provide a diagnostic feature. Summarising, xylotomically this species has much in common with the other members in the *Pinea* group. In part, the great similarity may find its explanation in the identical geographical distribution. *(Y., M.)*

PINUS HALEPENSIS MILL.
Aleppo pine
Pl. 292

Tree native to the Mediterranean.

C. 1,2. Following from the habitat of this species, practically no difference in the walls of early- and late *tracheids*. Occasionally there do occur thicker-walled tracheids, but they are not restricted to the latewood. The last-formed late tracheids are not flattened and so the *growth rings* are sometimes quite indistinct. *Tracheids*, in cross section, difficult to identify being variable in shape, sometimes with intercellular spaces between them. *Resin ducts* scattered. Horizontal walls of *ray parenchyma* with exceptional simple pits which differ from those in the *Pinus*, but are similar to the pits in the *Picea ;* they are mostly circular, rarely elliptic, and somewhat larger than the pits in *P. pinea*, with which they agree in arrangement, if they are not scattered.

T. 4. In tangential walls of last late *tracheids* only a few pits, which are fairly large (10—12 μ) and show faintly ; apertures circular, or short and eye-shaped. Exceptionally such pits also occur in the tracheids in the transition zone. Walls of *ray parenchyma cells* mostly lignified and rather thick, therefore not readily distinguished on this surface from the transverse tracheids with thinner walls. Occasionally, however, the walls of some ray cells, or even of all the parenchymatous elements in the ray, are not lignified, but remain quite thin and develop no pitting. Such rays frequently contain resin ducts. Parenchyma cells with lignified walls are in cross section elliptic, occasionally circular, and provided with numerous simple pits in their tangential walls, which are usually circular or, rarely, somewhat elongated in horizontal direction, aligned in two rows or scattered, giving the walls a cribriform appearance. Relatively large intercellular spaces between ray cells and longitudinal tracheids. *Rays* up to 8—10 cells high ; those with resin ducts slightly higher (15 cells).

R. 3. Pits in radial walls of *tracheids* uniseriate. Paired pits absent. This species is classed in the *Pinea* group, because the teeth barely emerge from the walls of the *transverse tracheids*, consequently do not give rise to reticulations. From *P. leucodermis* it can, however, be separated with some certainty on the ground that in that species the thin-walled parenchyma cells are predominant and the thick-walled cells less frequent ; in *P. halepensis* the reverse obtains. Differentiation from *P. pinea*, on the other hand, is possible by the fact that in the latter the thin-walled and unlignified parenchyma cells are not only infrequent or rare, but exceedingly exceptional. The pitting in the radial walls is about the same as in *P. leucodermis*, i. e., the pit apertures are circular, wider or narrower ellipses, or eye-shaped, included, rarely reaching the borders. This same pit structure, on the other hand, is an aid in separating the species under discussion from *P. pinea*, in which the apertures, though also eye-shaped or slitlike, reach the borders as a rule or are extended. Like in *P. leucodermis*, 1 to 3 pits in the cross field, though in very rare instances 4 occur in it. *(M.)*

PINUS HALEPENSIS VAR. BRUTIA ELWES et HENRY
(Pinus brutia TEN. ; P. pyrenaica DAVID)
Calabrian pine
Pl. 293

Distribution : the same as that of *P. halepensis* Mill, with which it also agrees xylotomically, apart from slight differences in the structure of pit apertures, which bring it nearer to *P. pinea*.

C. 1,2. Growth rings more distinct than in *P. halepensis* Mill, because of thicker walls in the latewood elements and a flatness of the last-formed late tracheids. Yet, growth rings as indistinct as in *P. halepensis* Mill. *Resin ducts* scattered chiefly in the latewood.

T. 4. No essential departures from *P. halepensis*. The rays are perhaps slightly higher, unless the difference observed is one due to a difference in age of the wood specimens examined. *Rays* uniseriate, occasionally with 1 or 2 paired cells in the body. The ratio of thin- to thick-walled *parenchyma* is about the same as in *P. halepensis*. The bordered pits in the tangential walls of tracheids are much smaller (5—7 μ) than in *P. halepensis*. The pit apertures are oblique, short, linear or eye-shaped, and included.

R. 3. The afore-mentioned differences in the structure of pit apertures are still more pronounced on the radial surface and permit distinction from

P. halepensis with greater certainty. Here, the outer apertures of the pits in the walls of *longitudinal tracheids* are mostly elongated, eye-shaped or slitlike, equal in length with the pit diameter, or extended, while the inner aperture frequently retains its circular or short-elliptic form and is distinct from the outer orifice. Still more elongated are the apertures in the pits in the cross field where, already in the earlywood, they frequently extend to the pit annulus or beyond it. While in the earlywood they often are still elliptical or lenticular, in the latewood they are fairly frequently extended slits. *(M.)*

PINUS LONGIFOLIA Roxb.

Long-leaved Indian pine

Pl. 302

Ditribution : the southern slopes of the Himalaya, Nepal, and Kashmir. In the group, the species stands nearest to *P. pinea ;* a few features nevertheless part it from this as well as from the entire group.

C. 1, 2. Growth rings more dinstinct than in *P. pinea*, their contours being delineated by somewhat more flattened and slightly thicker-walled late tracheids. *Resin ducts* scattered throughout the growth ring.

T. 4. While Hollendonner reports the rare occurrence of bordered pits in the tangential walls of *tracheids*, none were encountered in the material available to the present writer. *Ray* structure slightly different from that in *P. pinea :* thin-walled parenchyma cells here frequent, there rare. The transition from the thin to the thick cell type is not an abrupt one, there being many intermediates in wall thickness. Pitting distinct or indistinct in dependence on the thickness of the walls. In the thinnest walls, shallow indentations are indicative only of pits, or even these are absent. In the tangential walls, large circular, elliptical, or irregularly formed simple pits are well discernible ; depending on their size and the width of the cells, these are scattered or in 1 or 2 rows, giving the walls a sievelike or scalariform appearance. The cells are variable in height (20—40 μ) and width (10—20 μ), elliptical, occasionally angular. In cross section, the *transverse tracheids* are much smaller and easy to recognise on the tangential surface. *Rays* 10—20 cells in height ; those with resin ducts somewhat higher. Simple rays exceptionally with one paired cell in the body.

R. 3. Radial surface largely the same as in *P. pinea* and the other members of the group. A slight departure is the presence of a greater number of bordered pits in the walls of the longitudinal tracheids than in *P. pinea*, while in shape and size the pits in the two species more or less agree. Like the tangential surface, this surface, too, shows the *ray parenchyma cells* to be variable in wall thickness, but rarely to be wholly devoid of pitting. The horizontal walls are frequently unpitted. Another minor departure is that there are 3—4, occasionally 5, exceptionally 6, pits in the *cross field*, whereas in the other members of the group even 4 cross-field pits are rarely encountered. In shape and size the pits are similar to those in *P. pinea*, but the apertures are distinct from the borders even in the earlywood, where, in this species, they are mostly still circular, ovoid, or elliptic, and the borders around them crescent-shaped. In *P. pinea*, the apertures are not, or barely, distinguishable from the borders in the earlywood, but sharply distinct in the latewood, where they are lenticular, eye-shaped, or slitlike, extending to the pit annulus or crossing it. *(Y.)*

PINUS CANARIENSIS C. Sm.

Canary Island pine

Pl. 278

Tree native to the Canary Islands, growing in forests at altitudes of 1500—2000 m.

C. 1, 2, T. 4. No essential departures on these surfaces from *P. halepensis :* differentiation between the two species not possible.

R. 3. Radial surface shows the *ray parenchyma cells* very variable in wall thickness : from commonly thick with distinct simple pits, to quite thin with only vestigial pits ; the number of thicknesses intermediate between the two extremes is very great. *Transverse tracheids* few in relation to parenchyma cells ; the toothlike projections in their walls are minute, sometimes barely perceptible. The *cross-field* pits are largely similar to those in *P. halepensis*, but slightly larger. Frequently, the entire area is occupied by a single pit, leaving no free wall surface. The rule, however, is 2, rarely 3, pits in the cross field ; these are circular, or elliptic, or of some other roundish form ; their apertures, even in the largest pits, are in the earlywood nearly as wide as the borders and in this they differ from those in *P. halepensis*, which show distinctly even in the earlywood. In the latewood

there are narrower pit apertures in this species, too, but never slits, and the borders around them are invariably well discernible. The late tracheids are frequently striated, and this has a marked effect upon the shape and size of pit apertures.

VII. Silvestris-Montana group

PINUS SILVESTRIS L.

Scots pine; Yellow deal

Pl. 328

Distribution : Europe, Asia Minor, the Caucasus, northwards through Sibiria to the Amur, up to 70° N. L. The tree attains a height of 20 to 40 m.

C. 1,2. Growth rings medium in width. Latewood band fairly wide. Walls of *tracheids* slightly thicker in the late- than in the earlywood ; lumina rounded. Growth ring delineation fairly distinct and slightly wavy, due chiefly to the presence of resin ducts. *Resin ducts* encountered primarily in the latewood ; 100—150 μ wide ; in cross section, nearly circular, occurring singly or scattered. *Rays* uniseriate ; those with resin ducts 2—5 seriate and from 2—3 to 8—10, exceptionally 15—20, tracheids apart.

T. 4. In tangential walls of *tracheids* bordered pits exceptional and occurring singly in the early- and latewood alike. Their borders show faintly and are smaller than those in the radial walls (10—18 μ). Apertures narrow elliptic, commonly obliquely, occasionally nearly vertically oriented, mostly included. *Rays* uniseriate, very rarely biseriate ; those with transverse resin ducts bi- or several-seriate to include the ducts. Height of simple rays 1—12, that of rays with resin ducts generally 20—25, cells high. Resin ducts centrally located as a rule, sometimes displaced up- or downwards. Rays composed of thin-walled parenchyma cells and transverse tracheids with thicker walls. The latter, 1—3 rows of them, commonly terminate the rays, but sometimes occur in their interior. There are rays with no transverse tracheids at one end. Short rays, which are 1—3 cells high, consist sometimes entirely of transverse tracheids. The latter outnumber the parenchyma cells and the ray coefficient is accordingly less than 1. HOLLENDONNER arrived at a mean coefficient of 0,87 for *P. silvestris* from 720 data. *Ray parenchyma cells*, in cross section, slightly wider, and transverse tracheids from narrower to very narrow, ellipses or rectangles. Terminal *transverse tracheids*, with their free end tapered to points and usually triangular. Radial and tangential walls of parenchyma cells markedly thin; but the radial walls display slight local thickenings where they contact the tangential walls of longitudinal tracheids. Horizontal walls likewise thin throughout ; occasionally with sporadic but considerably thickened local areas and from short- to long-elliptic pits in them, which show on the tangential surface as from narrow to wider shallow indentations. The thin radial walls of the *ray parenchyma cells* commonly bulge into the lumina of the tracheids through the large pits in the radial walls of the latter, thereby giving the parenchyma cells a peculiar shape on the tangential surface. The thickenings appearing in the transverse tracheids are often of a peculiar form on the radial surface, where they are observed as «plates», sometimes with a smaller or larger, circular or elliptic, pit in the center or, not infrequently, nearer to the radial wall. Since they vary in location, the free surface of the plates is also variable in shape and size ; this accounts for the variability in the shape of the teeth visible on the radial surface. The intercellular spaces between the ray cells and the longitudinal tracheids are relatively large and triangular. Two superposed ray parenchyma cells or transverse tracheids sometimes move away from each other, causing two intercellular spaces to merge and take the form of a biconcave lens. Infrequently, the separation can be so extensive as to leave the arising intercellular space squarish. These separations may be secondary processes consequent upon cellular constriction.

R. 3. Walls of *longitudinal tracheids* much thicker in the latewood than in the earlywood and particularly pronounced at the point of contact with rays, where the lumina are reduced to almost nil. Radial walls, with bordered pits occurring singly and depending for size on the width of the tracheid, but not reaching across the wider early tracheids. Between more densely located superposed pits occasionally crassulae visible. Apertures in early pits round, in late ones ovoid or slitlike, in both cases obliquely or vertically oriented, occasionally as long as the pit diameter. Only those of these pits are extended which in relation to the border are dissymmetrically placed, yet as an exception there occur quite long and extended apertures in the latewood. The margins of the *tori* are well-discernible as narrow rings around the apertures, particularly in the earlywood ; their margins are as a rule delicately scalloped. In some late tracheids, the place of a large pit is taken by several pits, each the size of a minute tracheid ; their apertures are eye-shaped,

ncluded, and forming X figures. The *rays*, as has been seen, consist of two different elements. The *transverse tracheids* are trapezoid, triangular, or of irregular shape. The outward walls of marginal cells terminating rays, are wavy. The primary wall itself is thin, but may sometimes be rendered very thick by the many thickenings deposited on them. Its original thickness the primary wall retains in but very few places. These thickenings and bars are really the bars on the horizontal and radial walls seen in cross section. They are very variable in shape, size and arrangement. They arise from a broad base in the horizontal walls and commonly taper abruptly to sharp points. Occasionally, they largely retain their original breadth and end blunt or acute. Sometimes the common base ramifies to form several peaks or column-like processes, which differ in length, do not as a rule reach the center of the lumen, but occasionally extend beyond it. Commonly each peak or column-like process has a counterpart rising from the opposite wall and the two are often interlocked by fine threads flanking or surrounding the apertures described on the tangential surface. Depending on the site at which the cut has been made, the connecting line is sometimes more distinct and thicker. Such thickenings also occur in the tangential walls, are joined by the others and render the transverse tracheids markedly reticulate. In addition to vesturing the tracheids, these thickenings are of no mean diagnostic value. *P. silvestris* and the *Pinus* with similarly dentate or reticular transverse tracheids can always readily be distinguished from species in which the transverse tracheids are smooth. With one another and with longitudinal tracheids the transverse tracheids communicate through bilaterally, while with the parenchyma cells through unilaterally, bordered pits. These largely agree with the pits in the longitudinal tracheids, but are smaller. Their apertures are in the earlywood obliquely oriented ellipses, or eye-shaped, or circular; in the latewood, oblique or nearly vertical slits, like the pits in the tracheids.

Tangential and radial walls of *ray parenchyma cells* smooth and unpitted. The pits visible in the radial walls are really those in the longitudinal tracheids back of them and shining through them. Occasionally 1 or 2 parenchyma cells are wedged between the rows of transverse tracheids, in which case their walls thicken and become lignified. The radial walls sometimes do develop pits; these are simple, conform in size and shape to the half-bordered pits in the adjacent tracheids. In the *cross field* commonly a single pit occupying its entire area. Two pits in the field are a rare occurrence; they arise when the large pit is divided by a more or less wide, commonly oblique, but sometimes arched, bar. Two pits one above the other, are even rarer exceptions. Along with the procumbent pits, upright ones are occasional, particularly in the marginal cells. The orifices and the borders of the unilaterally bordered pits are fairly uniform in the walls of the late tracheids, but the borders show only in places and as narrow bands; they are rectangles or squares with rounded corners. In the latewood, the difference between borders and apertures is more conspicuous. The apertures resemble upright spindles or are perfect slits, vertical or slightly oblique, reaching the pit annulus or, less frequently, extended. The borders are mostly round or elliptic and but faintly visible.

The epithelial cells of the longitudinal resin ducts are thin-walled and unlignified. These are followed by rows of parenchyma composed of elongated cells with only slightly thicker walls which, because of their thinness, remain unpitted or are provided only with pitlike indentations. With one another, the epithelial cells communicate through simple pits; with adjoining tracheids, through bordered pits such as those in the ray parenchyma. These pits are variable in size, on the whole smaller than the others. The longitudinal tracheids communicating with the epithelial cells are parenchyma-like; the pits in them are smaller than in the other longitudinal tracheids. *(M. Y.* 74)

PINUS LARICIO VAR. PALLASIANA ENDL.

P. nigra bujotii var. caramanica Rehd.

Pl. 299

Distribution: Crimea and Asia Minor. Near Baile Herkulana, Rumania, it grows in a small forest. The tree is 25 to 30 m high. According to HOLLENDONNER, the wood anatomy of this species agrees with that of *P. laricio var. nigricans;* according to SCHRÖDER, it is closer to that of *P. silvestris*, since the ray coefficient is less than 1. The present writer includes this tree in the *P. silvestris* group on the ground of the dentation of the transverse tracheids and some other features, and separates it from *P. laricio var. nigricans* by the characters elaborated in the detailed description of the latter, following below. It is not easy to make a distinction

between this species and *P. silvestris ;* only minor departures can be established.

C. 1,2. The latewood occupies only a small portion of the growth ring, and the walls of *tracheids* in it are markedly thick. It is easily distinguished therefore from the earlywood even towards the centre. (The transition is gradual in *P. silvestris). Growth rings* distinct and even in consequence. *Longitudinal resin ducts* rather scattered in the latewood ; in size they more or less agree with those in *P. silvestris.*

T. 4. Tangential walls of *tracheids* devoid of pits, even in the latewood, excepting the short tracheids around resin ducts ; those sometimes seen in tangential walls belong to radial walls, transferred to this side in consequence of twists.

Rays composed of thick-walled *transverse tracheids* and thin-walled unlignified *parenchyma cells.* In appearance and arrangement they resemble the rays in *P. silvestris.* The conditions outlined in the description of the latter hold for this species as well. Transverse tracheids outnumber ray parenchyma cells ; accordingly the ray coefficient is less than 1. HOLLENDONNER established its mean value from 120 data as 0,72, i. e., below that for *P. silvestris,* which is 0,87 ; the limit values he fixed at 0,61 and 0,79, respectively.

R. 3. Radial surface very similar to that in *P. silvestris ;* the same structural conditions obtain. Separation with certainty is not possible. In size, the pits in the radial walls of the *longitudinal tracheids* in the latewood agree with the corresponding pits in *P. silvestris ;* but as regards apertures, while those in *P. silvestris* are markedly slitlike, sometimes extended and commonly vertical, in this species they are narrow-elliptic, linear, or lenticular, included and always oblique. The *transverse tracheids* are densely and strongly dentate, the teeth rise from a wide base, are sometimes branched or even interlocked by threads to form, especially in the latewood, reticulate or barlike thickenings. *Parenchyma cells* thin-walled, even the horizontal walls unpitted or only with shallow indentations, which are, however, not as definite as those in *P. silvestris.* In the *cross field* 1, infrequently 2, pits side by side ; their borders and apertures largely identical in size and shape with those in *P. silvestris,* but with the apertures commonly less narrow in the latewood. These apertures are mostly included and very nearly the length of the pit diameter ; they are never extended, unless asymmetrically located ; they are lenticular or sigmoid, and obliquely oriented.

The two last-mentioned features offer some means of separating the species from *P. silvestris. (M., Y.,* 74)

PINUS FUNEBRIS KOMAR.

Chinese pine

Pl. 289

Distribution : the Korean People's Democracy and Manchuria. Xylotomically a member of the *P. silvestris* group, this species stands nearest to *P. laricio var. pallasiana.* From *P. silvestris* it can be differentiated by the same characters as *P. laricio var. pallasiana.* The slight departures from these 2 spp. manifest themselves on the transverse surface.

C. 1,2. Growth rings wide, even, and rather indistinct. There is almost no difference in wall thickness between early and late tracheids ; the last rows of the latter not markedly flattened. *Resin ducts* scarce, in the latewood frequently in rows near the growth ring limits.

T. 4. No essential departures from *P. laricio var. pallasiana.*

R. 3. Teeth of *transverse tracheids* somewhat smaller than in *P. silvestris* or *P. laricio var. pallasiana,* i. e. reticulations less frequent. This difference, however, may depend on age and not hold for the adult wood. Pits in radial walls of *tracheids* and in cross field the same as in *P. laricio var. pallasiana* and can be differentiated from those in *P. silvestris* on the same basis.

An additional difference is that if there are two pits in the cross field, in the two afore-mentioned species they are always superposed, while in *P. funebris* they are side by side. Being also dependent on the age of the wood examined, this feature, too, is devoid of diagnostic value. *(M.)*

(P. montana Mill)

PINUS MONTANA VAR. MUGHUS WILLK.

Pl.307

Distribution : Central Europe. A species of small trees and erect or procumbent shrubs. Another representative of the group, yet well separable from *P. silvestris.* Differentiation is more difficult from *P. laricio var. nigricans.*

C. 1,2. Growth rings very variable in width : from barely visible to the unaided eye to a width

of 5 mm. Early and late tracheids plainly differentiated through discrepancy in wall thickness. Latewood from one third to sometimes as much as two thirds the width of the growth ring. Walls and lumina of *tracheids* more or less rounded, with numerous intercellular spaces between them. Occasionally, and particularly in the individuals growing at high altitudes, walls of early and late tracheids equally thick, leaving only the radially flattened late rows to mark the growth ring limits (HOLLENDONNER), which are nevertheless fairly distinct and even. Tracheids with trabeculae not infrequent. *Resin ducts* abundant, relatively more than in *P. silvestris*. (WILLKOMM reports less resin in trees growing in boggy soils.) Resin ducts of medium width: 100—125 μ; scattered throughout the growth ring.

T. 4. By the characters discussed in *P. laricio var. nigricans*, on this surface the species sharply differs from *P. silvestris*, but so greatly resembles *P. nigricans*, that the two cannot be differentiated. All that can be said is that the ray parenchyma cells are narrower in this species (10—15 μ), more or less agreeing in size with those in *P. silvestris*. From this it follows that the tracheids take a straighter course than in *P. laricio var. nigricans*, but number and height of rays are identical.

R. 3. On the evidence on this surface, species readily distinguished from *P. silvestris ;* less so from *P. laricio var. nigricans*, in which the pit apertures are horizontal, rarely oblique and never vertical ; they are circular or short-elliptic, exceptionally some pointed form, never slits ; they are invariably included. All this refers also to the pits in the late tracheids. In accordance with the group character commonly one large pit in the *cross field ;* if exceptionally two pits present, they are superposed and, consequently, have horizontal borders and apertures. (Their arrangement may be slightly different in adult wood.) Like in the other members of the group, the apertures are fairly large, and in the earlywood moderately, in the latewood definitely, distinct from the borders. In shape, they resemble in the earlywood those in *P. silvestris*, being in dependence on the width of the tracheids, from narrow- to wide-elliptic, ovoid, or rounded squares, occasionally regular circles, never angular or pointed ; the borders around them are discernible, though sometimes reduced to narrow stripes. In the latewood, the apertures are from narrow to wide ellipses, very frequently circles, but never eye-shaped, fusiform, or slitlike as in *P. silvestris ;* they are always included. In orientation, they are horizontal, unless forced by the narrowness of the tracheid to be vertical or obliquely inclined. The toothlike projections in the walls of *transverse tracheids* are less developed than in *P. silvestris*. Unlike in *P. laricio var. nigricans*, they rise from a narrow base, are more or less pointed and slightly higher (6—8 μ). In shape, they are pyramidal or acicular, less frequently identical with those in *P. laricio var. nigricans*. Accordingly, these teeth provide a diagnostic feature of doubtful value.

In conclusion, there appear to be no characters affording a reliable distinction between this species and *P. laricio var. nigricans. (Y., M.* 74)

PINUS LARICIO VAR. NIGRICANS PARL.

(P. nigra var. austriaca Aschers et Graebn.)

Austrian pine

Pl. 298

Distribution : the eastern regions of the Alps, Western Hungary, the northern parts of the Balkan Peninsula. Xylotomically, the species is very similar to *P. silvestris*, and only a few minor departures offer some means of separating the two.

C. 1,2. The individual *growth rings* alternate in width from narrow to wide. *Tracheids* variable in width within one and the same growth ring. In some growth rings, walls of late tracheids thick in contrast with those in early tracheids ; in others, of equal thickness, leaving it to 1 or 2 rows of flattened cells to indicate the outer face of the growth ring ; yet in others, wall thickness in the earlywood exceeds that of some tracheids in the latewood. Between such thick-walled tracheids many large-sized intercellular spaces. Lumina of these tracheids rounded, sometimes nearly circular, while those of thin-walled tracheids angular. *Growth rings* differently distinct, with somewhat wavy contours. Vertical *resin ducts* numerous, conspicuously large (100—150 μ), visible even to the unaided eye, arranged in more or less dictinct rows in the central portion of the growth ring ; some scattered in the latewood. In contradistinction, the growth rings of *P. silvestris* are less varied in width, and the transition from thin-walled early to thick-walled late tracheids is gradual ; the resin ducts are less in number.

T. 4. Height of *rays* about the same as in *P. silvestris :* commonly 6—8, maximally 15, cells ;

those with resin ducts, unlike in *P. silvestris*, not exceeding this maximum. *Ray parenchyma cells*, in cross section, wide-elliptic, not infrequently circular, 15—25 μ in height, 15—20 μ in width as against the 10—15 μ wide elliptic cells in *P. silvestris*. *Transverse tracheids*, being much narrower (8—12 μ) and having thicker walls, are readily distinguished from the parenchyma cells with thin and unlignified walls. The transverse tracheids being outnumbered by the parenchyma cells, the ray coefficient is above 1. Taking only the medium rays into account, SCHRÖDER fixed the mean value from 120 data at 1,47 (with 1,22 and 1,67 as extremes) and separated the wood on this ground from that of *P. silvestris* for which HOLLENDONNER calculated the ray coefficient to be 0,87. The number of rays is about twice as much as in *P. silvestris*. However, these features do not constitute specific constants.

R. 3. It is on the evidence of the projections from the walls of *transverse tracheids* that this species is placed in group VII. These teeth commonly rise from a broad base, are perpendicular to the wall, and seldom taller than 4—5 μ, generally have a blunt, rounded end, and frequently appear as mere bosses or knobs. (They probably undergo modifications in dependence on the age, the habitat of the tree, etc.) Unlike in *P. silvestris*, but more or less in harmony with *P. funebris* and *P. montana var. mughus*, the pit apertures in the late tracheids are circular, short-elliptic, linear, or eye-shaped, included, and obliquely or horizontally oriented.

Ray pitting separates the species from *P. silvestris*, but brings it nearer to *P. montana var. mughus*. In the latewood the apertures of the cross field pits are not slitlike as in *P. silvestris*, but wide and rounded, or even circular, like in *P. laricio var. nigricans ;* they are included, distinct from the borders, and obliquely oriented. Fusiform, eye-shaped, or other forms are rare. Two pits in the cross field are commonly superposed and very rarely side by side. Like in *P. silvestris*, a limited number of the *ray parenchyma cells* is thick-walled ; these are commonly unpitted, rarely show shallow indentations. In thick-walled cells, pits more frequent. HOFMANN distinguishes *P. silvestris* from *P. nigricans* on the basis of alternating transverse tracheids and ray parenchyma.

The present writer shares the view of HUBER and his collaborators, that this is a rather unreliable distinction. *(M., Y.* 74)

PINUS DENSIFLORA SIEB.et ZUCC.

Red pine of Japan

Pl. 287

Tree native to Japan. It attains a height of 25—30 m.

C. 1,2. Latewood rather narrow, fairly differentiated from earlywood. *Growth rings* distinct. *Resin ducts* located in the latewood ; 50—80 μ in diam. Since they are larger in the two last-described species, they furnish a means of differentiation.

T. 4. Tangential walls of *tracheids* sparsely pitted. *Rays* commonly lower than in the aforementioned two species : most frequently 1—4, very rarely 8—10, cells high and closely spaced ; probably higher in the adult wood. *Ray cells*, in cross section, wide elliptic or circular. Tracheids follow a slightly winding path.

R. 3. Radial surface similar to that in *P. montana var. mughus*. In radial walls of late *tracheids*, pit apertures circular, but smaller because of the tracheids being narrower. Toothlike projections from the walls of *transverse tracheids* shorter than in *P. montana var. mughus*, but possibly taller in the adult wood. *Parenchyma cells* for their major part unlignified and unpitted ; abundantly pitted thicker-walled cells occasional. Pits and apertures in the *cross field* large-sized, like in *P. montana var. mughus ;* apertures, even in the latewood, not as narrow as in *P. silvestris ;* their orientation not vertical nor quite horizontal like in *P. montana var. mughus*. Two cross-field pits, commonly superposed ; in some wider fields 3, occasionally 4, smaller pits one above the other. Pit apertures not as distinct from the borders as in *P. montana var. mughus. (M., Y.)*

PINUS RESINOSA AIT.

Red pine

Pl. 324

Distribution : Canada and Nova Scotia. Trees 20—30, exceptional individuals 50, meters high and 0,6 m in diam. Xylotomically, this species agrees with the members of the *Montana* group.

C. 1,2. Growth rings relatively wide and even. Latewood narrow and only slightly differentiated from earlywood. Longitudinal *resin ducts* scattered over transition zone and latewood ; of about the same size as in *P. densiflora :* 50—80 μ.

T. 4. No significant departures. *Rays* fairly dense, rather low and wide. *Ray cells*, in cross

section, circular or elliptic. The *tracheids* between them winding *(P. laricio var. nigricans)*.

R. 3. Walls of *ray parenchyma cells* mostly thin, occasionally thickened, thicker than the walls of the transverse tracheids, and lignified, with large simple pits in them. In other respects, no deviations from the other members of the group, the least from *P. densiflora. (M.)*

PINUS THUNBERGII PARL.
Black pine
Pl. 333

Tree native to Japan; 35—40 m tall. It is practically impossible to differentiate the wood from that of *P. densiflora.*

C. 1,2. Transverse surface essentially the same as in *P. densiflora.* Latewood band narrow, not always distinct from earlywood, *growth rings* then obscure. *Resin ducts* encountered throughout the growth increment, but mostly in the latewood; 60—100 μ in width. All these features dependent on the age of the wood. HOLLENDONNER reports conspicuous differentiation of early- and latewood, and resin ducts smaller than in *P. silvestris* and *P. laricio var. nigricans.*

T. 4. This surface, too, agrees with that in *P. densiflora,* but displays narrower *ray parenchyma cells,* therefore less winding tracheids. *Transverse tracheids* numerous, ray coefficient consequently less than 1, as in *P. silvestris.* (This agrees with SCHRÖDER's finding.)

R. 3. No departures from *P. densiflora* apart from lower toothlike projections in the walls of the *transverse tracheids. Parenchyma cells* with locally lignified areas in which large simple pits develop in the radial walls, complementing the half-bordered pits of adjacent tracheids. Apertures of the pits in the latewood narrower than in *P. densiflora.* Apertures of pits in the walls of *longitudinal tracheids* narrow-elliptic, eye-shaped, occasionally slitlike, included, commonly oblique, but in the last-formed narrowest tracheids sometimes vertical; this last-mentioned trait is unusual in the group.

Conditions different from the above probably prevail in the adult wood. *(Y., M.)*

PINUS SINENSIS LAM.
Pl. 329

Native to the temperate and subtropical regions of South China and Taiwan. The wood shows all the characters of the group, and cannot be separated from the other members.

C. 1,2. Tracheids thin-walled. Early- and latewood conspicuously differentiated. *Growth rings* distinct. *Resin ducts* abundant; 60—80 μ in width.

T. 4. Rays rather low: commonly 6—8 cells high. *Parenchyma cells,* in cross section, usually elliptic, occasionally circular. *Transverse tracheids* numerous in relation to parenchyma. Pits and pit apertures of longitudinal and transverse tracheids correspond to the group character, but with a lesser tendency than *P. montana var. mughus* to horizontal orientation.

R. 3. Almost invariably a single large pit in the *cross field,* occupying the entire area; if exceptionally two pits present, they are superposed and have large apertures. They slightly differ from those in *P. montana var. mughus* by being poorly discernible. Thick-walled and lignified *ray parenchyma cells* not uncommon. *(Y.)*

PINUS KHASIA ROYLE
(Pinus langbianensis A. Chev.)
Pl. 294

Distribution: Southwest Asia. For the sample (No. 7711), which originates from Central Vietnam, the author is indebted to Mr. D. NORMAND of Nogent sur Marne, France.

BURGERSTEIN, on xylotomical evidence, refers this species to the *P. silvestris* group, and the present writer shares his view. Although there do occur smooth-walled transverse tracheids, yet the internal walls of most ray tracheids, especially in the latewood, are distinctly and definitely *dentate,* on which ground the wood undoubtedly belongs to the *Diploxylon* group.

C. 1,2. Growth rings conspicuously distinct. Latewood of an average width, not more than one sixth the width of the growth ring. Late *tracheids* thick-walled; lumina usually circular, radially flattened near the outer edge of the growth ring. In some rings, thick-walled *wood parenchyma* abundant and clustered, mostly with dark resinous contents; in other rings, absent; horizontal cell walls in surface view reticulate. In thickness, tissue, and colour, these cells are different from those in the adjacent tracheids. It is very seldom for a *Pinus* species to display such an abundance of wood parenchyma.

T. 4. Rays typically heterogeneous; the *transverse tracheids* conspicuously numerous, bordering rays sometimes in 5—6 rows. Thick ray-cell walls

with fairly large pits, thin ones unpitted. Walls of *transverse tracheids* very seldom smooth, commonly covered with minute but blunt toothlike projections which as a rule do not extend to the centre of the lumen. Exceptionally opposite projections interlocked by thin threads or bars giving the tracheids a slightly reticulate appearance. Unlike in *P. silvestris*, in this species some cross fields with 2 or 3 pinoid pits, detached, contiguous, or coalescent. In the latter case, they occupy the entire field area and show the most varied forms. In radial walls of tracheids, bordered pits in loose longitudinal rows, sometimes paired, or in multiples, but free from mutual compression. Crassulae and unscalloped tori frequently well discernible. *(M., Y.)*

PINUS TABULAEFORMIS CARRIÈRE VAR. YUNNANENSIS (Shaw.) DALL.
(Pinus yunnanensis Franch.)
Pl. 330/a

Distribution: the southwestern regions of the Province Szechwan, and the Province Yunnan, in China. For the sample, a thick piece from a trunk, the writer is indebted to the wood anatomist YU of Peking.

By its minute anatomy, this wood perfectly fits the *P. silvestris* group, within which it stands nearest to *P. sinensis*, but while in the latter the transverse tracheids of the rays are only 1—2 cell rows high, they attain a height of 5—6 rows in the variety under discussion. Another departure seems to be that while in *P. sinensis* a single pinoid pit occupies the whole of the cross field area, in *P. yunnanensis* the latter is not taken up entirely by it and the ovoid aperture is plainly distinct from the border. Not infrequent are cross fields with two smaller pits in them side by side.

It is equally difficult to separate this wood from that of *P. silvestris*, unless perhaps by the fact that thick-walled ray parenchyma cells are rarer in the latter; this, however, may be the consequence of differences in the growing conditions. *(M., Y.* 171)

VIII. Banksiana group

PINUS BANKSIANA LAMB.
Jack pine
Pl. 276

Distribution: the eastern regions of North America up to 68° N. L., the regions of the Hudson Bay in Canada, Nova Scotia, and North Michigan. Tree moderately tall: commonly 10—20, very rarely up to 35, meters high. In Europe, extensively planted in parks.

C. 1,2. Tracheids for their greater parts thick-walled, rounded, with many intercellular spaces between them. In some *growth rings* early- and latewood not conspicuously differentiated; in others slight differences in wall thickness. Transition gradual. Growth ring limits sharp and even. *Resin ducts* scattered throughout the growth ring. In some growth rings, fairly extensive *parenchyma fields* in the earlywood.

T. 4. In the places mentioned above, *parenchymatous elements* occur in association with short *tracheidal elements*, very variable in shape and with conspicuously many pits in their tangential walls.

These pits are distinct, their apertures circular or eye-shaped and included. In other tangential walls, pits sporadic. Height of *rays* commonly 10—12, exceptionally 15—20, cells. Longitudinal tracheids winding but slightly.

R. 3. In radial walls of *tracheids*, pits uniseriate; paired pits very rare. Pit apertures, even in the narrowest late tracheids, short and eye-shaped, included, obliquely oriented. Slitlike vertical apertures, like in *P. ponderosa*, absent, this fact affording some means of separating the two species.

In some earlywood pits, radially striated structure of tori and borders particularly distinct. Toothlike projections in walls of transverse tracheids considerably lower than in *P. ponderosa* and its related spp. The teeth rise from a narrow base, are pointed or truncated and do not ramify. As a rule, they do not extend to the centre of the lumen, but occasionally opposite teeth are interlocked by faintly showing bars like in *P. ponderosa*, often giving rise to reticulations. Teeth occasionally emerge from the tangential walls, but are few in number. Bordered pits fairly large, apertures circular or eye-shaped and included. Pits fairly numerous in horizontal walls as well. Walls of *ray parenchyma cells* thin, unpitted, exceptionally with shallow indentations in the tangential walls. The thicker-walled parenchyma cells likewise unpitted. HOLLENDONNER reports parenchyma of two different wall thicknesses and compares the thick-walled cells to *P. palustris*, but does not present drawings.

On the sections examined by the writer they were not encountered. *(M.*, 74)

PINUS PSEUDOSTROBUS LINDL.

False Weymouth pine

Pl. 320

Tree native to Mexico.

C. 1,2, R. 3, T. 4. The sample examined was a piece from a young branch, wherefore the observations made do not permit of drawing exact xylotomical conclusions. The species is included in the *P. banksiana* group merely on the presumption that although the toothlike projections in the walls of the transverse tracheids are still delicate and reticulation rare in the young material, both these features can be expected to develop in the mature wood. The inclusion in this group is further favoured by the structure of the ray and the cross fields. Significant departures not traceable. No difference in wall thickness between early and late tracheids, nor are the last rows of the latter flattened; *growth rings*, in consequence, from indistinct to barely perceptible. *Resin ducts* scattered throughout the growth rings. *Rays* and ray pitting in accordance with the group character. *(Y.)*

PINUS COULTERI D. DON

Big-cone pine

Pl. 286

Distribution: the coastal mountains of California. Tree commonly 25—35, exceptional individuals up to 46, meters tall.

C. 1,2. Growth rings wide and even. Latewood reduced to a thin band on the outer face of the growth ring. Transition from early- to latewood gradual. *Resin ducts* located in the narrow latewood band, sometimes immediately on the outer edge of the growth increment.

T. 4. Parenchymatous elements in the *rays* thin- and thick-walled, alternating like in the other *Pinus*. Mean height of rays 8—10, maximal height 20, cells; those with resin ducts not higher than the others.

R. 3. Paired pits exceptional in the radial walls of the wider longitudinal tracheids of the earlywood. Toothlike projections rise from a narrow base in the walls of transverse tracheids, are commonly low and do not ramify, yet densely reticulate areas do very rarely occur. The apertures of the pits in the longitudinal and the transverse tracheids are invariably canting from the vertical. Number of pits in the *cross field* seldom exceeds 4, is frequently only 2 or 3 even in the larger earlywood fields, leaving large areas of the wall smooth. Pit borders commonly circular or elliptic, but apertures narrow ellipses or lenticular already in the earlywood and distinct from the borders. All the thick walls of *parenchyma cells* equipped with large simple pits. These cells are sometimes wedged between rows of transverse tracheids, sometimes themselves aligned in distinct rows. *(M.)*

PINUS MURICATA D. DON

Bishop pine

Pl. 311

Tree native to California; grows on the Coast; is commonly 8—10, rarely 25—36 meters tall and from 0,30 to 0,75 m in diam. Referred to the *P. banksiana* group because of its teeth in the transverse tracheid walls being less developed than in members of the *P. ponderosa* group and because of the combined appearance in them of thin- and thick-walled parenchyma cells. Cross field commonly with 1—4 pits. Individual differences rare.

C. 1,2. In wall thickness practically no difference between early and late tracheids. *Growth rings* indistinct; contours rendered perceptible by a few rows of last-formed tracheids being flattened. *Resin ducts* scattered or aligned in more or less distinct rows in the central portion of the growth ring.

T. 4, R. 3. Of the three kinds of elements thin-walled *parenchyma cells* predominant in the rays. Pit apertures not even in the latewood slitlike, indistinct from borders. They are obliquely oriented. In the walls, particularly in the horizontal walls, of the thicker-walled parenchyma cells the pits, which are 5—8 μ in diam., or the corresponding indentations, are clearly visible. *(M.)*

PINUS MARITIMA LAMB.

(P. pinaster Ait.)

Maritime pine

Pl. 303

Distribution: the western Mediterranean. Tree 20—30 m high. Species referred to the *Banksiana* group; individual differentiation within the group intricate.

C. 1, 2. In the available material, *growth rings* variable in width, occasinally very narrow. (According to HOLLENDONNER, the growth rings are wide.) Frequently, no appreciable difference in wall thickness between early and late *tracheids*, consequently growth rings often indistinct. *Resin ducts* were scarce in the specimen examined. (HOLLENDONNER reports the wood to be rich in resin).

T. 4. Tangential walls of *longitudinal tracheids* pitted, mostly in the latewood. Pits 5—7 μ in diam.; pit apertures linear or elliptic and included. *Rays* composed of the three kinds of cells mentioned before ; their arrangement is the usual ; they are somewhat lower than is common in the group : generally 6—8, not infrequently 2—4, maximally 15, cells high. *Transverse tracheids* fairly numerous.

R. 3. Toothlike projections in *transverse tracheids* conforming to those common in the group. Reticulate tracheids rare. In cross fields of *parenchyma* 1—4 pits, exceptionally more. Pit apertures from circular to elliptic and included ; in the latewood occasionally some tapering form and extending to the pit annulus but not beyond it. Slitlike are not even those in the narrow walls of the early longitudinal tracheids. The apertures are invariably obliquely oriented, and even in the latewood distinct from the borders. Thick *ray parenchyma* walls abundantly pitted ; pits in the horizontal walls, 2—3 μ ; in the radial walls, 6—8 μ in width. *(M.,Y.)*

PINUS TEOCOTE Schlecht. et Cham.
Twisted-leaved pine
Pl. 332

Native to Mexico.

The sample available, originating from a young branch, was not suited to render a reliable picture of the xylotomical characters of the wood. By the toothlike projections in the walls of the *transverse tracheids* and the combined presence of thin- and thick-walled *ray parenchyma cells*, the species is referred to the *Banksiana* group. Departures, particularly from the other group members, could not be established. All characters are those usual in the group. *(Y.)*

PINUS MONTEZUMAE Lamb.
Rough-branched mexican pine
Pl. 308

Distribution : Mexico, where the tree grows in large stands in the mountains and attains a height of 30 m.

C. 1, 2. Tracheids thin-walled ; in cross section angular ; in wall thickness, size, and shape, no appreciable differences between early and late tracheids ; *growth rings* consequently very indistinct, barely perceptible. *Rays* closely spaced. *Resin ducts* sparse, scattered, only 60—80 μ in diam.

T. 4. Rays conspicuous for their great number ; in the specimen from young wood, rather low : generally 1—10 cells high, very seldom higher. In accordance with the group character, transverse tracheids simultaneously present with thin- and thick-walled parenchyma cells. In the sections examined, tangential walls of *longitudinal tracheids* unpitted.

R. 3. In radial walls of *tracheids* pits one by one in a row ; paired pits, though rare, not uncommon. Walls of transverse tracheids commonly with but little developed toothlike projections, occasionally almost perfectly smooth. Branching of teeth and reticulation exceptional. Pitting corresponds to the group character. Along with the thin-walled unpitted *parenchyma cells*, abundantly pitted thick-walled cells. In the cross field, 2—5 small pits, mostly oblique ellipses with distinct apertures. *(M.)*

PINUS ATTENUATA Lemm
Knob-cone pine
Pl. 273

Distribution : California and Oregon, U. S. A. Trees 1—6, rarely 10—12 m tall with trunk diameter of 0,15—0,30 m.

C. 1, 2. Xylotomically, this species stands near to *P. montezumae*, but early- and latewood are more conspicuously differentiated, wherefore the *growth rings* are more distinct. Last rows of late *tracheids* flattened. Transition markedly gradual. *Resin ducts* sparse like in *P. montezumae ;* 100—150 μ in diam.

T. 4. Rays somewhat higher than in *P. montezumae :* occasionally up to 28 cells. Taller rays divided into several parts by *transverse tracheids.*

R. 3. In the material studied paired pits were not encountered. *Ray* structure, that of the group. Walls of transverse *tracheids* then and when perfectly smooth, but sometimes with fairly developed toothlike projections. *Thick-walled parenchyma* seen only wedged between rows of transverse tracheids. *Cross-field* pitting the same as in *P. montezumae*, except for the apertures being more distinct from the borders, already in the earlywood. Apertures more obliquely than horizontally oriented. *(M.)*

PINUS GLABRA Walt.
Spruce pine
Pl. 291

Distribution : South Carolina, the central and northwestern regions of Florida, Louisiana, U. S. A. Xylotomically, the species stands nearest to *P.*

clausa, from which it cannot be reliable differentiated.

C. 1, 2. Growth rings very wide. Transition from earlywood to the rather wide and thick-walled latewood gradual or staggered. *Resin ducts* scattered throughout the growth increment. In one instance, the writer encountered them on the very limit of a growth ring at fairly equal distances from one another and rendering the limit pleasingly wavy.

T. 4. Rays about the same as in *P. clausa*. Low rays of 2—3 cell rows, commonly composed purely of *transverse tracheids*, are fairly frequent. *Thick-walled parenchyma* absent. It is on these grounds and in view of the transverse tracheid walls being but minutely teethed, that the species is classifyable with *P. clausa* and separable from *P. coulteri* and its allied spp. with two kinds of parenchyma cells. *Cross-field* pitting similar to that in *P. banksiana*. Essential departures undetectable. Thickenings in ray-cell walls occasionally form continuous scalloped plates. *(M.)*

IX. Ponderosa group

PINUS PONDEROSA DOUGL.

Western yellow pine

Pl. 318

Distribution: California and Oregon, U. S. A., where the tree attains 70 to 90 m in height and 1 to as much as 4 m in trunk diam.

In HOLLENDONNER's view, xylotomically the species agrees with *P. leucodermis*, but it appears that there are several definite departures permitting of the separation of the two woods. Accordingly, in this work they are classed in two different groups.

C. 1, 2. Growth rings fairly narrow and even. Latewood reduced to a few rows of tracheids and conspicuously differentiated in wall thickness, flatness, and colour from the early tracheids in both the same and the succeeding growth increments; growth ring demarcation consequently sharp. Longitudinal resin ducts are occasional in the earlywood. Commonly, they are located near the outer face of the growth ring which then yields to the pressure and bends outward. Sometimes a resin duct comes to lie directly on the demarcation with one half in the latewood and the other in the succeeding earlywood, thereby subjecting the edge of the growth ring to marked modifications. The *rays* consist of three kinds of elements like in *P. leucodermis*. The horizontal walls of *transverse tracheids*, on the other hand, differ from those in *P. leucodermis*, for while they are more or less smooth or provided with small teeth in the latter, there are bars proceeding horizontally or obliquely in them in this species. These bars sometimes branch out or interlock, dividing the walls into minute fields. Such bars occasionally arise not as thickenings of the horizontal walls but penetrate the cell lumen to connect the two radial walls. Another feature separating this species from *P. leucodermis* is that the pits in the horizontal walls of its *thick-walled parenchyma cells* are considerably larger (8—10 μ), aligned mostly in one, occasionally in two rows. Sometimes a pit is as wide as the wall leaving the latter to appear as a rim around it. The pits are circular, procumbent ellipses, angular, or of irregular shape.

T. 4. Tangential pits were not encountered by the writer, not even in the walls of the late tracheids. They are only present in the walls of short tracheids surrounding resin ducts; these have then vertical or oblique, eye-shaped and included apertures. *Rays* up to 20—30 cells high, uniseriate, very rarely with two paired cells in the body. The *transverse tracheids* terminate the rays on both sides, mostly in several rows, but in the taller ones are not infrequently encountered in one or more rows. In cross section they are narrower than the thin-walled parenchyma cells. Lower rays often composed exclusively of tranverse tracheids but, unlike in *P. leucodermis*, rays without tracheids are not seen. *Tracheids* outnumber parenchyma cells and the ray coefficient is accordingly below 1. The parenchyma cells are of two kinds: thick- and thin-walled. The walls of the former grow commonly thicker than those of the tranverse tracheids; the thin- and thick-walled parenchyma cells alternate in the interior of the rays. Some rays consist of transverse tracheids and thick-walled parenchyma cells only. In general, these two are the dominant elements. In cross section, the cells are elliptic or angular. The thin-walled parenchyma are much wider than the thick-walled or the transverse tracheids. Between the ray cells and the longitudinal tracheids sometimes very large triangular intercellular spaces. In the tangential walls of the thick-walled parenchyma cells commonly 1—2, infrequently several, large, circular, elliptic or irregularly shaped simple pits occupying so much of the wall as to leave the free areas appear as narrow stripes only.

R. 3. Bordered pits in the radial walls of *tracheids* uniseriate; according to some investigators, paired pits occasional. Pits circular, in the latewood sometimes elongated in a slightly oblique

direction. Apertures also circular in the earlywood but, already in the transition zone, the inner orifice is eye-shaped and definitely vertical. In the latewood, the aperture then becomes quite narrow and slitlike, is likewise vertical, sometimes as long as the pit diameter, and not infrequently slightly extended.

The toothlike projections in the transverse tracheids are well developed (yet HOLLENDONNER refers the wood to the group of small-teethed *Pinus* species). Joining such teeth, or growing out from them narrow bars and girders are visible which cross the entire tracheid and give it a variagated pattern. The said bars or girders rise from a more or less wide base, end pointed before they reach the opposite wall, or join the latter on a wide surface. Frequently, they are interrupted or interlocked with other similar processes coming from other directions. On these grounds, *P. ponderosa* is justifiable grouped with the spp. of transverse tracheids with well-developed dentation and reticulation. For this reason and on the basis of some other characteristics in it, this species has been chosen to typify the group.

The pitting in the thick-walled parenchyma cells has already been discussed. The unlignified thin-walled cells are unpitted. The pits in the *cross field* conform in shape to the complementary half-bordered pits in the tracheids and are very varied, also in the shape and arrangement of the apertures. Quite exceptional forms result from the occasional fusion of two or more smaller pits. The pit borders are indistinct, barely perceptible; they are round, horizontally or vertically oriented ellipses, bean-shaped, bone-shaped, or of irregular form. The larger pits occupy almost the entire area of the cross field, while of the smaller ones as many as 6 find room. The most extreme sizes and forms may meet within the same cross field, small pits covering the surface left free by the large ones.

Apertures are even more variable. The general rule is that they conform to the border outlines, yet sometimes they differ from the latter already in the earlywood. In the early zone they are circular, elliptic or eye-shaped, sometimes narrow slit, and these different forms may appear immediately next to one another. In the latewood they show more regularity in that they are mostly eye-shaped or slitlike, although here some wider forms may appear. Commonly, the apertures are included, but the eye-shaped or slitlike orifices may be extended, particularly in the latewood. Generally, they are oblique or vertical, in the latewood definitely and constantly so, but in the earlywood horizontal orientation may occur. Apertures merging into each other can give rise to quite extraordinary forms. In some instances, the two borders are still separate while the apertures are already fused. In others, the borders, too, unite and nothing, or only a ligament, is left to indicate the fusion completed.

The coalescence of pits discussed in the foregoing seems to afford proof of the conception that a large pit, which occupies the whole area of a cross field, is the product of the union in one body of several small pits; a probability of which mention has already been made in describing *P. palustris*. (*M.*74)

PINUS PUNGENS LAMB. et MICHX.

Hickory pine

Pl. 322

Tree native to the southern parts of the Allegheny Mountains, North America; it attains a height of 18 m. Xylotomically, the wood agrees with that in the other members of the group.

C. 1,2. Early- and latewood conspicuously differentiated through discrepancies in the size of the *tracheids*, in wall thickness, and colour. *Growth rings* very distinct. Lumina angular in the early and rounded in the late tracheids. *Resin ducts* scattered throughout the latewood.

T. 4. Rays commonly 4—6, maximally 10—12, cells high; the few with *resin ducts*, not much higher. *Ray cells* from narrow- to wide-elliptic, occasionally elongate rectangles. *Transverse tracheids* differentiated from *parenchyma cells* through their narrowness.

R. 3. In the very wide early *tracheids*, sometimes paired pits. Pits moderately elongate ellipses. In rays more *transverse tracheids* than *parenchyma cells*, ray coefficient consequently above 1. Their walls equipped with toothlike projections extending to one third, exceptionally one half of the cell lumen. Not infrequently, fine threads interlock the projections giving rise to reticulations. On the ground of these characters the species is referred to the *P. ponderosa* group. Bordered pits in transverse tracheids, as usual. Walls of parenchyma cells commonly thick, equipped with simple pits, between which the wall surface left free looks like a narrow stripe. Thin-walled and unpitted parenchyma cells uncommon. *Cross field* with 1—4, exceptionally 5, pits variable in shape and size (4—16 μ), with indistinct apertures even in the latewood. *(M.)*

PINUS TORREYANA PARRY
Soledad pine
Pl. 335

Tree native to South California ; ramose ; 10—13 m high and 0,30—0,40 m in diameter. Wood the same as in *P. occidentalis.*

C. 1,2. Transition gradual. *Resin ducts* located chiefly in earlywood or the transition zone.

T. 4. Rays the same as in *P. occidentalis. Thin-walled parenchyma cells*, in cross section, angular because of large intercellular spaces ; sometimes 2 cells next to each other and causing biseriation in ray. *Thick-walled parenchyma cells* less in number than in *P. occidentalis.*

R. 3. No definite departures, but the 1—2, sometimes 3—4, pits in the cross field of ray parenchyma commonly aligned in only one row. Pits seldom circles, mostly upright or oblique ellipses. The total area covered by them is less than in *P. occidentalis*, hence the free wall surfaces larger. Apertures distinct, narrow, lenticular or linear, included or, very rarely, extended, nearly vertically oriented ; the round borders nearly always visible, though faintly, around the narrow apertures. *(M.)*

PINUS VIRGINIANA MILL.
Scrub pine
Pl. 336

Distribution : the East of the U. S. A., from New York to Georgia and S. E. Indiana. Xylotomically, the species agrees with *P. occidentalis* and *P. torreyana.*

C. 1,2. Transition more gradual than even in *P. torreyana.* Walls of late *tracheids* not particularly thickened. *Resin ducts* in more or less distinct rows in the central part of the growth ring; elsewhere rare.

T. 4. Rays, in cross section, similar to those in the two last-treated spp. Intercellular spaces smaller, sometimes missing, ray parenchyma cells therefore quadratic or oval.

R. 3. The transverse tracheids being markedly reticulate, the number of pits in the cross field of ray parenchyma being greater, and the pit apertures larger, the species greatly resembles *P. occidentalis* on the transverse surface. *(M.)*

PINUS PALUSTRIS MILL.
Pl. 313

Distribution : the Southeast and the South of the U. S. A.

C. 1,2. Early- and latewood conspicuously differentiated. Early *tracheids* (about $^1/_3$rd the width of the growth ring) with walls so thick as to render the lumina quite narrow. *Growth rings* very conspicuous and definitely wavy. *Resin ducts* few but large (150—250 μ), located at the outer face of the earlywood band ; rarely in the latewood, not far from the growth ring limit and rendering it wavy. Despite their very thick walls (8—10 μ), late tracheids, and even their lumina, angular ; intercellular spaces not particularly frequont between them.

T. 4. Rays composed of *transverse tracheids* and *thin-walled parenchyma cells.* No *thick-walled parenchyma cells* in the material examined (HOLLENDONNER reports their occurrence and represents them by drawings). Transverse tracheids as many in number as, or slightly more than, parenchyma cells. *Rays* commonly 1—10, exceptionally 15—20, cells high, higher rays usually the result of a fusion of two smaller ones ; those with resin ducts up to 30 cells in height. Rays consisting entirely of transverse tracheids and rays containing only 1—2 parenchyma cells not infrequent. No rays without tracheids were observed by the writer. *Longitudinal tracheids* between the relatively narrow rays straight.

R. 3. Paired pits conspicuously numerous, absorbing a large portion of the radial walls of late tracheids. Margins of primary pits, and the *tori*, well discernible. Pits flattened from mutual compression. Scattered pits, horizontally elongate ellipses ; those in later tracheids, regularly circular ; those in the latewood elements, occasionally upright ellipses. Pit apertures conform to the borders or are circular in the earlywood; in the latewood ; long-elliptic, linear, or lenticular, but never slit-like. They are always vertical and included.

Transverse tracheids markedly dentate and reticulate, of a structure similar to that in *P. ponderosa.* Pits in radial walls of parenchyma cells also like those in the said species, but occasionally 7 or 8 of them in the wider early fields, commonly clustered. In the course of evolution, these smaller pits probably coalesce to one large pit occupying the whole cross field as seen in *P. silvestris.* From this it appears to follow that *a single large pit which takes up the entire area of a field is indicative of a higher evolutionary stage.* Pits only in the latewood distinct from the border, where they are linear or fusiform, and vertical.

Only in the compression wood do they appear as extended slits, but merely on account of the striae and cracks in it. *(M.* 75)

PINUS CLAUSA VASEY
Sand pine
Pl. 284

Tree native to the South of the U. S. A.; up to 24 m high. The frequency of paired pits and the absence of thick-walled parenchyma cells bring this species close to *P. palustris*.

C. 1,2. Growth rings wider than, and as distinct and wavy as, in *P. palustris*. Transition from thin-walled early tracheids to thick-walled late tracheids gradual. *Resin ducts* smaller than in the said species (80—100 μ), of a similar arrangement, but less in number.

T. 4. Thick-walled parenchyma cells sporadic in the rays, but their walls not as thick as in *P. ponderosa*, and unpitted or with only vestigial pits. *Tracheids* outnumber parenchyma cells. *Rays* approximately as high as in *P. palustris*. Course of longitudinal tracheids straight.

R. 3. Paired pits, though not as numerous as in *P. palustris*, fairly frequent in the walls of late tracheids. Borders and apertures the same as in the said species. Pit apertures in late tracheids nearly vertical, but never quite so, and included. Rays, and parenchyma pitting, roughly the same as in the preceding species. *(M.)*

PINUS TAEDA L.
Loblolly pine
Pl. 331

Distribution: Virginia and Florida, U. S. A., where it grows in large forests, attains a height of 20—30 m and a diameter up to 0,8—1 m.

C. 1,2. Growth rings wide, distinct and even. Thick-walled latewood, consisting of 8—10 cells in width, markedly distinct from earlywood. *Resin ducts* visible to the unaided eye (200—250 μ), located near the growth ring limits or scattered throughout the latewood band; sometimes encountered on the very edge of the late increment, or beyond it in the succeeding earlywood.

T. 4. Thick-walled parenchyma very exceptional, usually 1—2 cells between the transverse tracheids. *Ray* structure like in the preceding spp. Tangential walls of *tracheids* here, too, unpitted.

R. 3. Paired pits fairly frequent in the radial walls of early *tracheids*. Pit apertures in late tracheids linear, eye-shaped or slitlike, and vertical and included. Toothlike projections in *transverse tracheids* less developed than in *P. ponderosa* or *P. palustris*, but giving fairly frequently rise to reticulations. In the latewood, pit apertures in tracheids as well as parenchyma, vertical slits, commonly included, occasionally extended. In the *cross field* never more than 6 pits. *(M.)*

PINUS SEROTINA MICHX.
(P. rigida var, serotina Loud)
Pond pine
Pl. 327

Distribution: the southeastern states of the U. S. A. Tree up to 24 m high. On xylotomical evidence, the species not separable from *P. palustris*.

C. 1,2. Growth rings, and the latewood in them, wider than in *P. palustris*; contours markedly wavy. Walls of late *tracheids* very thick (10—12 μ); transition from early tracheids gradational; lumina, unlike in *P. palustris*, with rounded corners: circular or elliptic; the primary walls nonetheless angular and forming no intercellular spaces. *Resin ducts* slightly smaller (150—180 μ) than in *P. palustris* and frequently in twos or threes.

T. 4. In rays the *transverse tracheids* more numerous than in *P. palustris*, ray coefficient consequently below 1. Between ray cells and longitudinal tracheids intercellular spaces large and fairly frequent.

R. 3. Paired pits less in number than in *P. palustris*, but not uncommon. Crassulae distinct. Rising from narrower bases than in *P. palustris*, the projections from the tracheidal walls extend to the center of the cell lumen and are seldom ramified. The threads interlocking them are finer than in *P. palustris*. Tracheids with trabeculae fairly numerous. *(M.)*

PINUS RIGIDA MILL.
Northern pith pine
Pl. 325

Distribution: from Maine to the Allegheny Mountains in the U. S. A. Tree 10—15, exceptional individuals 20—25 m high.

C. 1,2. Wood varies with the habitat; it is heavy and resinous on dry rocky soil; less heavy, less compact, and commonly lacking resin contents if grown on humid soil. *Resin ducts* sparse, 100—150 μ in diam.; in some growth rings wanting. Tracheid walls variable in thickness. *Growth rings* differently wide, some with distinct, others with more obliterated limits.

T. 4. No essential departures from the spp. previously dealt with.

R. 3. Paired pits from sporadic to abundant. Pit apertures in late tracheids elliptic, lenticular

or linear, oblique, never vertical or reaching the borders. Transverse tracheids conspicuous for marked dentations and reticulations. Parenchyma cells present no varieties, only slight indefinite differences in wall thickness. Cross-field pitting the usual in the group. Pit apertures in the latewood distinct from borders; occasionally slitlike. *(M.)*

PINUS CONTORTA Dougl.

Beach pine

Pl. 285

Distribution: the West Coast of North America, from Mendocina to Alaska. Tree low: 2—5, rarely 6—8, meters in height and 0,17 in diam. On xylotomical evidence, species referred to the *P. palustris* group.

C. 1,2. Growth rings fairly wide. *Tracheid* walls of medium thickness. Early- and latewood barely differentiated. *Growth rings* indistinct. Earlywood restricted to a narrow stripe. Longitudinal *resin ducts* unevenly scattered; 80—100 μ in width. The projecting transverse bars in the horizontal walls of *transverse tracheids* well discernible. Horizontal walls of *ray parenchyma cells* unpitted, very rarely with vestigial pits.

T. 4. Tangential walls of late *tracheids* unpitted. *Rays* relatively dense and low: commonly 5—6, not infrequently 1—2, maximally 10—16, cells high. *Ray cells*, in cross section, circular or short-elliptic. *Longitudinal tracheids* follow a winding path. Rays composed of *thin-walled parenchyma* and slightly thicker-walled *transverse tracheids*, the latter located mostly on the margins of rays, sometimes in the interior of higher rays. The walls near parenchyma cells not, or only slightly, lignified. Tangential walls unpitted. Along with thin-walled parenchyma, thicker-walled cells encountered sporadically with initial pits perceptible in them, not to be compared of course with the corresponding pits in *P. ponderosa*. By this evidence, the species stands nearer to *P. palustris*, which possesses only one kind of ray parenchyma. From the *P. ponderosa* group it would appear to be excluded by the orientation of its pit apertures. Rays with resin ducts, multiseriate and somewhat higher than others.

R. 3. No appreciable departures from the group, except an essential one consisting in that all kinds of pit apertures in the radial walls of this species are definitely horizontal or tending to be horizontal. They are, of course, circular in the walls of the longitudinal tracheids in the earlywood, and only become eye-shaped and horizontally oriented in the latewood. Transverse tracheids reticulate, like in the *P. ponderosa* group. In the *cross field* 1—3 (4) pits, more or less circular, occupying nearly its entire area. Apertures distinct already in the earlywood, where they are commonly eye-shaped, less frequently elliptic. The same forms prevail in the latewood, but are somewhat narrower with better distinction from the borders. It follows from their horizontal, or nearly horizontal orientation that they are included throughout.

In the writer's opinion, these definite and general features in the pit apertures afford a reliable means of separating this species from the other members of the *P. ponderosa* group. *(M.)*

PINUS MURRAYANA Balf.

Pl. 310

Distribution: Sierra Nevada in California. Tree 30—40 m tall.

Some investigators regard this wood as an independent species named as above, while others claim it to be a variety of *P. contorta*. From the point of view of xylotomy, it merits to be dealt with separately.

C. 1,2, T. 4. On the transverse surface none, on the tangential surface some, appreciable departures from *P. contorta*. *Ray cells*, in cross section, more circular in the latter species, but from short- to long-elliptic in the species under revient. Besides, in the interior of the rays there are more *transverse tracheids* in *P. murrayana*. These being slightly narrower in cross section than the ray parenchyma cells, there are more or less conspicuous inlets observable on the tangential surface of uniseriate rays.

R. 3. The departures are more pronounced on the radial surface. The marginal part of *rays* is sometimes composed of 4—5 cell rows, which is a *P. ponderosa* feature. *Transverse tracheids* with well-developed toothlike projections, occasionally with reticulations, particularly in the latewood. *Ray parenchyma cells* thin-walled. In the *cross field* 1, most frequently 2, elliptic or long-elliptic pits, mostly superposed. Apertures commonly slitlike, especially in the latewood, occasionally elliptic. The borders around them distinct. Walls of ray cells thin and smooth. Thick-walled parenchyma cells not encountered in the rays. *(M.)*

PINUS MITIS MICHX.

Pl. 306

Distribution : the central and southern states of the U. S A. Tree 15—30, sometimes 40, meters high. Wood difficult to distinguish from that of others of the group.

C. 1,2. Growth rings wide. The latewood, composed of thick-walled tracheids, conspicuously differentiated from the earlywood. Cells, in cross section, rounded and with numerous intercellular spaces between them. *Resin ducts* very sparse, scattered throughout the growth ring ; 100—120 μ in diam.

T. 4. Rays composed of three kinds of elements with the *transverse tracheids* predominant. The *thick-walled parenchyma cells* few in number and inserted between transverse tracheids. Owing to the narrowness of the latter, the rays are alternatingly narrow and wide. Ray height largely the same as in the other group members : commonly 8—10, infrequently up to 20, cells high. Thick-walled wood parenchyma occasional.

R. 3. In radial walls of late *tracheids* paired pits not uncommon : a departure from *P. ponderosa*, where they are wanting. Transverse tracheids, on the other hand, markedly dentate and often reticulate, like in the said species. *Cross field* with 1—6 smaller, occasionally with 1—2 larger, pits occupying its entire area. Pit apertures of the group type, in the earlywood not distinct from the borders. Late tracheids markedly striated. *(M.)*

PINUS OCCIDENTALIS SW.

Pl. 312

Distribution : S. Domingo and Cuba.

This species is not typically fit for inclusion into the group ; in some respects it could be referred to the *P. banksiana* group as an intermediate between the two.

C. 1,2. Growth rings uniformly and very wide. Very thin-walled (1—2 μ) early tracheids conspicuously distinct from fairly thick-walled (5—6 μ) late tracheids. The two zones equal in proportion. Transition abrupt. Growth ring demarcation sharp and slightly wavy. *Resin ducts* predominantly in the transition zone, sporadically in either increment.

T 4. In tangential walls of *tracheids* a few scattered pits, 10—12 μ wide, regular circles, with borders distinct. Apertures circular or short-elliptic. In the composition of rays thin-walled parenchyma cells dominant. Transverse tracheids encountered only on margins of rays in 1—2 rows, inside the rays quite exceptional. Thick-walled parenchyma cells few in number, with distinctly pitted walls. Cross sectional picture of rays peculiar : transverse tracheids being exceptional in their interior, the rays are wide with abruptly tapering ends. Parenchyma cells in cross section squares, rectangles or circles, but most frequently polygons which give rise to large intercellular spaces between parenchyma cells and longitudinal tracheids. By this trait the wood can be readily distinguished. Rays commonly 8—10, exceptionally 20, cells high and those with resin ducts not much higher. The transverse tracheids between the rays follow a slightly wavy path.

R. 3. In radial walls of longitudinal *tracheids* paired pits not encountered. The teeth in the transverse tracheids fairly developed, occasionally branched and quite frequently reticulate. In the *cross field* seldom more than 4 pits, sometimes 1 or 2 of them fill up the entire area, at other times large portions of the wall remain free. Apertures tapering to points, commonly reaching the pit borders, occasionally beyond them and invariably distinct from them already in the earlywood. *(M.)*

PSEUDOLARIX AMABILIS REHD.

Golden larch

Pl 338

Distribution : N. E. China.

C. 1,3. Resin ducts absent. *Growth rings* 10—15 to 50—60 tracheids apart, distinct and wavy, delineated by rows of markedly flattened and thick-walled late tracheids followed by unusually large and thin-walled tracheids in the succeeding earlywood. *Rays* proceed at intervals of 3—4 to 10—12 tracheids ; uniseriate ; their horizontal walls with tiny pits. *Ray cells* rather short, not longer than the combined width of 3—4 tracheids. *Tracheids* in the earlywood 4—5 sided, in the latewood predominantly radially flattened hexaogns. Some rows of tracheids, mostly those near rays, traverse several growth increments. In the last two rows of late tracheids *wood parenchyma cells* scattered with sievelike pitting in their horizontal walls. Per sq. mm. 2700 tracheids.

T. 4. Rays uniseriate, very exceptionally with 1 or 2 paired cells in the body. Mean height of rays 6—10, maximal height 24, cells. These are in cross section moderately long-elliptic, while the marginal cells are mostly triangles, sometimes 3 to

4 times the height of internal cells and looking like heterogeneous rays. Tangential walls, like those in the cedars, with sievelike pitting. *Ray cells* 13—18 μ, in single-row rays exceptionally up to 50 μ high. Per sq. mm. 75—80 rays and 470—480 ray cells. If the cut is made near the latewood, parenchyma cells are seen pressed against the ray cells. These are about as wide as the tracheids, their horizontal walls are abundantly, their tangential walls sparsely pitted. One parenchyma cell commonly with 8—12 superposed simple pits. Pits in tangential walls of tracheids much smaller (12—13 μ) than those in the radial walls (13—18 μ).

R. 3. Pits in radial walls of *tracheids* occurring singly, in wider early tracheids occasional paired pits. Pits mostly moderately flattened ellipses with apertures conforming to them, but in the latewood often nearly upright longish ellipses. *Wood parenchyma cells* about as wide as the late tracheids; their walls with simple pits. *Ray cells* variable in height; marginal cells occasionally much higher than internal ones. Outward walls varied. Rays composed entirely of parenchyma cells. *Transverse tracheids* were not encountered. Horizontal and tangential walls of rays abundantly pitted, radial walls less so. *Cross field* in the marginal cells with 2—4, exceptionally 5 (10) superposed pits in 2—3 rows; in the internal cells commonly with 1—2 superposed, exceptionally 2—3 juxtaposed or diagonally disposed pits. These pits are short-elliptic, 4—6 μ wide, in the latewood nearly horizontal. Ray structure, thus, largely reminiscent of that in *Cedrus*. There is also a likeness to that in the *Abies*, but while in that genus the pits are more often in a horizontal row, in this species there are 2—3 superposed pits or 3—4 pits in quadratic arrangement, exceptionally even 10 pits in 2—3 rows. *(Y., 74)*

A PSEUDOTSUGA TAXIFOLIA (Lamb.) Britt.

(P. menziesii Franco)

Oregon Douglas fir

Pl. 340

Distribution: Pacific Coast of the U. S. A.

C. 1,2. Transverse surface essentially the same as in the *Larix*, from which, however, the species is readily distinguished on the longitudinal sections by its *spiral tracheids*. *Growth rings* distinct. Transition from early- to latewood commonly gradual, occasionally abrupt. Major part of growth rings occupied by latewood. Walls of tracheids thick, lumina rounded; intercellular spaces between them fairly large. About 2700 tracheids per sq. mm. *Resin ducts* like in *Larix*, located mostly in the latewood, fairly often immediately near the growth ring limits; 40—50 μ in width. *Wood parenchyma* present, but mostly scattered.

T. 4. Commonly all *tracheids* with spiral thickenings. Bordered pits round, apertures short-elliptic or eye-shaped and included, obliquely or nearly horizontally oriented. *Rays* without resin ducts uniseriate, very seldom with 1 or 2 paired cells in the body; composed of transverse tracheids and parenchyma; relatively low: 8—10, exceptionally 16, most frequently 1—5, cells high; those with resin ducts somewhat higher: up to 15—18 cells. Sometimes two ducts superposed. *Ray cells*, in cross section, rather wide, short-elliptic or circular, except the marginal cells and the cells of single-row rays; height 13—21 (27) μ, width 6—13 μ. Tangential walls of *ray parenchyma* densely covered with minute, circular simple pits. Intercellular spaces between ray cells and longitudinal tracheids frequently triangular. *Wood parenchyma* and their tangential walls like in *Larix* and *Tsuga*; their horizontal walls pitted.

R. 3. According to Hollendonner, the early *tracheids* and the few near the growth ring limits have spirally thickened walls, while the others are, apart from the pitting, smooth-walled. In the writer's material, the walls of all tracheids were found to be spirally thickened, pronouncedly so in the latewood; but very slightly, or not at all, in the earlywood. This seems to be a feature aiding in separation from the *Larix*. Pits uniseriate, in wider early tracheids occasionally biseriate. Pit apertures circular in the earlywood, eye-shaped in the latewood, included. *Transverse tracheids* fewer in number in the inner growth rings; the walls of some of them in places spirally thickened. Pits of the same size as in ray parenchyma; apertures eye-shaped and oblique. Walls of *parenchyma cells* thick, radial walls with many simple pits; the half-bordered pits complementing them, rather small, about the size of those in the tangential walls; they are round or elliptic; apertures in the earlywood wide and eye-shaped or elliptic. The borders are often barely perceptible. Apertures in the latewood eye-shaped and distinct from the borders; they nearly attain the borders in the earlywood and are extended in the latewood. In the *cross field* 2—4 pits in the latewood, commonly 3—6 in the earlywood; 4—7 μ in width. They are less regular in arrangement than in *Larix*, *Picea* or *Abies*.

Like the tangential walls, the radial walls of *wood parenchyma* the same as those in *Larix* and *Tsuga*. *Resin ducts*, in structure, similar to those in *Larix*, i. e., lined with lignified parenchyma cells : these are, however, fewer in number. The ducts are furnished with a rim of parenchyma composed of elongated and scarcely pitted cells ; short tracheids envelop all these tissues. These elements are absent from around the transverse resin ducts.

The species under discussion agrees in essence with *Pseudotsuga macrocarpa* Mayr (Pl. 339), but the latter commonly possesses higher rays, the simple ones in it attaining a height of about 16 cells. Besides, while in the latter the 2—3 (5) pits in the cross field are mostly irregular or diagonal in arrangement, in *Pseudotsuga taxifolia* they are located side by side. Indentures well discernible. *(Y.*, 74*)*

TSUGA CANADENSIS Carr.
Eastern hemlock
Pl. 341

Distribution : the East of North America, from the Hudson Bay to North Carolina.

C. 1,2. Resin ducts absent. *Growth rings* distinct, slightly wavy, fairly uniform in width. Transition from the earlywood to the darker latewood gradual. Early and late tracheids about the same in wall thickness. *Tracheids* in cross section commonly squares ; if occasionally rounded, there are intercellular spaces between them. Horizontal walls of *ray parenchyma* richly covered with small round pits, scattered or in a row, occasionally in pairs. *Wood parenchyma cells* located mostly near growth ring demarcation and on either side of it ; occurring singly, seldom tangentially contiguous ; their horizontal walls with round simple pits. About 5000 tracheids per sq. mm.

T. 3. Tangential walls of late *tracheids* with pits 8—10 μ in diam., occurring singly or in a contiguous row ; they are circular. Pit apertures also circular or short-elliptic, occasionally long-elliptic or eye-shaped, but invariably included. *Rays* consist of *parenchyma cells* and *transverse tracheids*, the latter arranged as in the *Pinus* and the *Picea*. Some low rays composed entirely of tracheids, which, however, may be missing altogether from others. Rays commonly 1—6, exceptionally 10—12, cells high. Height of *ray cells* 13—18 μ, width 5—10 μ ; in cross section, from narrow to wide-elliptic, very seldom short-elliptic or circular. Horizontal and tangential walls equipped with numerous minute round simple pits giving the walls a cribriform appearance. Per sq. mm. 70—75 rays and 280—290 ray cells.

R. 3. In radial walls of *tracheids* pits uniseriate, 13—16 μ in diam., but occasionally biseriate in the early tracheids of the trunk. Pits circular and in the latewood much smaller than in the earlywood. Apertures also round, in the latewood very frequently eye-shaped and reaching the pit annulus. Walls of *transverse tracheids* slightly thinner than those of parenchyma cells, with sporadic elevations and thickenings. The bordered pits in them relatively large, yet smaller than those in the longitudinal tracheids. Pit apertures oblique, eye-shaped or short-elliptic. Walls of *ray parenchyma cells* fairly thick ; radial ones with round simple pits ; their apertures in the earlywood wide-elliptic or eye-shaped and the borders indistinct ; in the latewood, narrow slits ; in both cases oblique and, particularly in the latewood, very frequently extended. *Cross field* with 1—6, occasionally 8 (9), pits 2—5 μ in diam.

Apart from minor or major differences, the *Tsuga* spp. greatly resemble. A departure, though not an always definite one, manifests itself in the height of rays. These are roughly the lowest in the species under discussion and in *Tsuga dumosa* Sarg. (Pl. 343), where they are up to 14 cells high. In *Tsuga chinensis* Pritz. (Pl. 341a) the height is 24 cells ; in *Tsuga diversifolia* Mast. (Pl. 342) 18 cells ; in *Tsuga heterophylla* Sarg. (Pl. 344) as much as 26 cells, and finally in *Tsuga mertensiana* Carr. (Pl. 345) 24 cells. Some inferences can be drawn from the number of rays and ray cells per sq. mm. *(M.*, 129)

C. XYLOTOMY OF THE CHLAMYDOSPERMAE

It is by no means a simple task to characterize the *Chlamydospermae* xylotomically, since the features in the three families belonging to this class show essential differences. To the *Chlamydospermae* are referred the *Ephedraceae*, the *Gnetaceae*, and the *Welwitschiaceae*. Some authors consider that these families got stuck in one of the blind alleys of phylogenetic evolution and that the *Angiospermae* cannot possibly be derived from them. In the view of other investigators, they are

intermediate forms between the *Gymnospermae* and the *Angiospermae*. Their xylotomical features seem to afford support for the latter contention. One of the characters common to all *Chlamydospermae* is, in contradistinction to the *Gymnospermae*, that along with the water-conducting tracheids true vessels develop in them, the individual evolutionary stages of which can be established with great precision. Unfortunately, such common characteristics are accompanied by xylotomically essential differences in these three families. *Welwitschiaceae*, with their parallel venation of leaves, differ markedly from the other two families not only in respect of their structure but also in regard to the evolutionary process of their tracheae. In *Welwitschia*, the tracheary perforations are always simple and round, the walls are invariably covered with dense bordered pits in 2—4—6 longitudinal rows, the borders polygonal from crowding, and the apertures horizontal slits like in some *Agathis*, the *Cycadofilices*, and the *Cordaites*. On this evidence, in the author's view, it is not possible to dispute the common descendancy of these types. On the other hand, in *Gnetum*, with their reticulate venation of leaves (reticulate at least in the *Gnetum Gnemon* examined), there are, along with the round or oval simple perforations, frequently such perforations as are due to 3—5—6 bordered pits; besides, the bordered pits to vessels are scattered, and not polygonal from crowding, and the *crassulae* are clearly discernible in the narrower tracheae, where the bordered pits are only uniseriate. In *Welwitschia*, like in *Cycas* and *Araucaria*, there occur no crassulae.

In *Ephedra*, with verticillate leaves, tracheary perforation appears to be invariably reticulate, the reticulation arising through a dissolution of the walls overarching the cavities in the pits clustered at the ends of the vessel segments, leaving solely the areas between the former pits to form the reticulation. Being characteristic of *Ephedra*, this type of perforation may be designated as *ephedroid* perforation.

In *Ephedra*, the bordered pits in the walls of tracheae are scattered, or aligned in 2 or 3 tight rows, but never polygonal from mutual compression. This presents an additional definite departure from the vascular structure of the *Welwitschia*, and seems to permit the conclusion that *Ephedra* and the two other forms are not of common origin.

Apart from tracheary structure and arrangement there are a number of other, though minor, xylotomical and external morphological characters in which these three types differ and which, too, make it difficult to defend any assumption of their common descent.

DESCRIPTIONS OF THE CHLAMYDOSPERMAE BY SPECIES

EPHEDRA DISTACHYA L.

Pl. 346

Distribution: the South of Europe, particularly the Mediterranean.

C. 1,2. Resin ducts absent. *Growth rings*, which consist predominantly of wide-lumened *vessels*, relatively small: from 1—2 to 10—12 vessels wide, from indistinct to conspicuous. In narrower rings, vessels solitary or in groups of 3 to 5; in wider ones, forming a continuous ring on the outer face of the growth increment. They wane in number as they approach the next growth ring limit, while the ground tissue between the vessels increases. Shape of vessels 6—8—10 sided, but radially somewhat elongated. Between the wide-lumened vessels, narrow-lumened vessels, *tracheids*, and *parenchyma cells* with equally thick walls and therefore difficult to distinguish. Parenchyma cells with reddish-brown resinous contents. *Rays* from uni- to multiseriate. *Ray cells* radially different in length; their horizontal walls more or less verrucose; paired vessels not uncommon, the walls between them invariably radial.

T. 4. Uniseriate *rays* sporadic, with cells, in cross section, elongate ovoid, rectangular or triangular. Marginal cells commonly markedly elongated. Rays 3—7—8 seriate, thereby very reminiscent of the ray structure in *Casuarina*. The other ray cells irregular in shape, from ovoid and circular to polygonal with rounded corners. Between the largest rays occur smaller ones which are uniseriate and have thick walls. Tangential walls with simple pits horizontally aligned and slitlike. Rays bounded by vessels or tracheids or parenchyma cells. In the tangential walls of vessels, pits circular or procumbent ellipses; apertures comforming to the border outlines and mostly extended. In the tracheids, the pits smaller, the apertures oblique and continued in *spiral thickenings*. Longitudinal walls of wood parenchyma cells sometimes wavy.

R. 3. Radial surface conspicuous for the *perforation plates* and their gradations, respectively. In the wide vessels, the bordered pits scattered, paired, or occasionally in 3 rows. This transition from solitary pits to clusters of pits fully corresponds to what has been designated above an *ephedroid* pitting. The apertures of the bordered pits are commonly horizontally oriented and markedly extended. The same structure and the same gradations are observed in the thinner tracheids. Parenchyma cells frequently associated with the vessels. Their horizontal walls abut at right or oblique angles on the longitudinal walls. Both these walls are densely equipped with simple pits. Between the parenchyma cells thin-walled *tracheids* encountered. The pits in them are obliquely inclined, chiefly in the latewood. *Rays* of great height : occasionally attaining 40 to 50 cells. Upright, procumbent, and obliquely inclined cells in one and the same ray. Horizontal ray-cell walls, as a rule, sparsely pitted ; the tangential walls abound in pits ; the radial walls display slitlike simple pits in irregular disposition. On the radial surface, the presence of vessels and their peculiar perforation is as strikingly characteristic that it precludes the confusion of *Ephedra* with any other conifer or, for that matter, any foliaceous wood. *Ephedra major* Host. (Pl. 347) and *Ephedra virilis* Covile are of almost exactly the same structure. *(M.)*

GNETUM GNEMON L.

Pl. 349

Tree native to Indonesia. Sample from the Botanic Gardens of Hong Kong.

C. 1,2. The transverse surface proclaims at a glance that in structure this wood differs essentially from that of the *Coniferae*, but bears likeness to that of *Ephedra*, and quite great likeness to that of *Fagus*, *Quercus*, and *Casuarina*, respectively. Outer edges of *growth rings* barely perceptible : marked by 1 or 2 rows of tangentially somewhat elongated flattened tracheids ; variable in width : some comprising 2—3, others 8—10, successive large vessels. *Vessels* vast and scattered, not radially aligned, but paired pores occasional. The areas between vessels occupied by thick-walled *fiber tracheids* and *parenchyma cells*, respectively. Vessels in cross section radially somewhat elongated angular ellipses. The thick-walled tracheids and fiber tracheids between them very variable in shape : from triangular to multangular and, occasionally, ovoid. *Rays* 1—2—4—8—10 seriate. *Ray cells* varied in cross section : generally radially elongated rectangles, short rectangles, or squares, decreasing somewhat in size as they approach the outer face of the growth ring ; all their walls equipped with numerous simple pits. Minute crystals of calcium oxalate encountered everywhere in the rays.

T. 4. The tangential surface also shows important departures from the wood of the *Coniferae*. The wide-lumened *vessels* follow a slightly winding path. Vessel walls densely covered with bordered pits, not infrequently 3 or 4 of them in the width of a trachea ; some pits contiguous, with the line of juncture between them a straight and the pits consequently compressed almost the araucarian type. Apertures horizontally or somewhat obliquely oriented, occasionally pointlike, commonly included.

Vessel perforations are *simple*, *scalariform*, or the two vessel segments communicate through openings arising from the bordered pits. This structure is very reminiscent of the perforation in *Ephedra* and of the comparable pit aggregations in some *Corylus* species. The gradual transition is clearly observable on some sections. *Fiber tracheids* rather elongate cells with pointed ends and fairly numerous, commonly uniseriate, bordered pits in their tangential walls. Pit apertures generally horizontal or oblique. *Parenchyma cells* conspicuous for their abundance ; their tangential and radial walls densely covered with simple pits, while the horizontal walls are smooth, quite exceptionally with one or two pits in them. Uniseriate *rays* fewer in number than multiseriate ones. The latter attain a height of 70—80, or even 100, cells and are up to 7—10 cells wide. The vast rays are frequently divided into 2 or 3 parts by fiber tracheids, quite like in *Quercus* and *Fagus*. The tangential surface, furthermore, shows remarkable similarity to that in *Quercus* and *Fagus*; this analogy, if not homology, is rather remarkable. In cross section, the cells of the individual rays vary in size and shape. Tangential ray-cell walls equipped with several minute pits. Marginal ray cells occasionally much higher than internal cells, i. e., some rays are definitely of a heterogeneous character, and 1 cell in height. Cells in single-row rays almost invariably and considerably higher than internal cells.

R. 3. Parenchyma cells conspicuous for their abundance on this surface, too. *Rays* remarkably

high ; although the internal cells in them are radially elongate, the marginal cells are frequently upright rectangles or squares. Internal ray cells very varied in size. The ray cells, especially those near marginal cells, contain very many minute crystals in the form of cubes, octahedra, or druses. All ray-cell walls with well-defined simple pits. Tangential walls perpendicular, or assuming various angles, to the horizontal walls. Course of *vessels* winding, the same as on the tangential surface ; their walls from scarcely to abundantly covered with bordered pits ; sometimes 4—5, or even 6, pits extend across the width of a vessel. Perforation plates commonly *simple*, occasionally *scalariform* with 2 or 3 bars, or, as has already been mentioned, arising from pits. The pits in the ray-cell walls complemented by minute simple pits in the vessel walls.

The structure of *tracheids* and fiber *tracheids*, respectively, is essentially the same as that of the vessels.

The horizontal walls of the very numerous *parenchyma cells* are commonly smooth, occasionally equpped with 1 or 2 exceedingly minute pits. In the radial walls, the simple pits are mostly aligned in longitudinal rows. *(Y.)*

WELWITSCHIA MIRABILIS Hook. F.

Pl. 350

Distribution : South Africa, the Kalahari Desert. Sample, a piece from a stem about 8—10 years old, by courtesy of the Botanic Gardens of Coimbra, Portugal.

C. 1, 2, 3. The structures on the transverse surface differ essentially from those in any of the *Gymnospermae*, or in *Ephedra* and *Gnetum*. Groups of vascular bundles occur isolated in the stele of the young stem. Where one of these groups is more developed, there the wood elements fan out radiately, and yet dichotomously. This arrangement of the vascular bundles is strikingly similar to that in the extinct *Bennettites ;* a fact which seems to favour the assumption of rather close phyletic connections between them and *Welwitschia*. Among the radiately arranged wood elements are dispersed the thin-walled cells of the fundamental tissue, which in some respect can be regarded as rays. In the individual complex bundles thin-walled *cambial cells* separate the xylem from the phloem. In the xylem, the vessels are commonly circular or angular in cross section, and mostly scattered in between them there are narrow-lumened tracheids and parenchyma cells.

Viewed in cross section, the *tracheids* are angular : 5—6 sided or irregular polygons ; the lumina are circular, or they conform to the outer circumference of the wall. Quite *thin-walled parenchyma cells* of the ground tissue dispersed sporadically amongst the thick-walled wood elements. The phloem consist principally of thick-walled *bast fibers* with slitlike or dotlike lumina. Between them are thin-walled parenchyma cells. Another characteristic feature on the transverse surface is the presence of exceedingly thick-walled and narrow-lumened *idioblasts*, spiculate cells, amongst the thin-walled ground-tissue cells. The layers of the spiculum walls are well discernible on cross sections. The individual complex bundles are so disposed in the stele that their cambium comes to form a more or less circular line, representing in some degree a cambium ring. Between the individual bundles there are bands of ground-tissue and ray cells, respectively, 5 or 6 cells in width. *Mucilage ducts* in cross section are sometimes encountered in the fundamental tissue.

Because of its structural peculiarities and inconsistencies, it is almost impossible to cut adequately characteristic sections in the tangential and radial planes from the wood of the *Welwitschia*. The longitudinal sections reveal the structure of *tracheids* and *tracheae*. It is striking that vessel segments communicate with each other through simple round perforation plates. The ends of vessel segments are commonly flat, the tips rounded and extending only a little beyond the perforation. Obviously, the perforation in the species under discussion differs in structure substantially from that of *Ephedra* and *Gnetum*.

In the tangential and radial walls of the *tracheae* the pitting is alternate, i. e., of the araucarian type, and thus definitely differs from that in *Ephedra* and *Gnetum*, but very much resembles the pitting in *Cycas* and *Araucaria*. The great likeness or, probably, relatedness to *Cycas* is further brought into prominence by the very fine *spiral threads* in the walls of some tracheids. These threads cross, and form areas occupied by apertures of bordered pits, which are commonly horizontal in position and in this respect agree not only with *Cycas*, but also with some *Agathis* species, moreover, with the *Cordaites* that lived in the *Carboniferous* and the *Permian*. It seems safe to assume that as the minute structure of the tra-

cheids and the spiral thickenings in *Welwitschia* is also recognizable in *Ginkgo*, the two forms may be of common descent. Finally, in *Welwitschia* the bordered pits in the tracheae are markedly elongated in horizontal direction, occasionally they are nearly as wide as the facet, in consequence whereof almost staggered thickenings arise in the walls of the tracheae ; it should be remembered that this is a feature which is fairly often encountered in the tracheids of ferns as well as in the tracheae of the monocotyledonous *Palmae*.

To the trachea there adhere elongated parenchyma cells with very thin and unpitted walls. These cells might be regarded as *parenchyma cells*, but in a recent paper (1953) MÄGDEFRAU and HUBER have shown that this structure is more probably an intermediate in the transition from the longitudinal parenchyma cell to the procumbent ray cell. *Spiculum* cells are best observed on the tangential surface ; they are covered with exceedingly minute centrifugal thickenings very variable in shape ; these are projections like spines, but are truncated ; they cover the entire surface of the spiculum cells and have very minute free areas around their bases. The spiculum cells have long ends gradually tapering to points. The tangential as well as radial walls of tracheids are very densely and spirally thickened. Frequently, these spiral thickenings branch out, follow zigzag paths, and reticulate.

In conclusion, the *Welwitschia* display several remarkable xylotomical features which, on the one hand, point to ancestors and descendants in the *Pteropsida* line and, on the other hand, to phyletic connections with the more advanced *Monocotyledones*.

As regards tissue structure, the departures from *Ephedra* and *Gnetum* are so substantial as to preclude contending for a direct common origin of the three types. *(Y.)*

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I.

CYCADACEAE

SYMBOLS IN TABLES

a : Tracheids, radial side

b : Thick-walled ray cells

c : Tracheids, tangential side

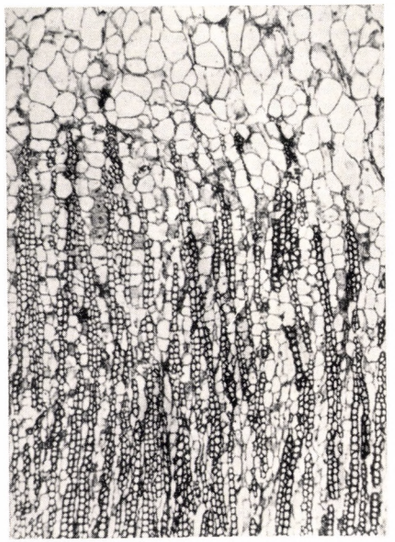
d : Wood parenchyma

f : Thin-walled ray cells

g : Ray tracheids

i : Wood parenchyma

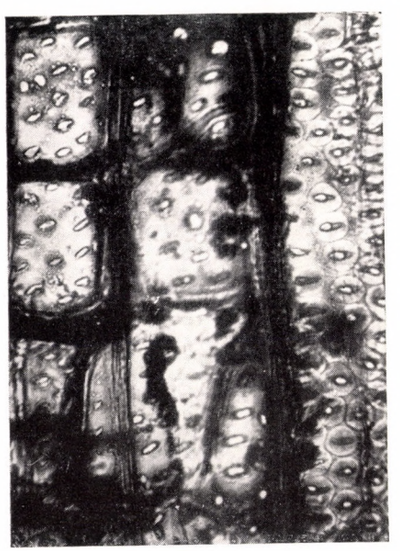
l : Trabeculae



1. (30×)



2. (100×)



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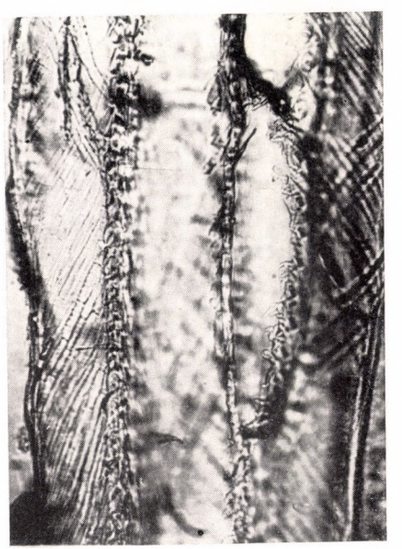

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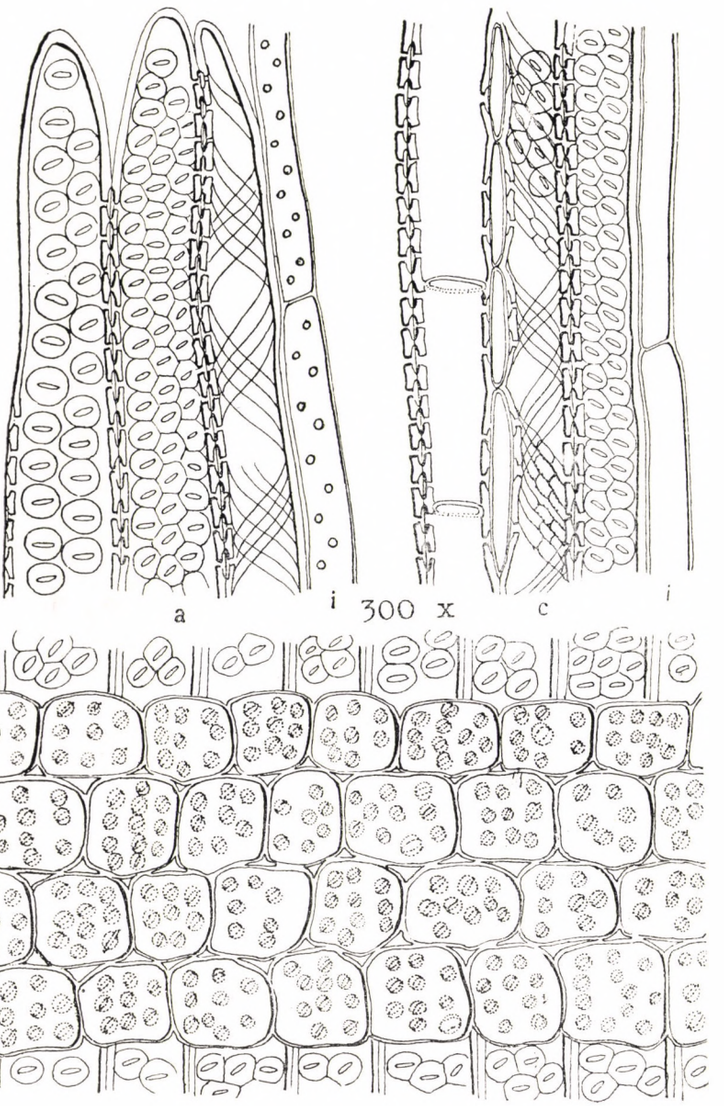


1. Cycas revoluta THUNBERG

II.

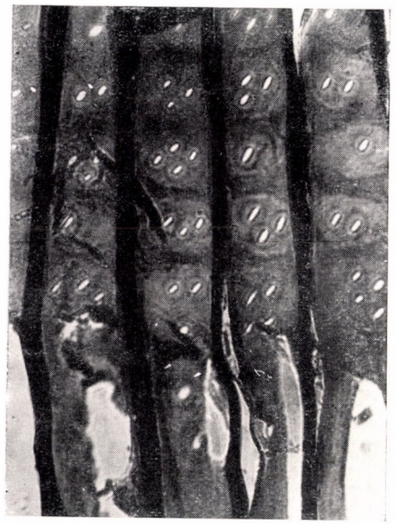
GINKGOACEAE



1. (100×)



2. (100×)



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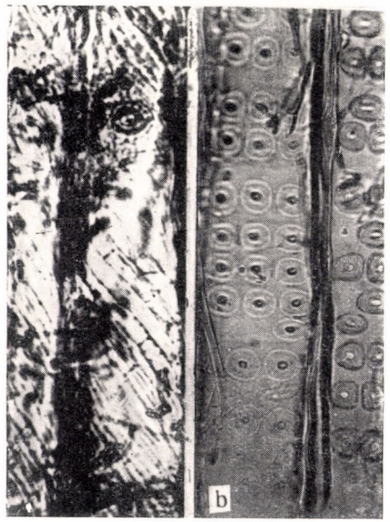

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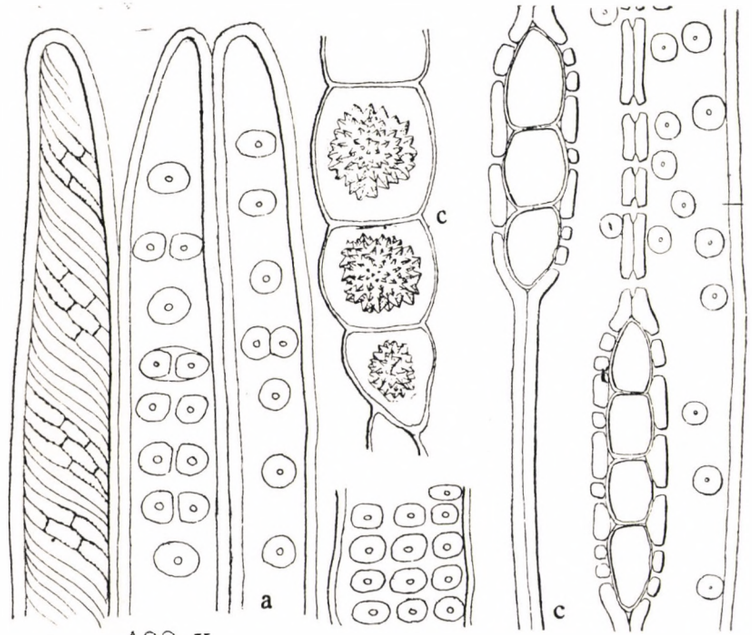
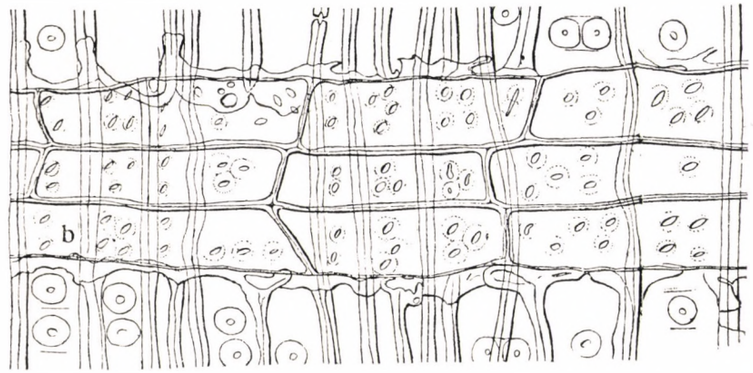
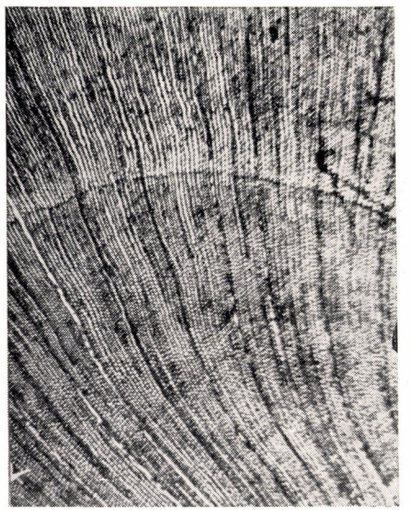




2. Ginkgo biloba L.

III.

ARAUCARIACEAE



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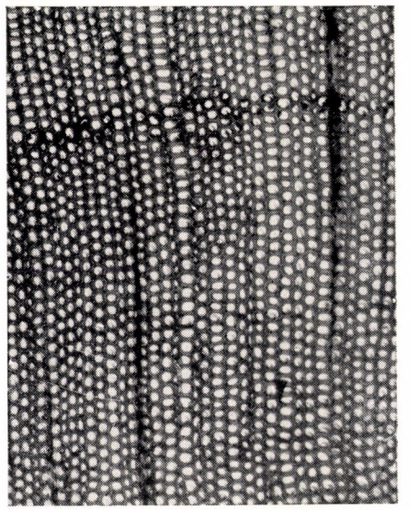
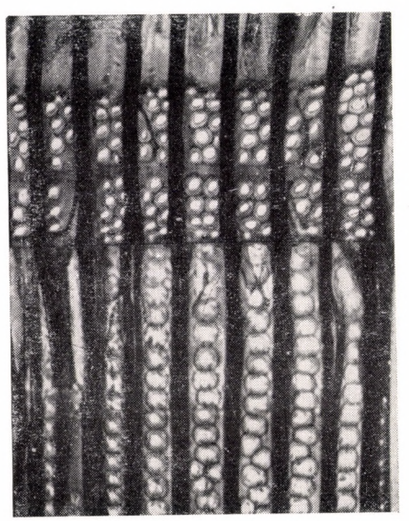


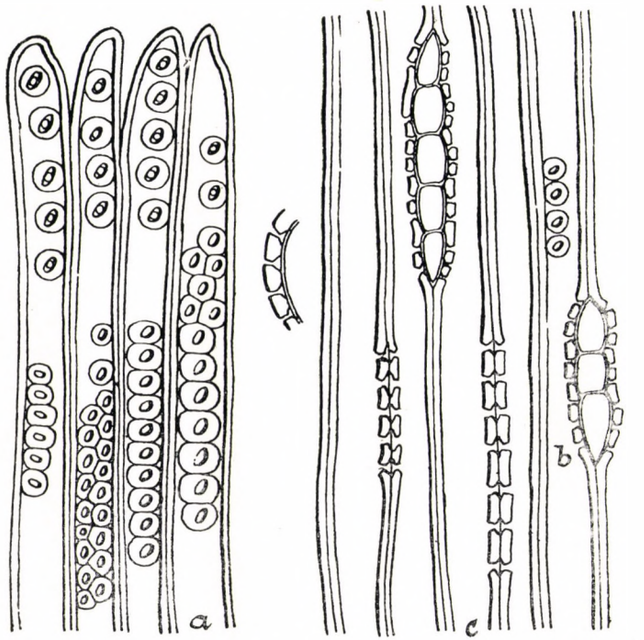
2. (100×)

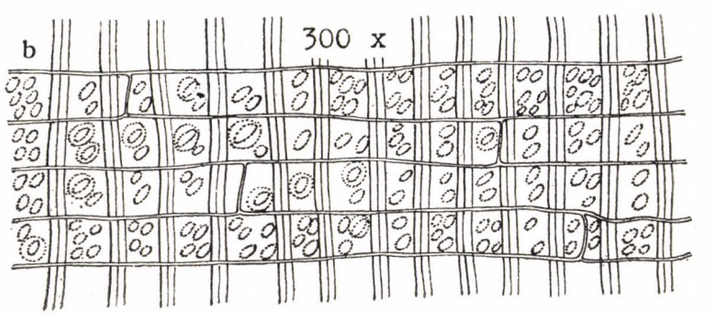


3. (300×)*

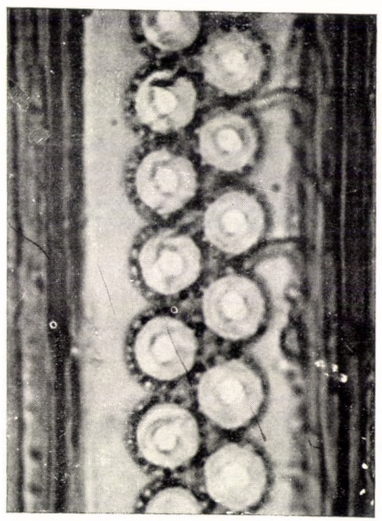


4. (100×)





3. Agathis alba (Rumphius) WARB.



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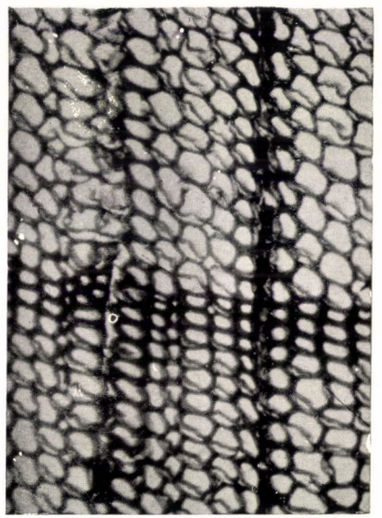
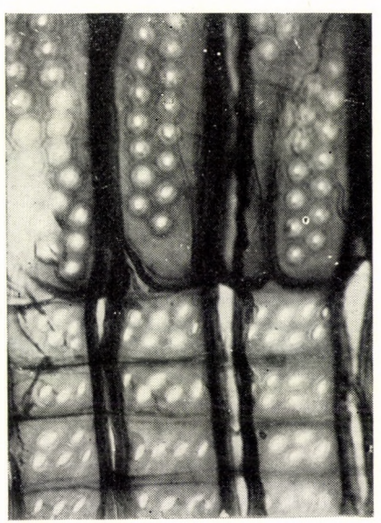
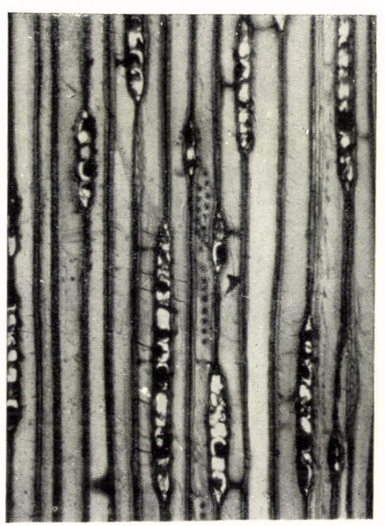


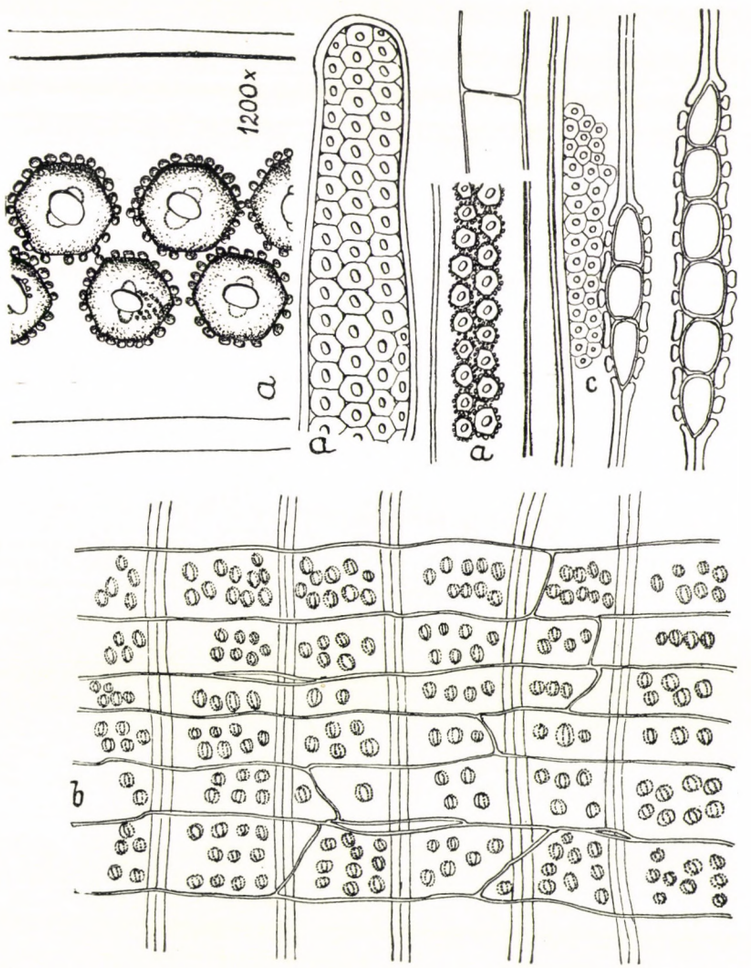
2. (100×)



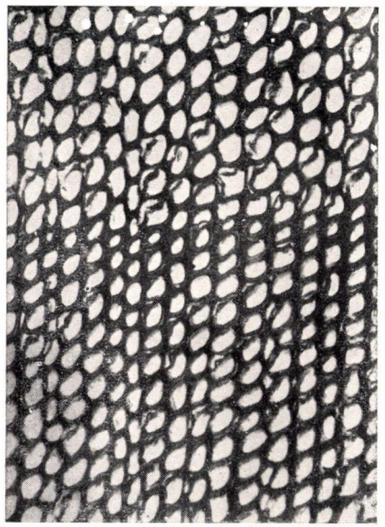
3. (300×)



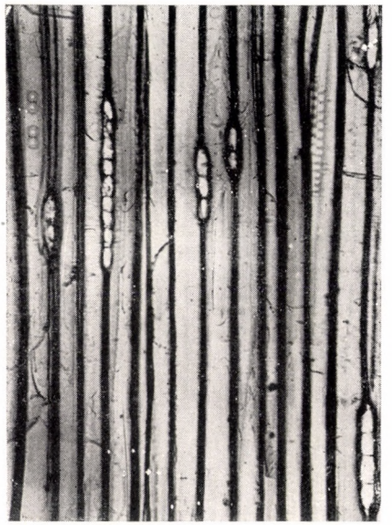
4. (100×)



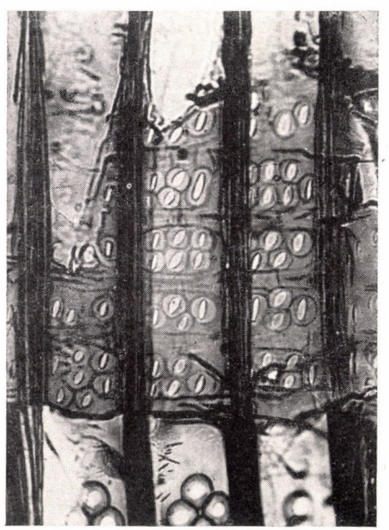
4. Agathis australis SALISB.



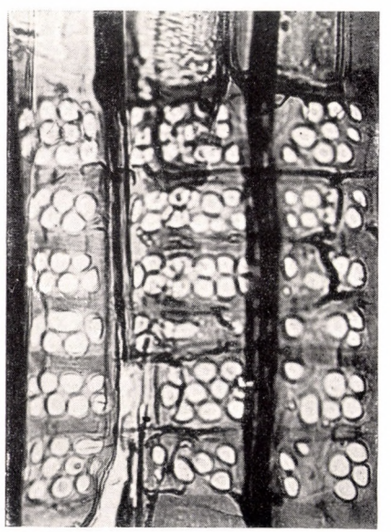
1. (100×)



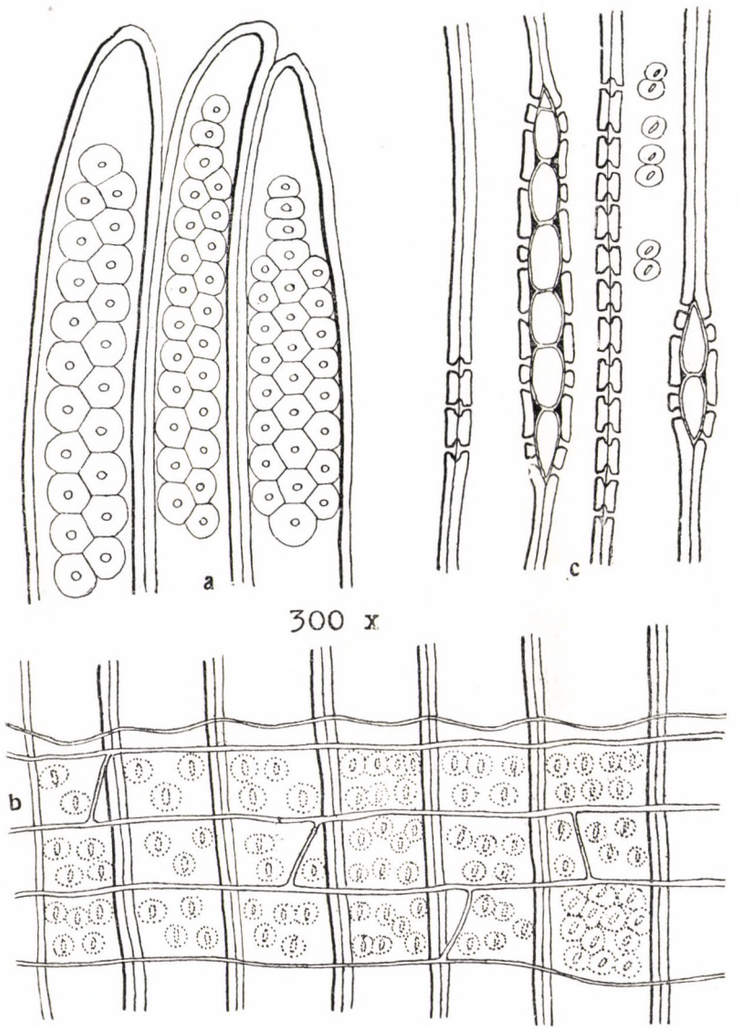
2. (100×)



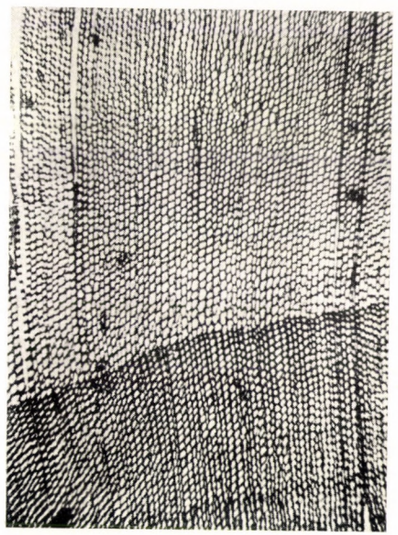
3. (300×)



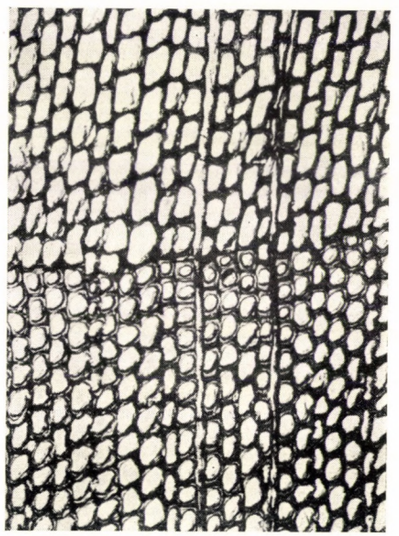
4. (300×)



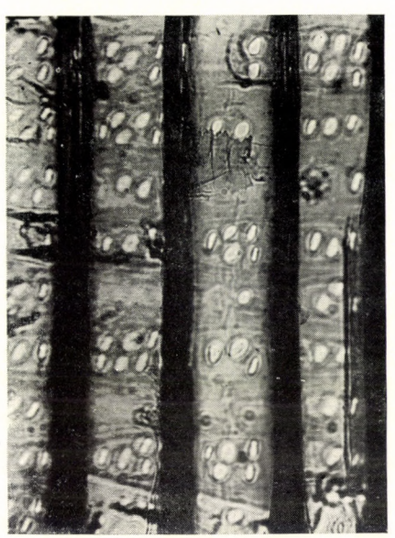
5. Agathis Beccarii WARB.



1. (30×)



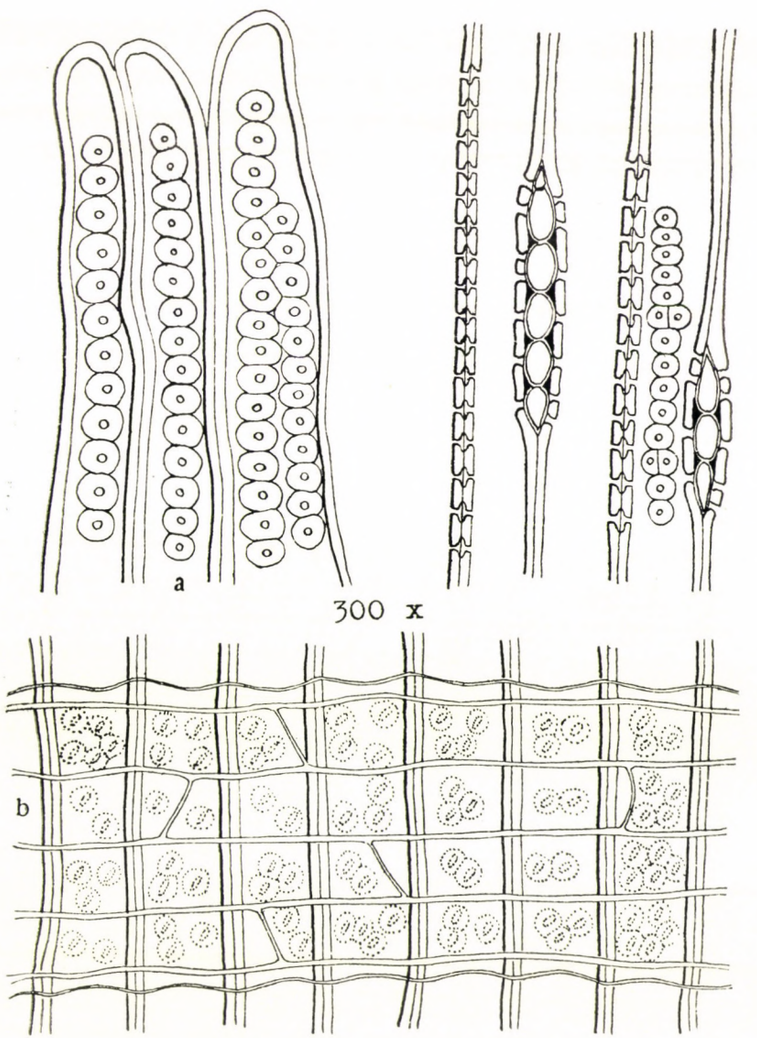
2. (100×)



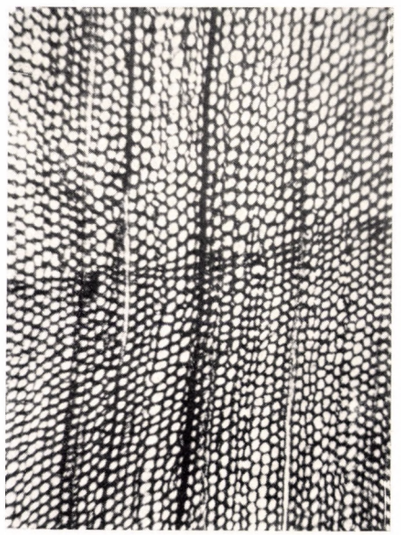
3. (300×)



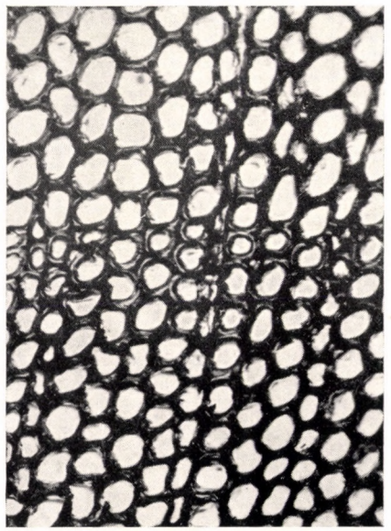
4. (100×)



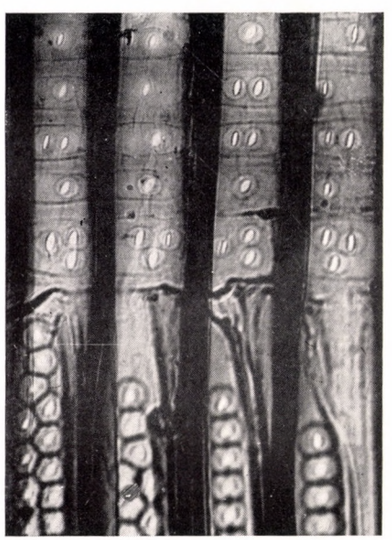
6. Agathis borneensis WARB.



1. (30×)



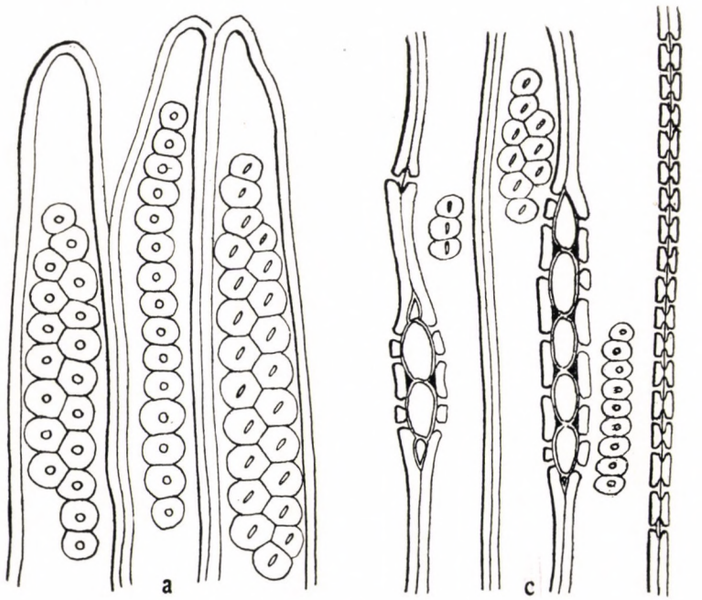
2. (100×)



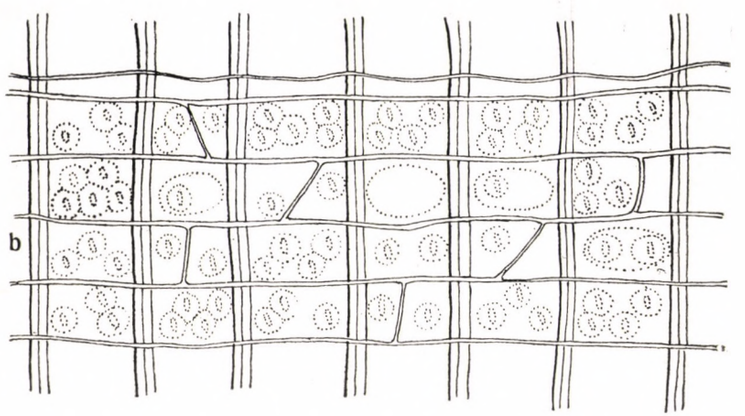
3. (300×)



4. (100×)



300 x



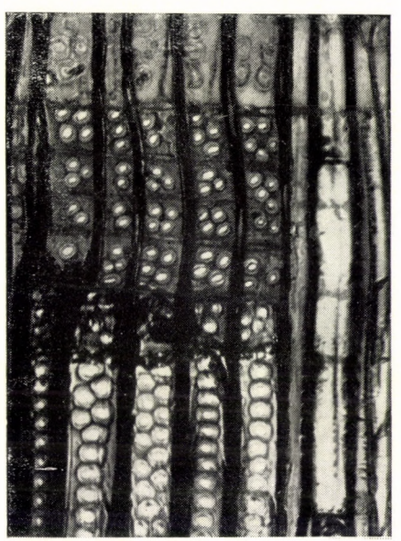
7. Agathis celebica WARB.



1. (30×)



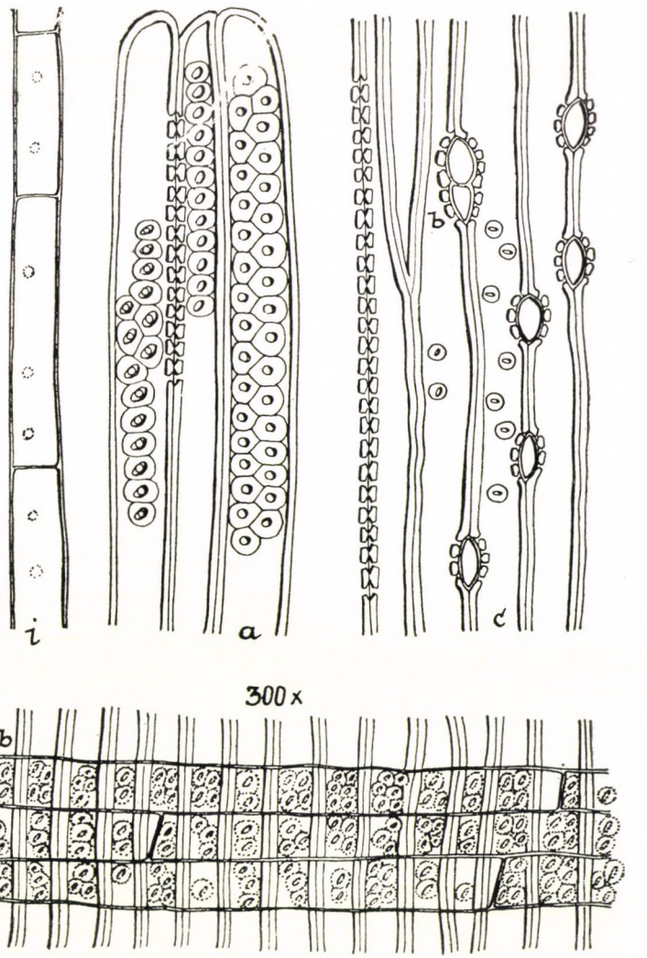
2. (100×)



3. (300×)*



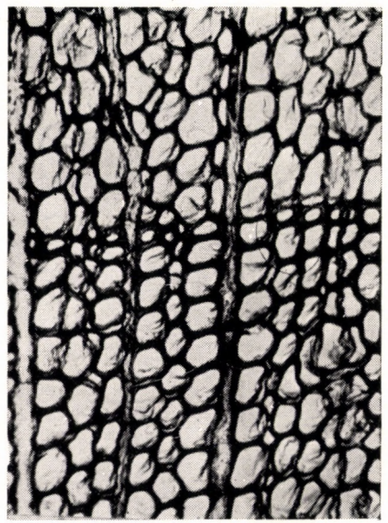
4. (100×)



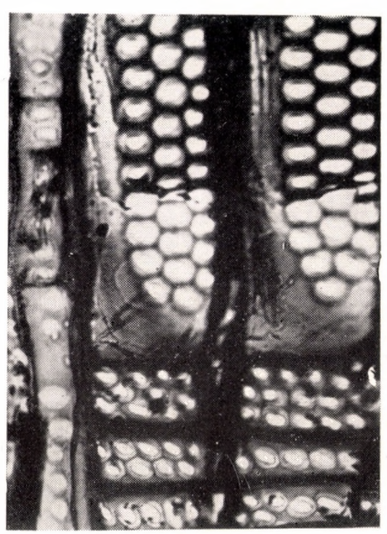
8. Agathis hypoleuca C. Moore



1. (200×)



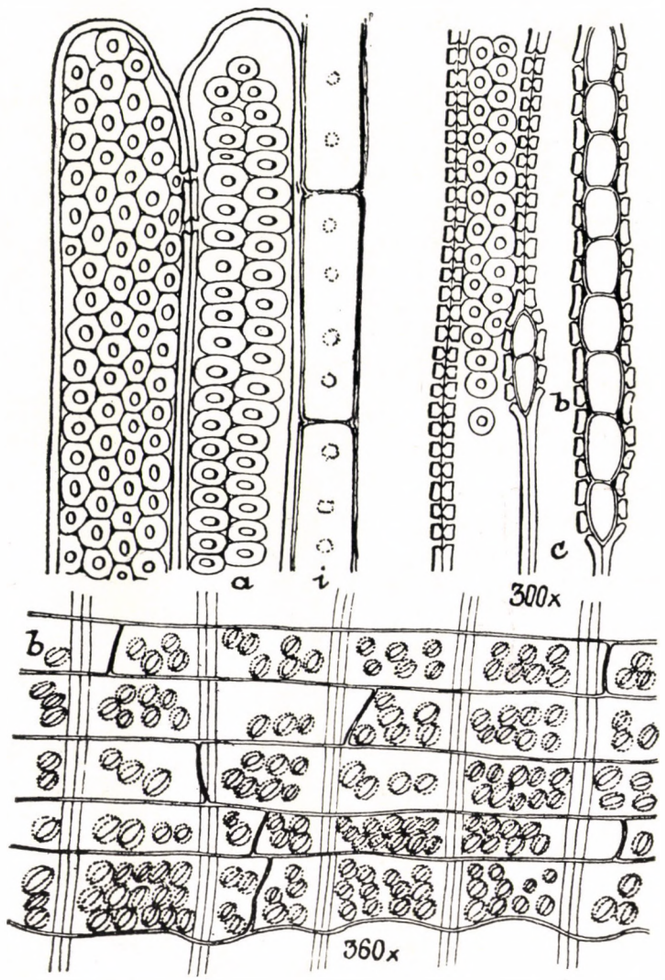
2. (100×)



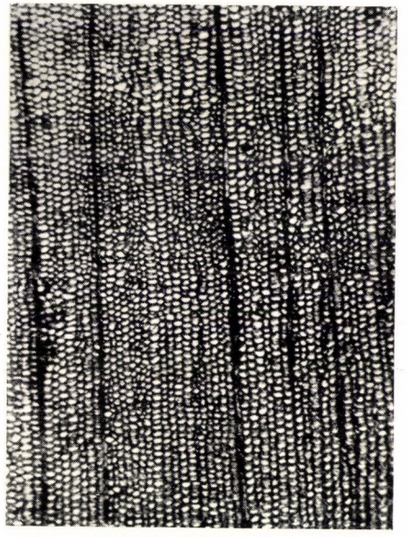
3. (300×)*



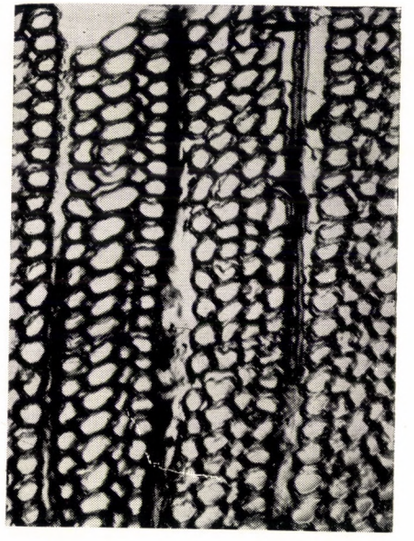
4. (100×)



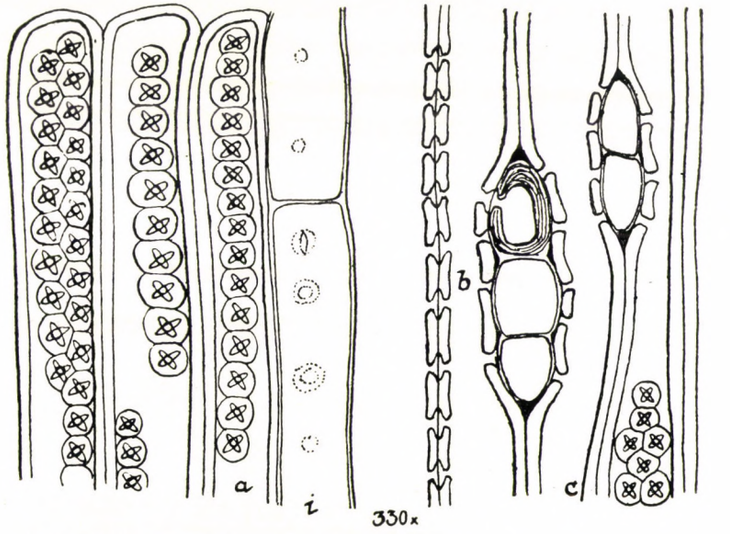
9. Agathis lanceolata (Pancher) WARB.



1. (30×)



2. (100×)

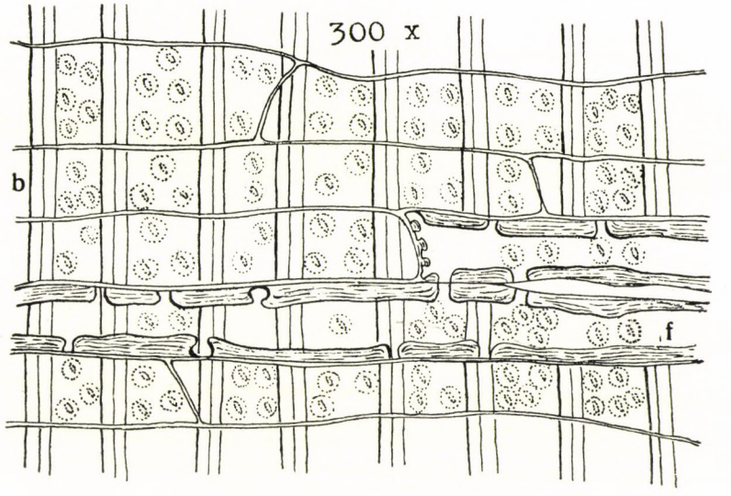




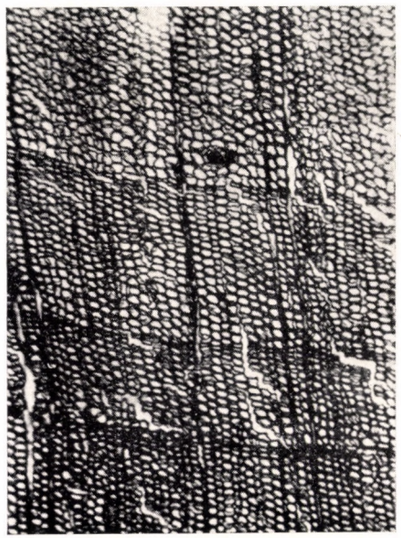
3. (300×)*



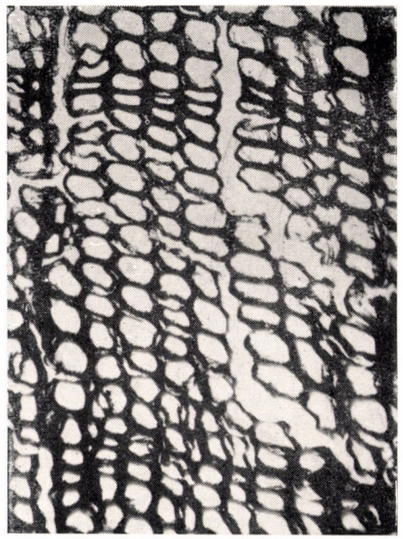
4. (100×)



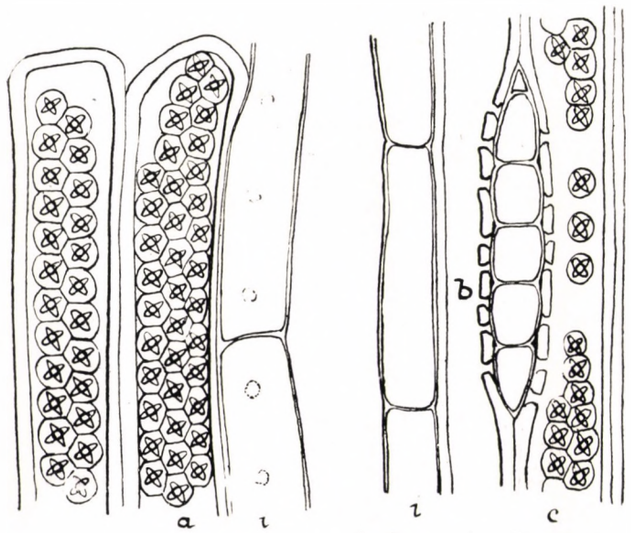
10. Agathis macrophylla (Lindley) MAST.



1. (30×)



2. (100×)

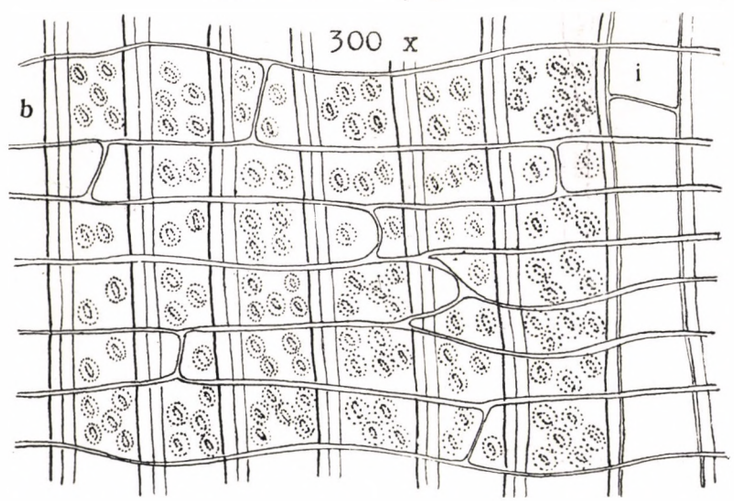




3. (300×)



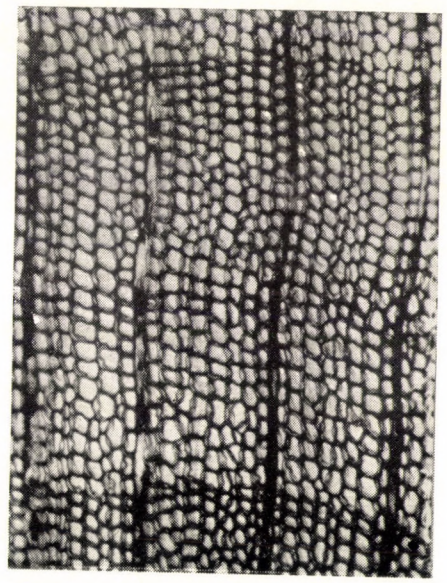
4. (100×)



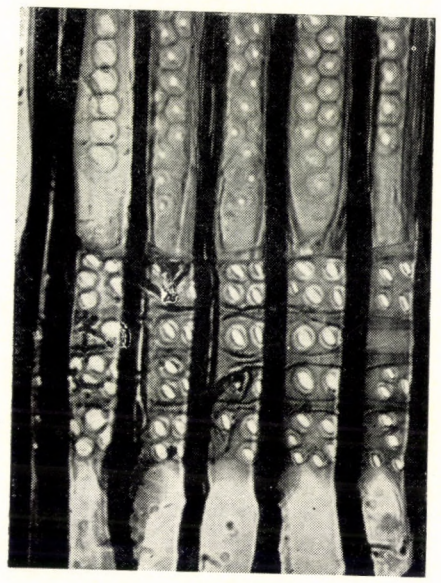
11. Agathis microstachya B. et W.



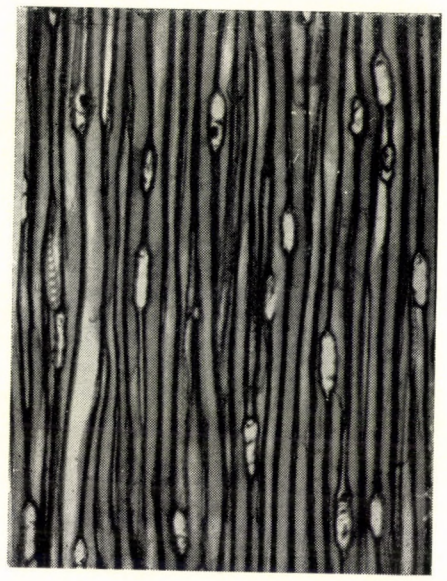
1. (30×)



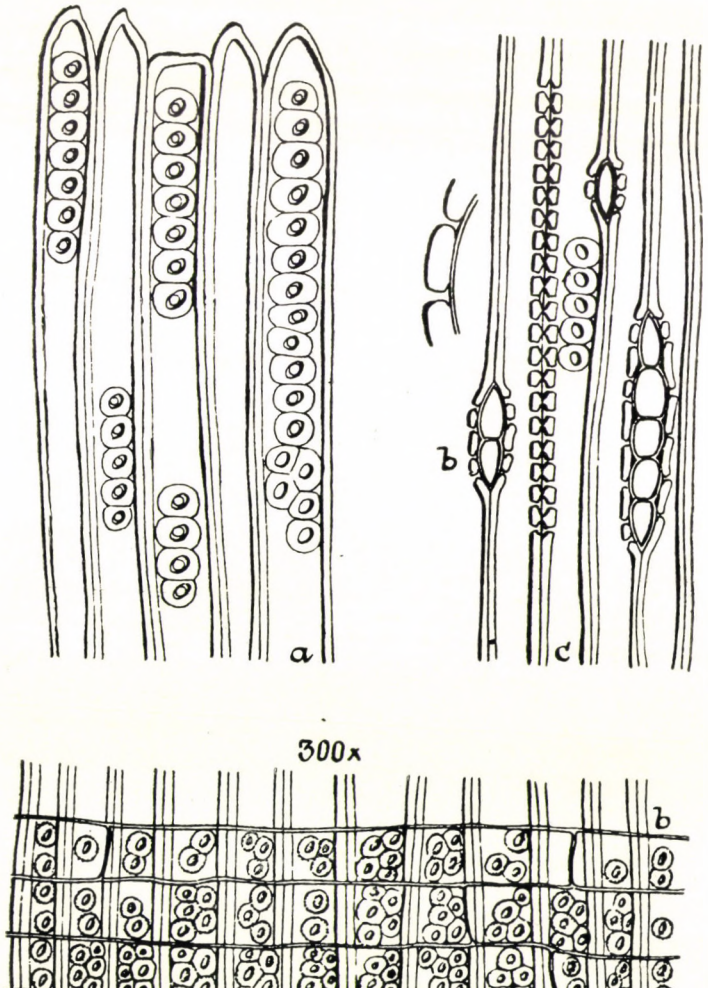
2. (100×)



3. (300×)



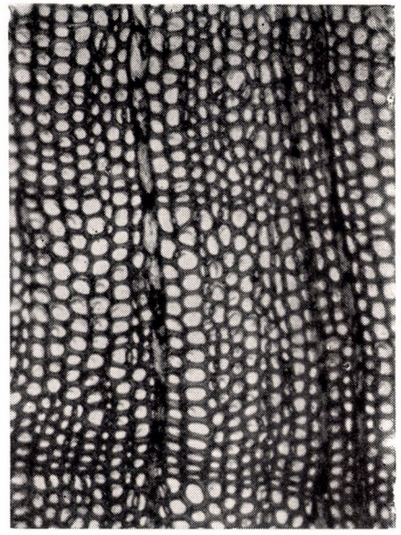
4. (100×)



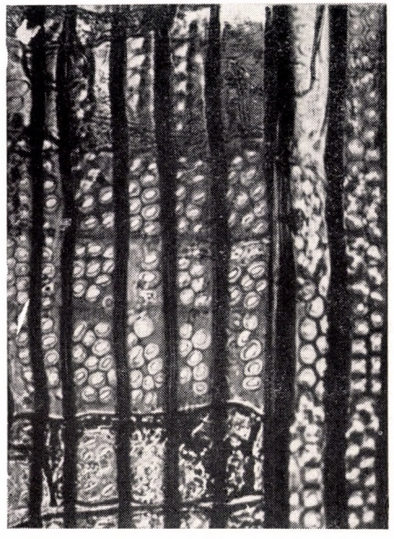
12. Agathis Moorei (Lindley) MAST.



1. (30×)



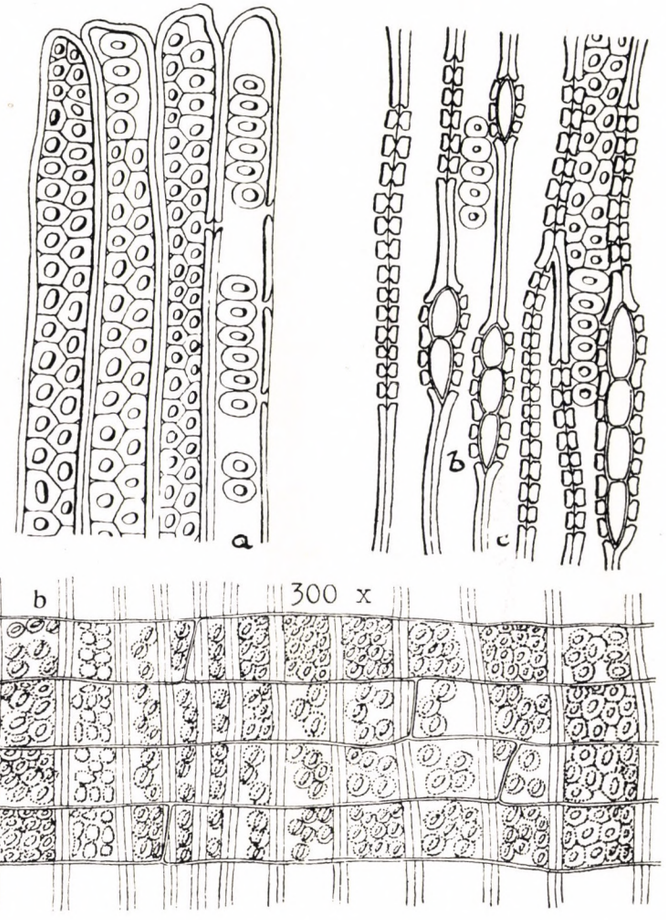
2. (100×)



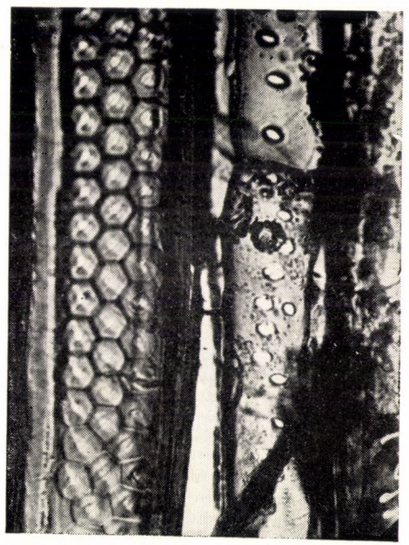
3. (300×)*



4. (100×)



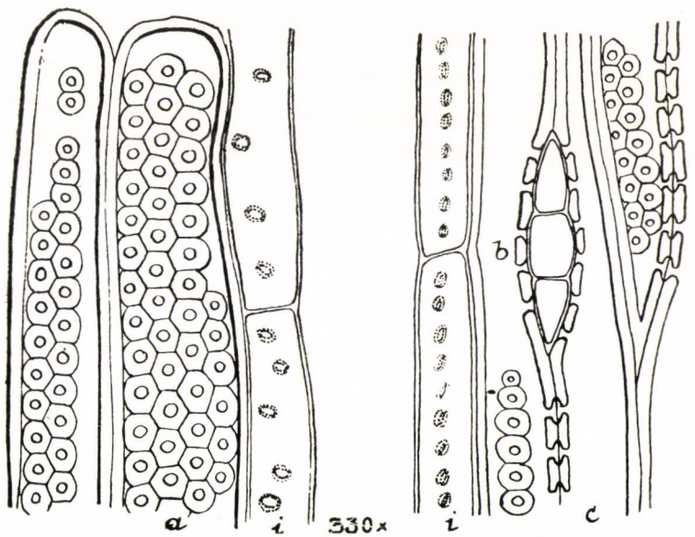
13. Agathis ovata WARB.



1. (300×)



2. (100×)

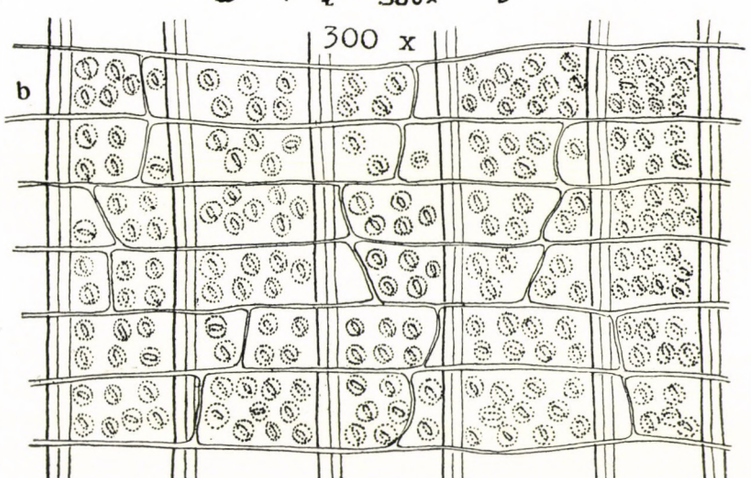




3. (300×)



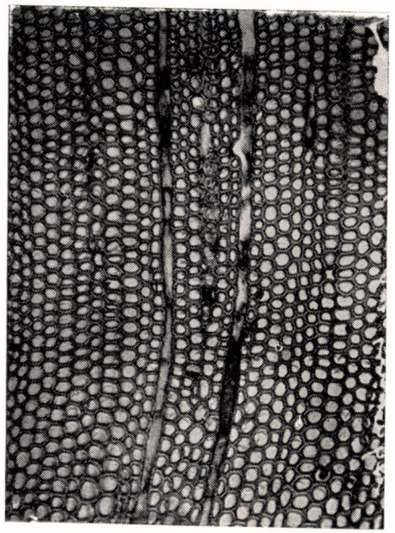
4. (100×)



14. Agathis Palmerstonii F. v. MUELLER



1. (30×)



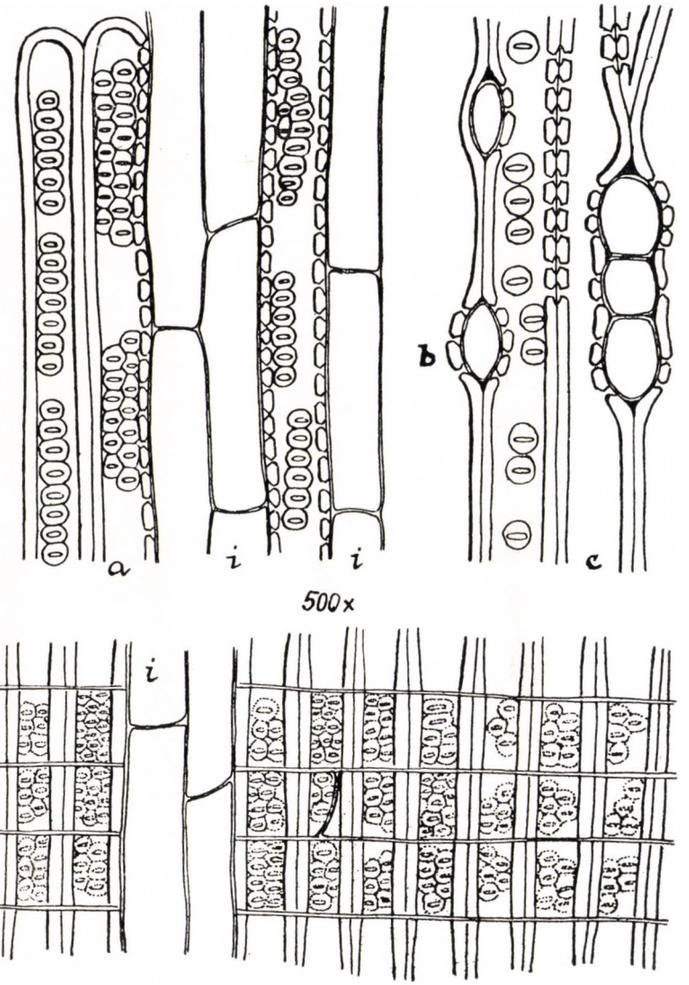
2. (100×)



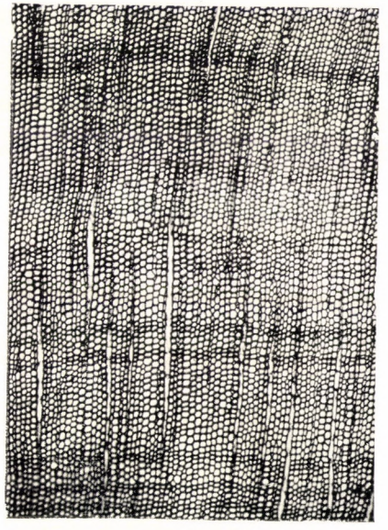
3. (300×)



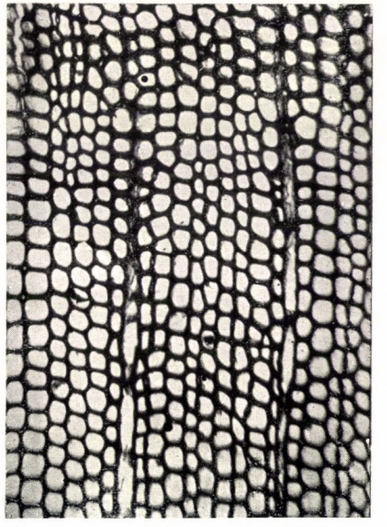
4. (100×)



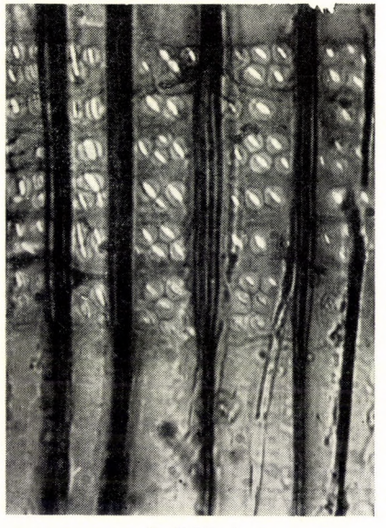
15. Agathis robusta MAST.



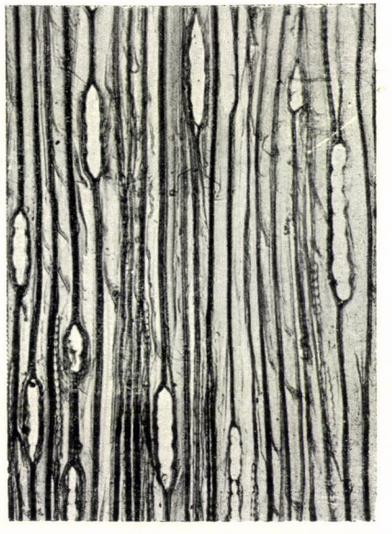
1. (30×)



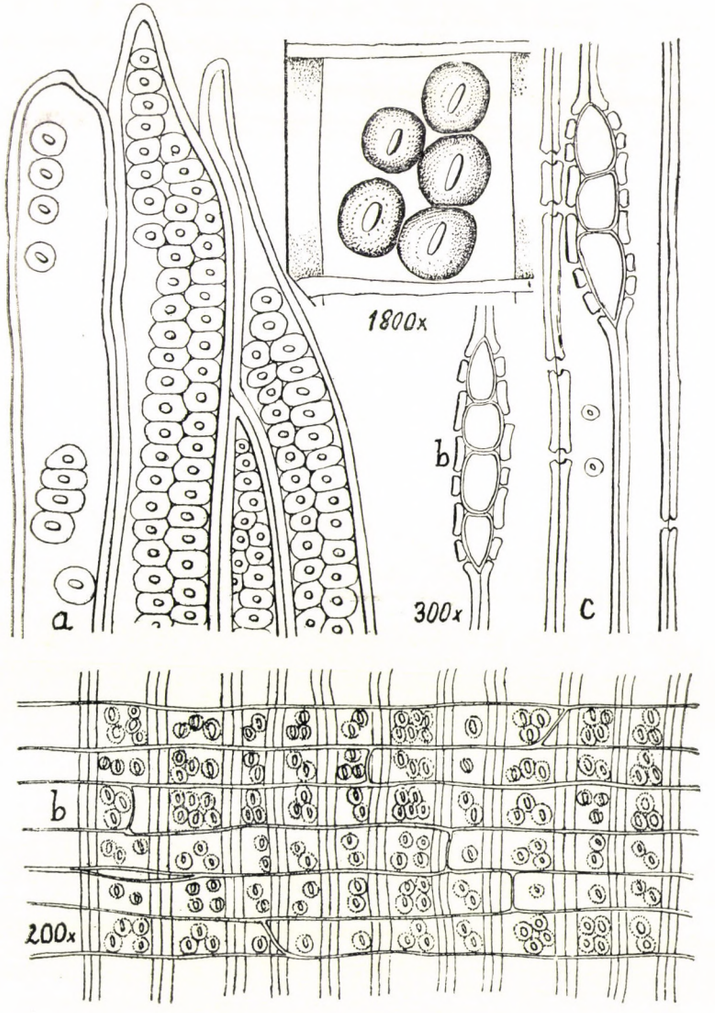
2. (100×)



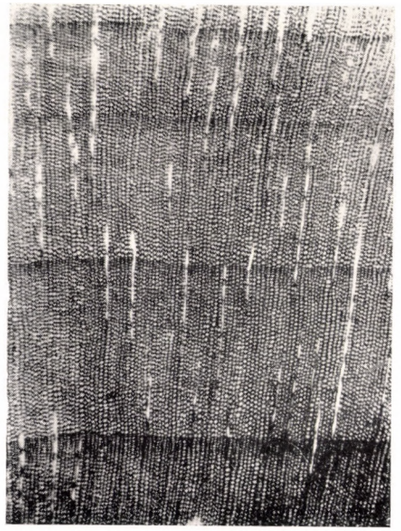
3. (300×)



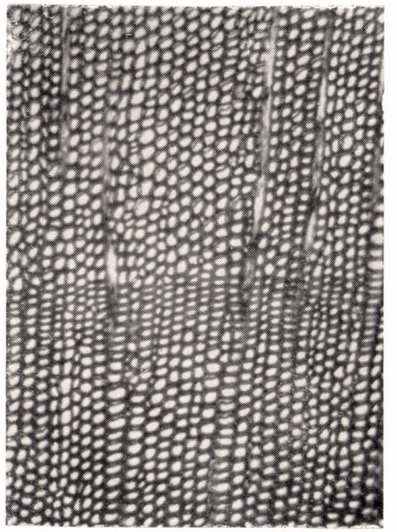
4. (100×)



16. Araucaria angustifolia (Bertoloni) O. KUNTZE



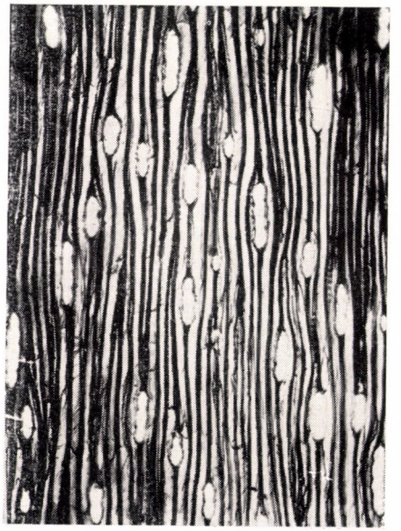
1. (30×)



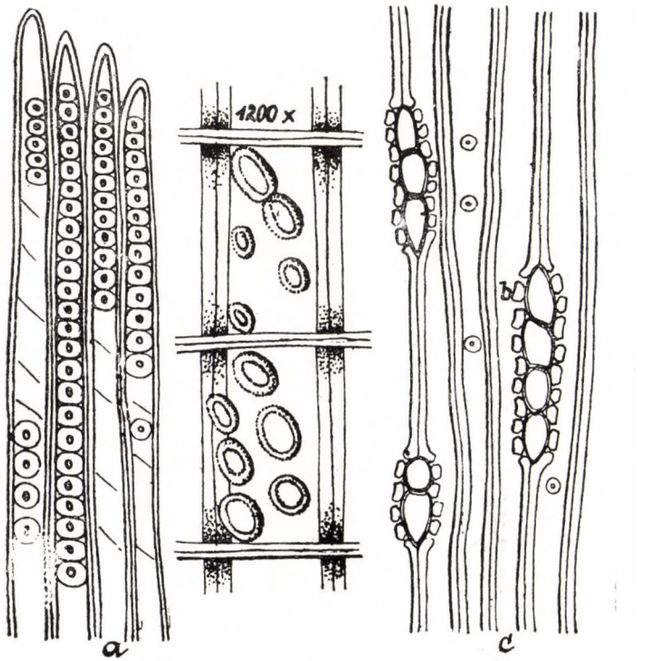
2. (100×)



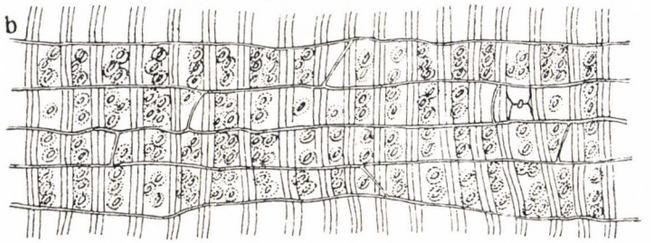
3. (300×)



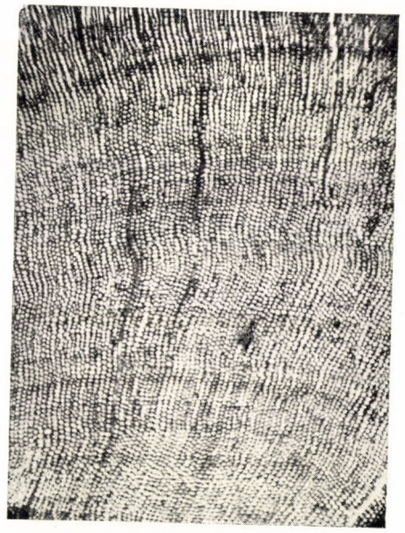
4. (100×)



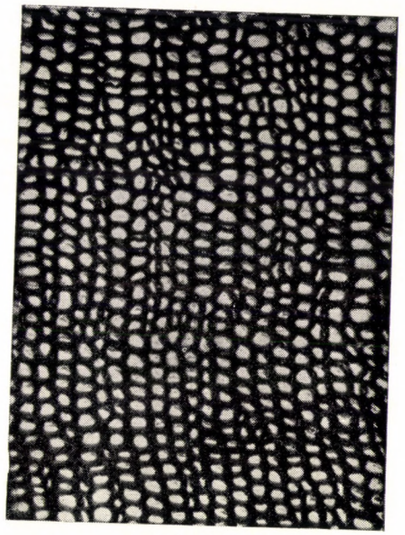
300 x



17. Araucaria araucana (Molina) K. Koch



1. (30×)



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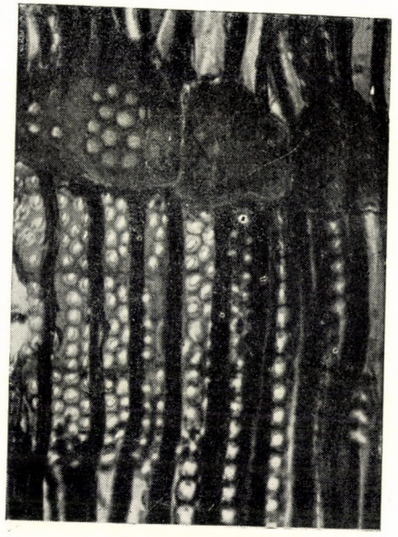

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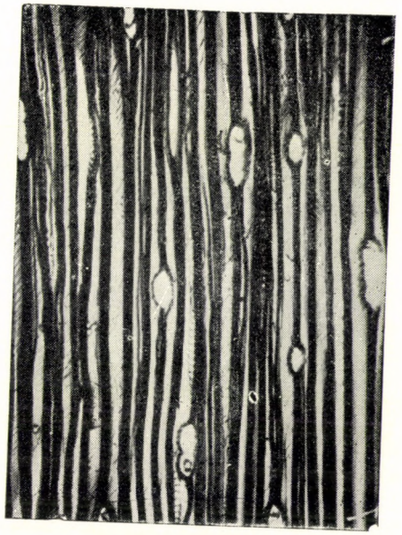

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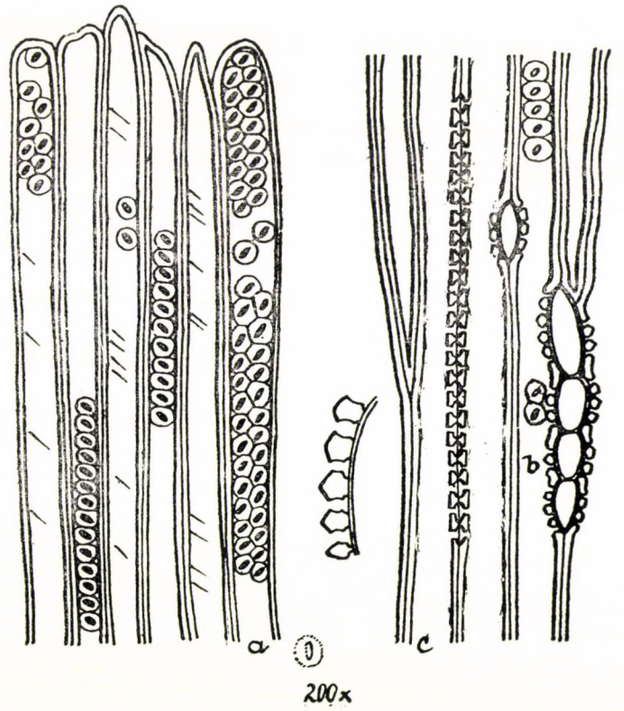
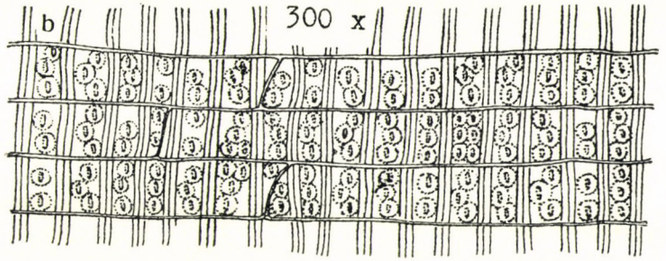
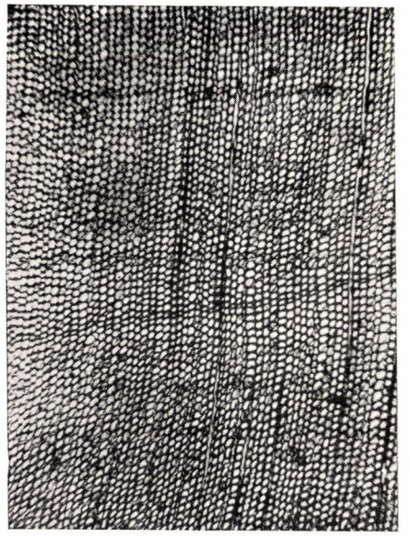




18. Araucaria Balansae Brong. et Gries.



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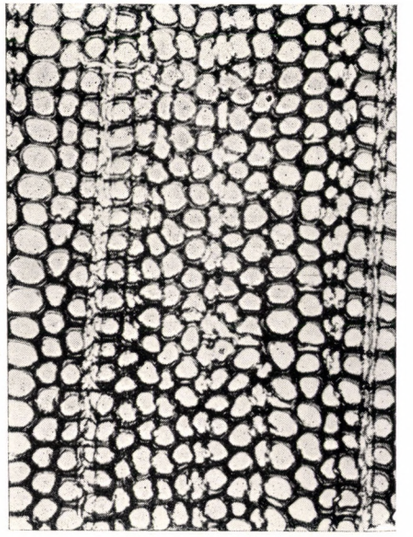

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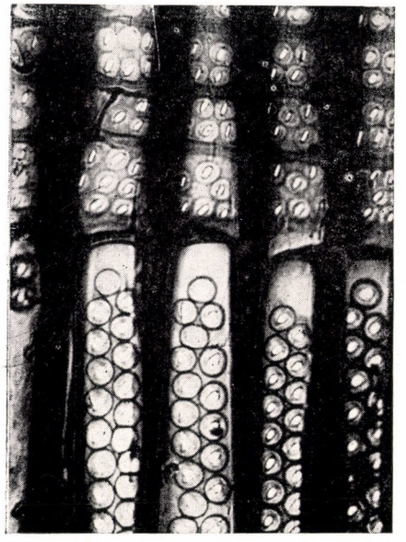
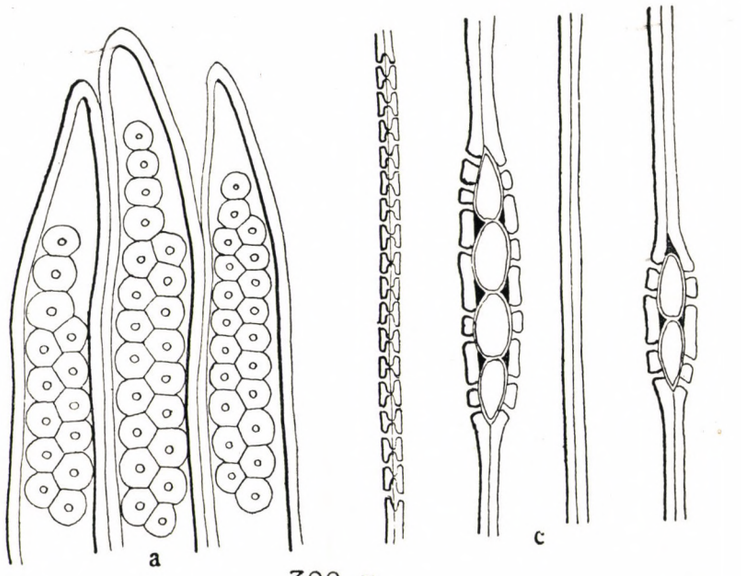


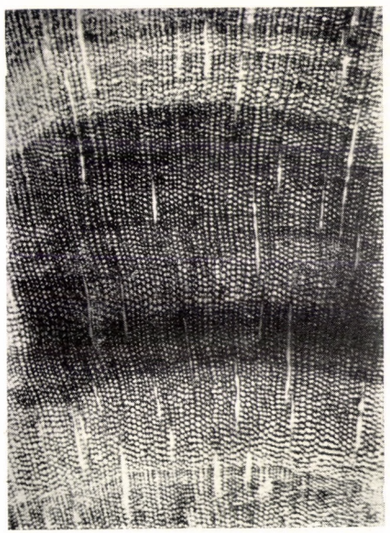
3. (300×)



4. (100×)



19. Beccari WARB.



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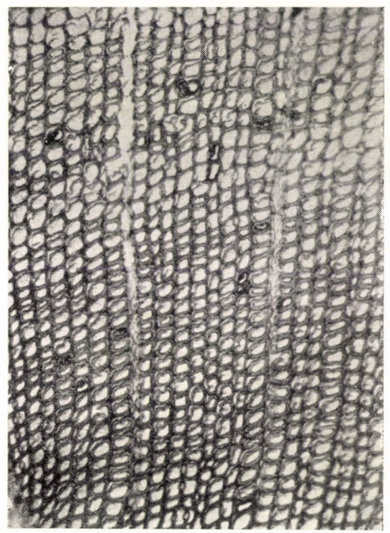

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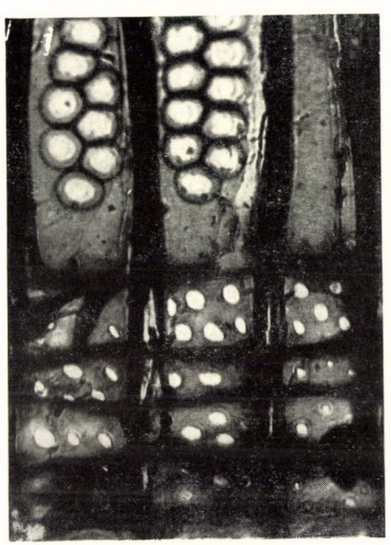

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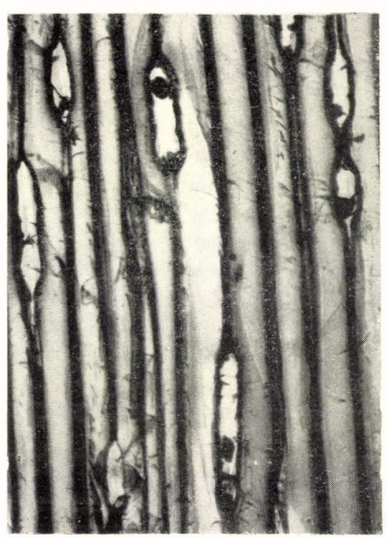

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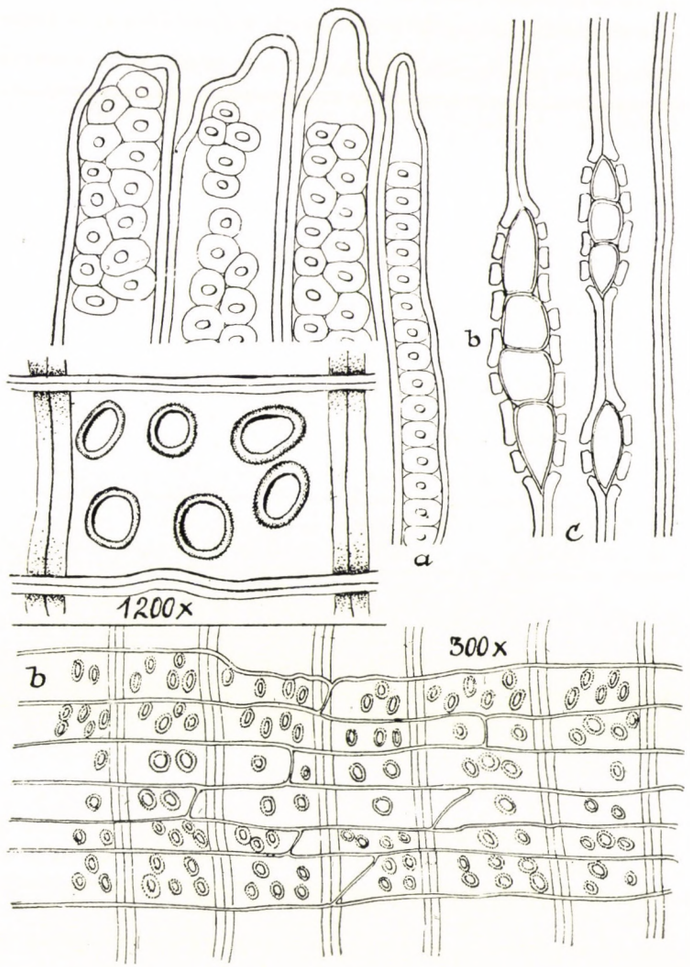
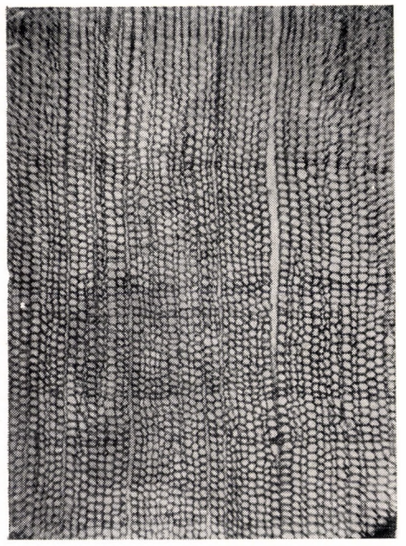


20. Araucaria Bidwillii Hook.



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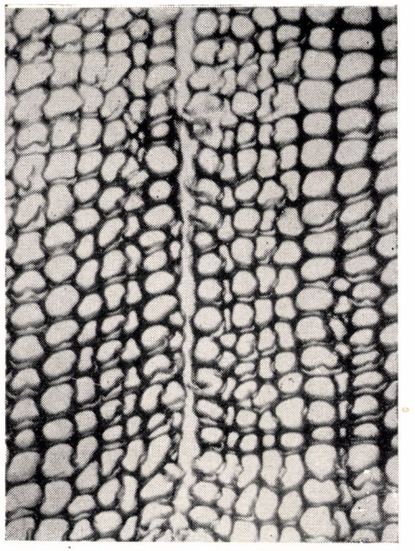

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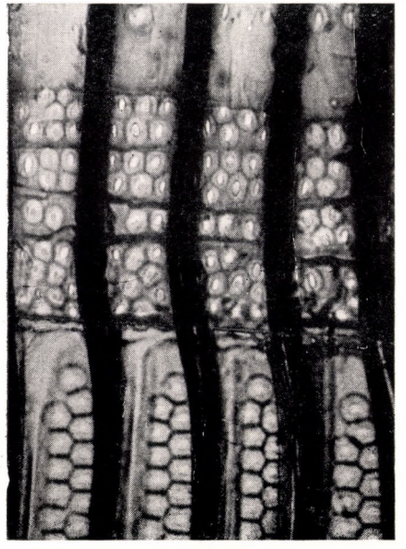
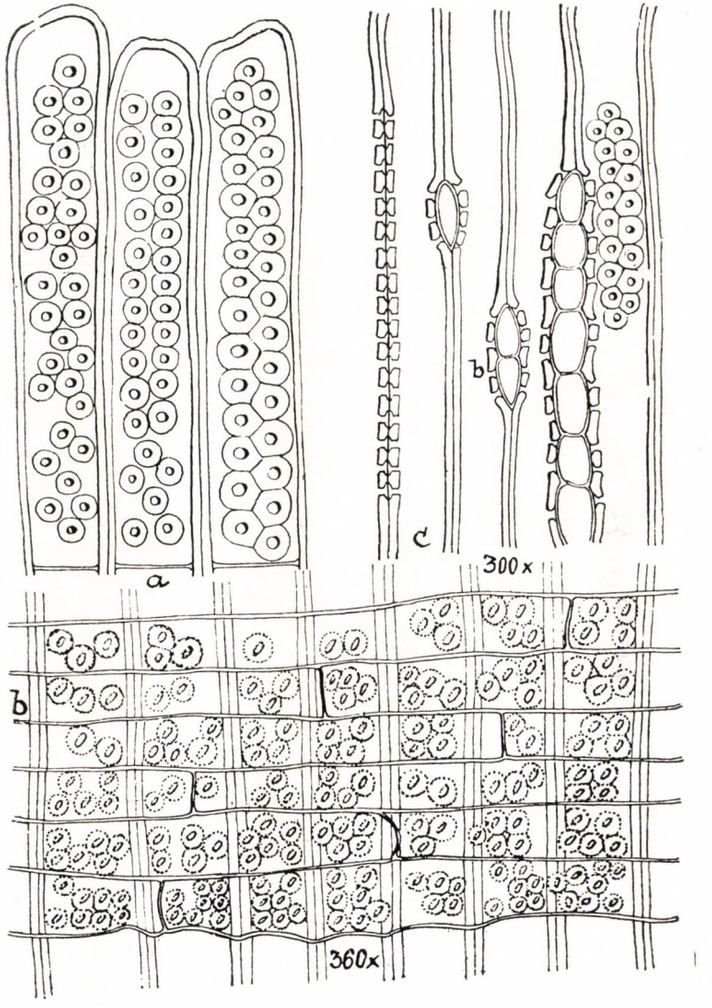


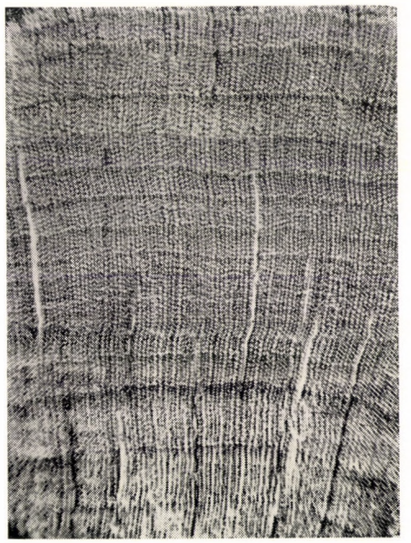
3. (300×)



4. (100×)



21. Araucaria columnaris (Forster) Hook.



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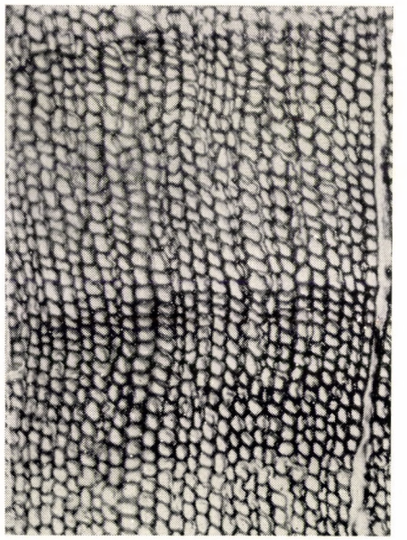

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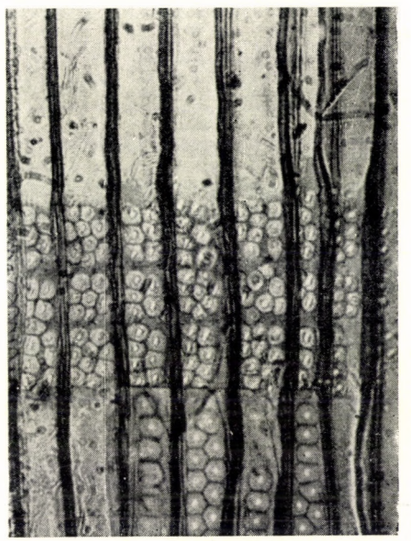

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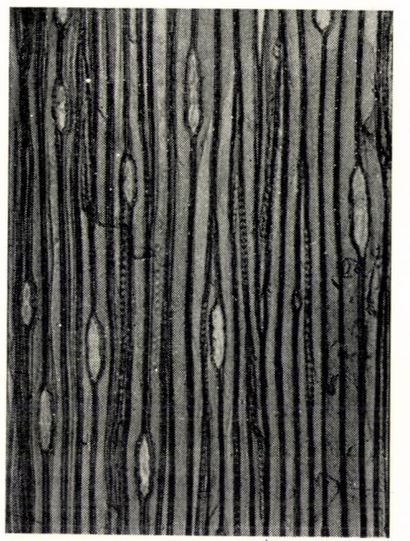

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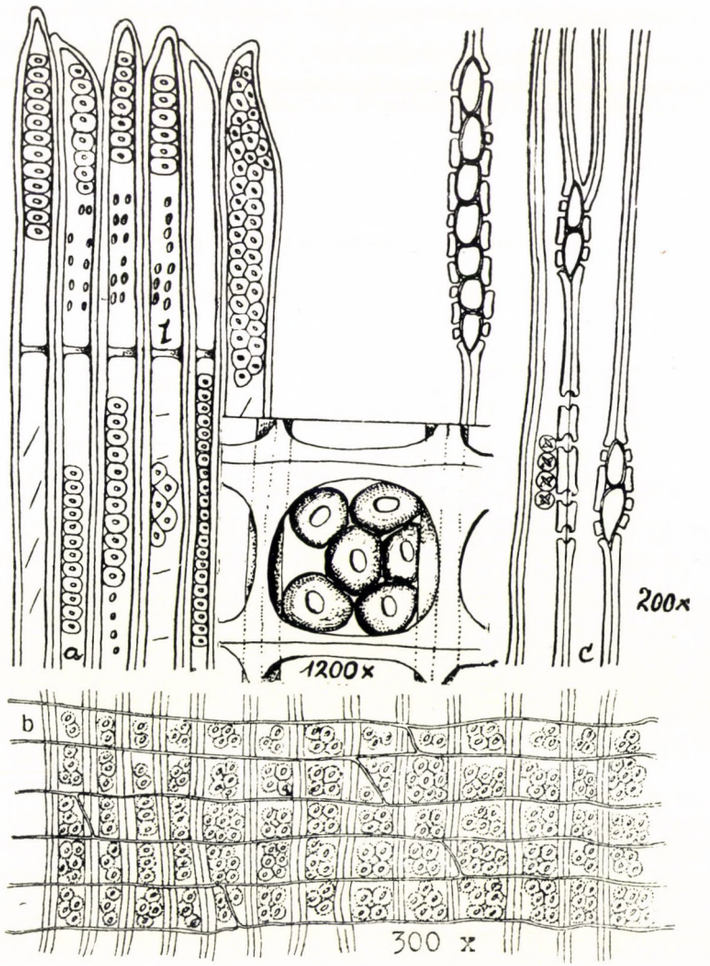
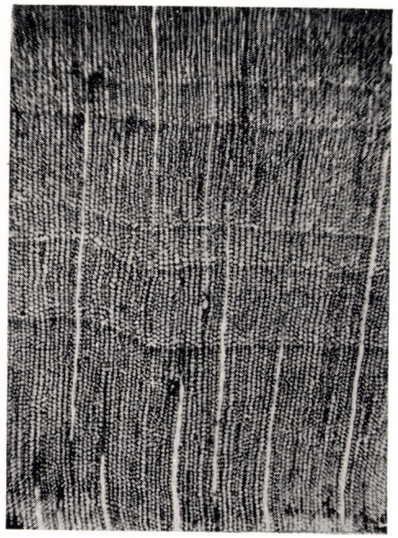
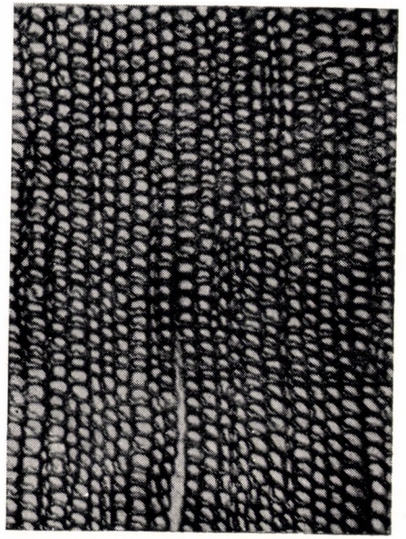


22. Araucaria Cunninghamii SWEET



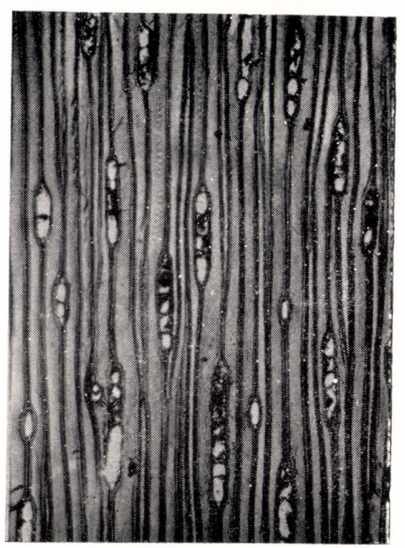
1. (30×)



2. (100×)



3. (300×)



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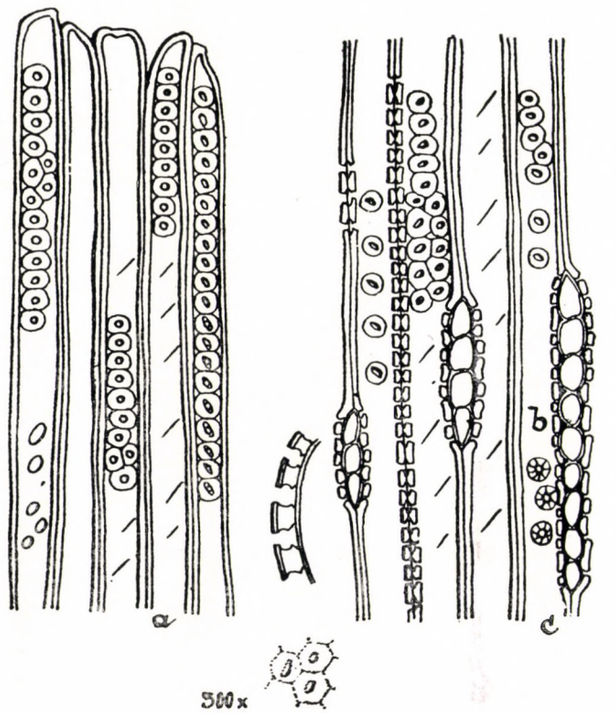

23. Araucaria Cunninghamii v. glauca (Loddiges) ANTOINE



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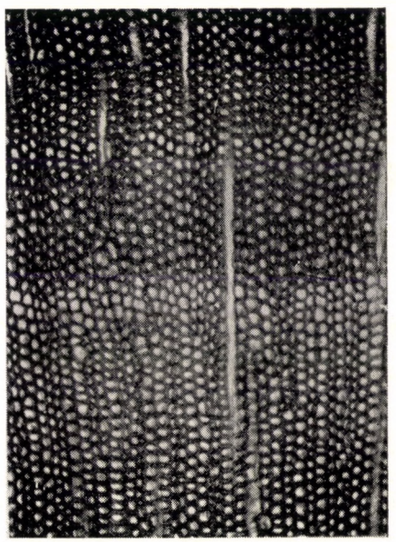
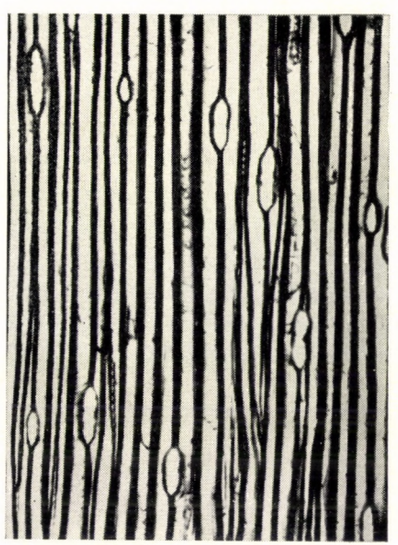


2. (100×)



3. (300×)*



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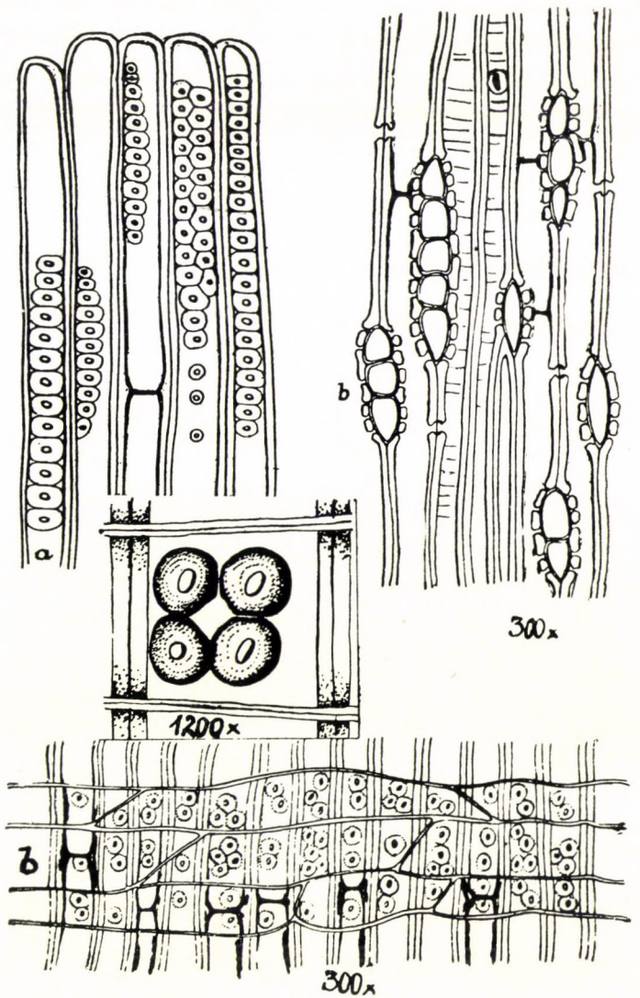
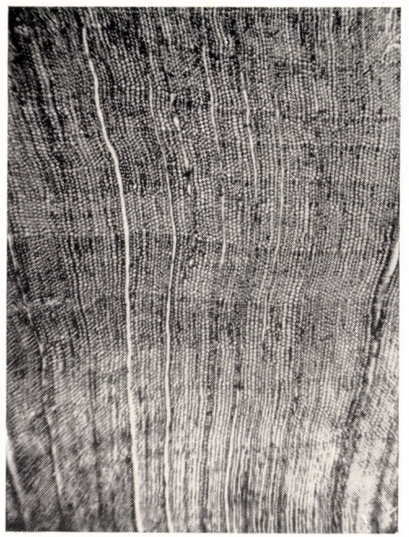


24. Araucaria excelsa R. Brown



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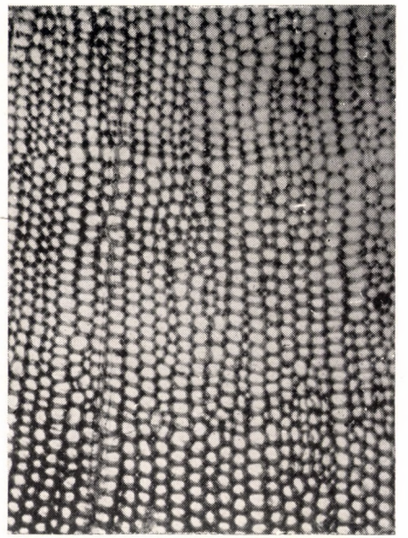
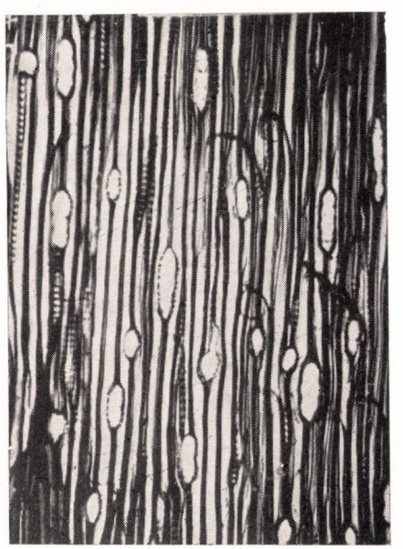


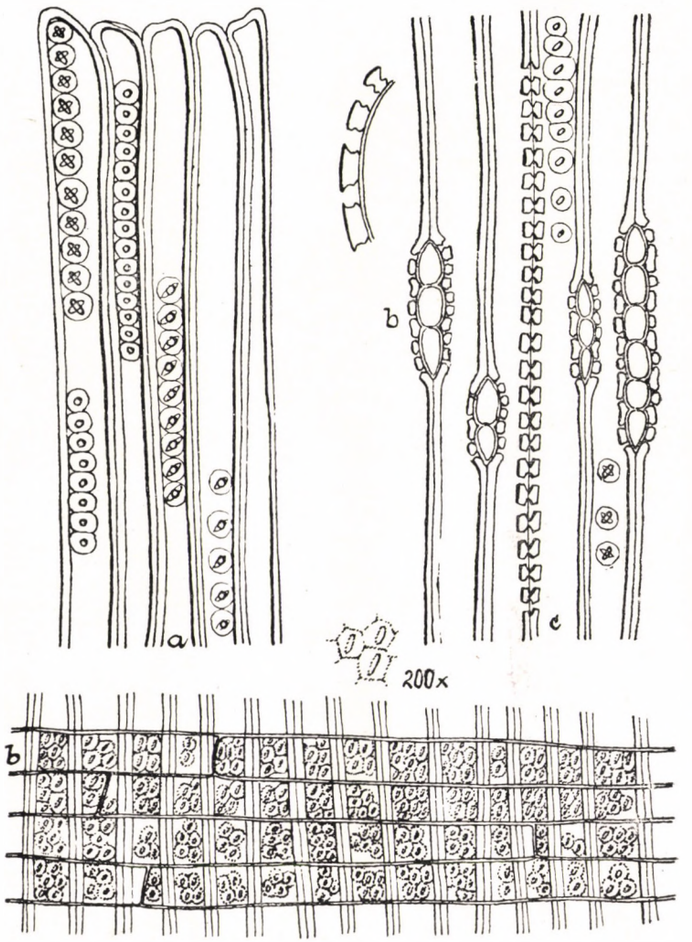
2. (100×)



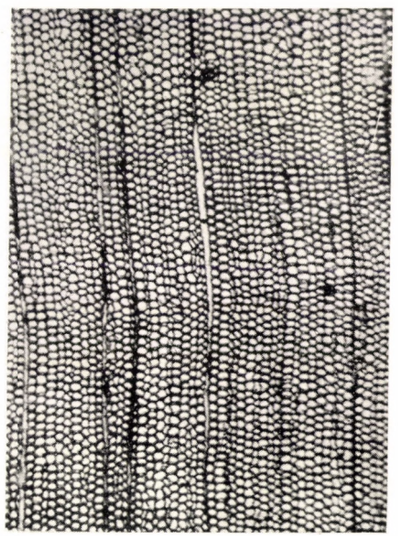
3. (300×)



4. (100×)



25. Araucaria Humboldtiensis Buch.



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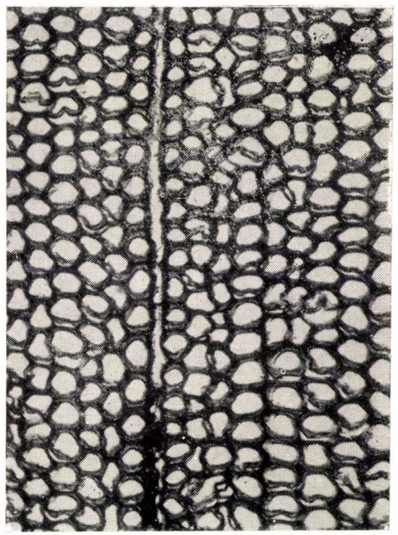

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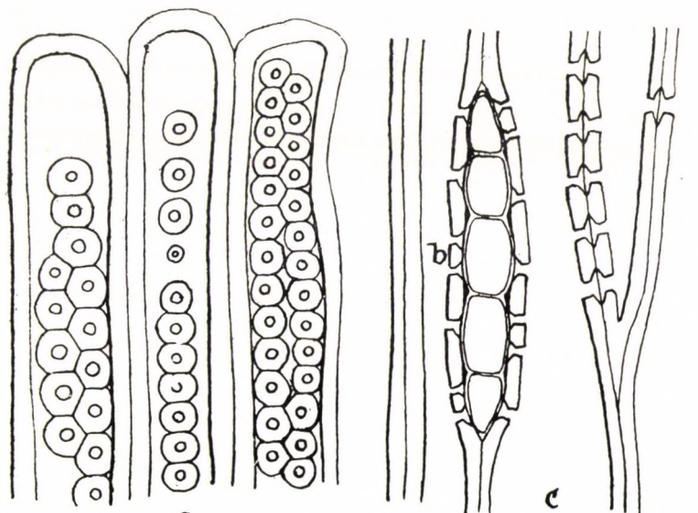
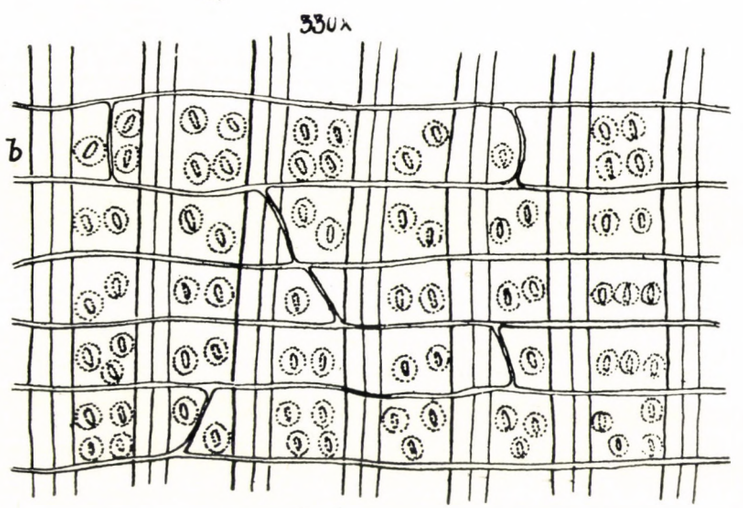




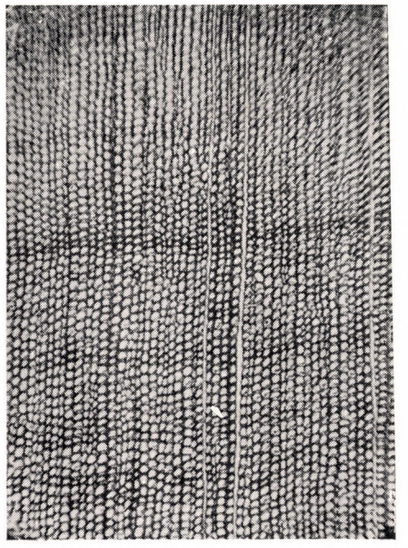
3. (300×)



4. (100×)



26. Araucaria Klinkii LAUT.



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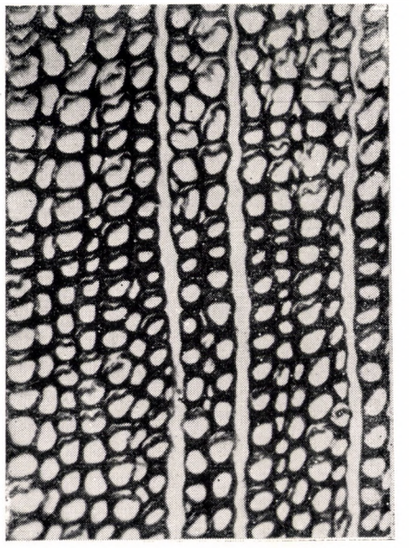

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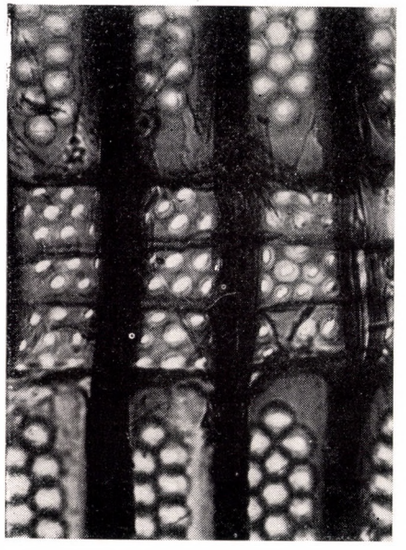
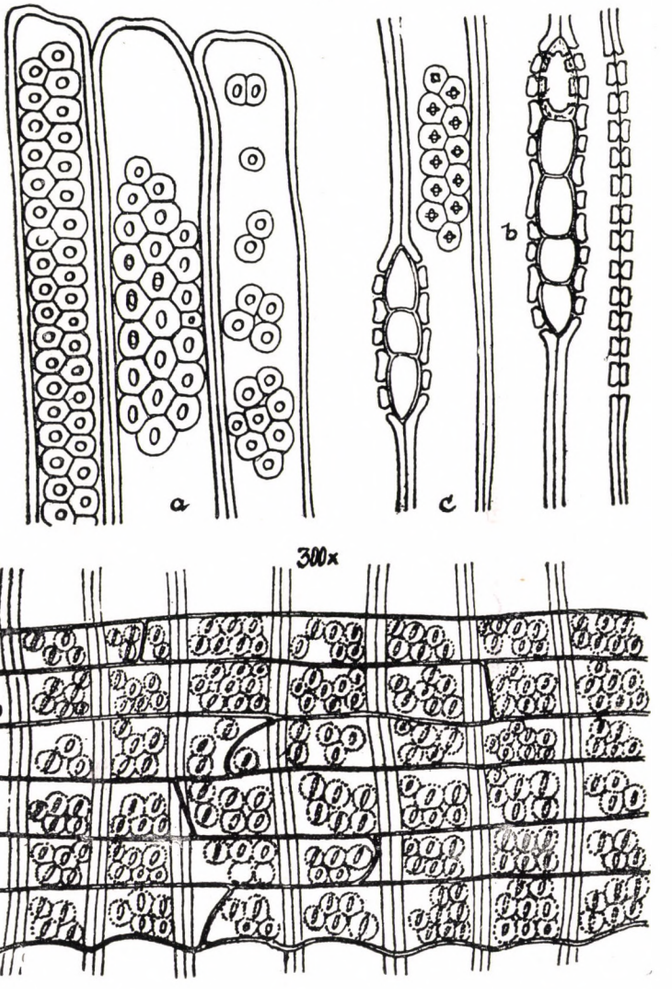


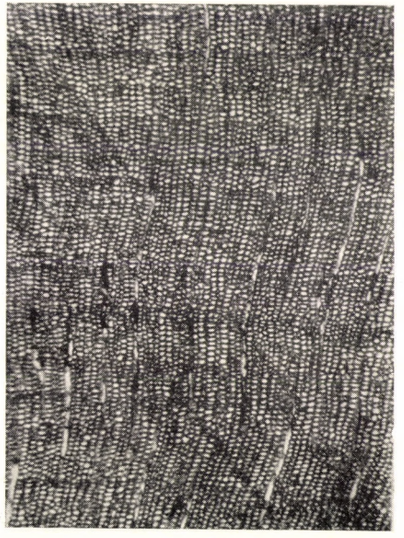
3. (300×)



4. (100×)



27. Araucaria montana Br. et Gr.



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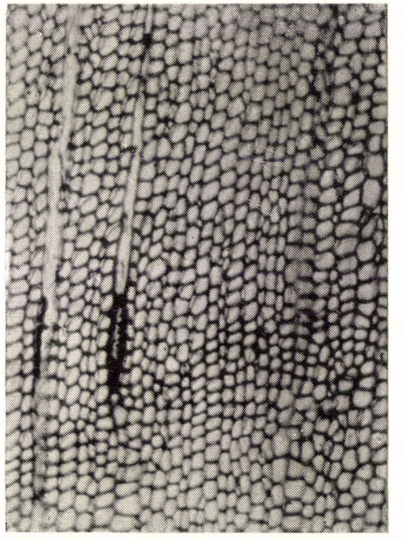

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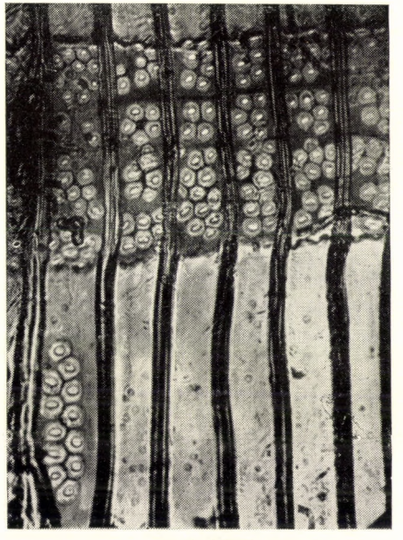

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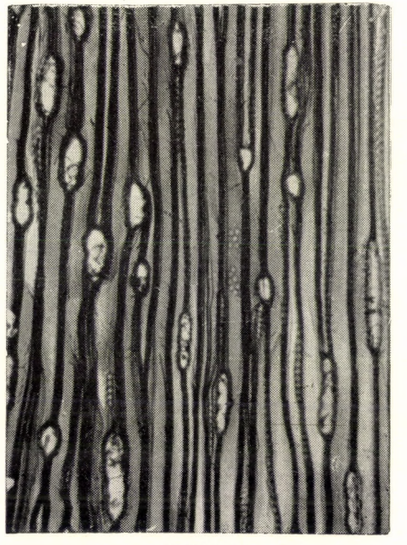

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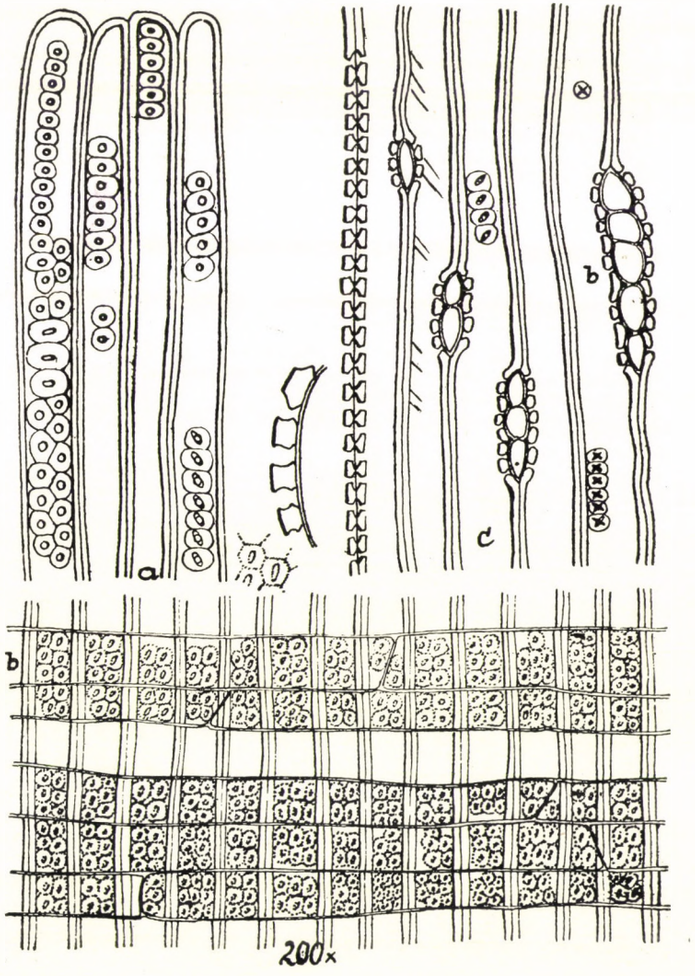
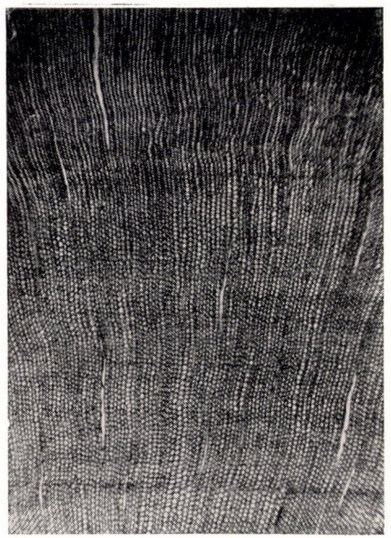
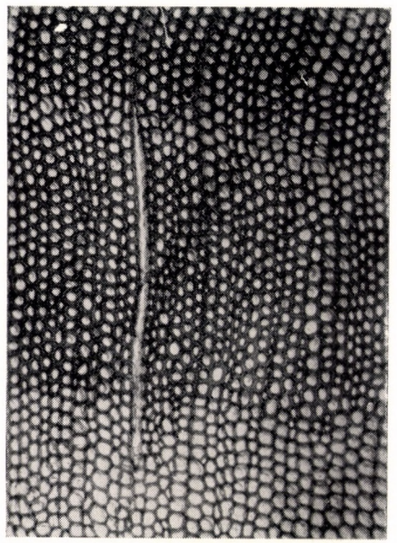


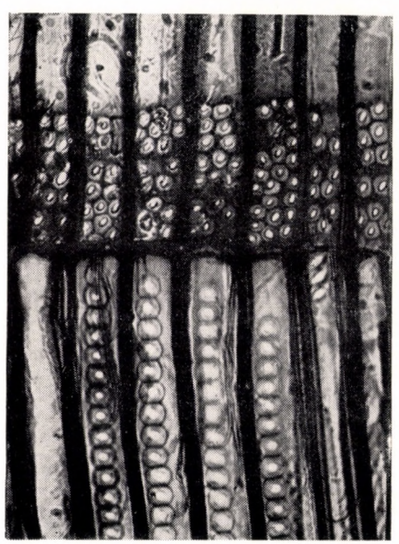
28. Araucaria Muelleri Br. et Gr.



1. (30×)



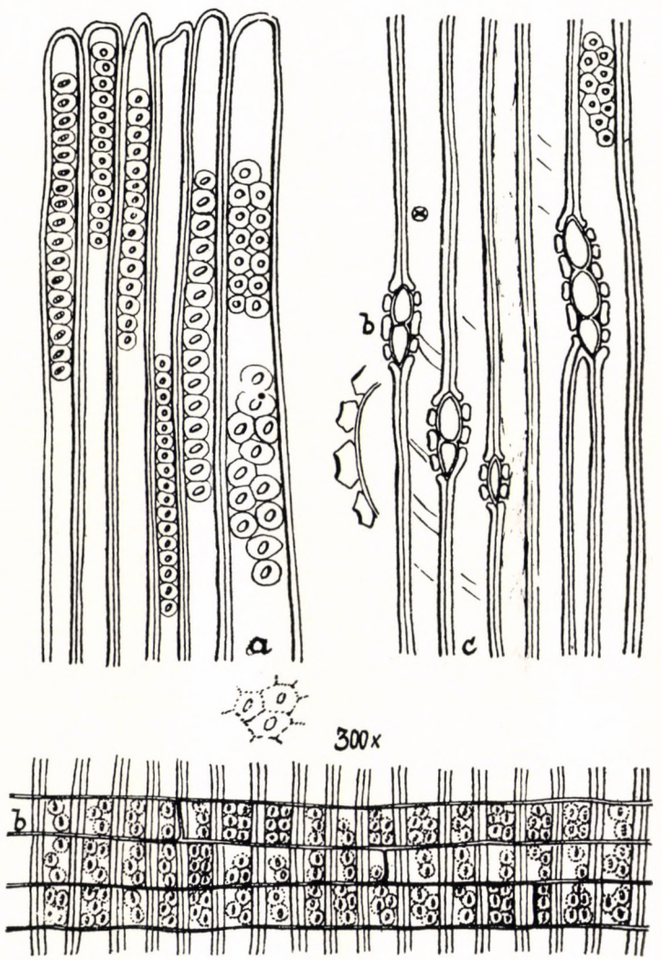
2. (100×)



3. (300×)*



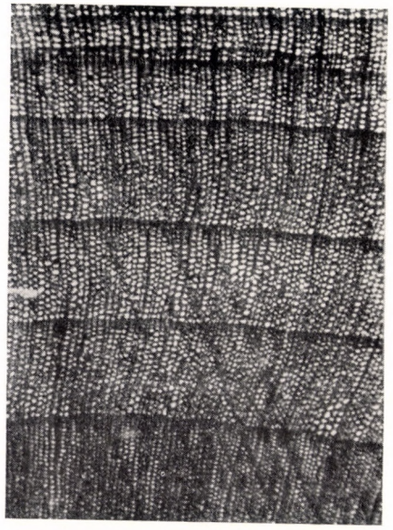
4. (100×)



29. Araucaria Rouley F. v. M.

IV.

PODOCARPACEAE



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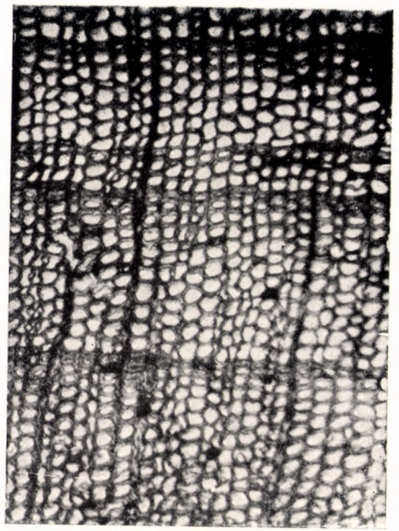

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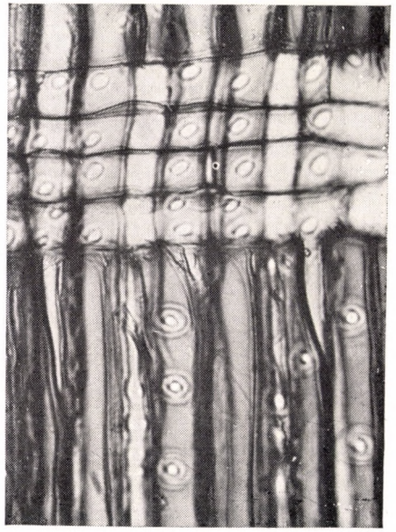
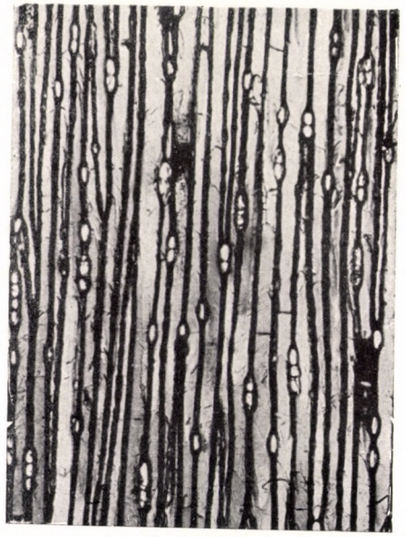
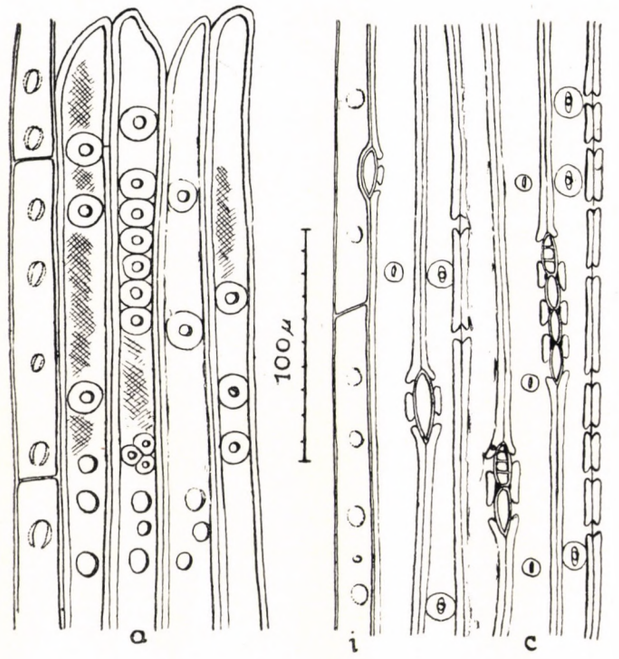
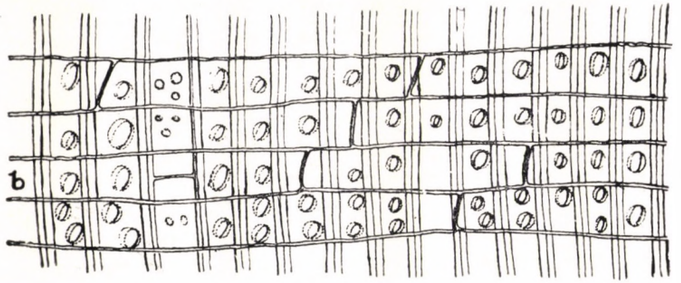


3. (300×)

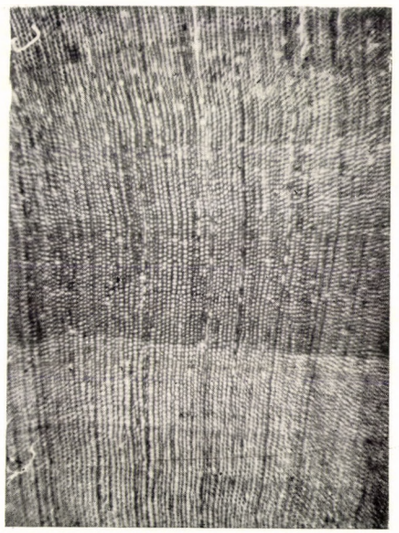


4. (100×)

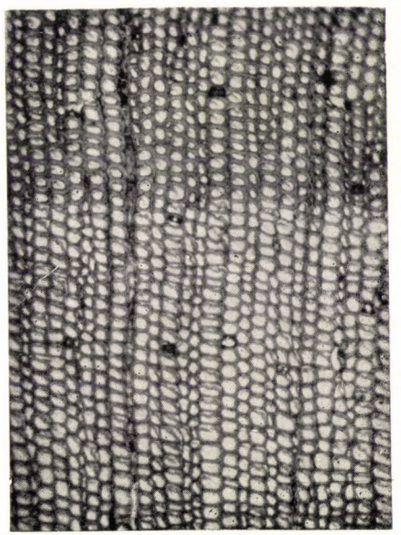




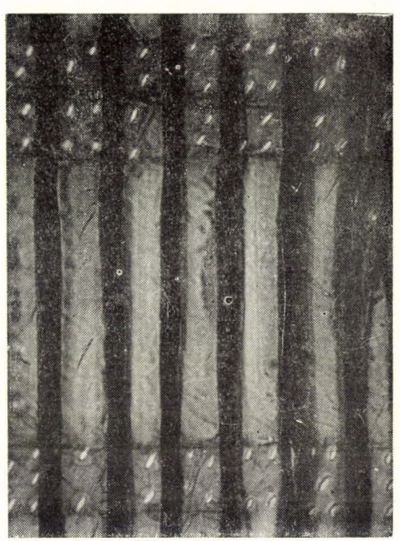
30. Acmopyle Pancheri PILGER



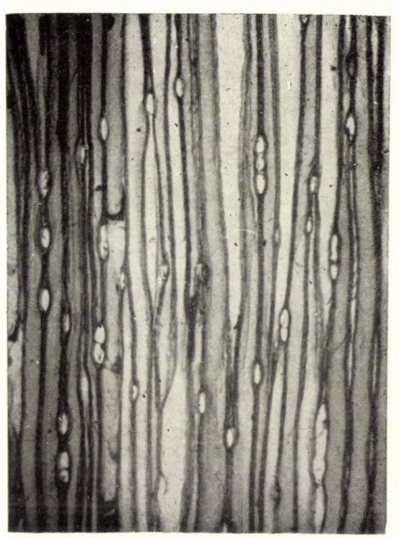
1. (30×)



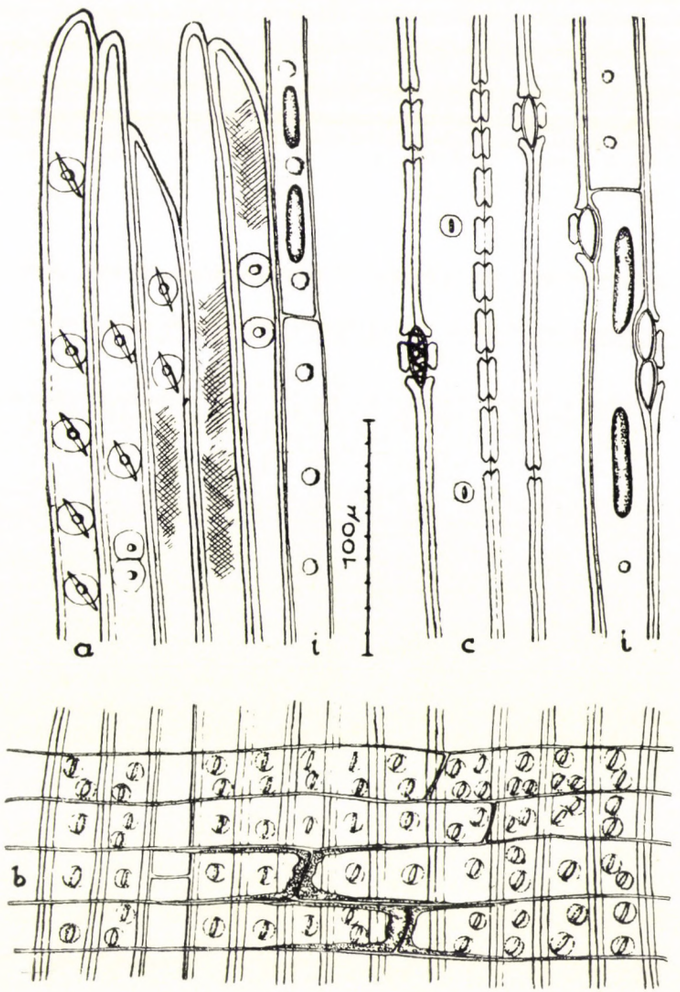
2. (100×)



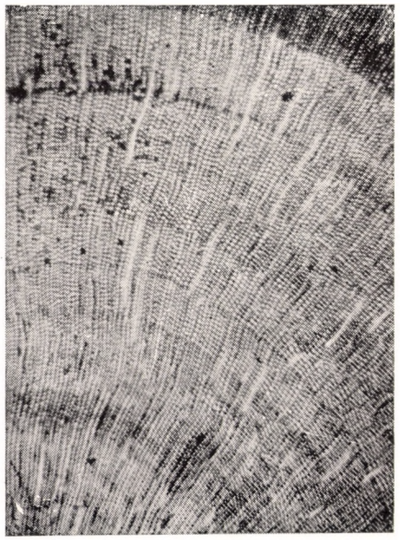
3. (300×)



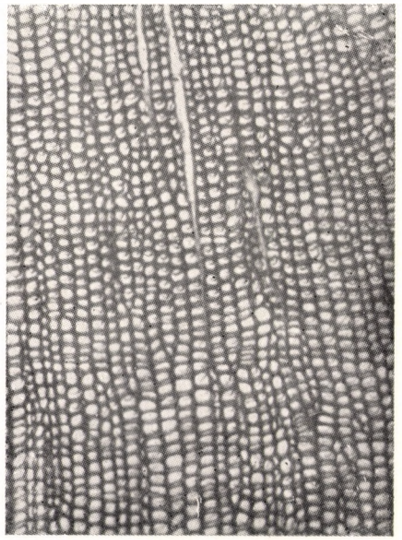
4. (100×)



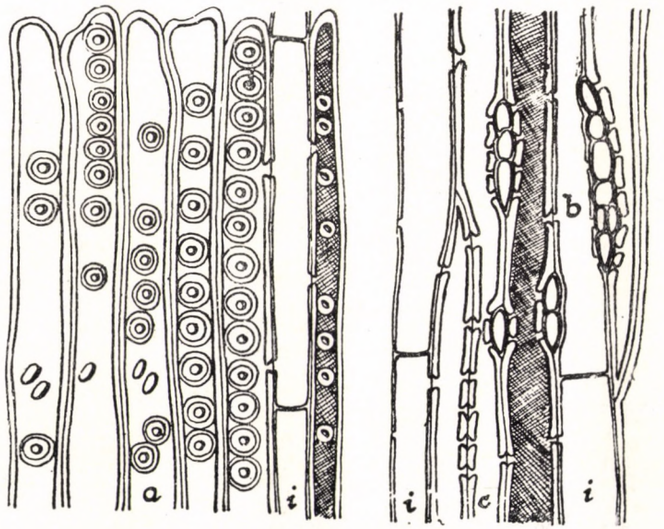
31. Austrotaxus spicatus COMPT.

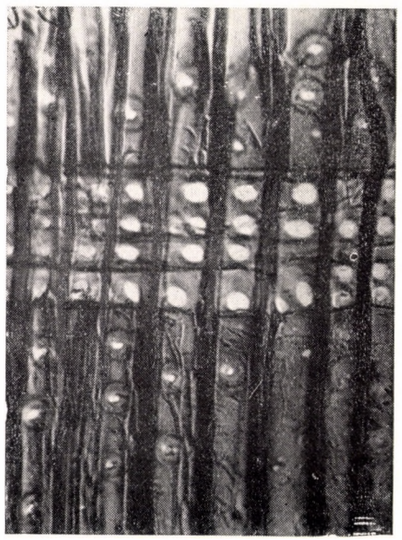


1. (30×)

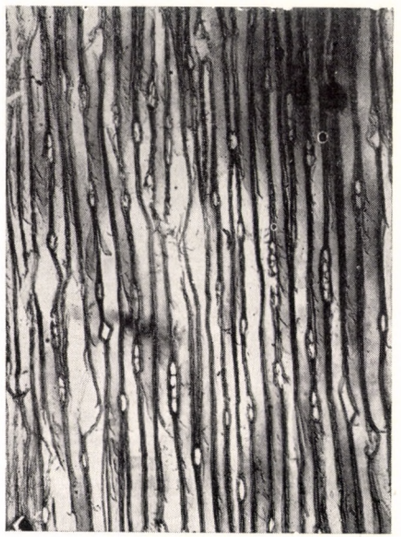


2. (100×)

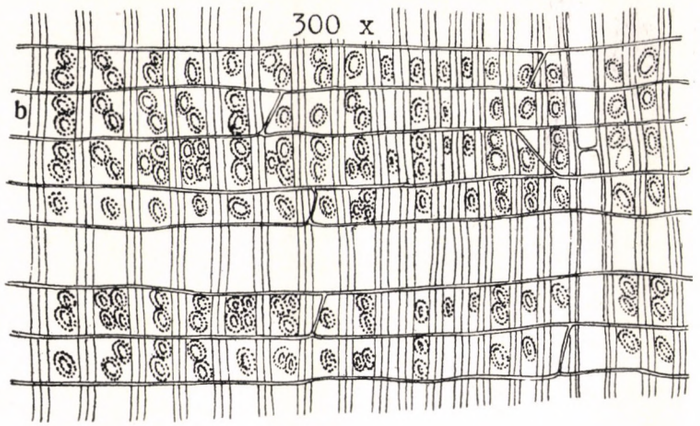




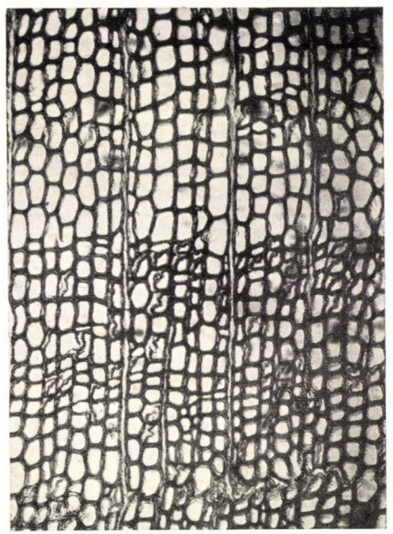
3. (300×)



4. (100×)



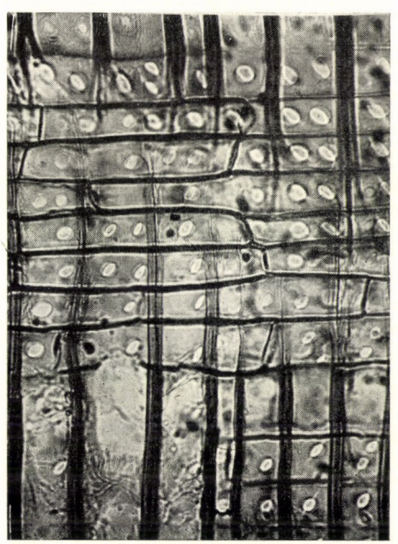
32. Dacrydium araucarioides Br. et Gr.



1. (100×)



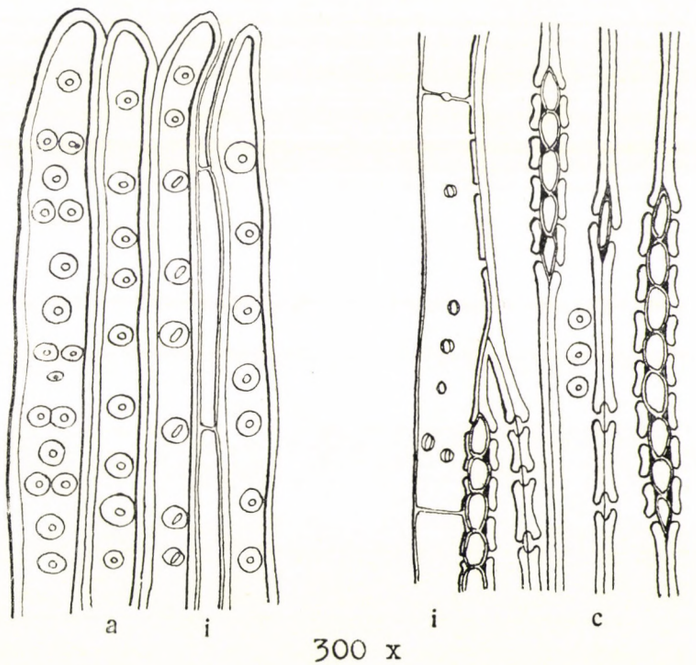
2. (100×)

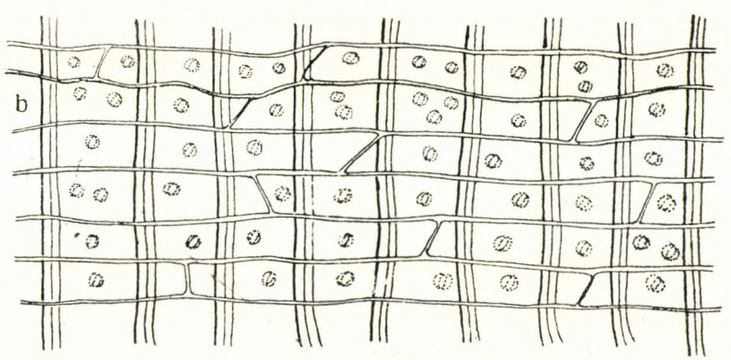


3. (300×)

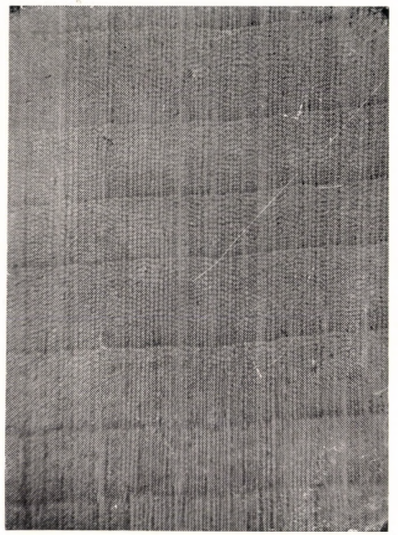


4. (300×)

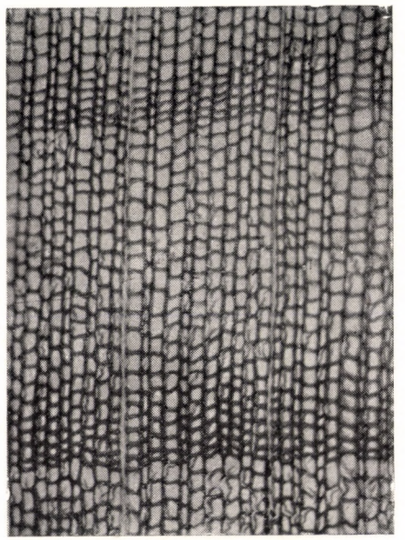




33. Dacrydium Balansae Br. et Gr.



1. (30×)



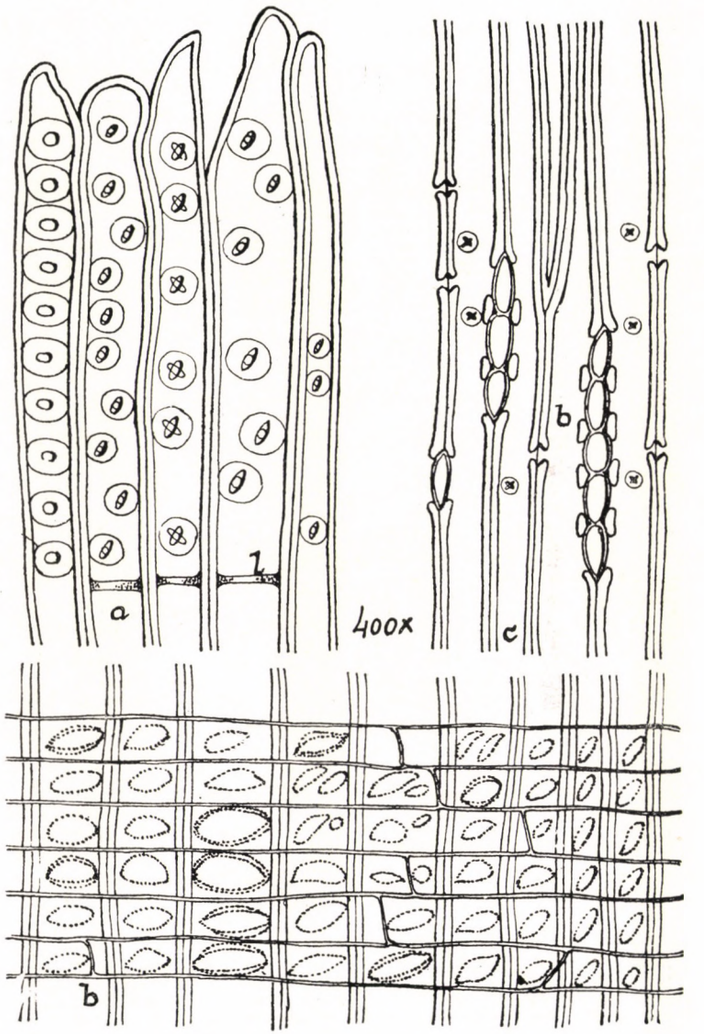
2. (100×)



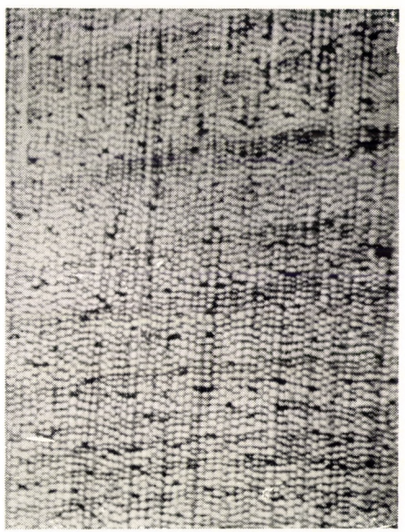
3. (300×)



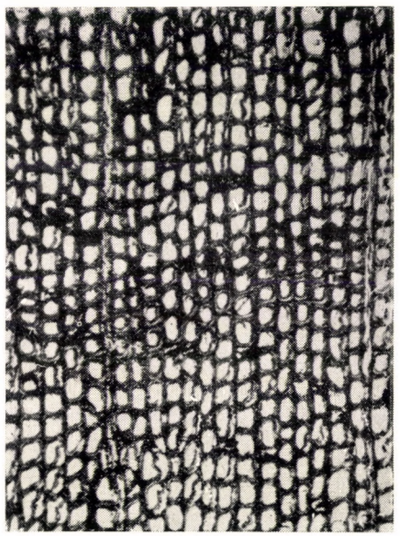
4. (100×)



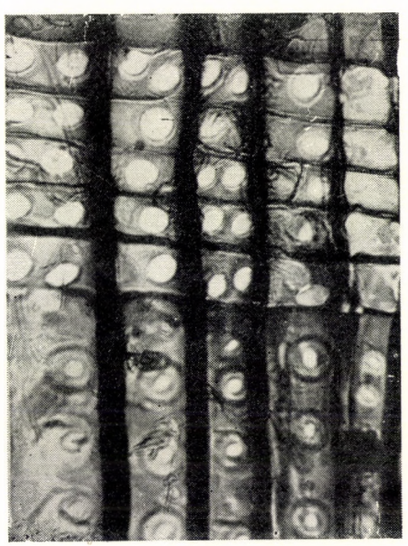
34. Dacrydium Colensoi Hook.



1. (30×)



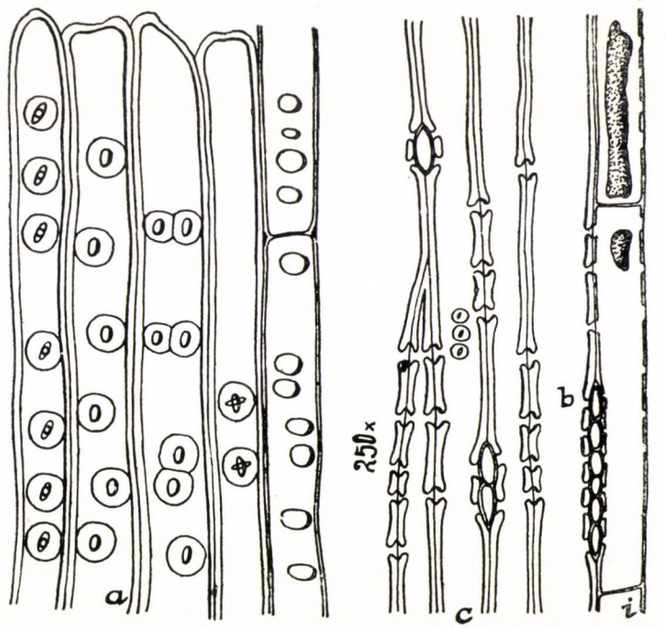
2. (100×)

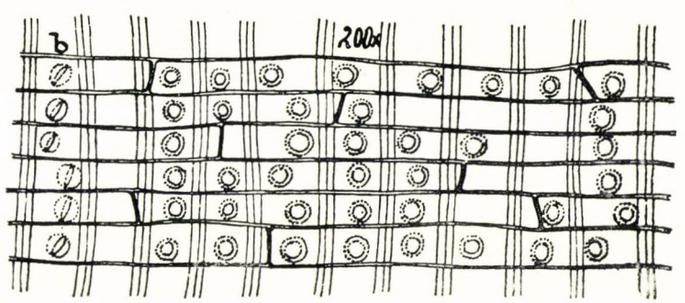


3. (300×)

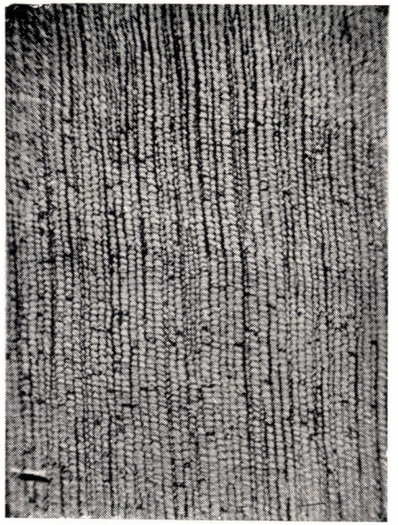


4. (100×)

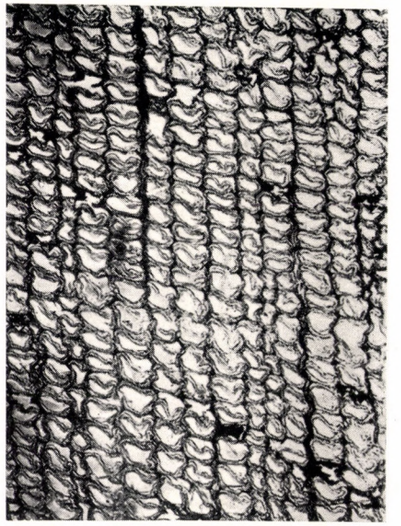




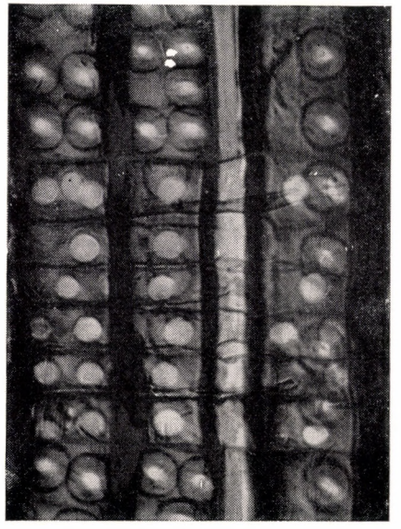
35. Dacrydium cupressinum SOLAND



1. (30×)



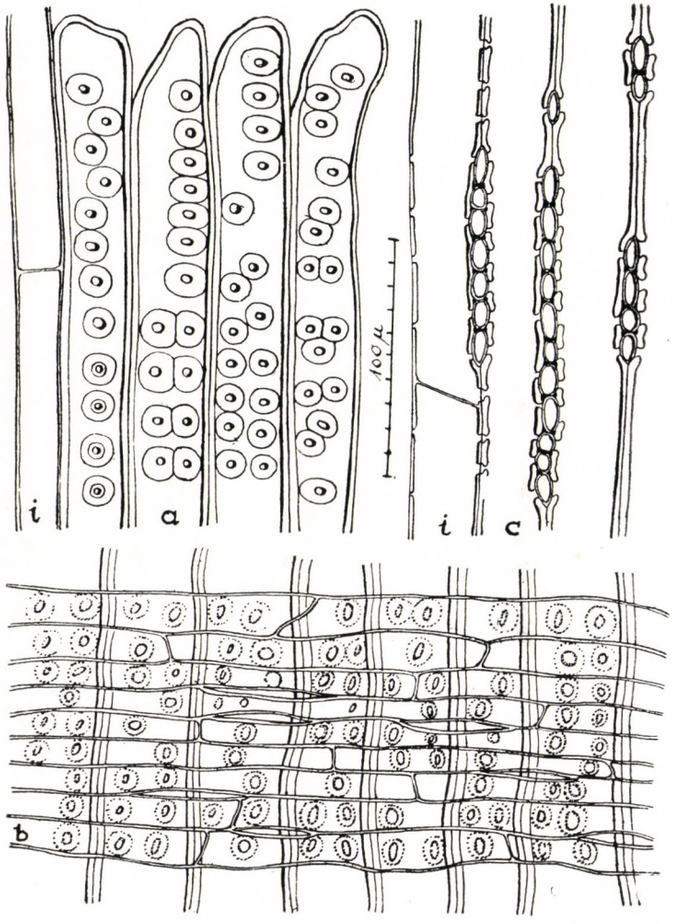
2. (100×)



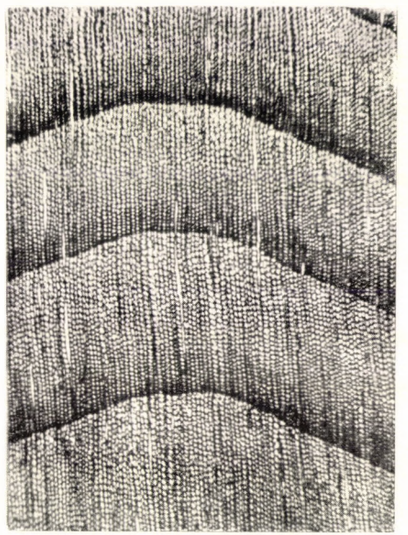
3. (300×)



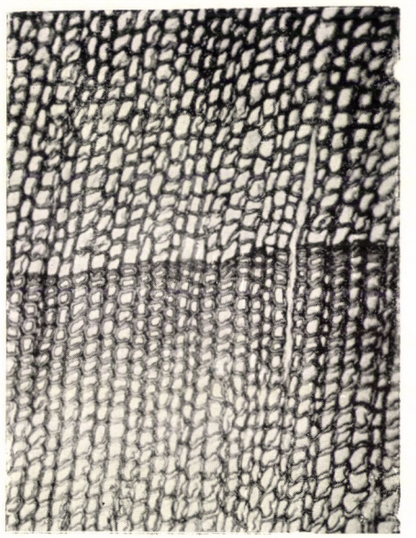
4. (100×)



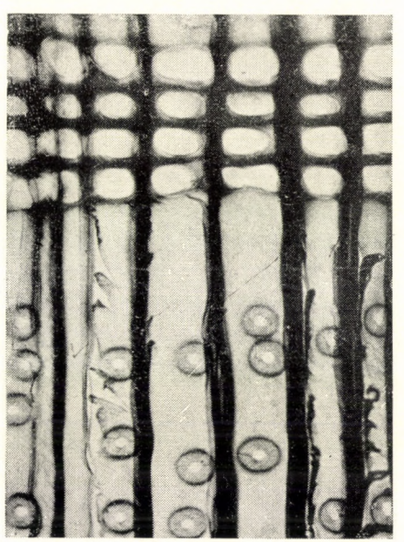
36. Dacrydium elatum WALL.



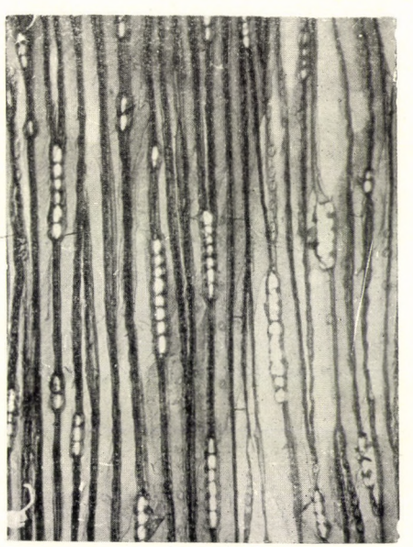
1. (30×)



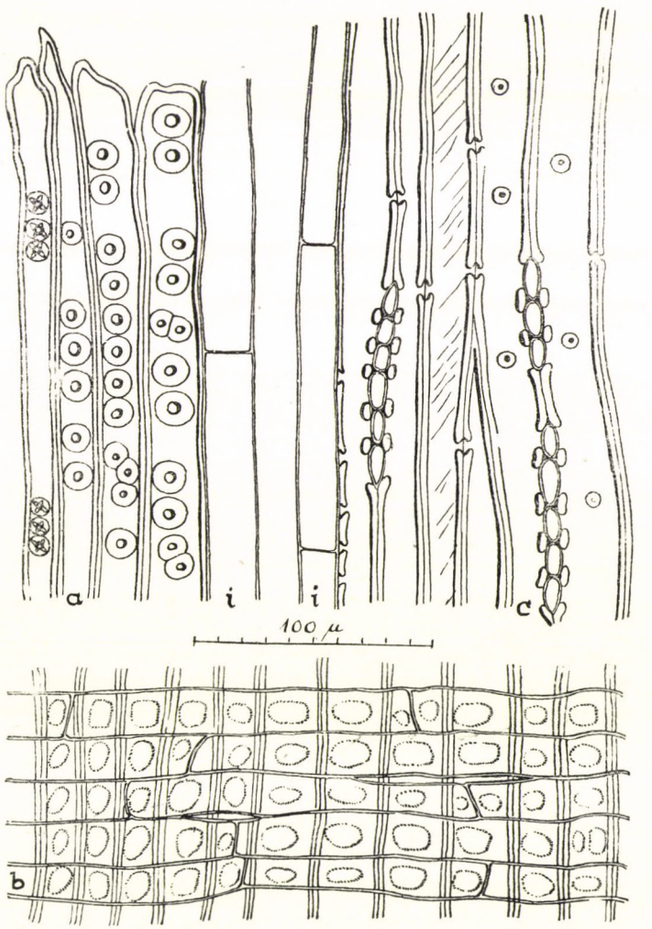
2. (100×)



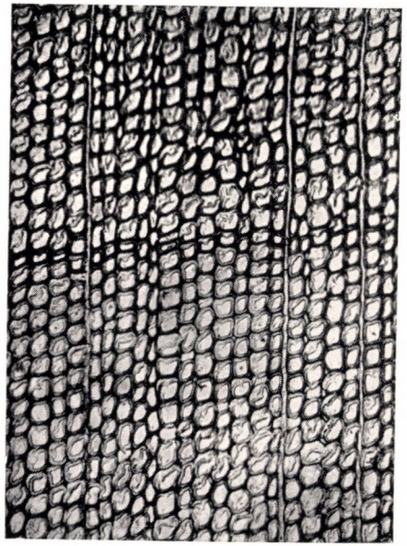
3. (300×)



4. (100×)



37. Dacrydium Franklinii Hook. f.



1. (100×)



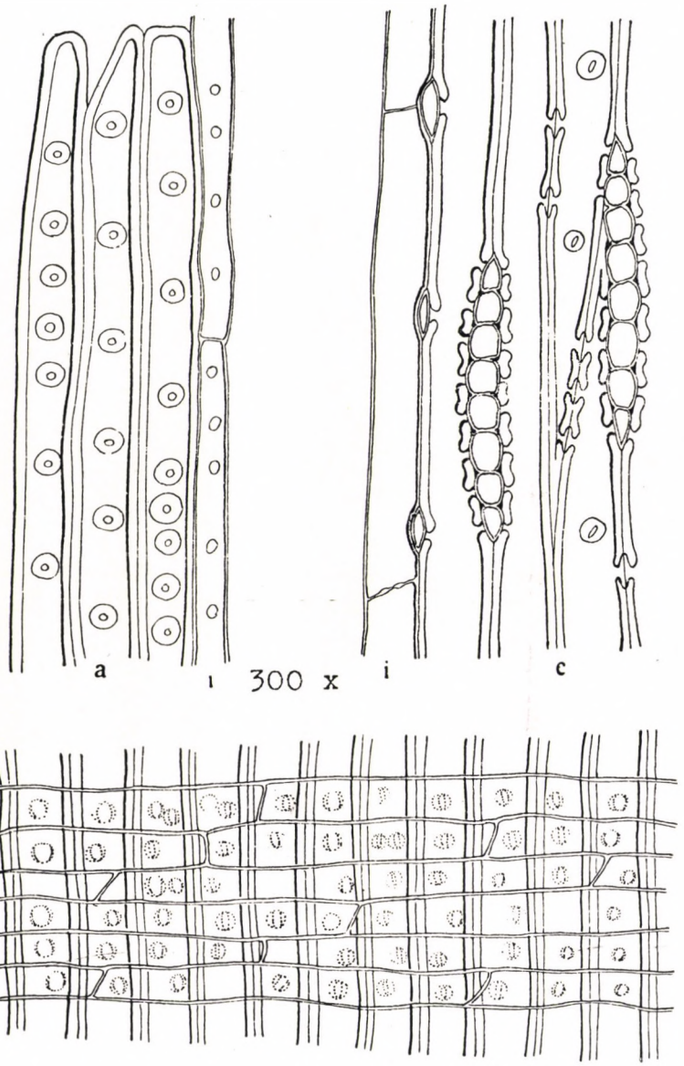
2. (100×)



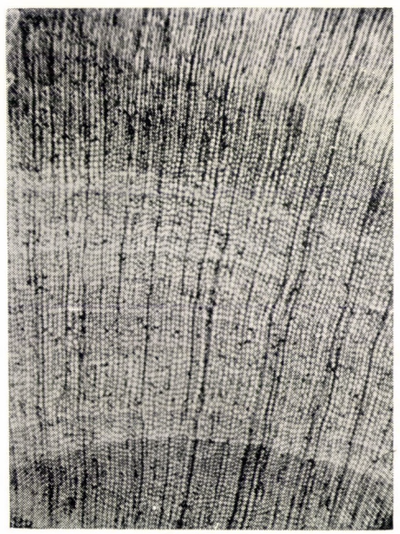
3. (300×)



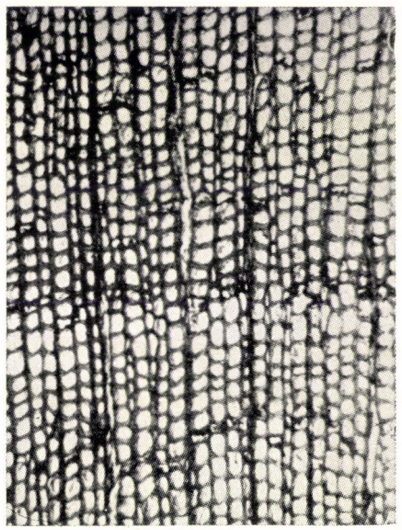
4. (300×)



37/a Dacrydium pierrei HICKEL



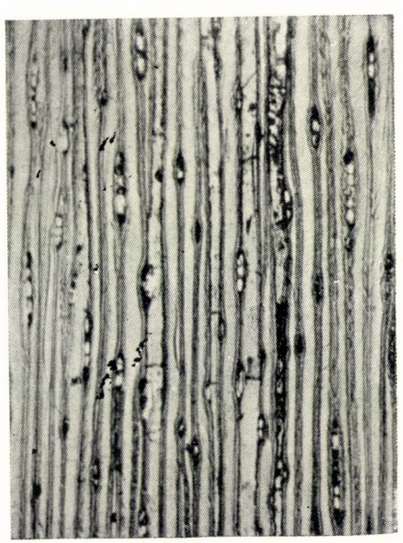
1. (30×)



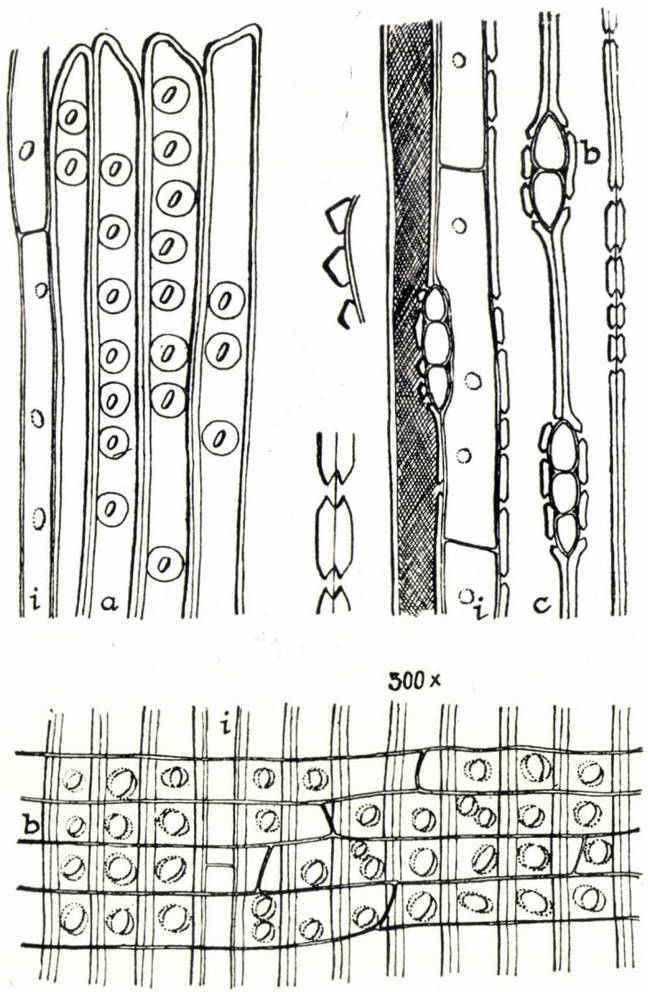
2. (100×)



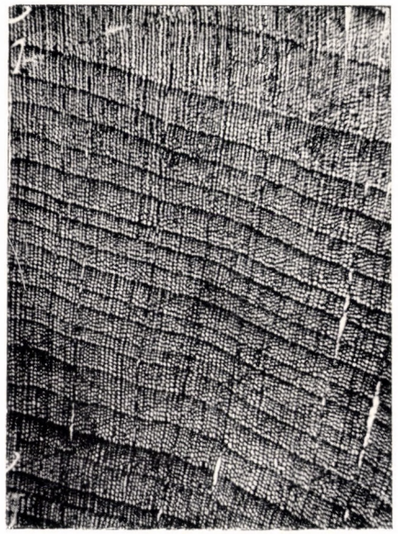
3. (300×)



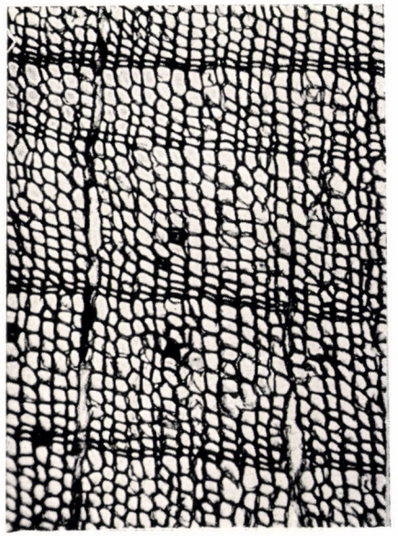
4. (100×)



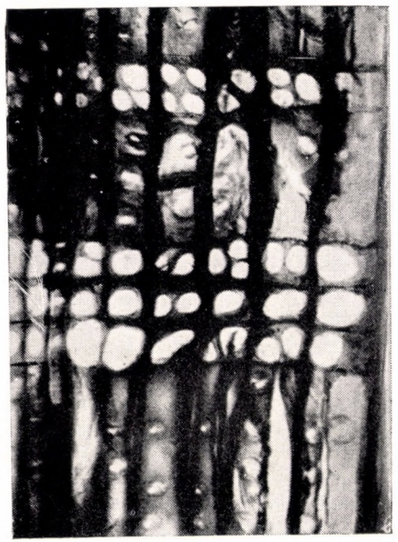
38. Dacrydium taxoides Br. et Gr.



1. (30×)



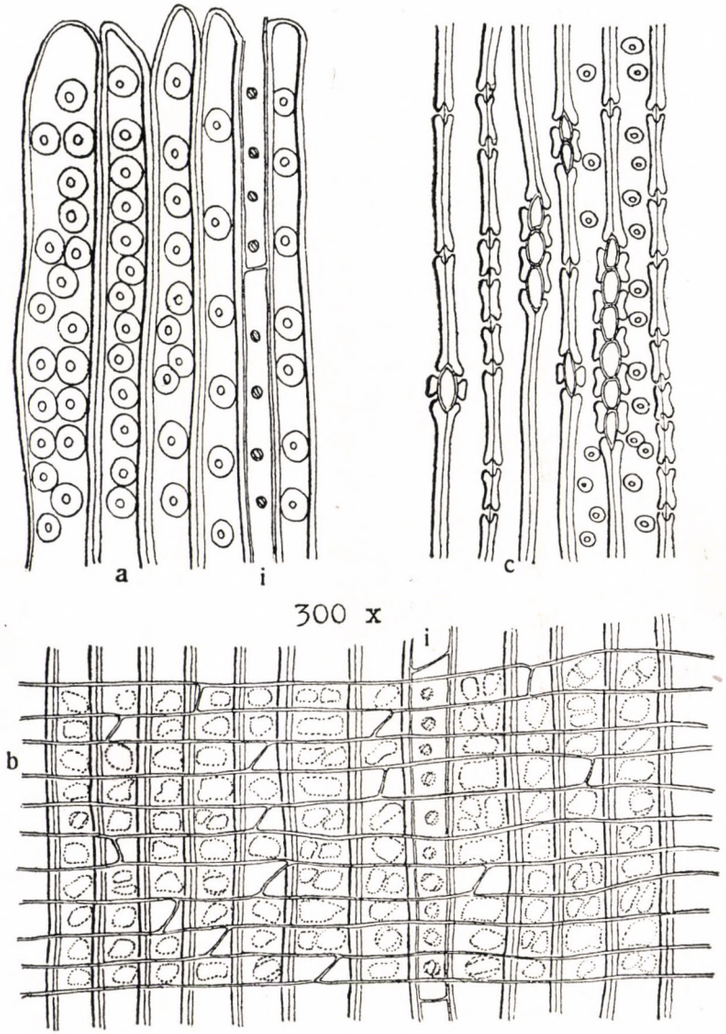
2. (100×)



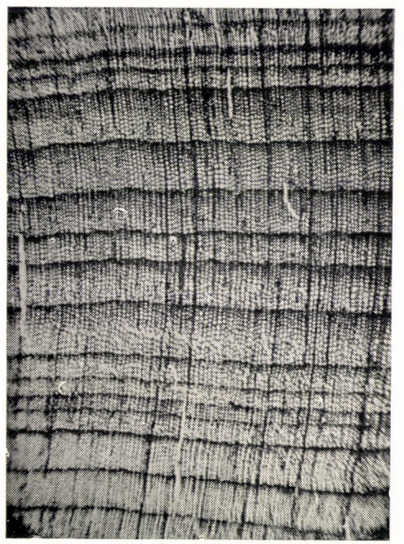
3. (300×)



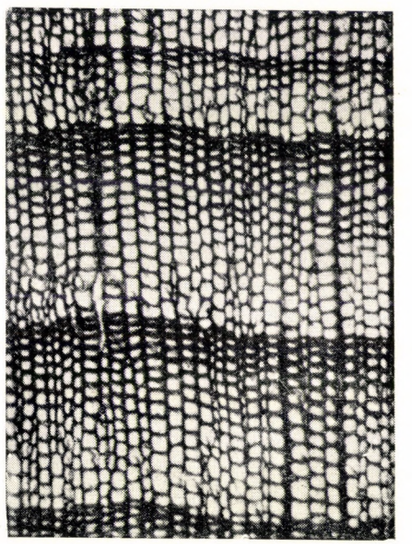
4. (100×)



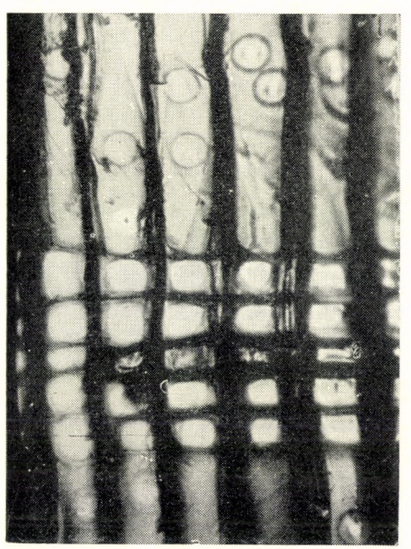
39. Microcachrys tetragona Hook. f.



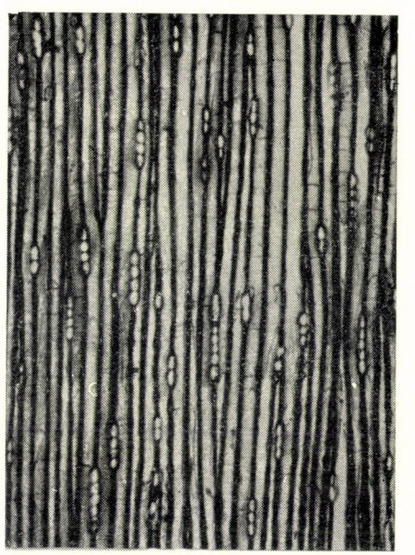
1. (30×)



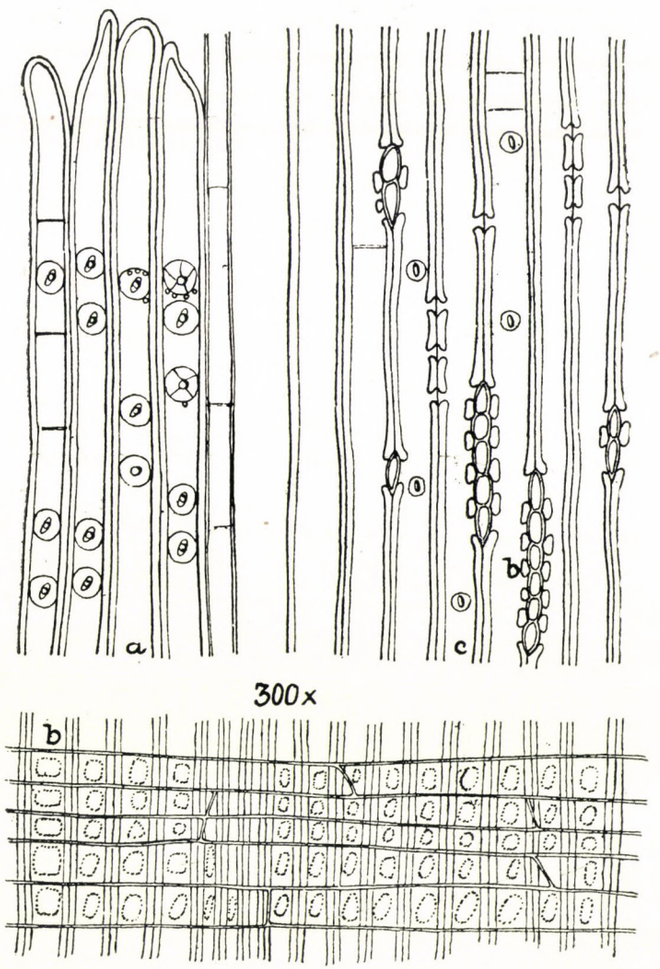
2. (100×)



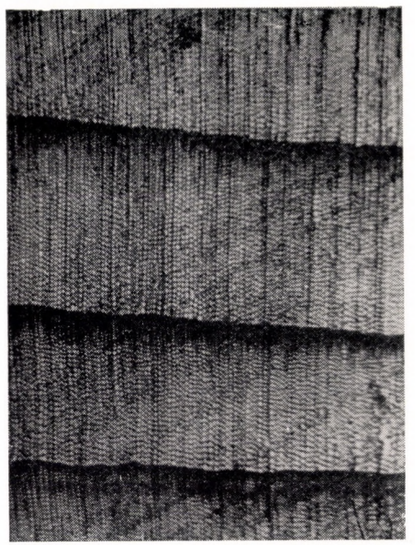
3. (300×)



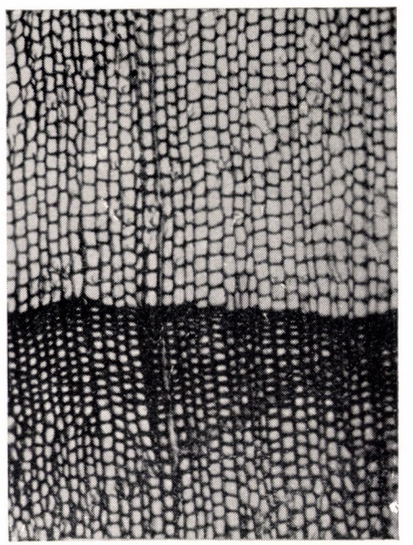
4. (100×)



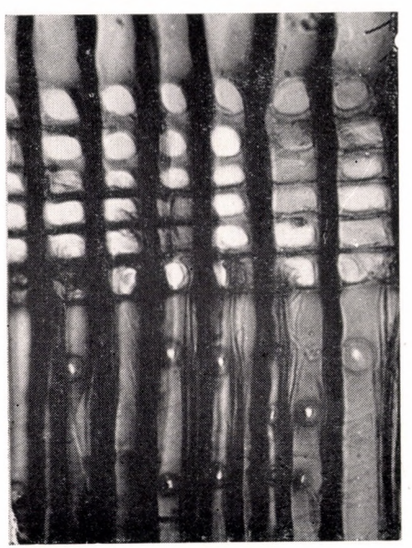
40. Phyllocladus alpinus HOOK. f.



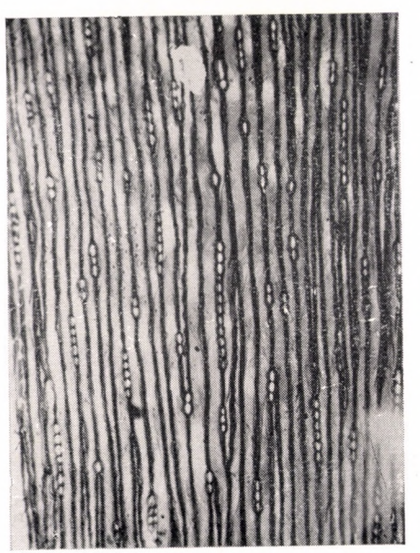
1. (30×)



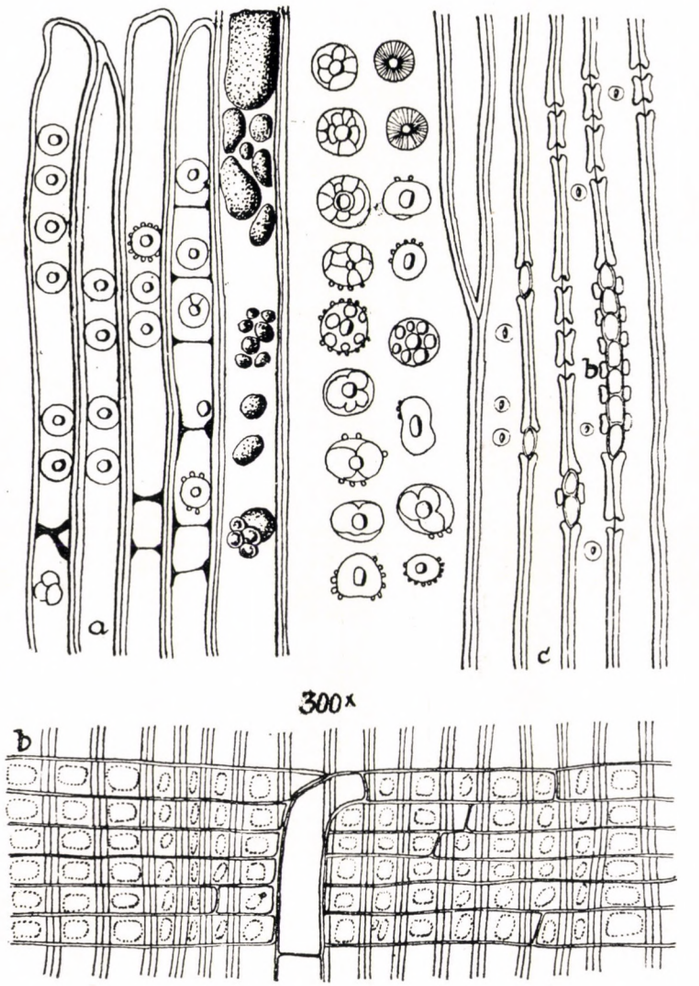
2. (100×)



3. (300×)



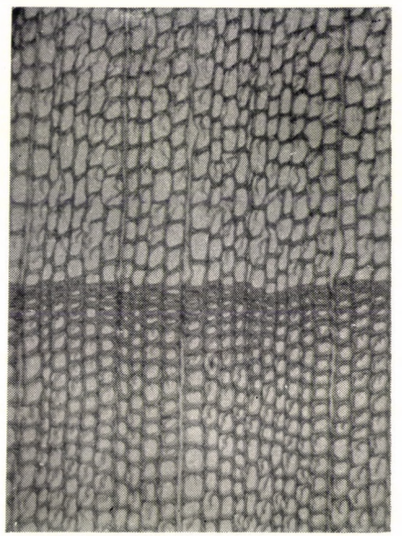
4. (100×)



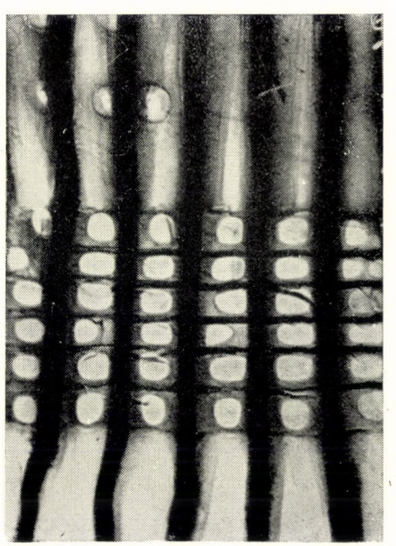
41. Phyllocladus glaucus CARR.



1. (30×)



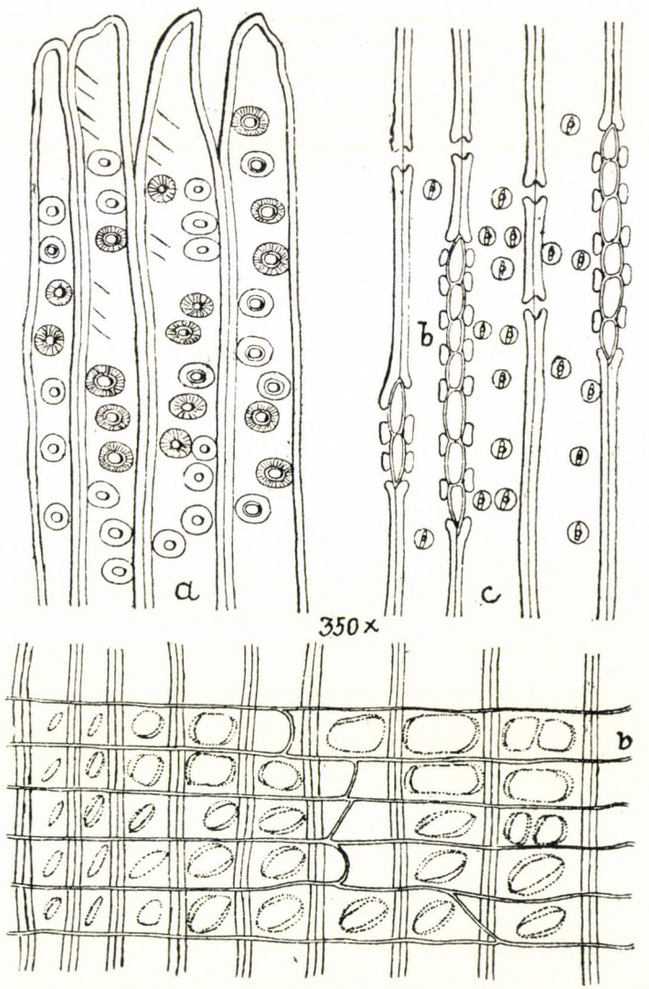
2. (100×)



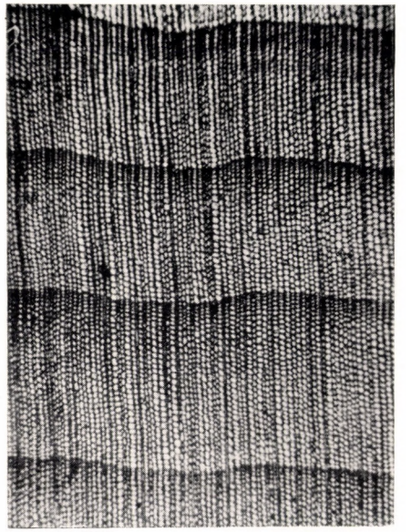
3. (300×)



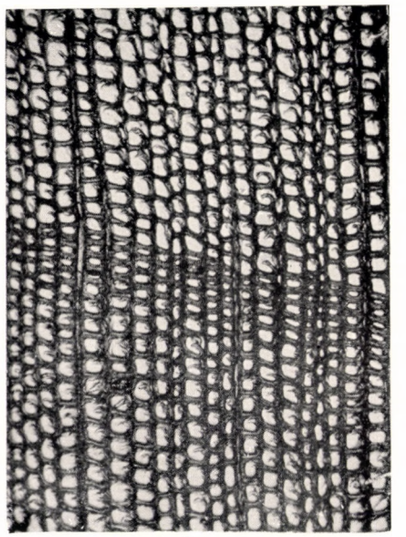
4. (100×)



42. Phyllocladus rhomboidalis Rich.



1. (30×)



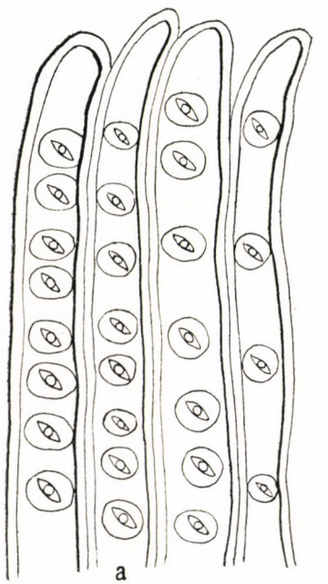
2. (100×)

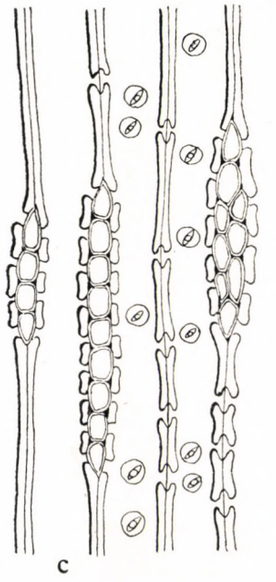


3. (300×)

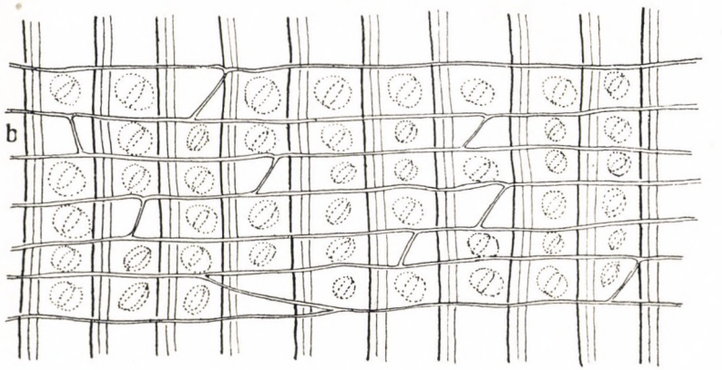


4. (100×)

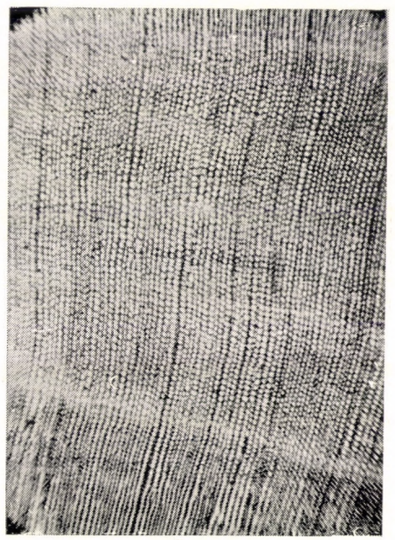




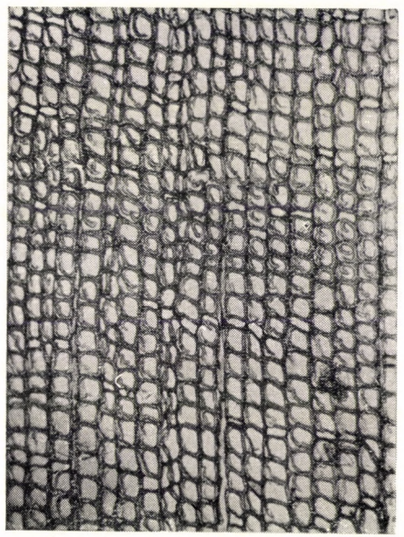
300 x



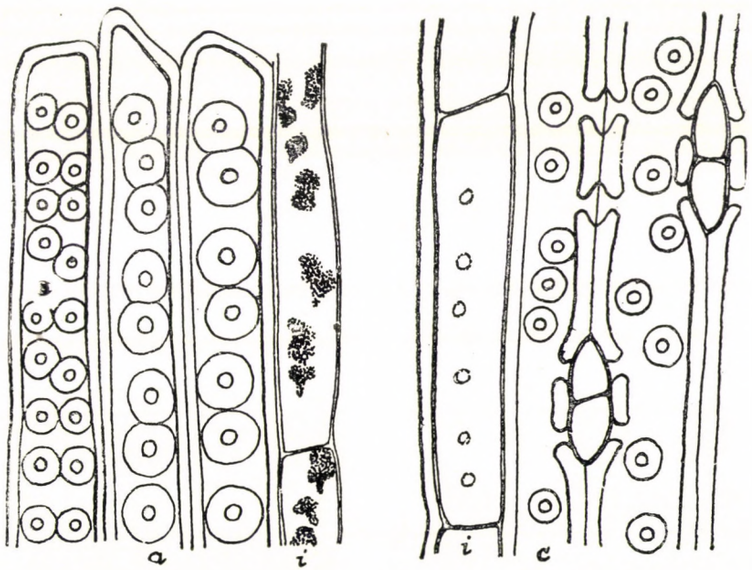
43. Phyllocladus trichomanoides D. Don

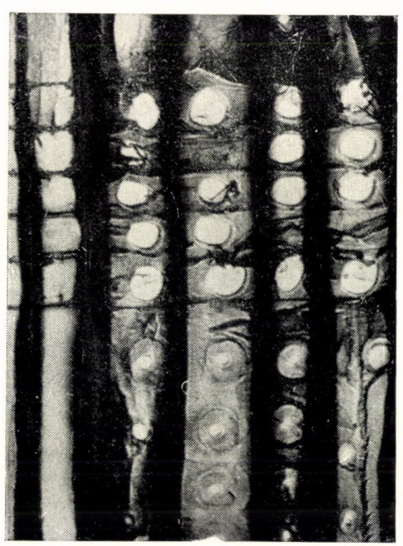


1. (100×)

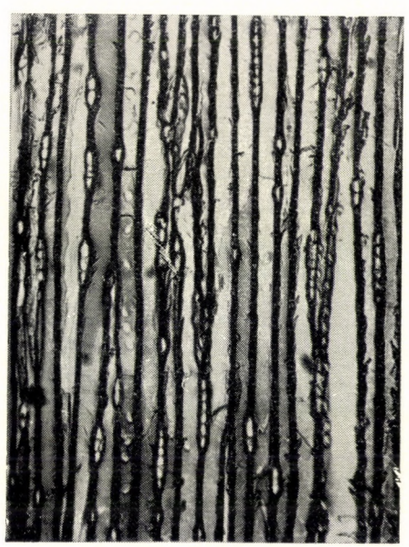


2. (100×)

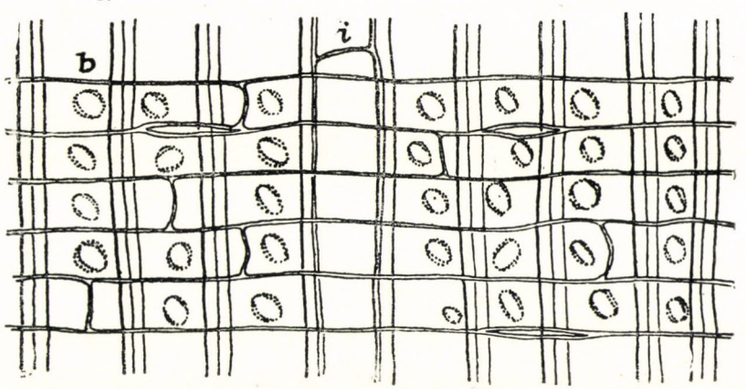




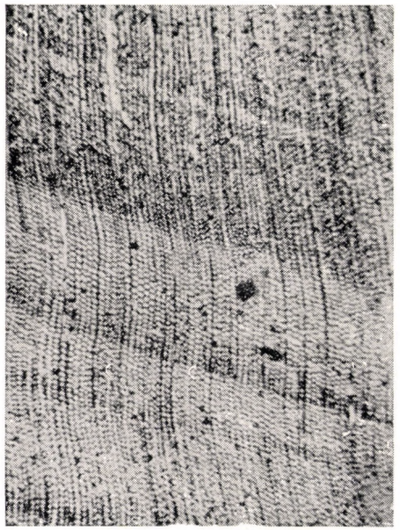
3. (300×)



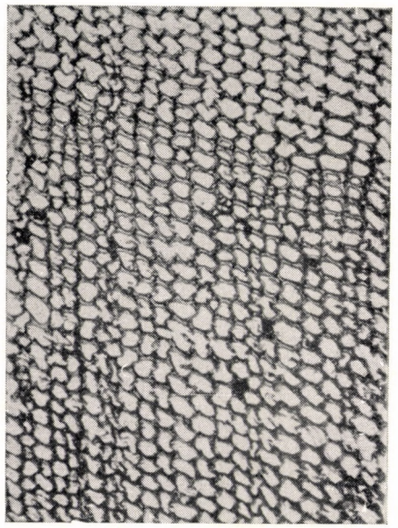
4. (100×)



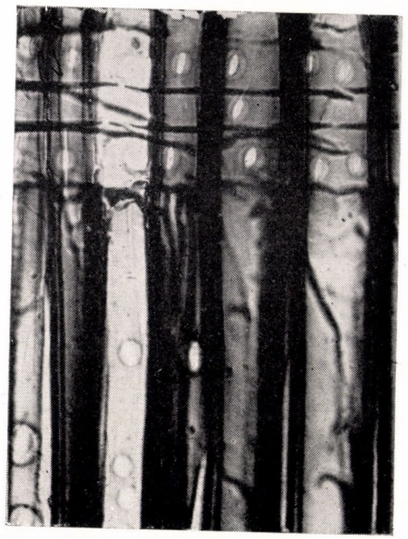
44. Podocarpus Blumei ENDL.



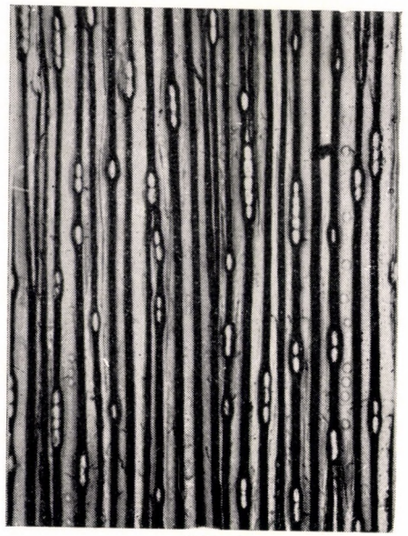
1. (30×)



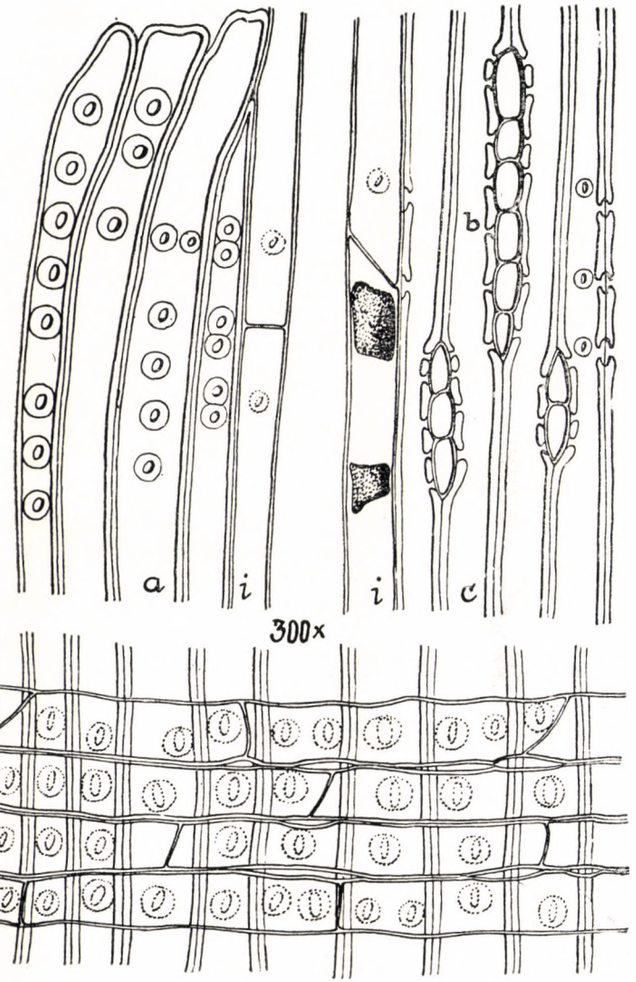
2. (100×)



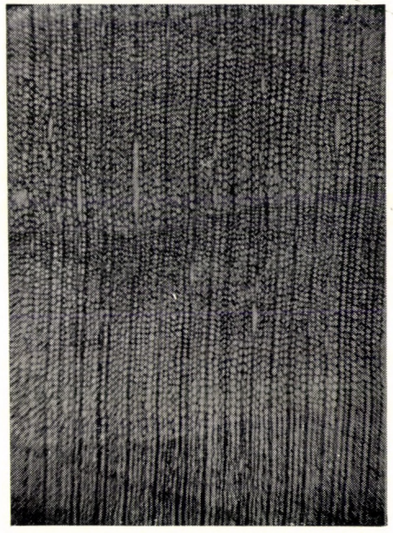
3. (300×)



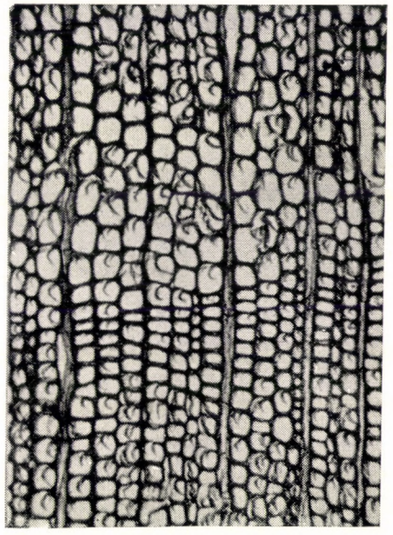
4. (100×)



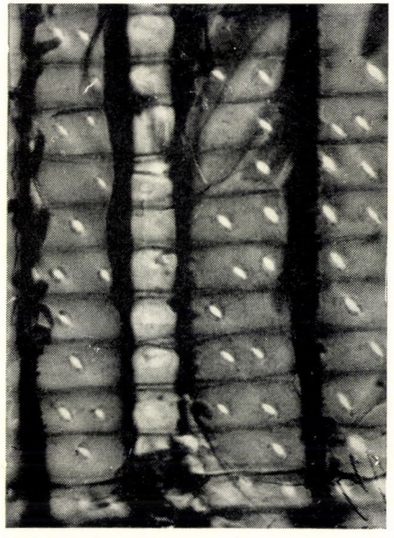
45. Podocarpus coriaceus A. Rich.



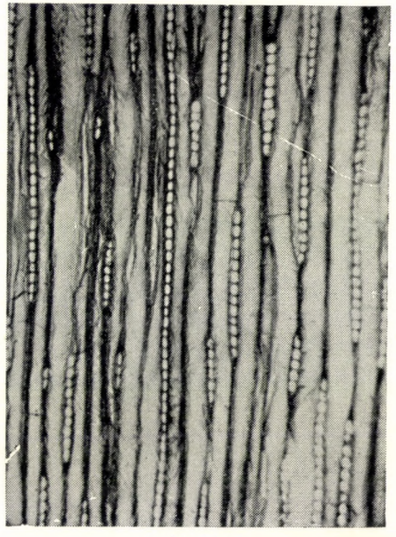
1. (30×)



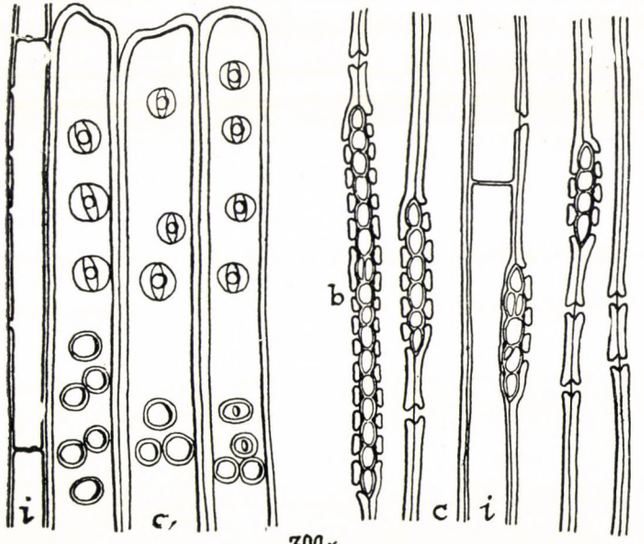
2. (100×)

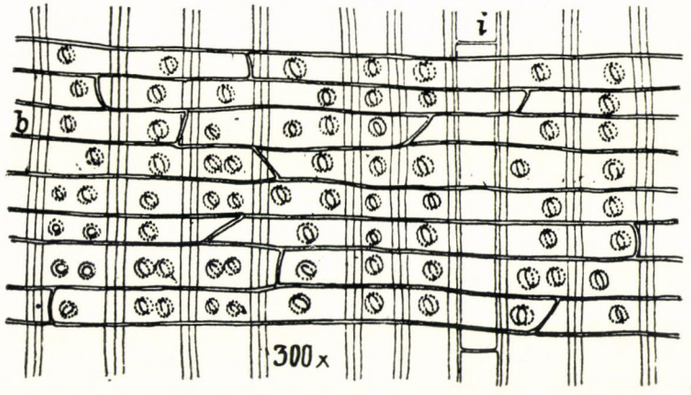


3. (300×)

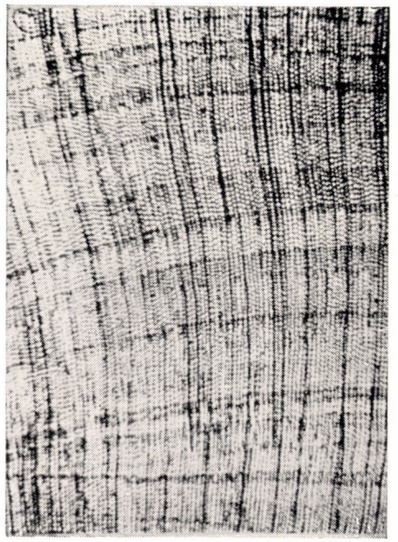


4. (100×)

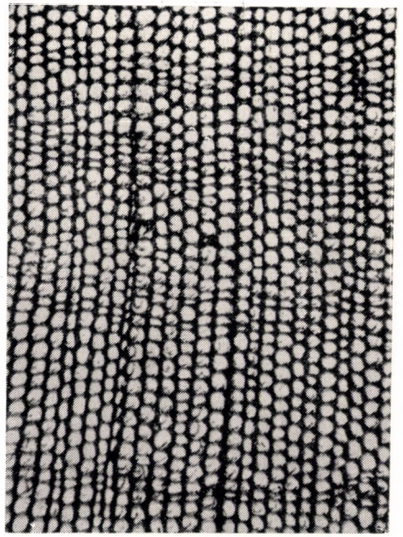




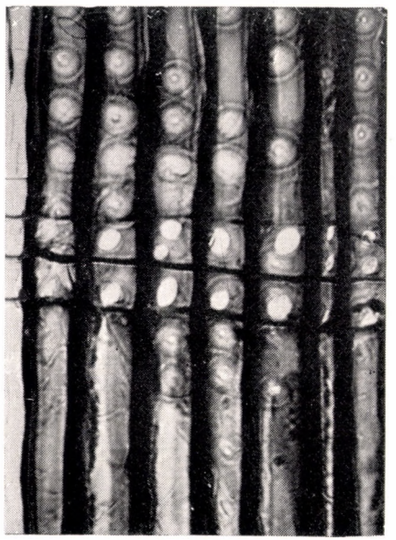
46. Podocarpus dacrydioides A. Rich.



1. (30×)



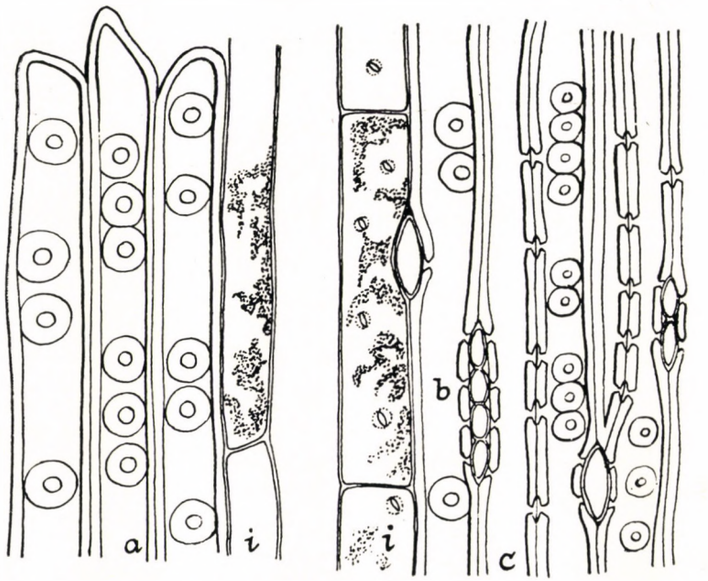
2. (100×)



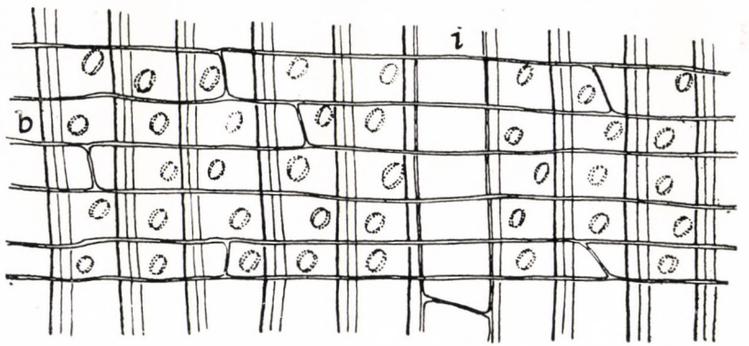
3. (300×)



4. (100×)



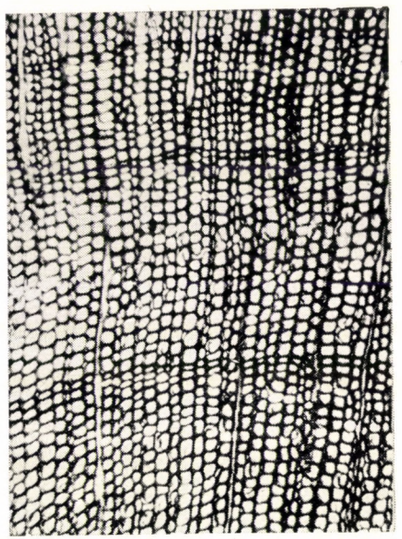
500×



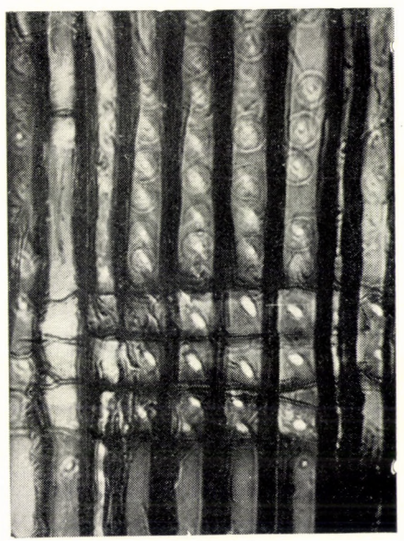
47. Podocarpus elatus R. Br.



1. (30×)



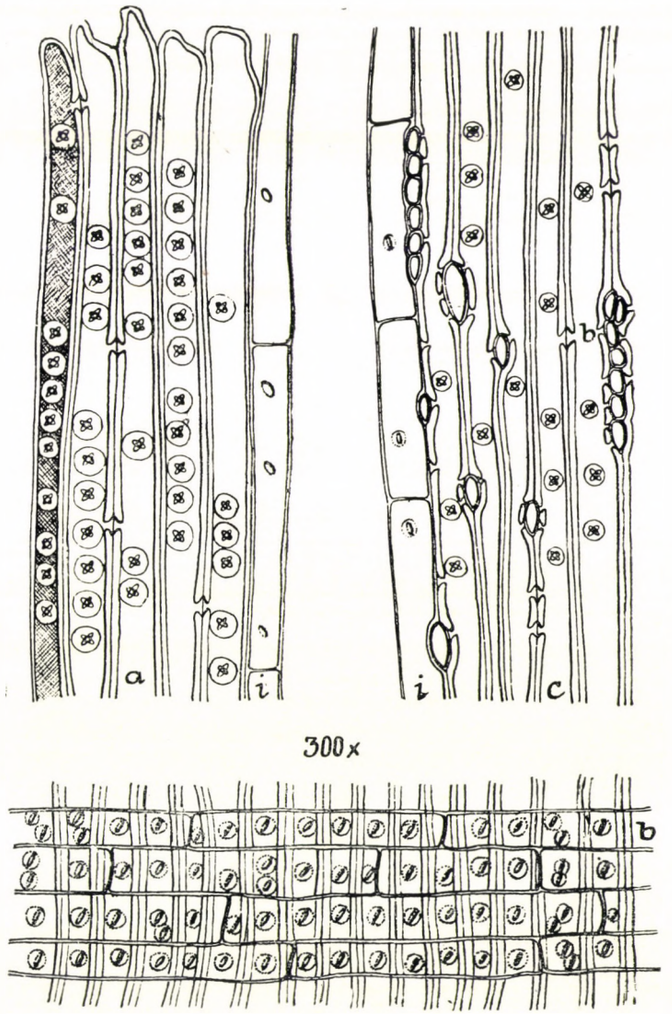
2. (100×)



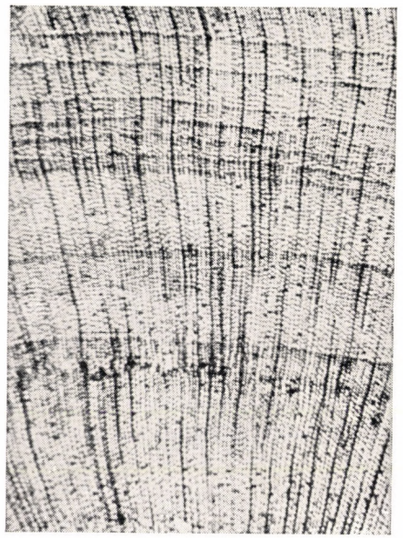
3. (300×)



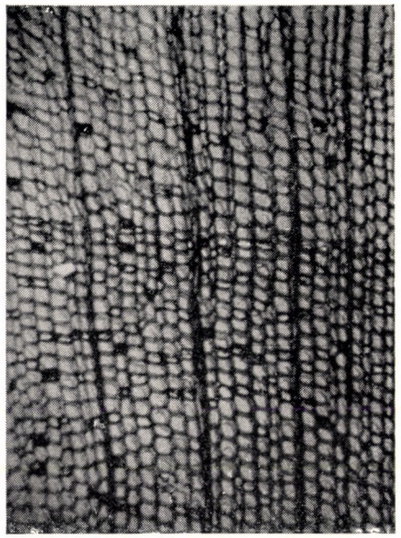
4. (100×)



48. Podocarpus elongatus L. Hér.



1. (30×)



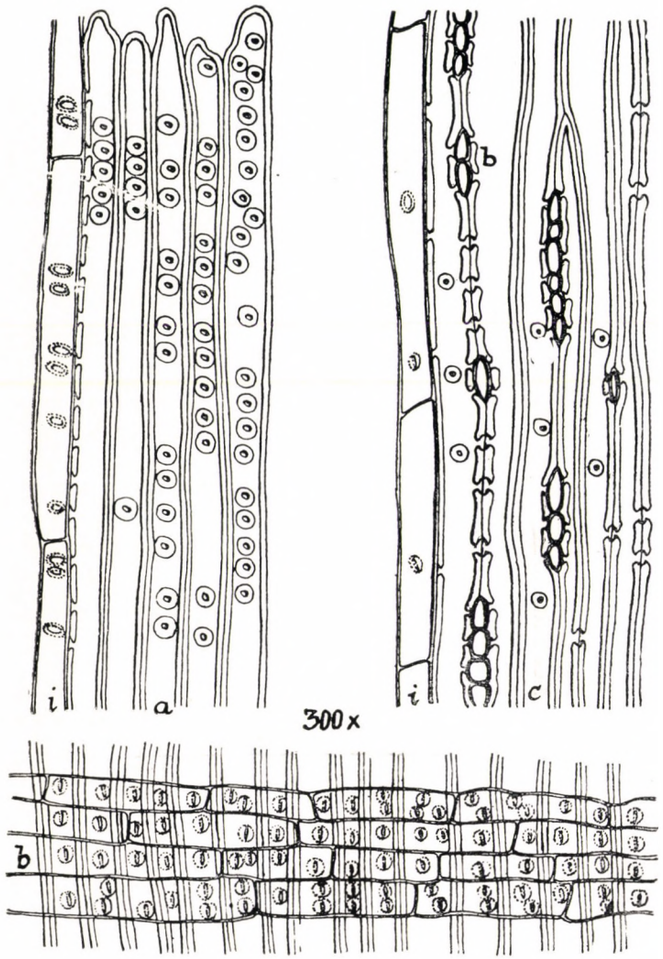
2. (100×)



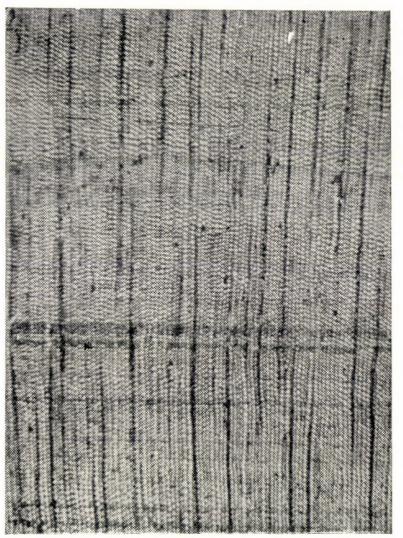
3. (300×)



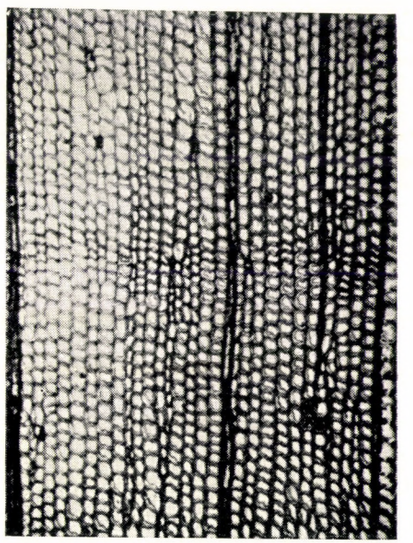
4. (100×)



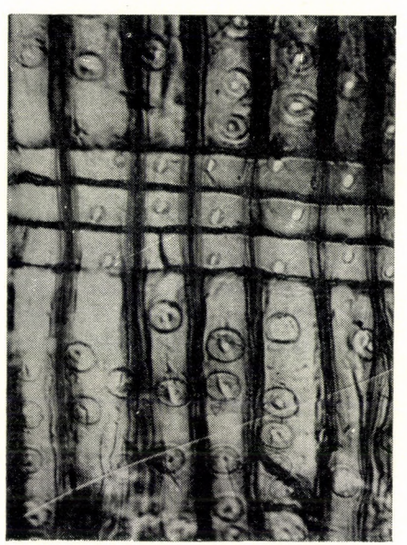
49. Podocarpus falcatus R. Br.



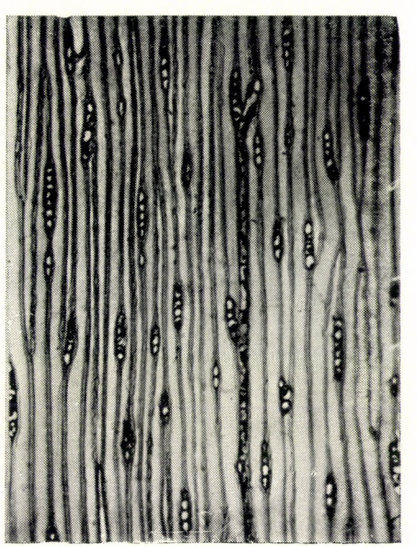
1. (30×)



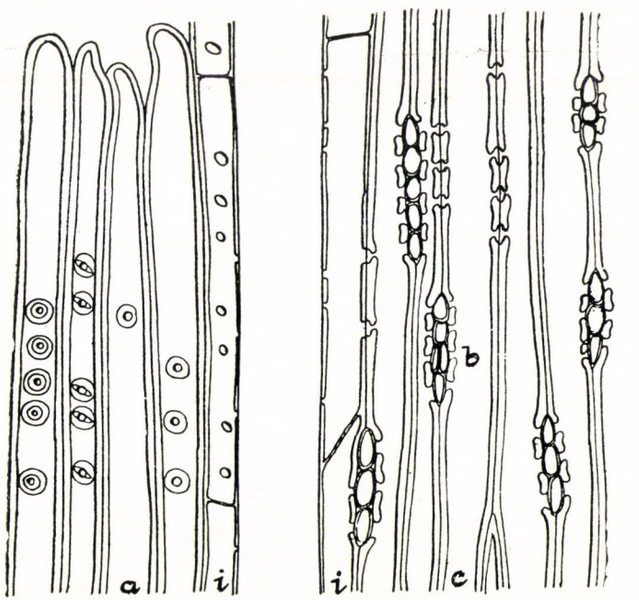
2. (100×)

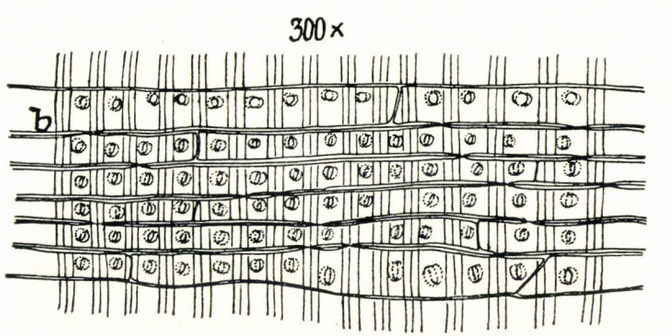


3. (300×)



4. (100×)

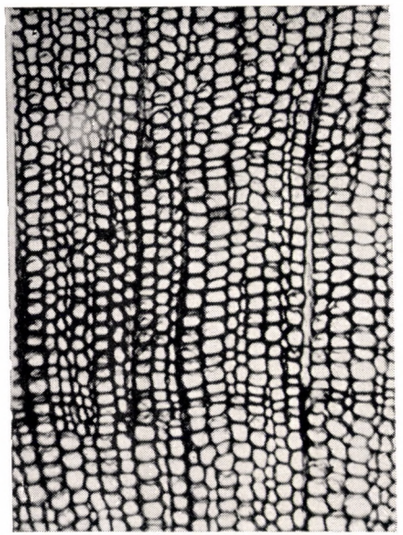




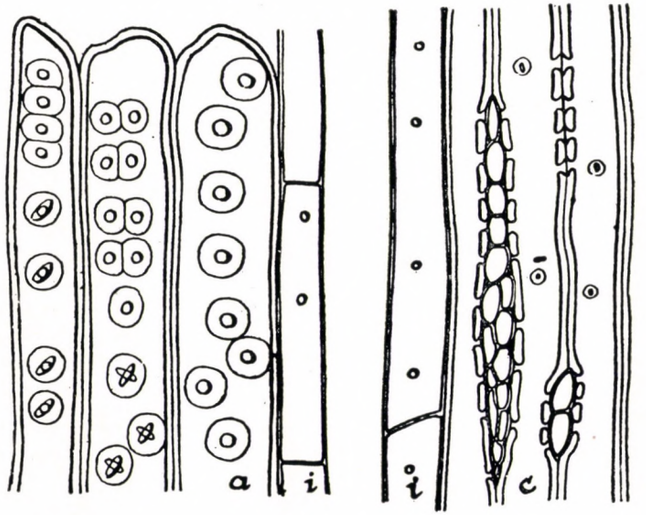
50. Podocarpus ferrugineus D. Don



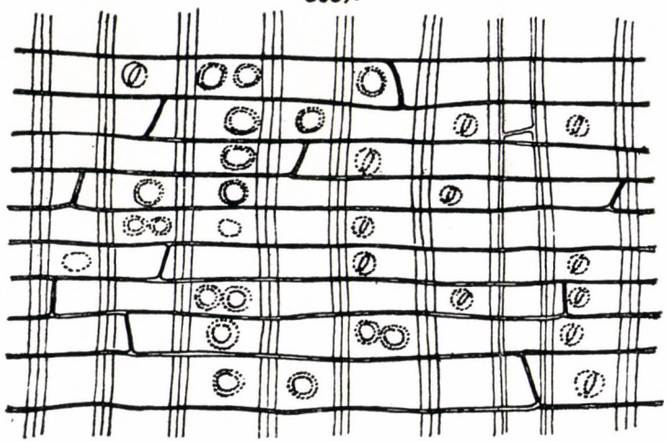
1. (30×)

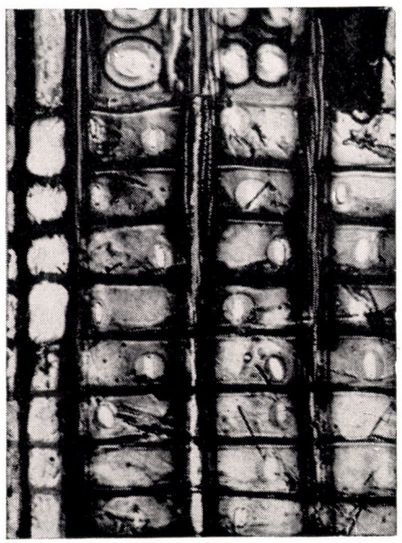


2. (100×)



300×



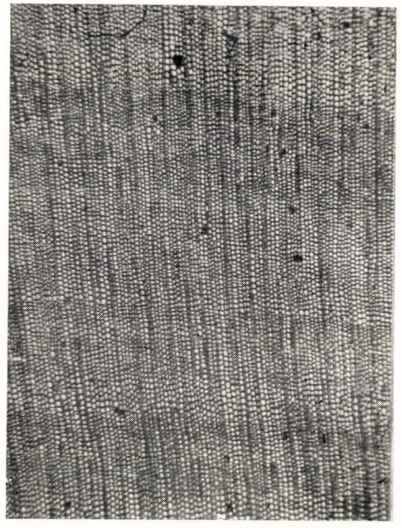


3. (300×)

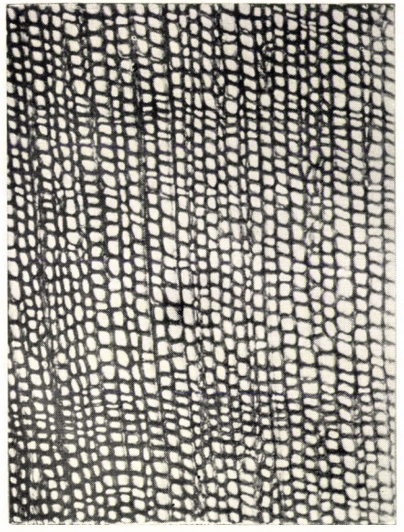


4. (100×)

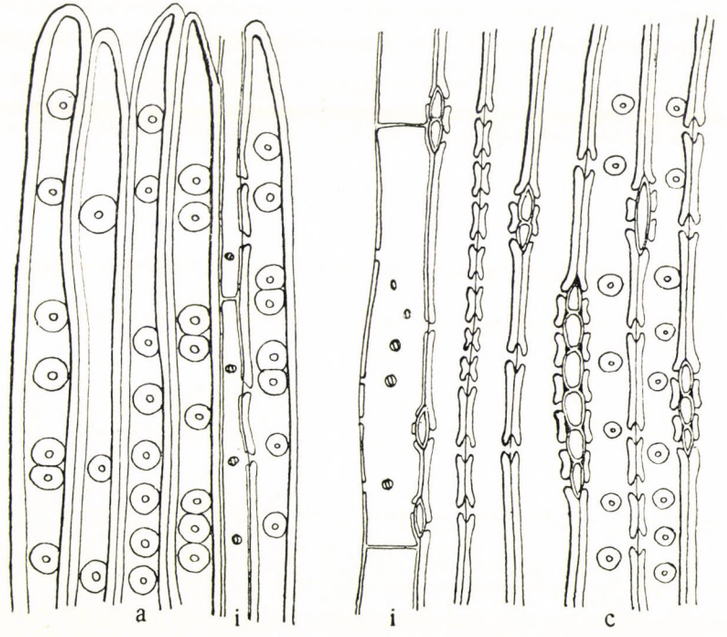
51. Podocarpus ferruginoides COMPT.



1. (30×)

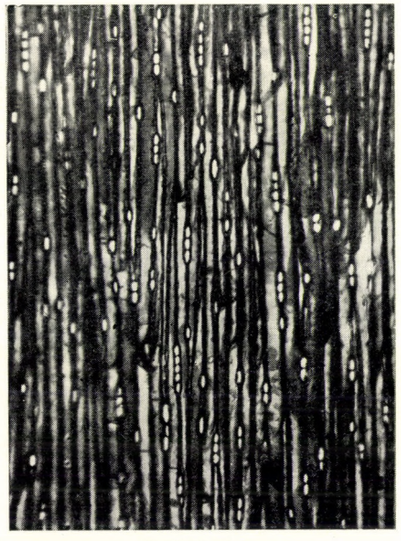


2. (100×)

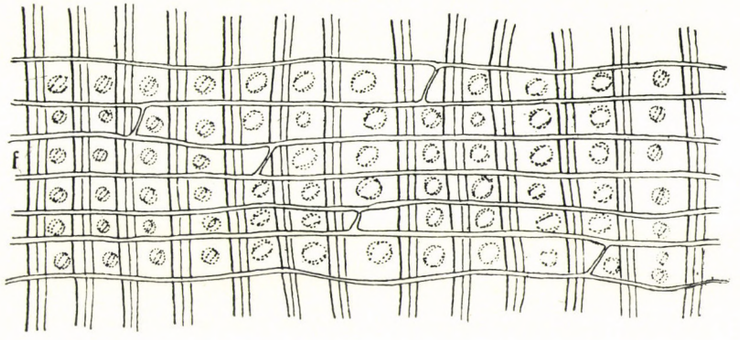




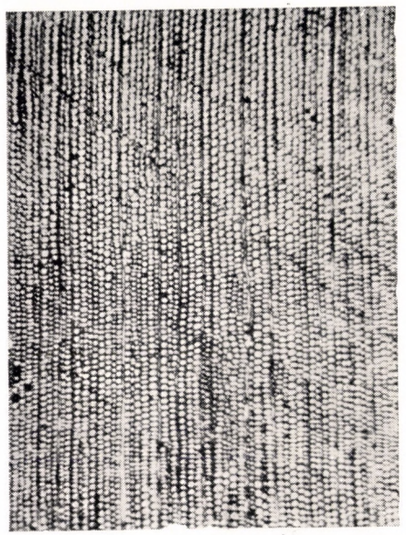
3. (300×)



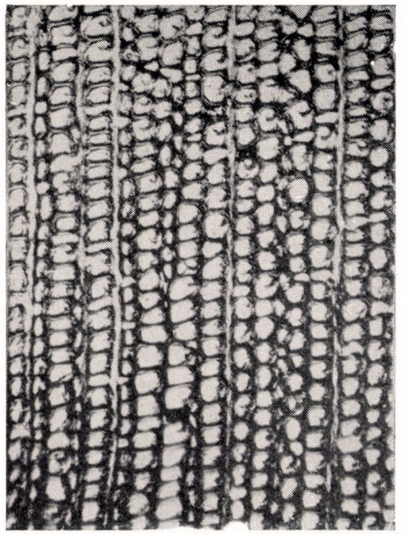
4. (100×)



52. Podocarpus glomeratus D. Don



1. (30×)



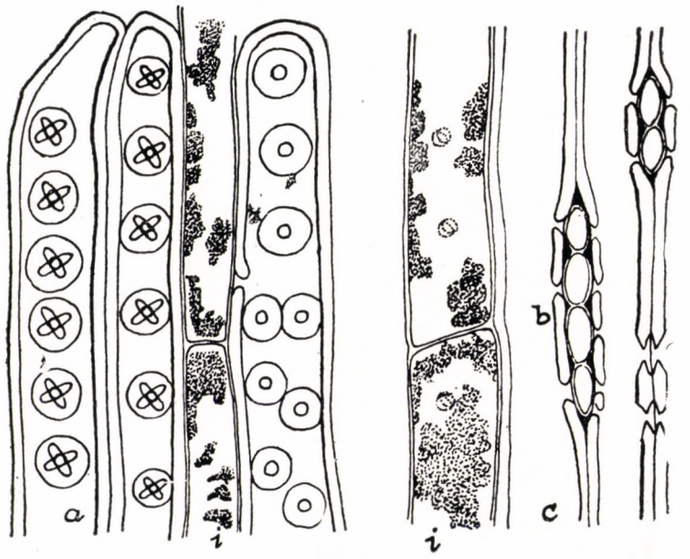
2. (100×)



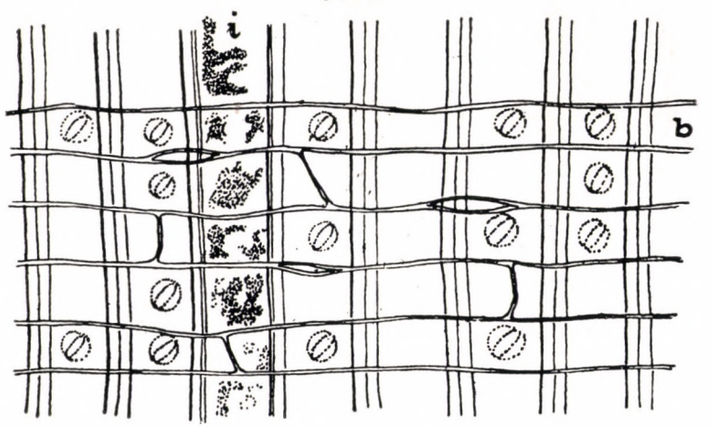
3. (300×)



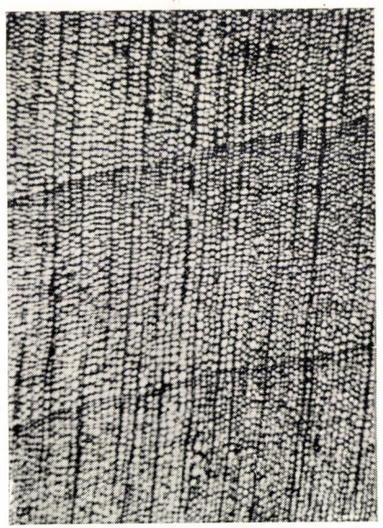
4. (100×)



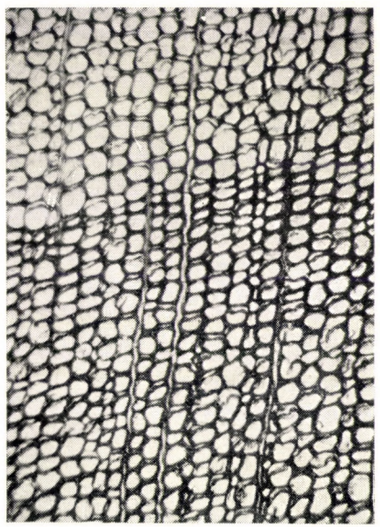
500×



53. Podocarpus gracilior PILGER



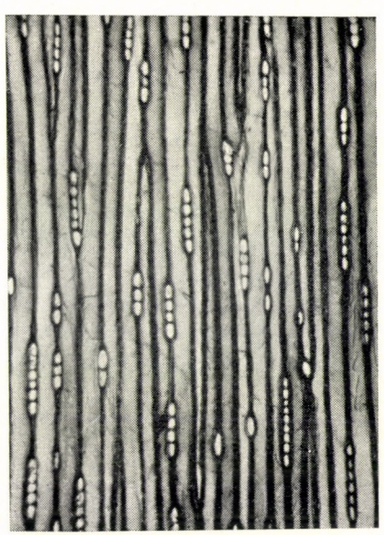
1. (30×)



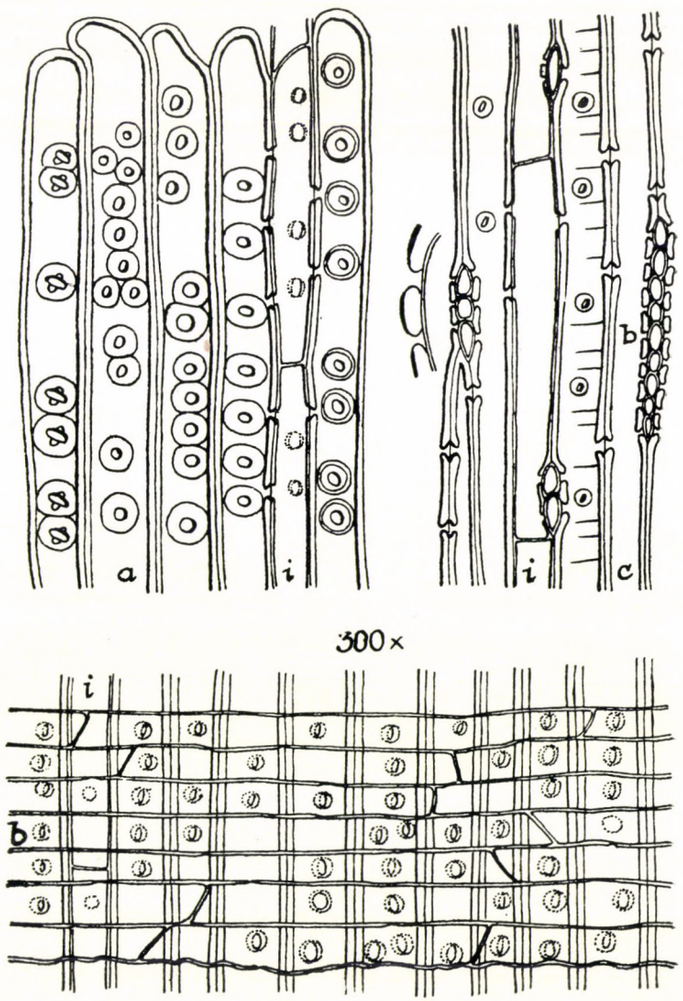
2. (100×)



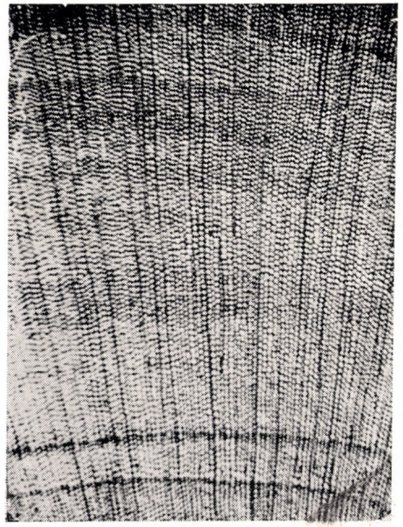
3. (300×)



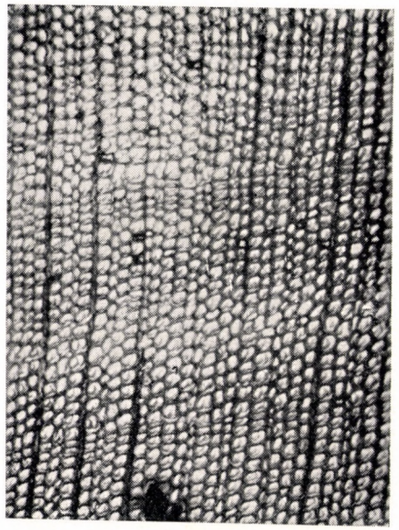
4. (100×)



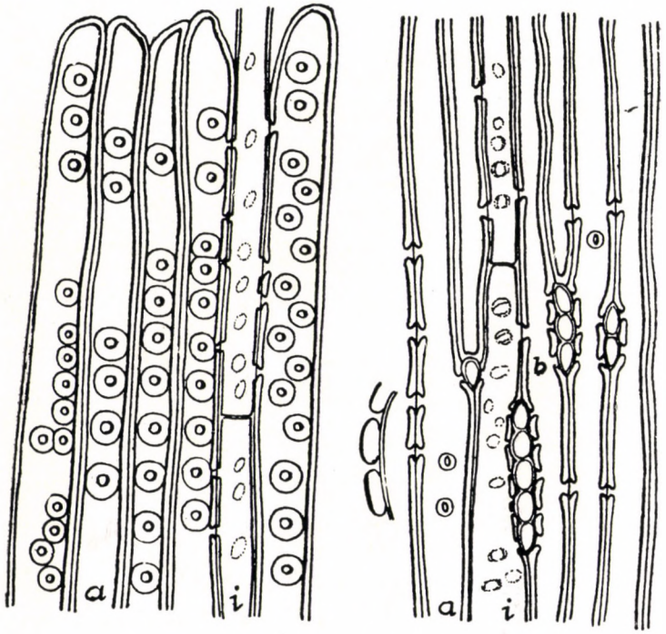
54. Podocarpus Henckelii STAPF



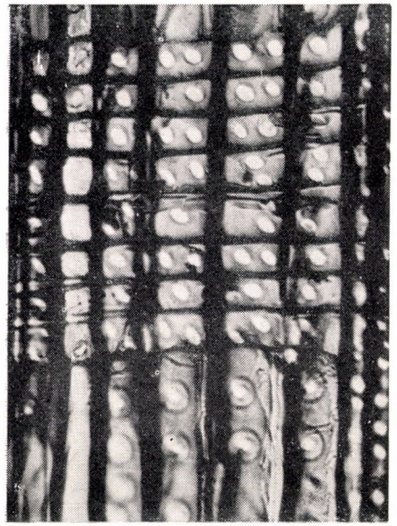
1. (30×)



2. (100×)



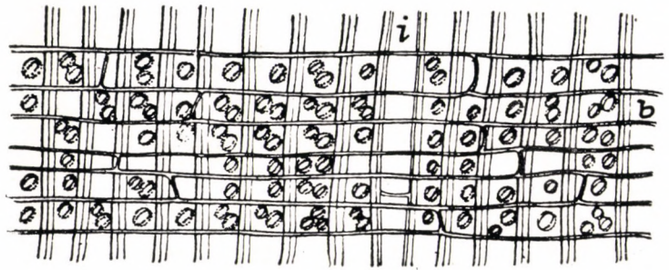
250×



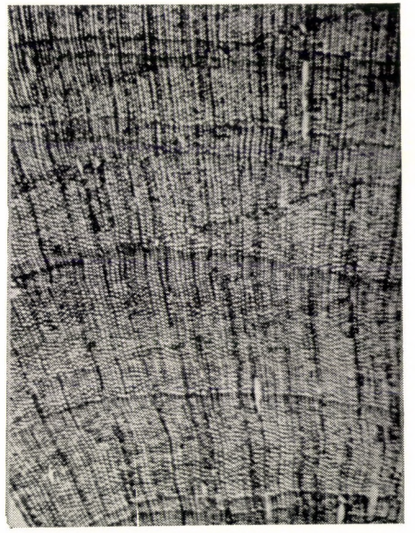
3. (300×)



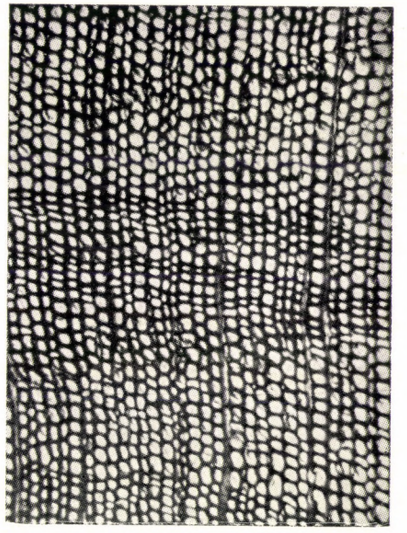
4. (100×)



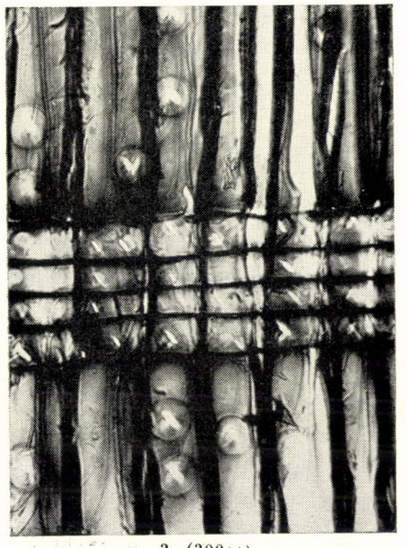
55. Podocarpus javanicus Bl.



1. (30×)



2. (100×)



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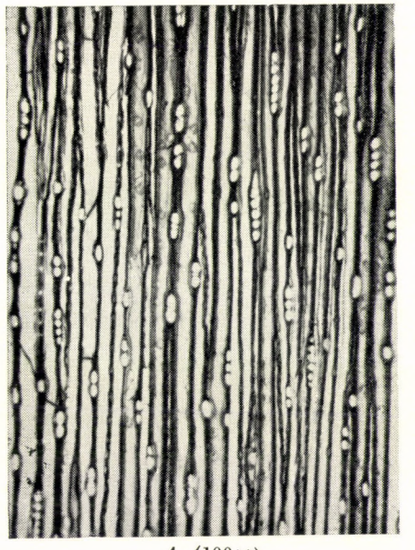
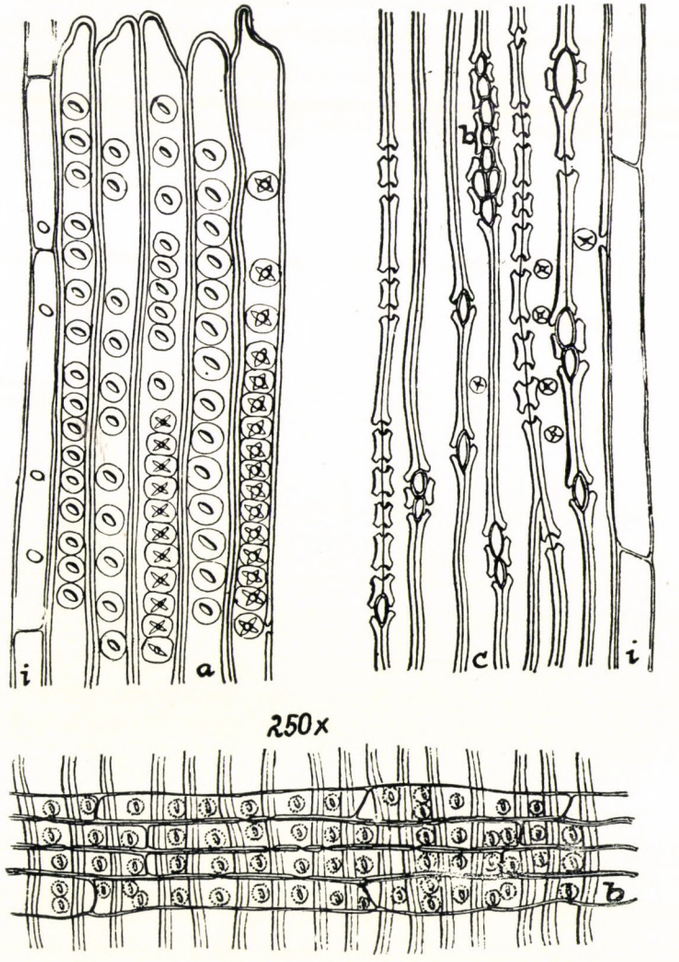


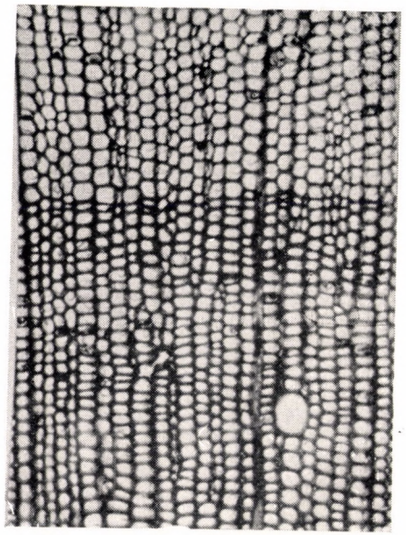
4. (100×)



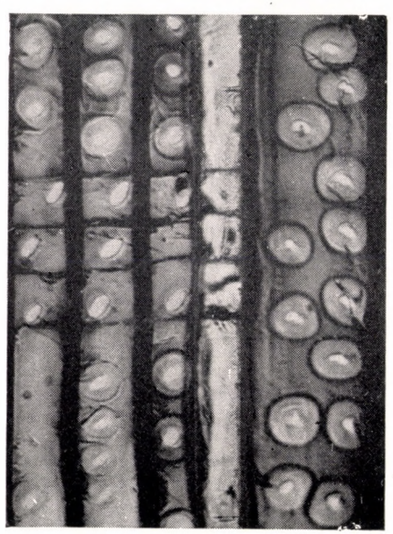
56. Podocarpus latifolius R. Br.



1. (30×)



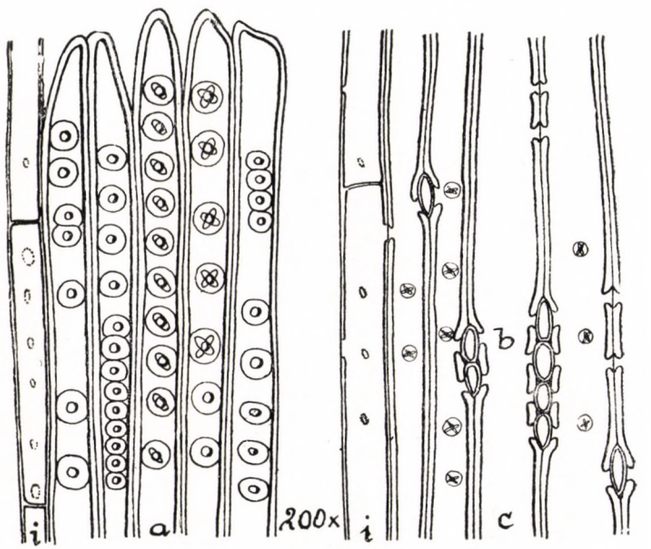
2. (100×)

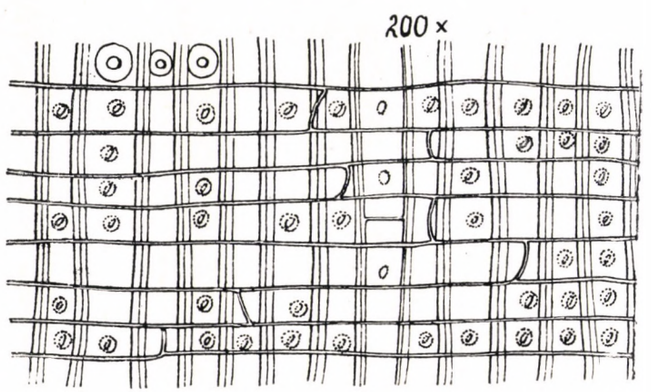


3. (300×)

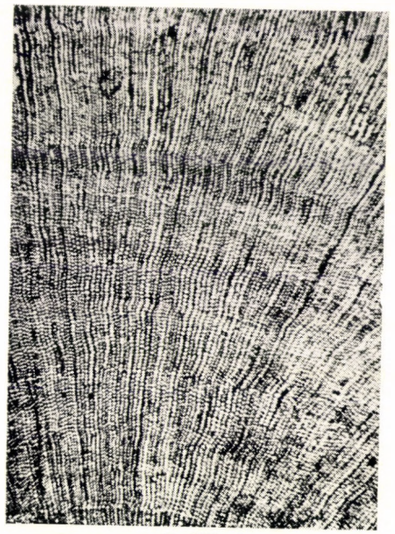


4. (100×)

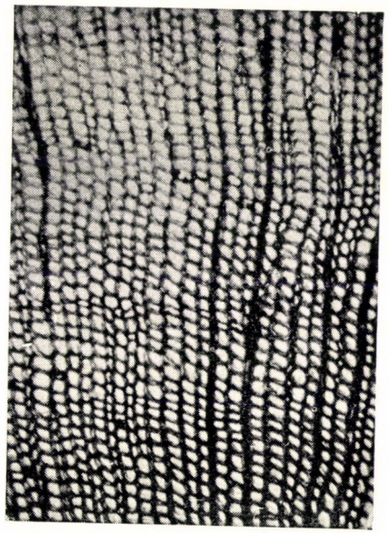




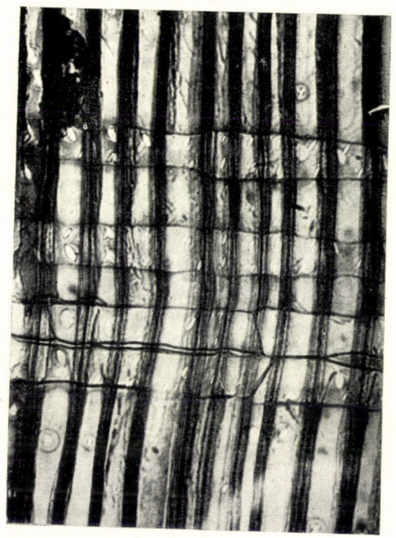
57. Podocarpus longifoliatus PILGER



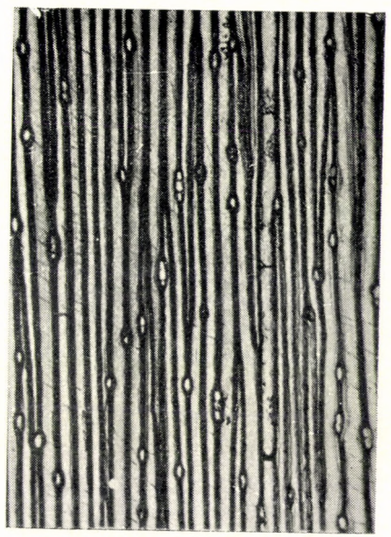
1. (30×)



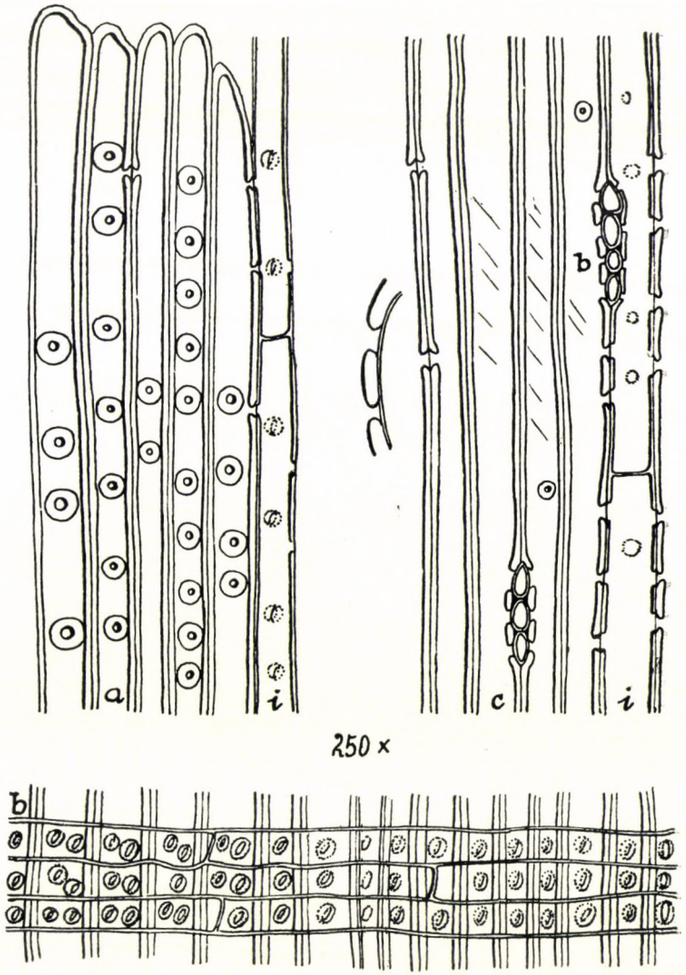
2. (100×)



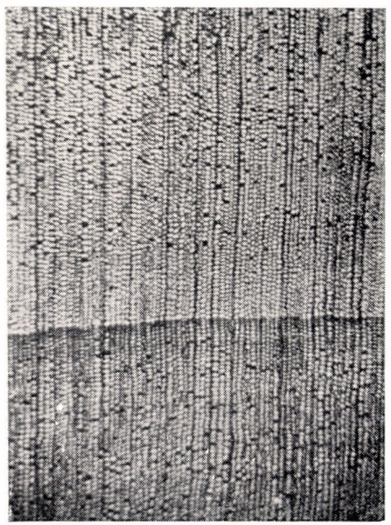
3. (300×)



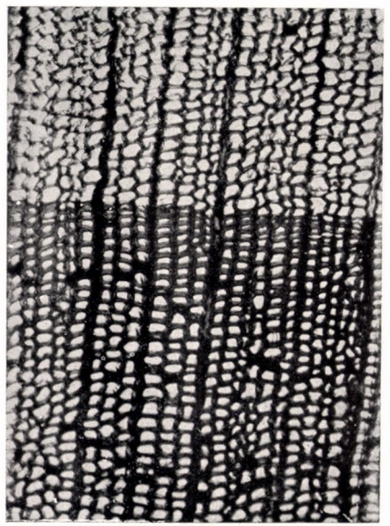
4. (100×)



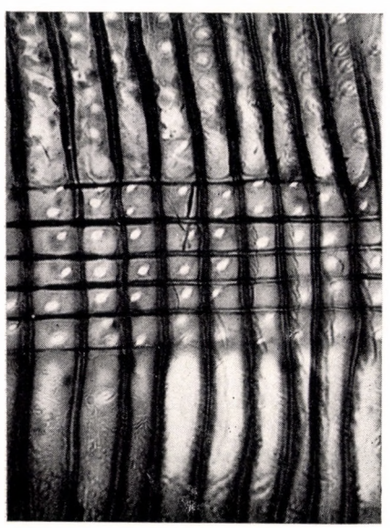
58. Podocarpus lycopodioides



1. (30×)



2. (100×)



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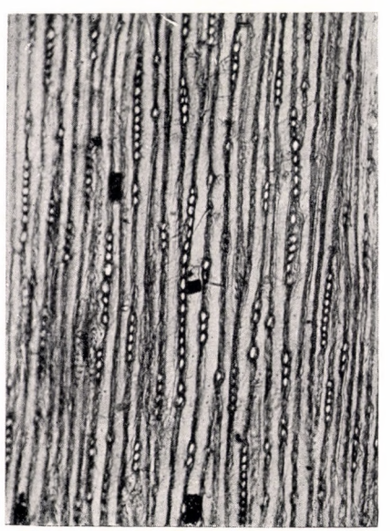
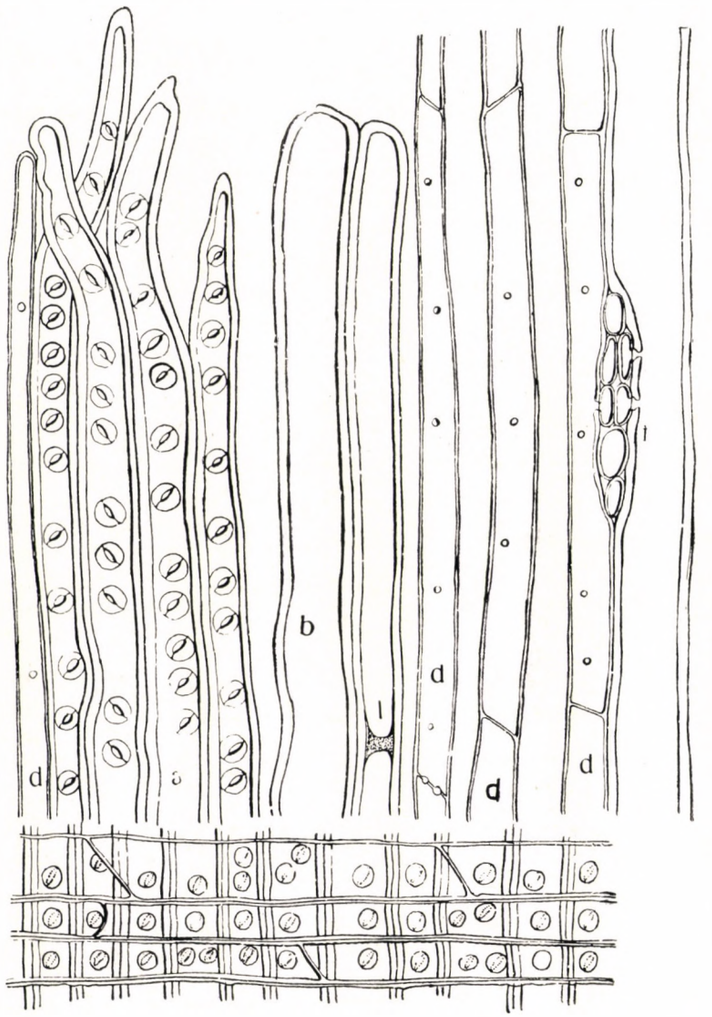
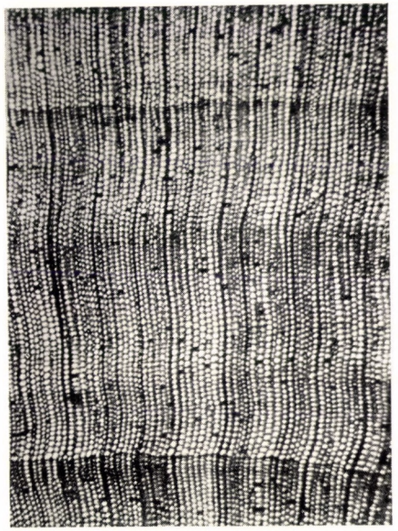


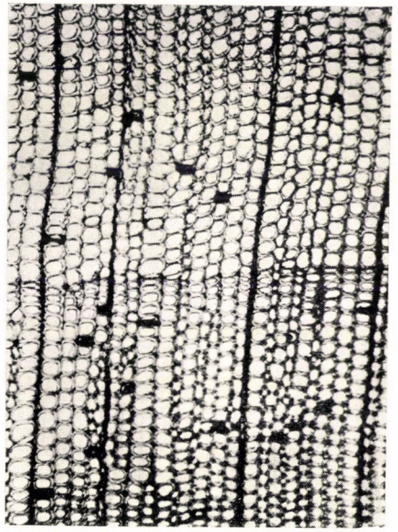
4. (100×)



59. Podocarpus macrophyllus D. Don.



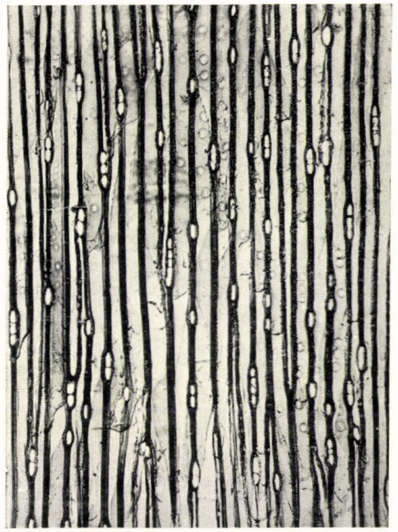
1. (30×)



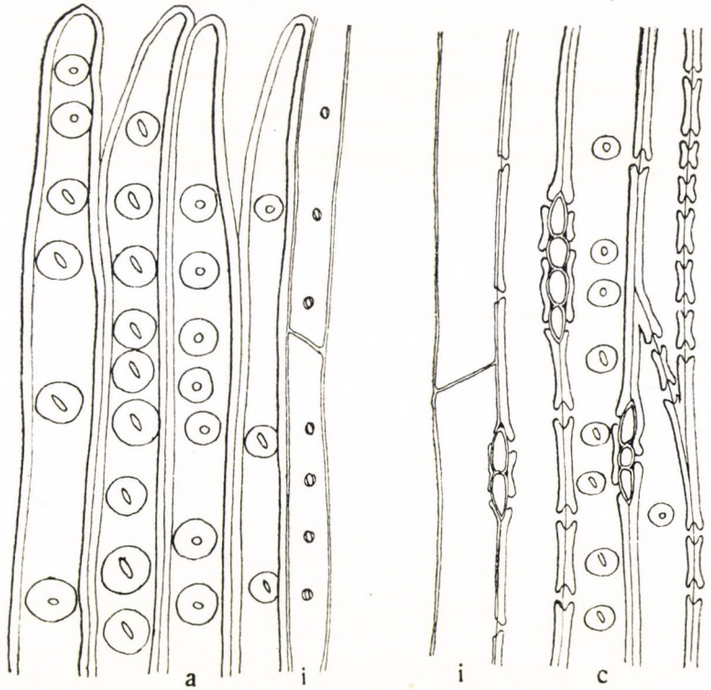
2. (100×)



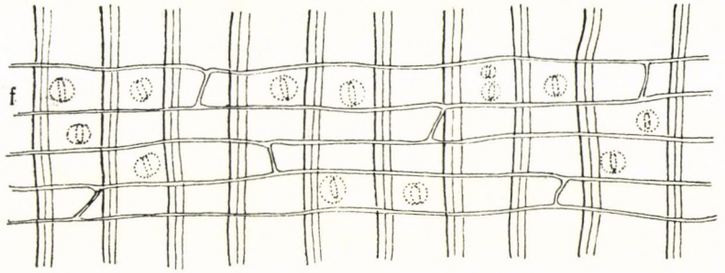
3. (300×)



4. (100×)



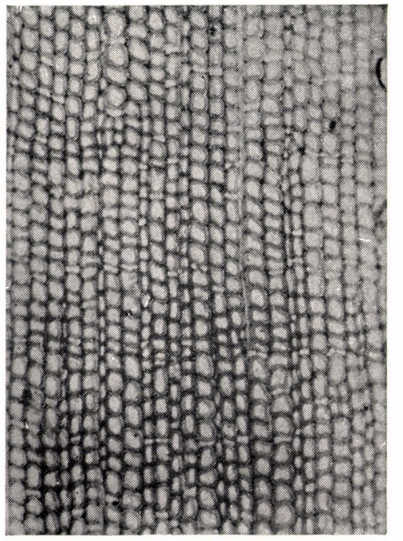
300 x



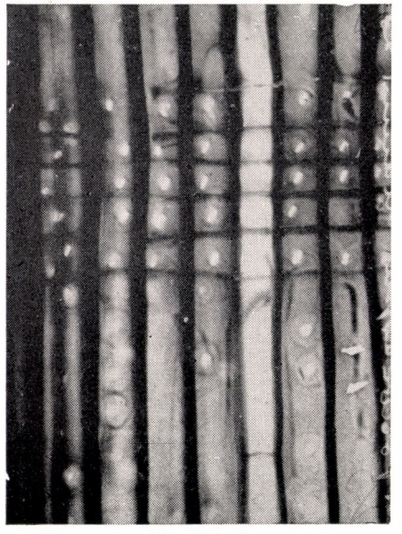
60. Podocarpus macrostachyus PARL.



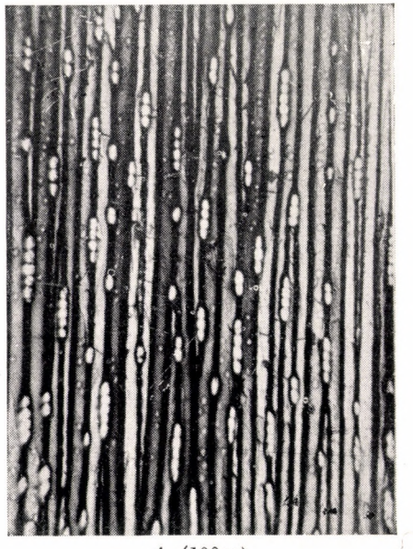
1. (30×)



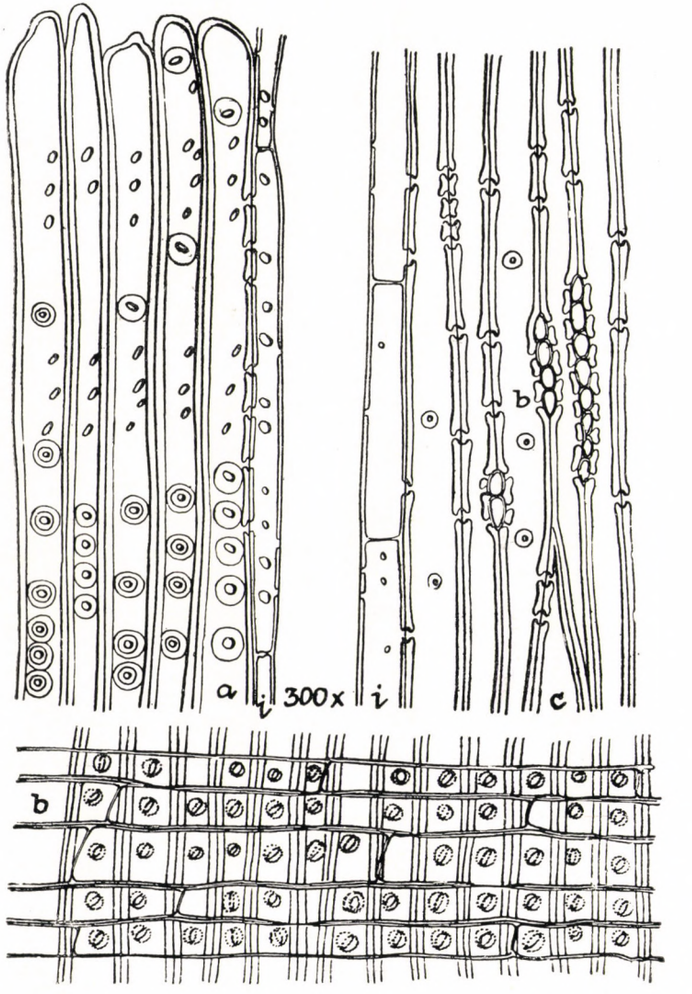
2. (100×)



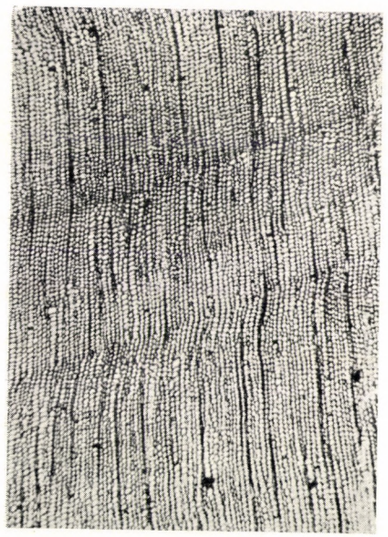
3. (300×)



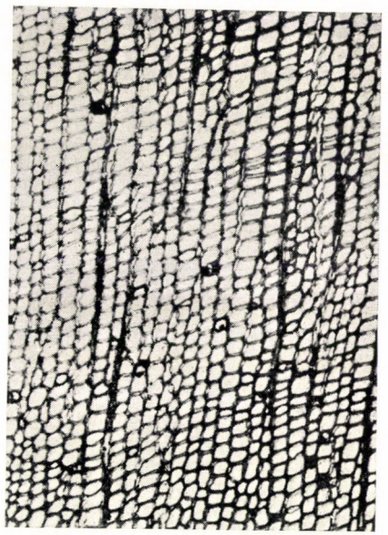
4. (100×)



61. Podocarpus Mannii Hook.



1. (30×)



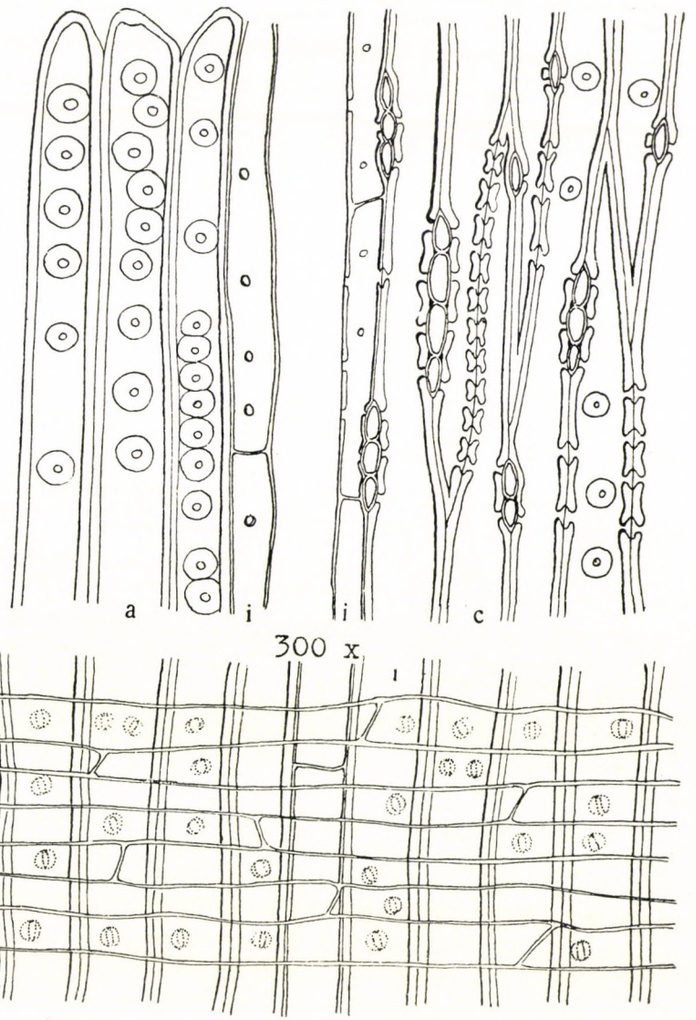
2. (100×)



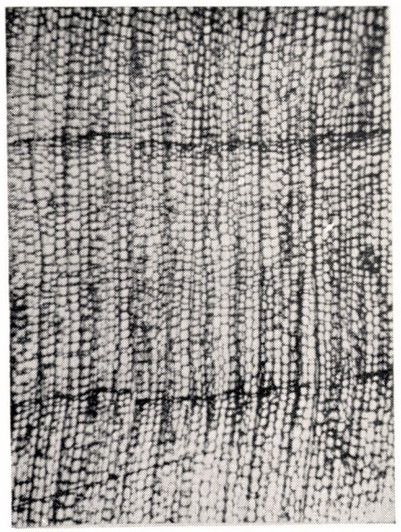
3. (300×)



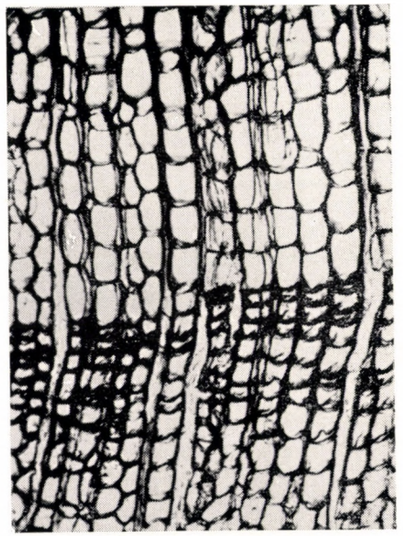
4. (100×)



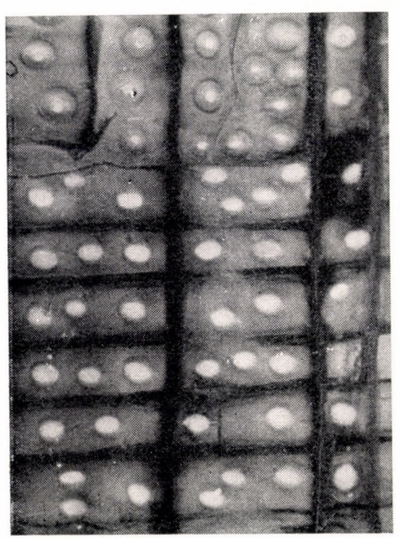
62. Podocarpus milanjianus RENDLE



1. (30×)



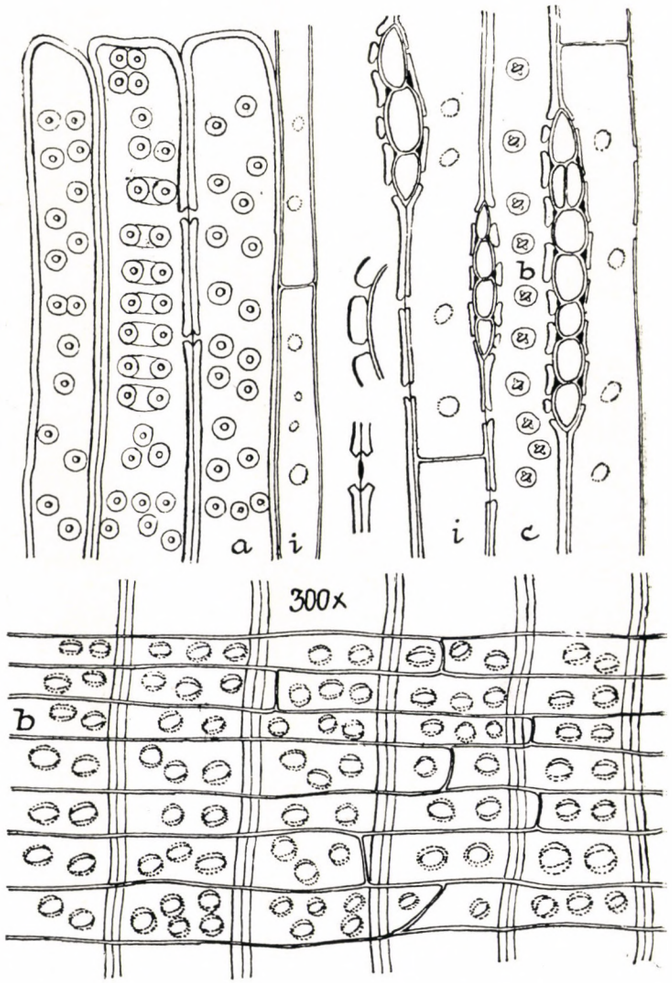
2. (100×)



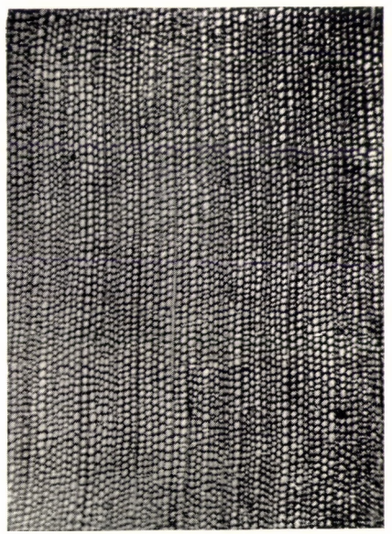
3. (300×)



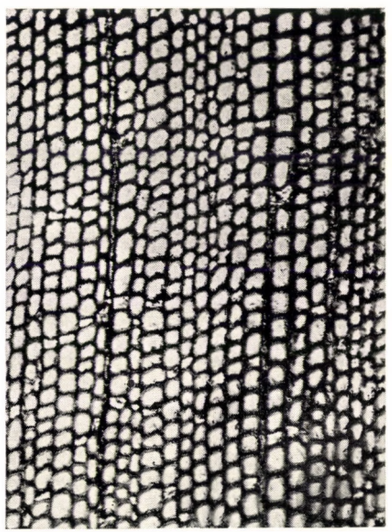
4. (100×)



63. Podocarpus **minor** PARL.



1. (30×)



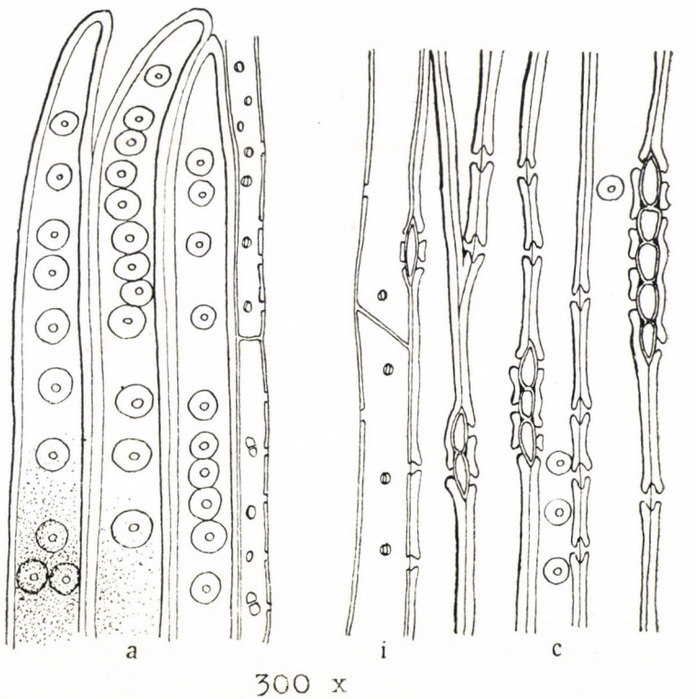
2. (100×)

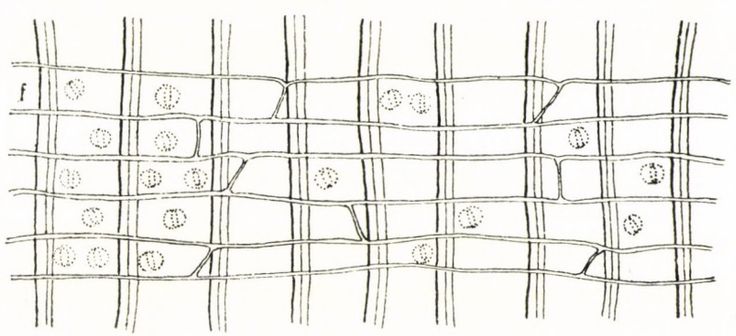


3. (300×)

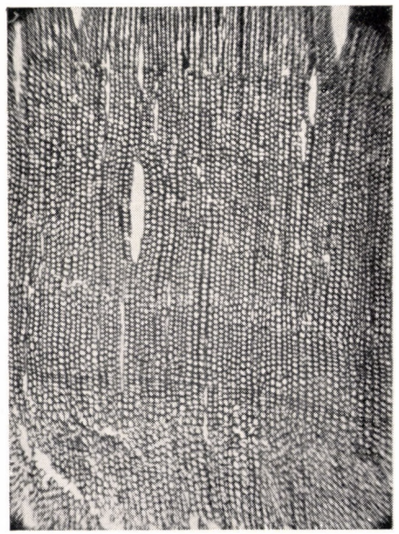


4. (100×)

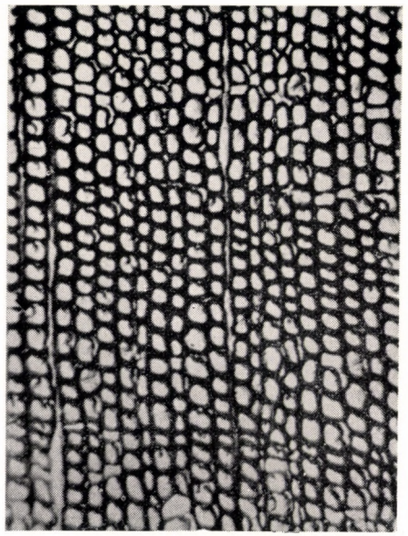




64. Podocarpus montanus LODD.



1. (30×)



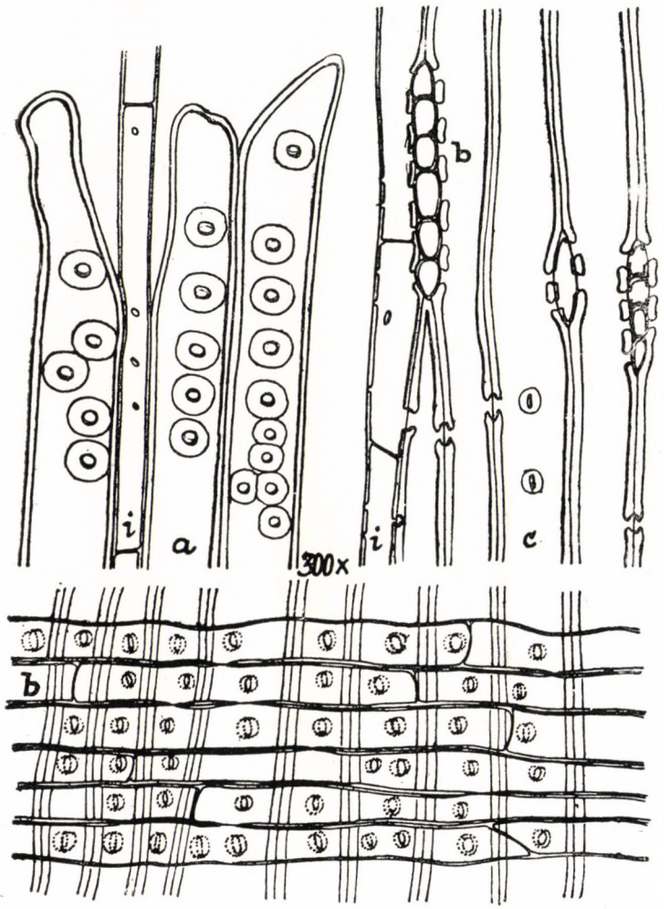
2. (100×)



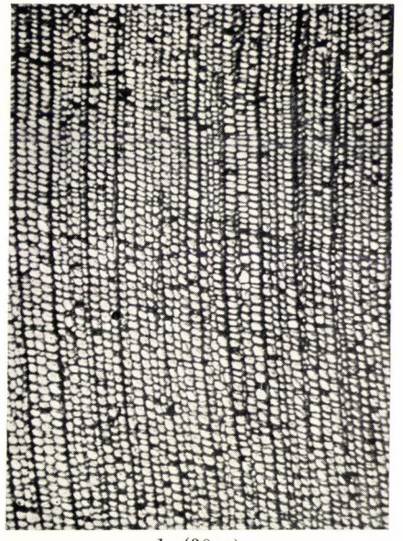
3. (300×)



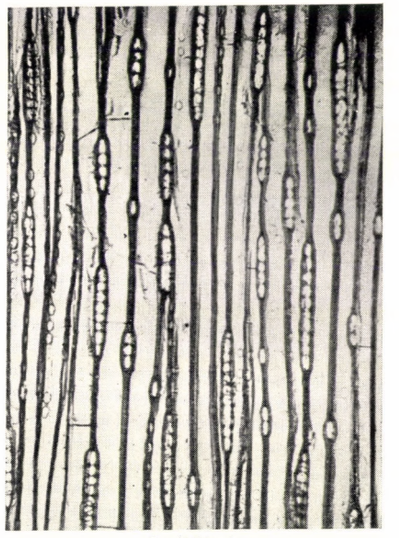
4. (100×)



65. Podocarpus neriifolius D. Don



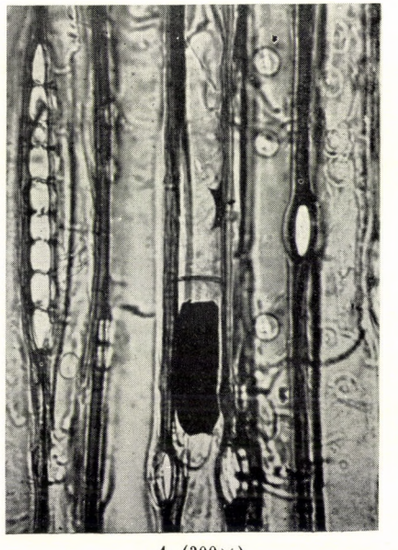
1. (30×)



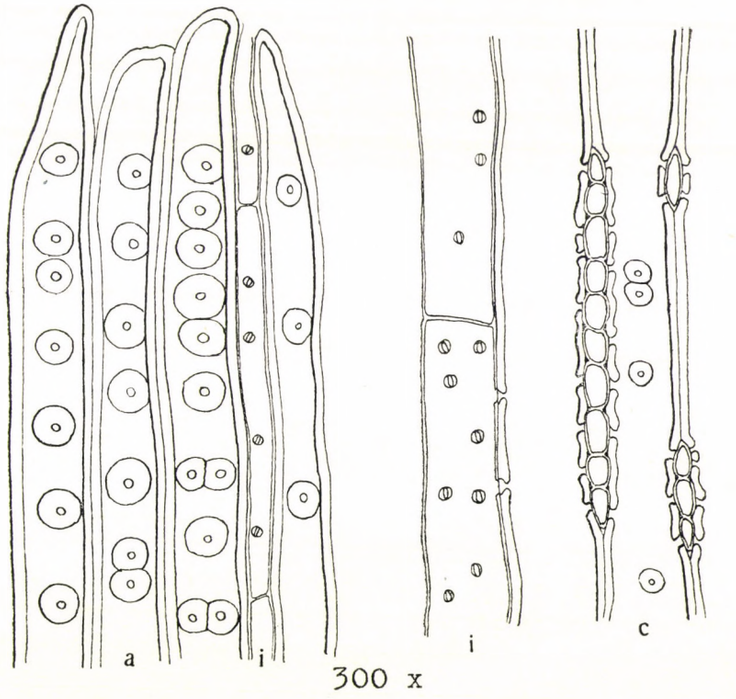
2. (100×)

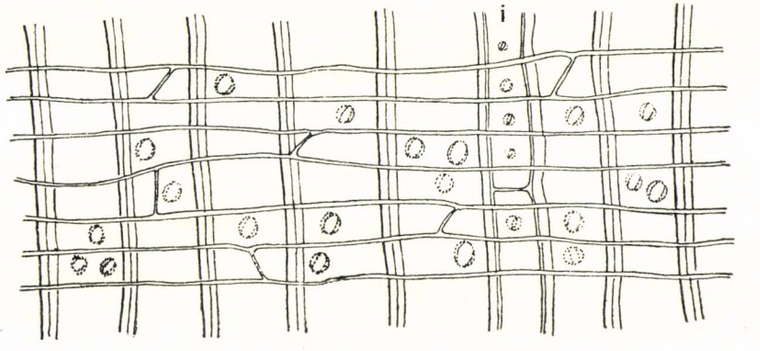


3. (300×)

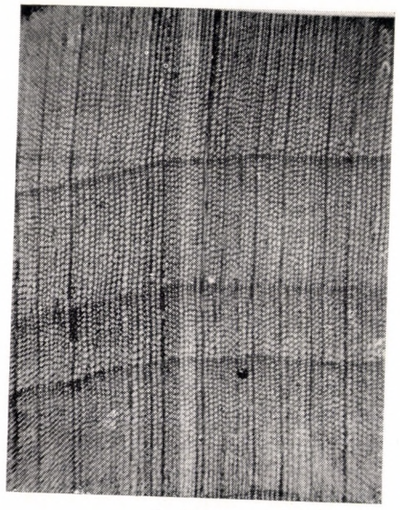


4. (300×)

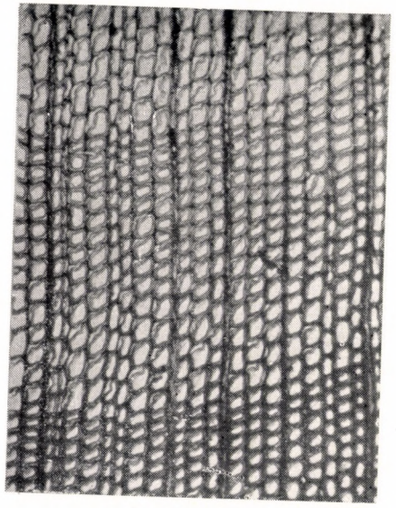




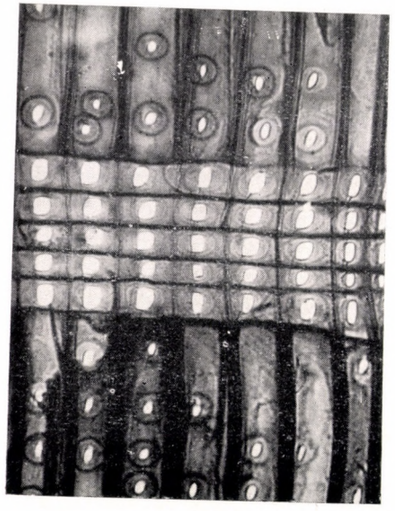
66. Podocarpus oleifolius D. Don



1. (30×)



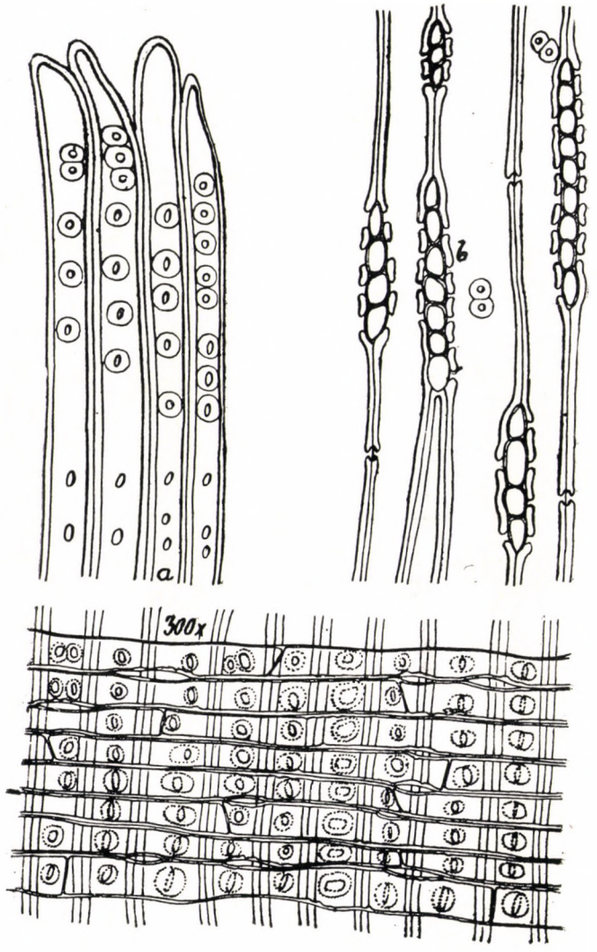
2. (100×)



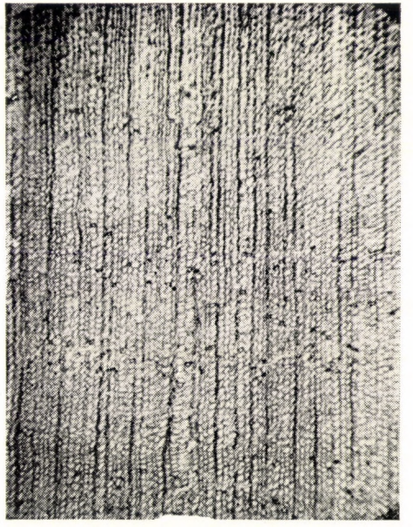
3. (300×)



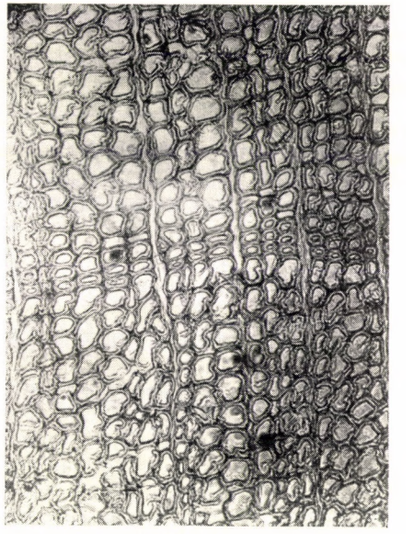
4. (100×)



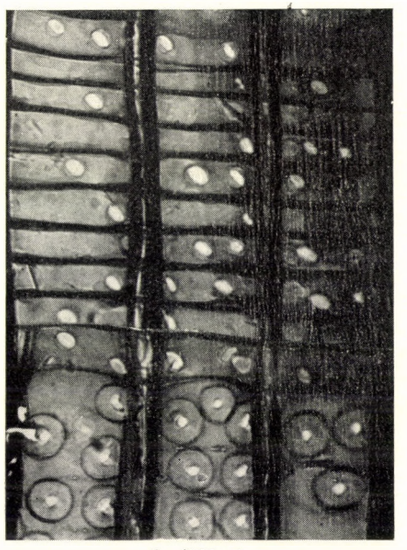
67. Podocarpus spicatus R. Br.



1. (30×)



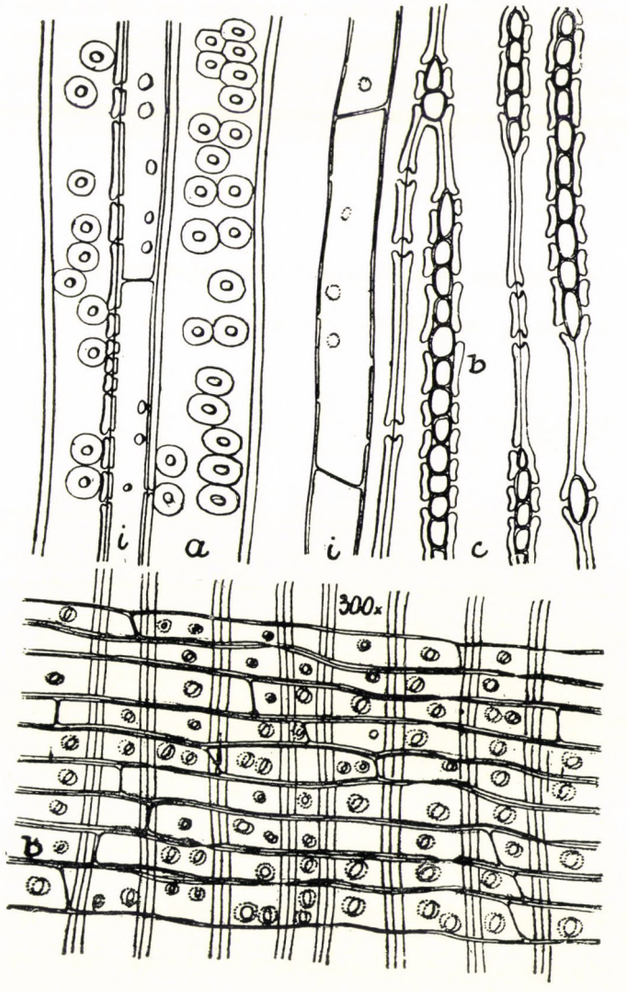
2. (100×)



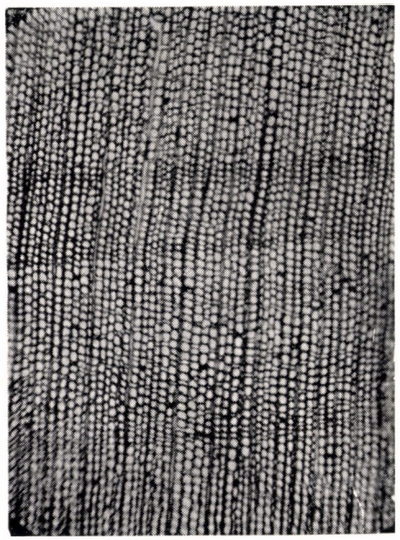
3. (300×)



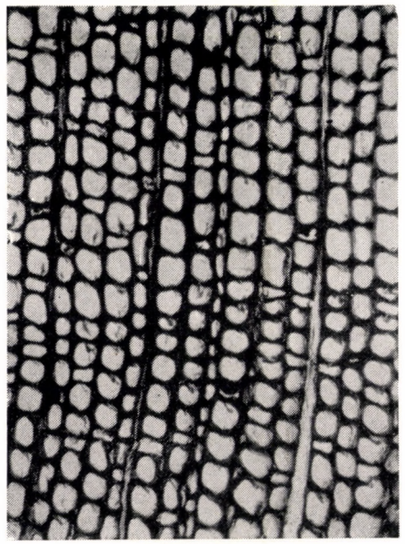
4. (100×)



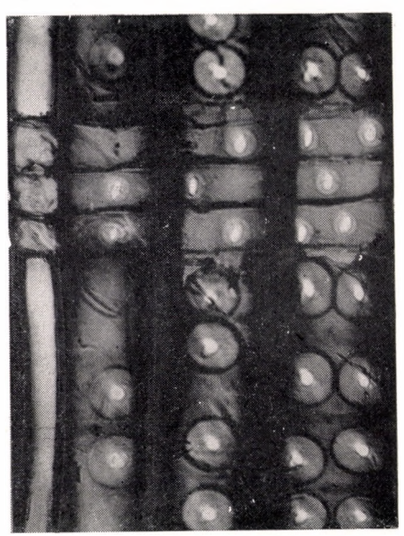
68. Podocarpus Totara D. Don



1. (30×)



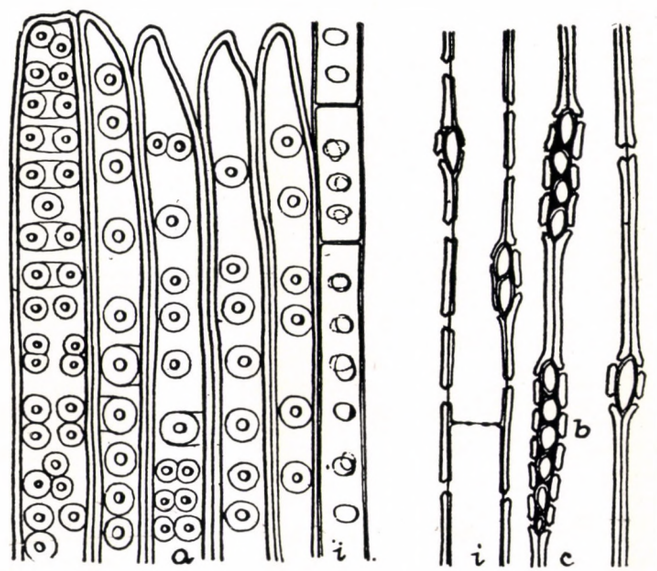
2. (100×)



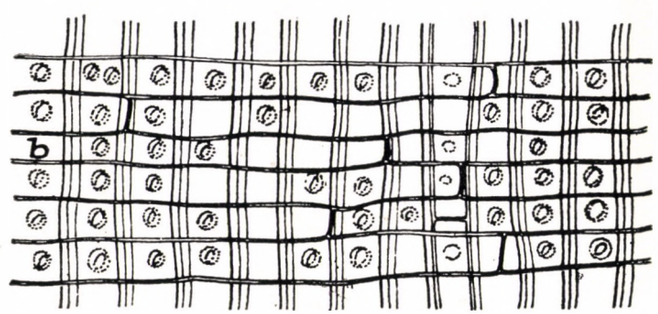
3. (300×)



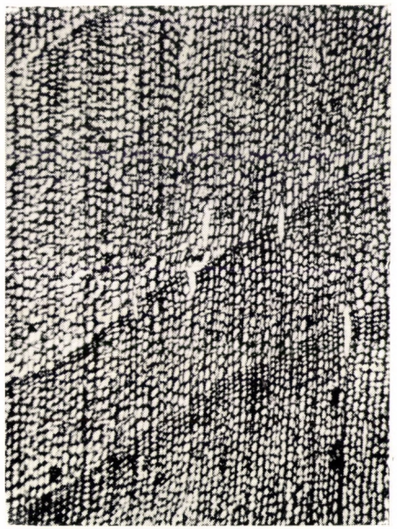
4. (100×)



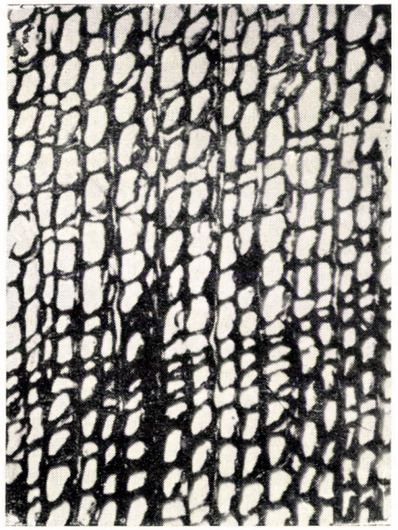
300 x



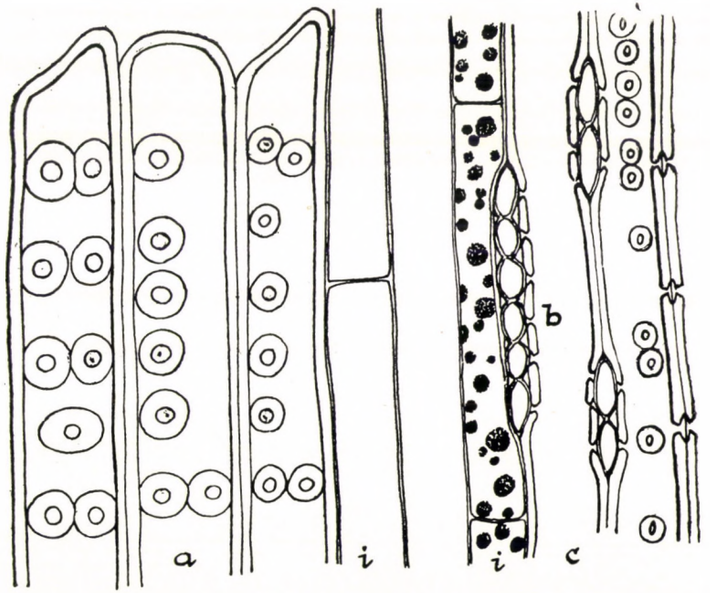
69. Podocarpus usambarensis PILGER



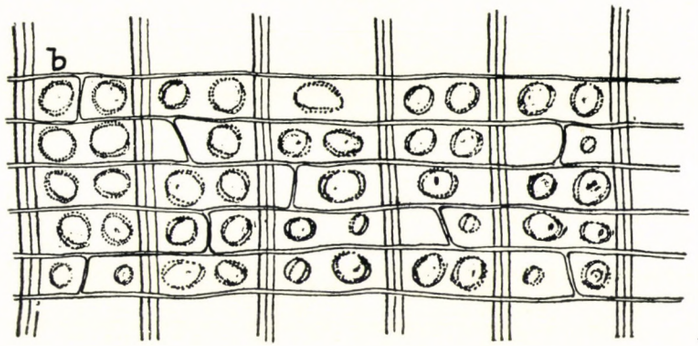
1. (30×)

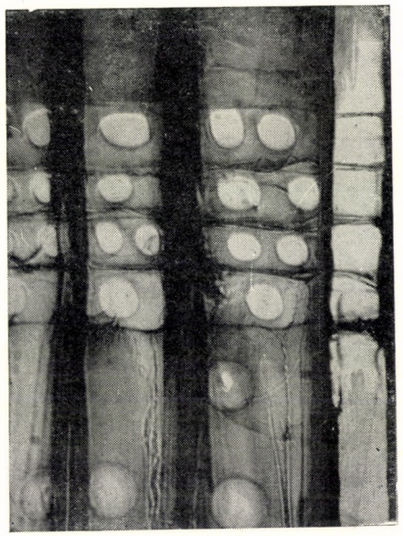


2. (100×)



330×



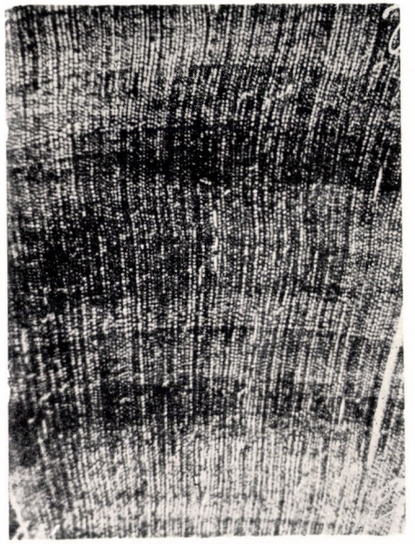


3. (300×)

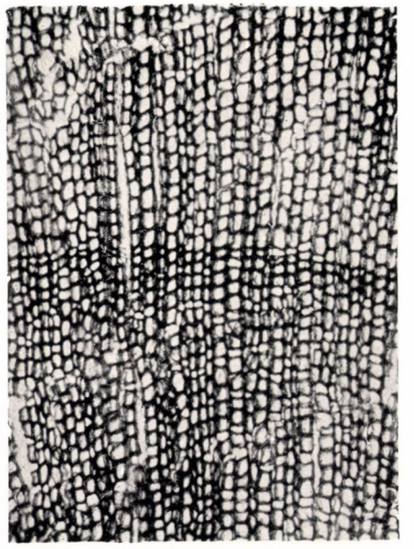


4. (100×)

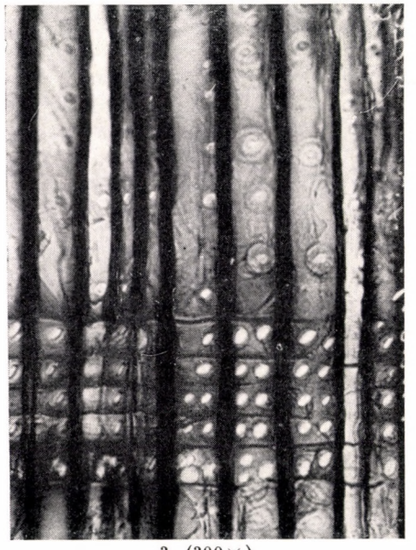
70. Podocarpus Wallichianus C. PERSL.



1. (30×)



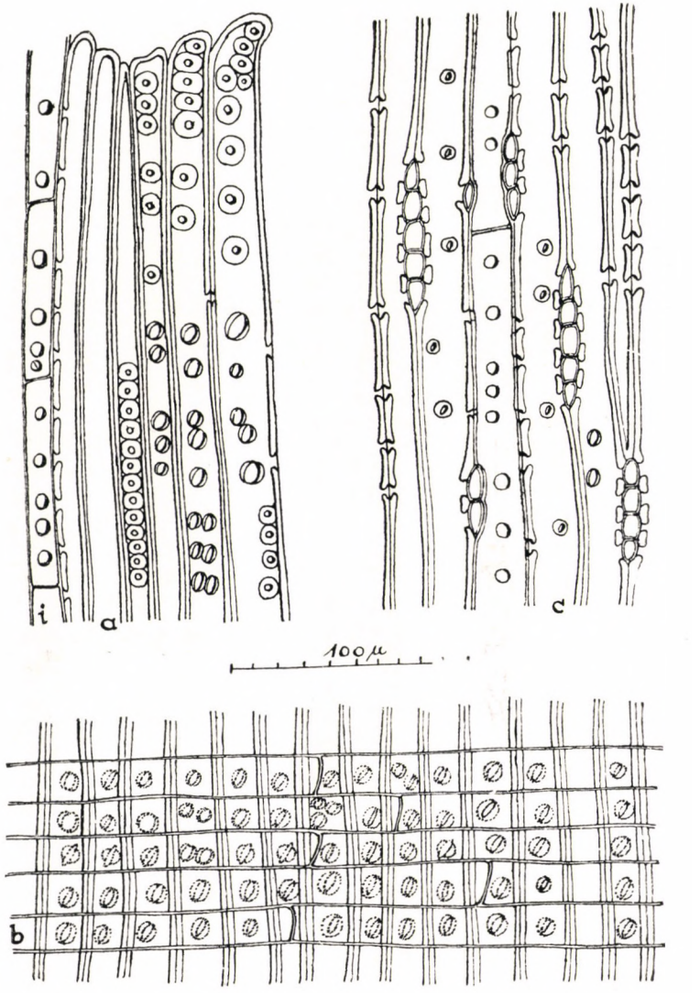
2. (100×)



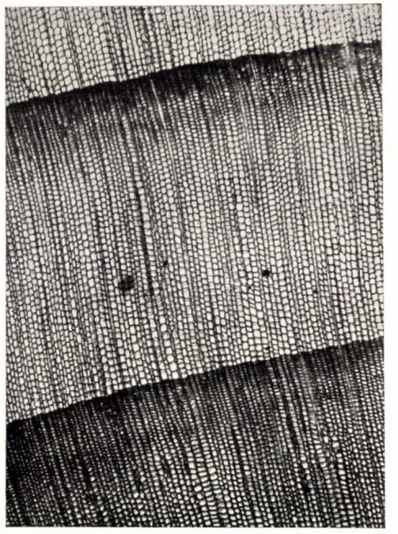
3. (300×)



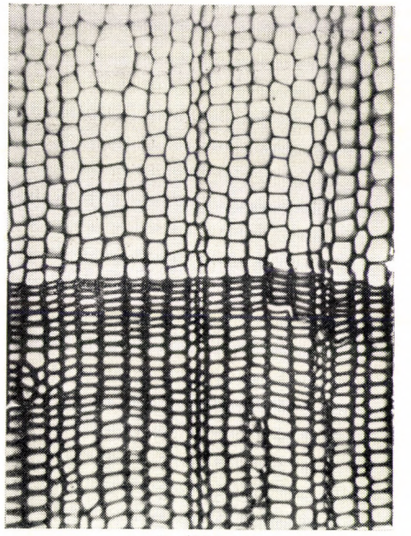
4. (100×)



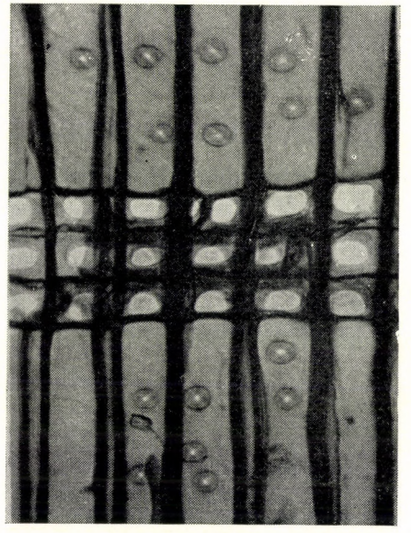
71. Prumnopitys elegans PHILIP.



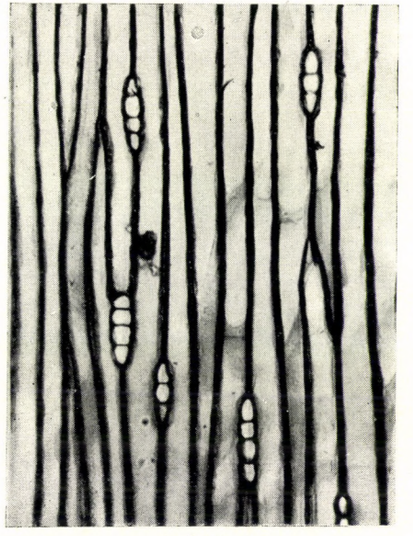
1. (30×)



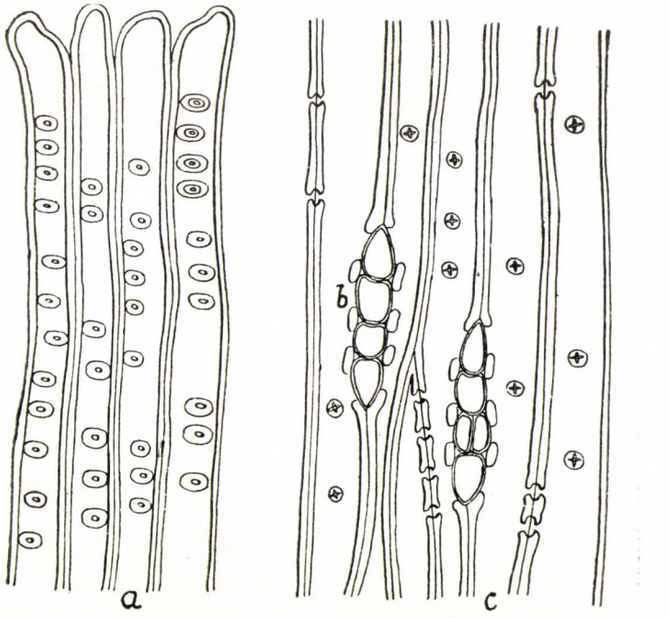
2. (100×)

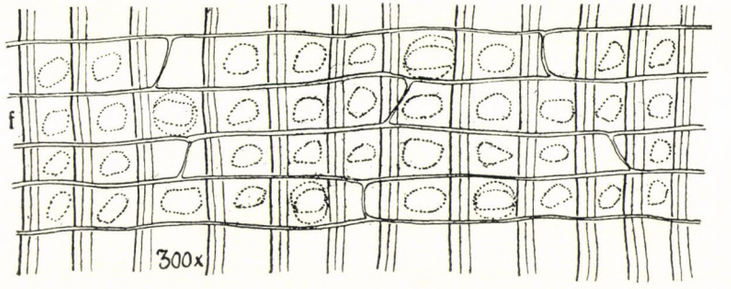


3. (300×)



4. (100×)

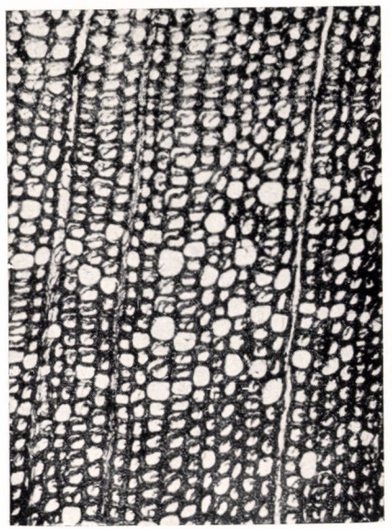




72. Sciadopitys verticillata (Thunberg) SIEB. & ZUCC.

V.

TAXALES
(TAXACEAE, CEPHALOTAXACEAE)



1. (100×)



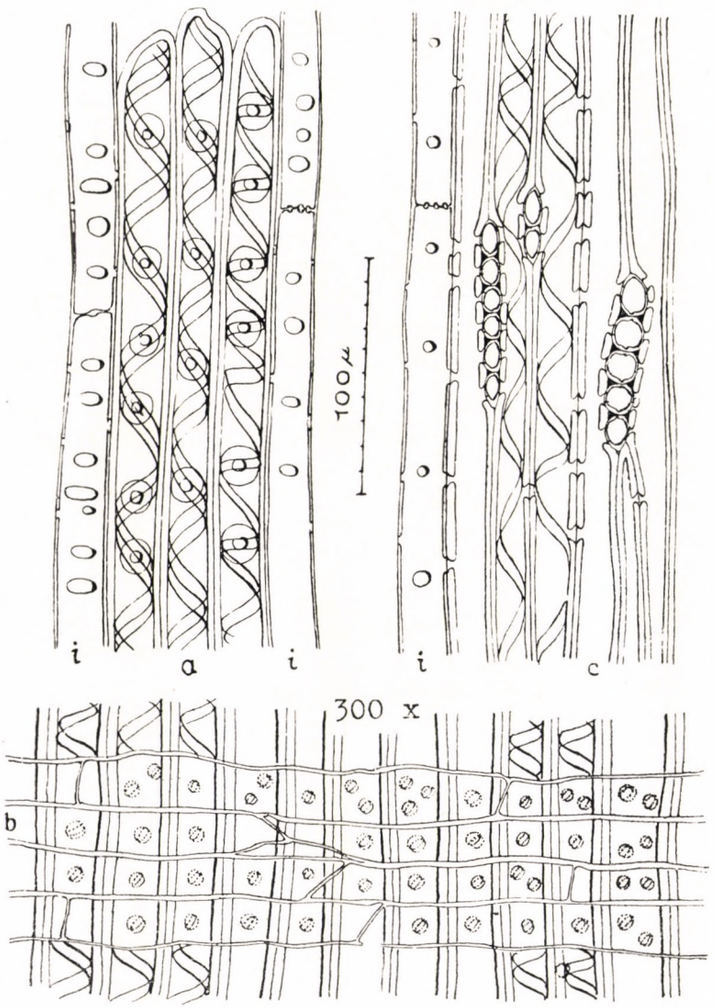
2. (100×)



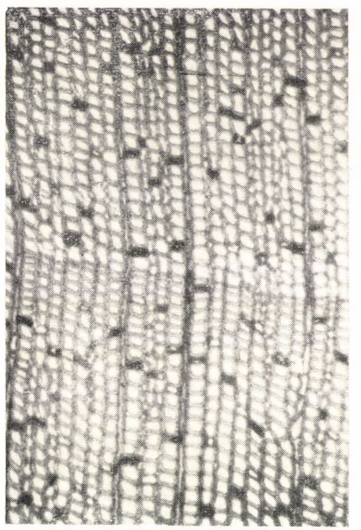
3. (300×)



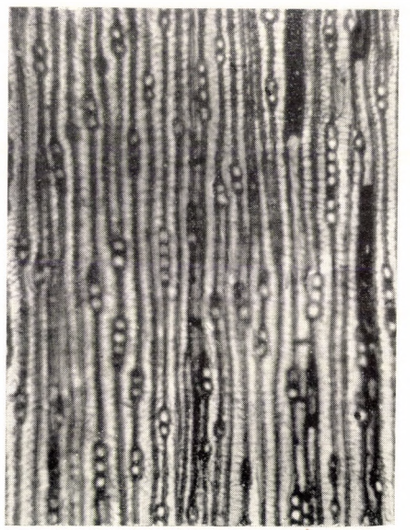
4. (300×)



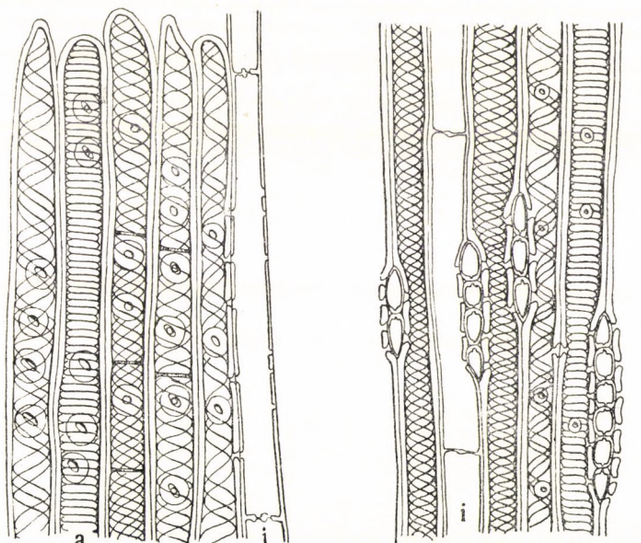
73. Amentotaxus argotaenia PILGER



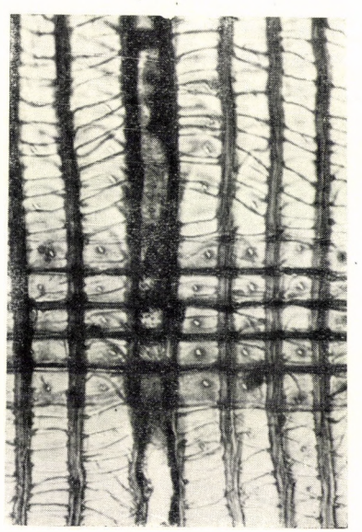
1. (100×)



2. (100×)



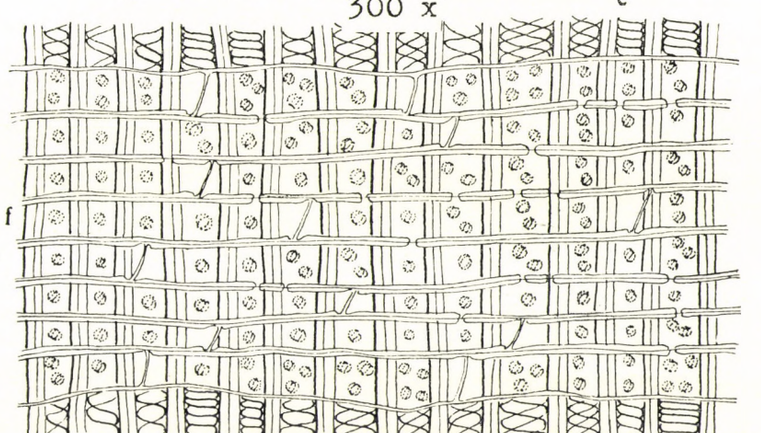
300 x



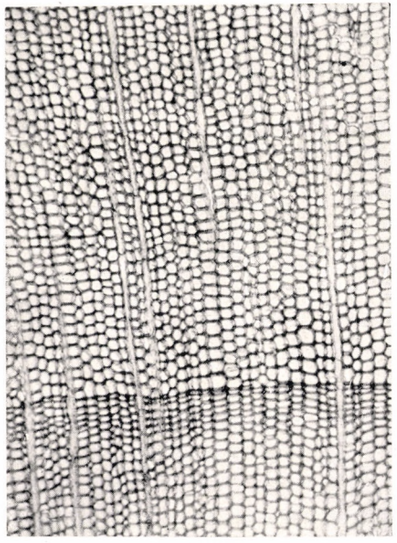
3. (300×)



4. (300×)



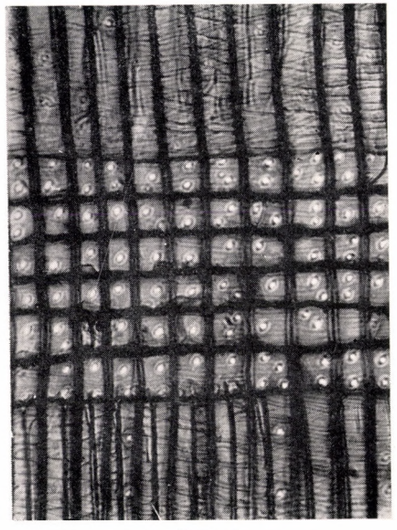
74. Cephalotaxus drupacea SIEB. et ZUCC.



1. (100×)



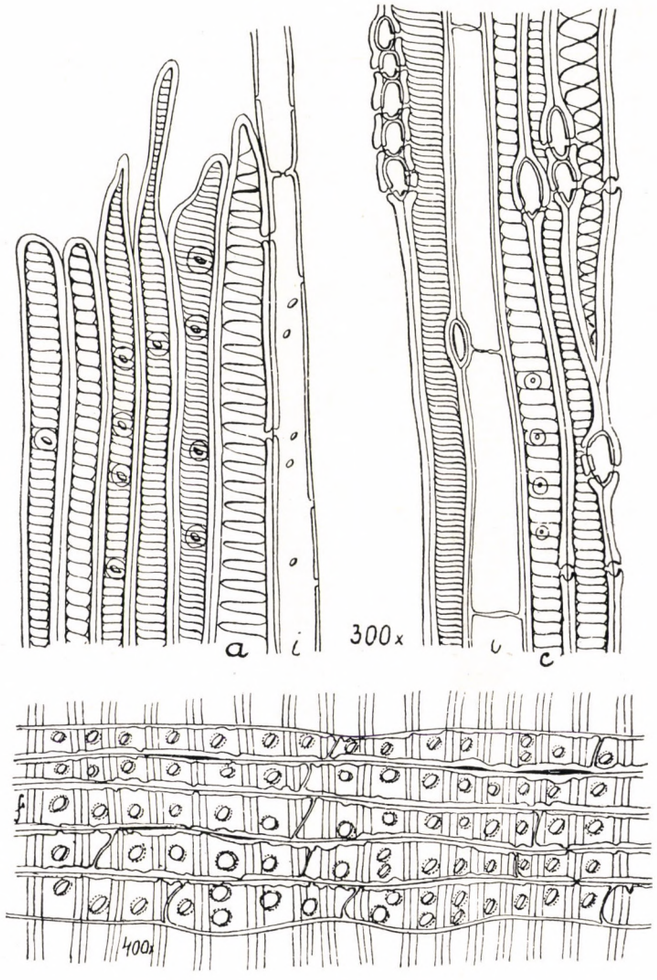
2. (100×)



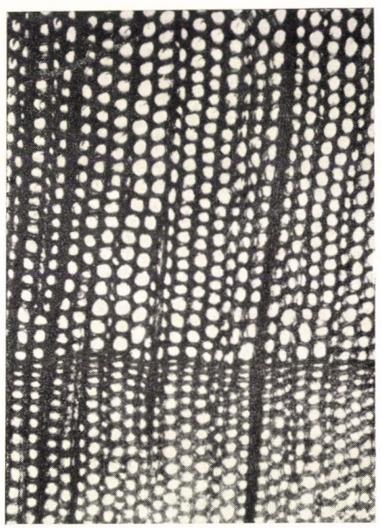
3. (300×)



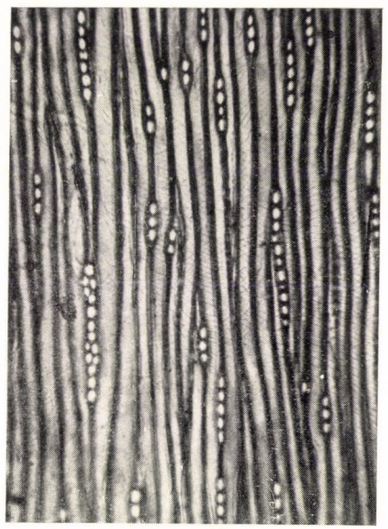
4. (300×)



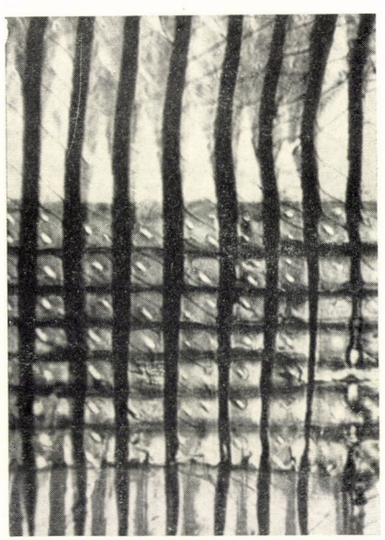
75. Cephalotaxus Fortunei Hook.



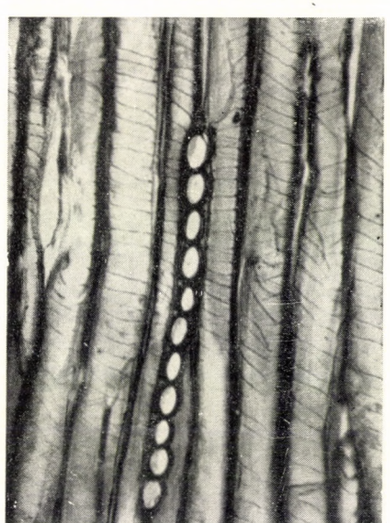
1. (100×)



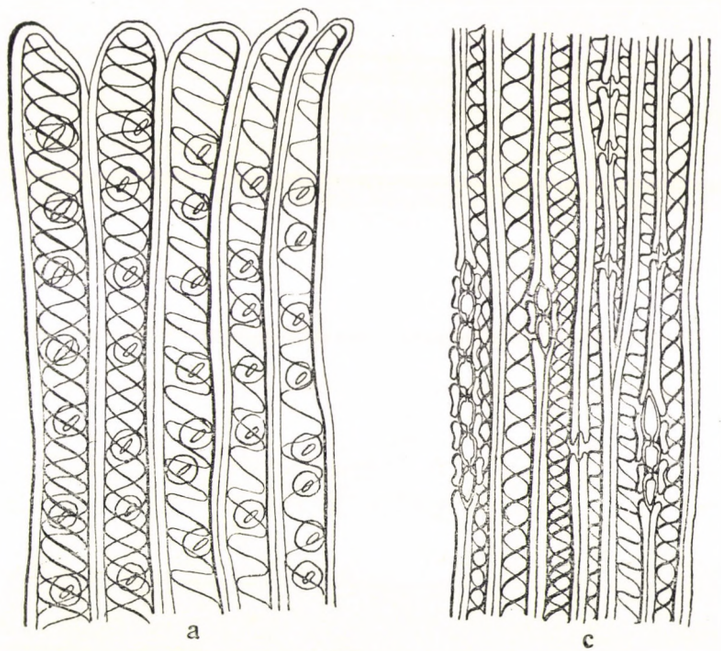
2. (100×)



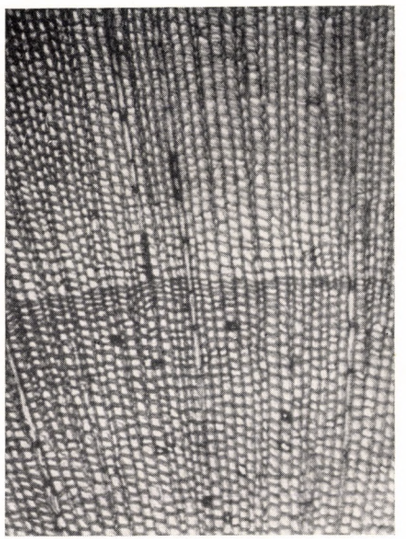
3. (300×)



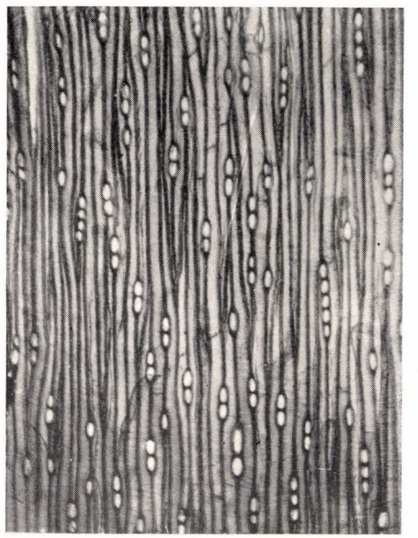
4. (300×)



76. Cephalotaxus Oliveri MAST.



1. (100×)



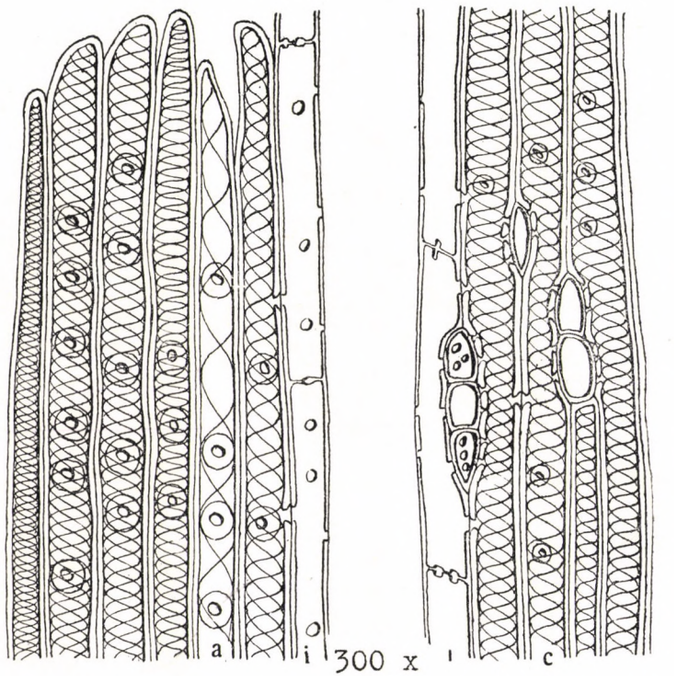
2. (100×)

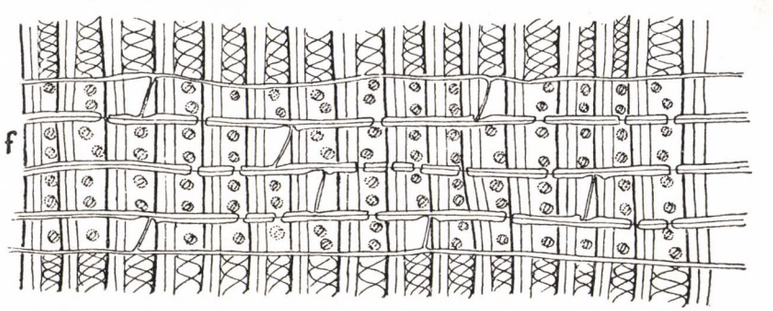


3. (300×)



4. (300×)

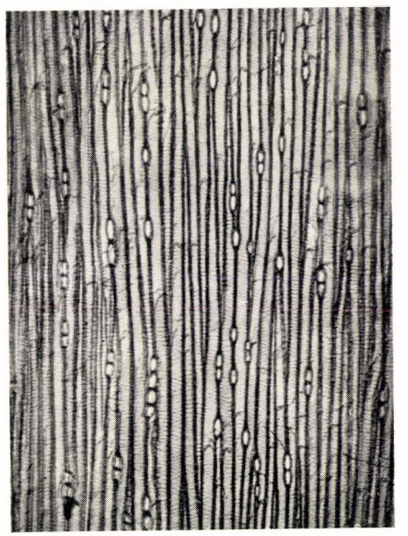




77. Cephalotaxus pedunculata SIEB. et ZUCC.



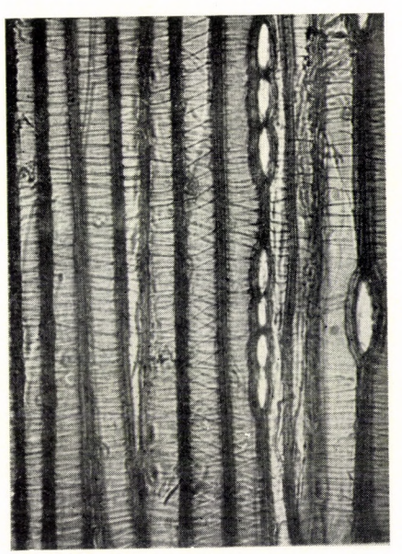
1. (100×)



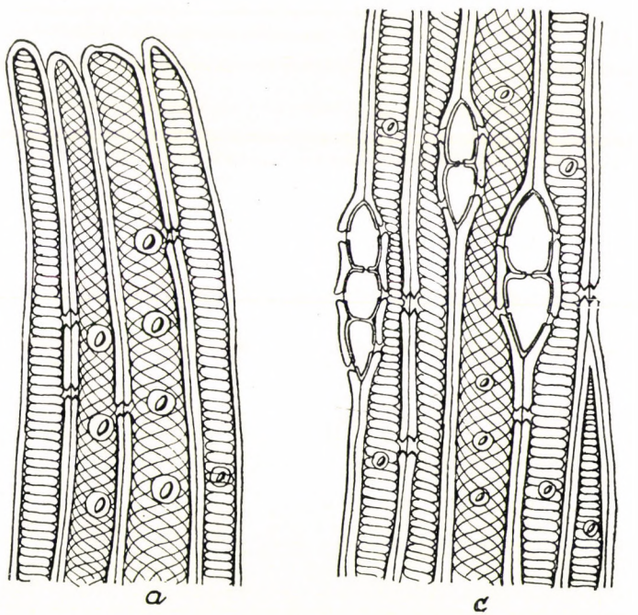
2. (100×)

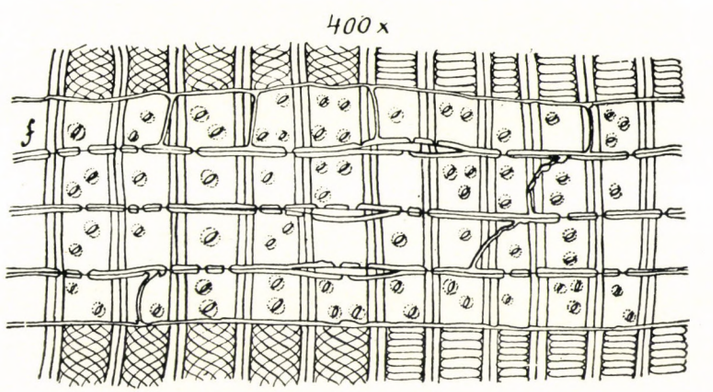


3. (300×)

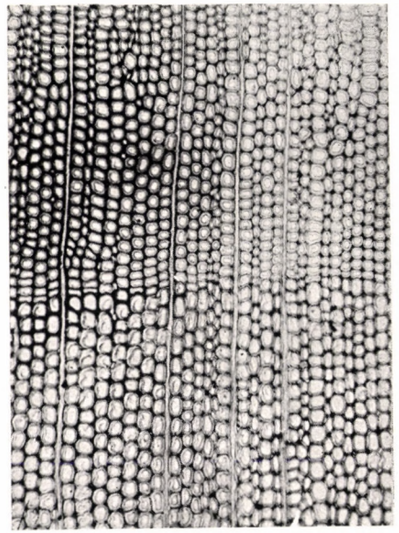


4. (300×)

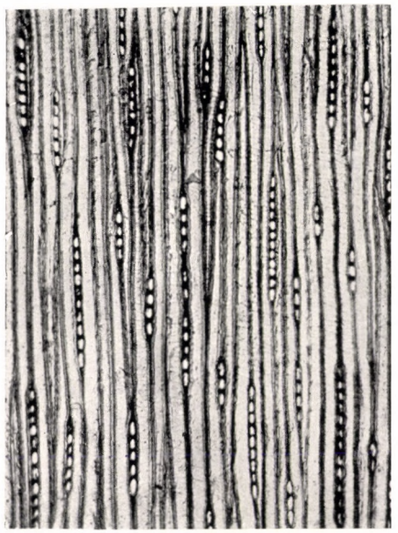




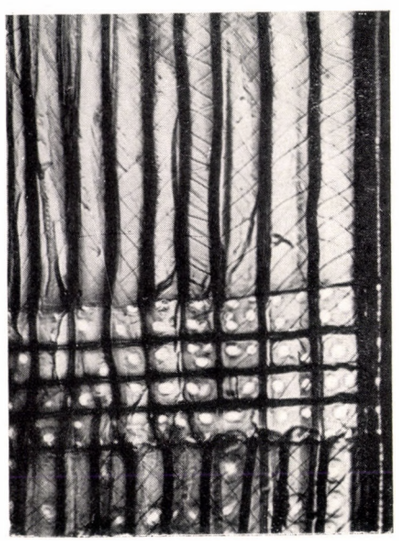
78. Nothotaxus Chienii Florin



1. (100×)



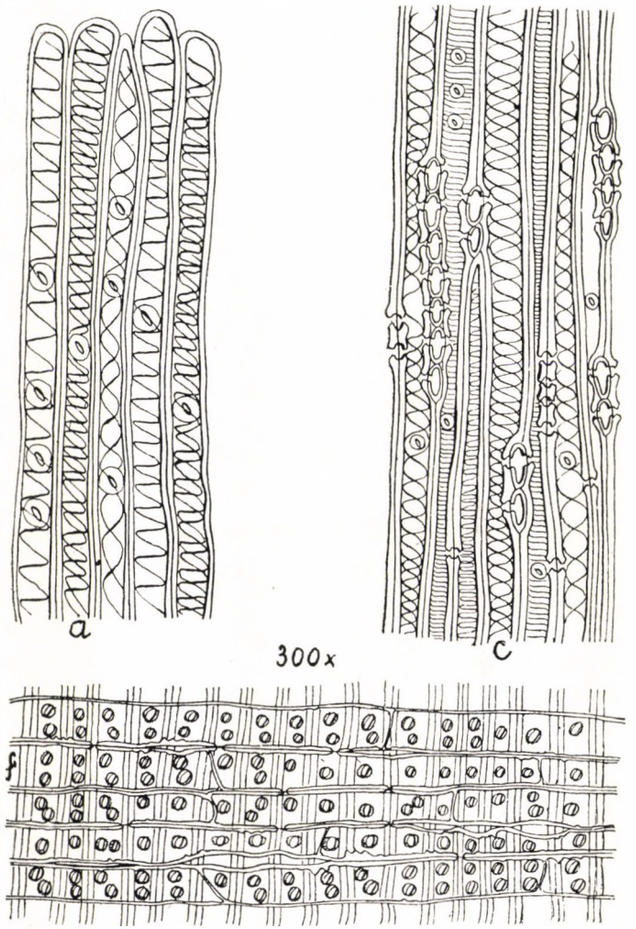
2. (100×)



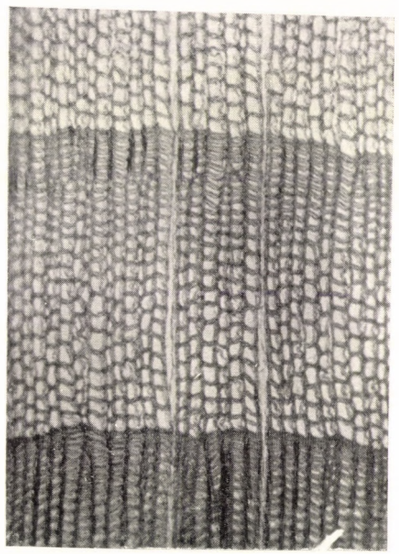
3. (300×)



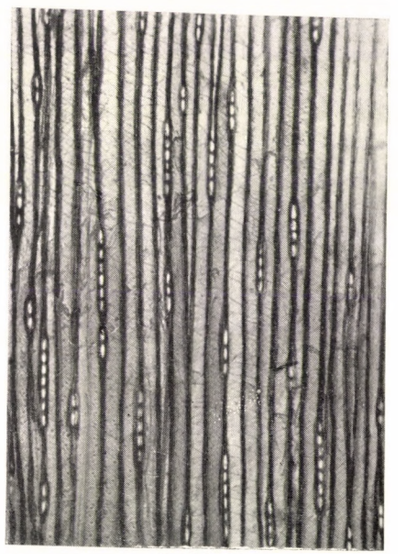
4. (300×)



79. Taxus baccata L.



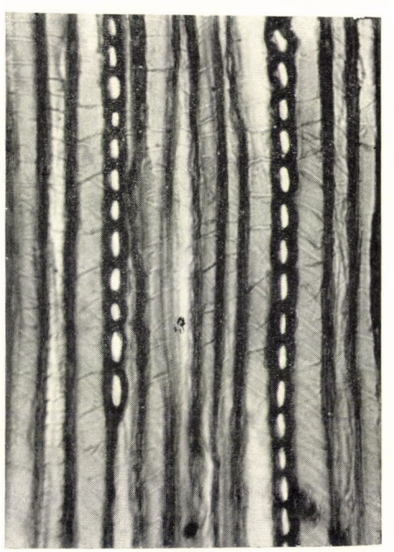
1. (100×)



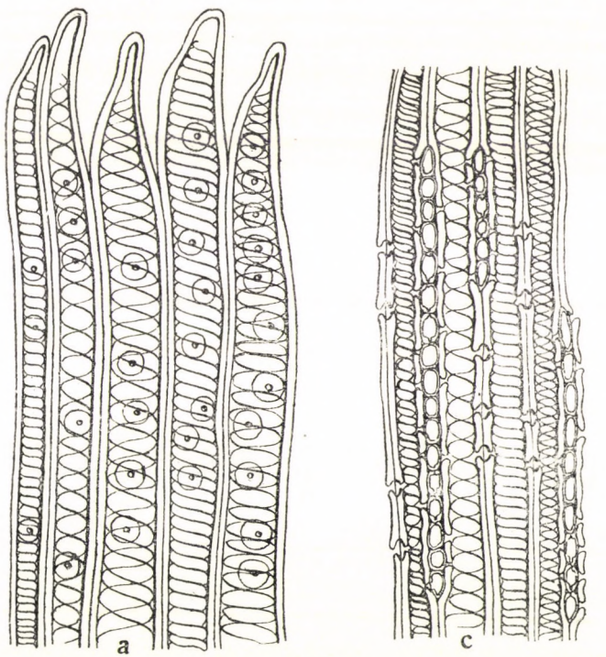
2. (100×)



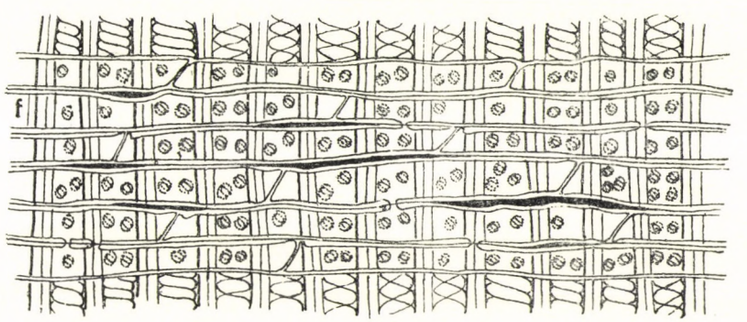
3. (300×)



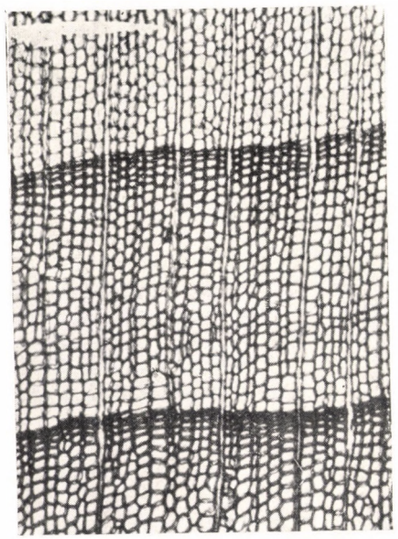
4. (300×)



300 x



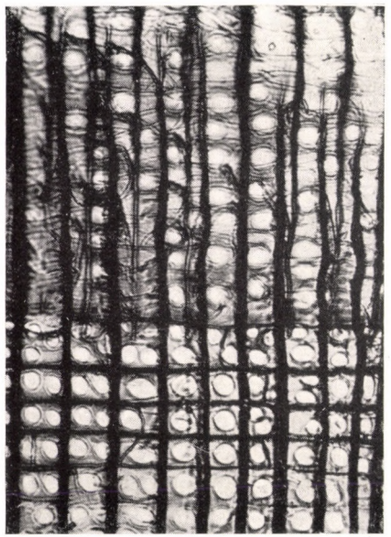
80. Taxus brevifolia NUTTAL



1. (100×)



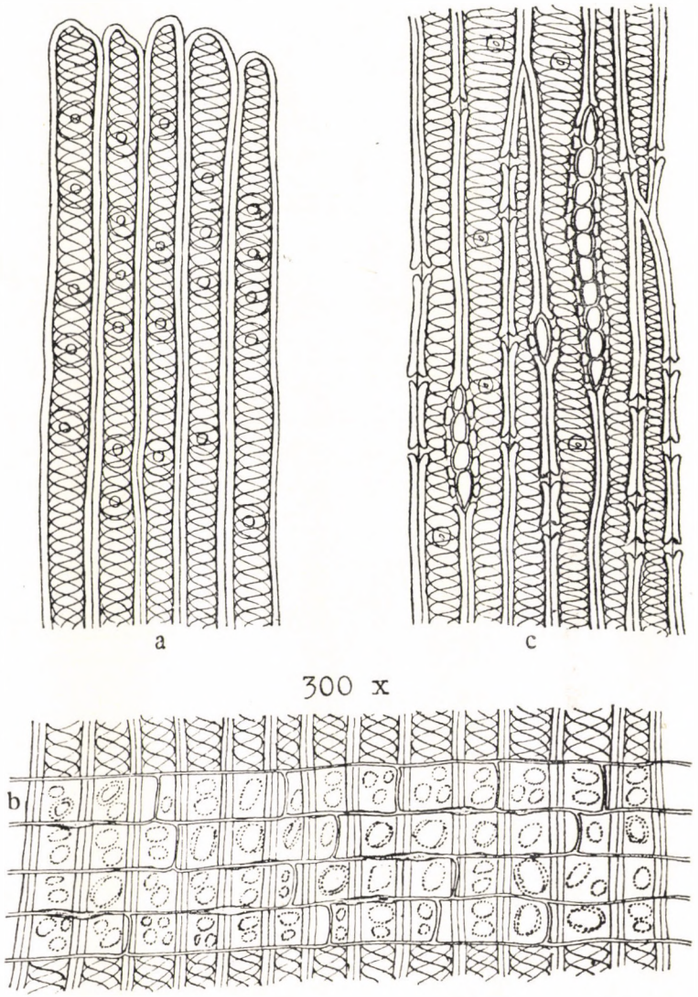
2. (100×)



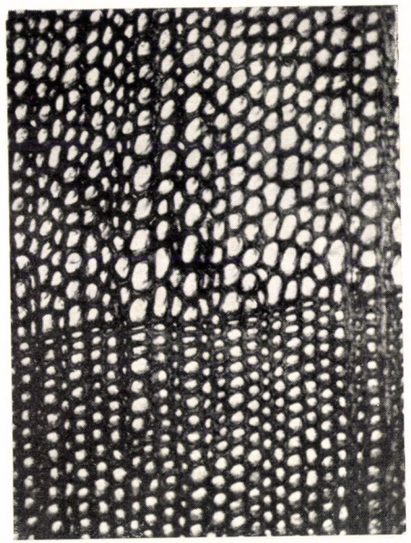
3. (300×)



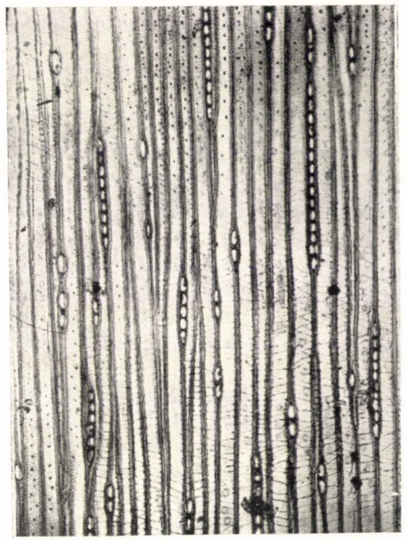
4. (300×)



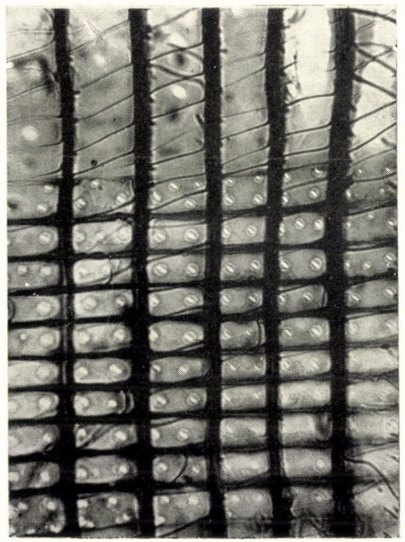
81. Taxus canadensis MARSHALL



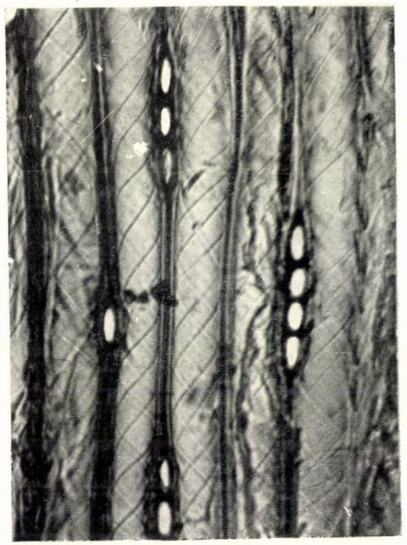
1. (100×



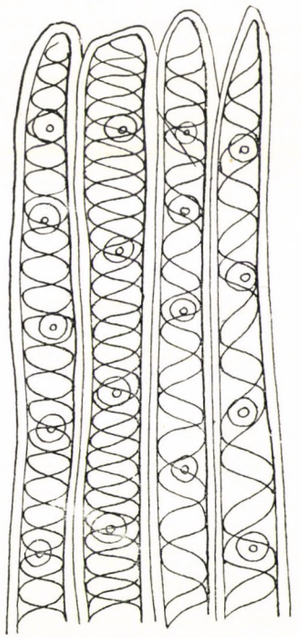
2. (100×)



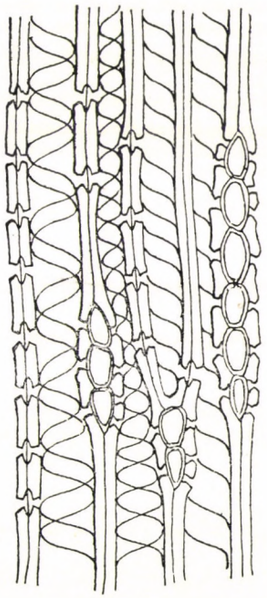
3. (300×)



4. (300×)

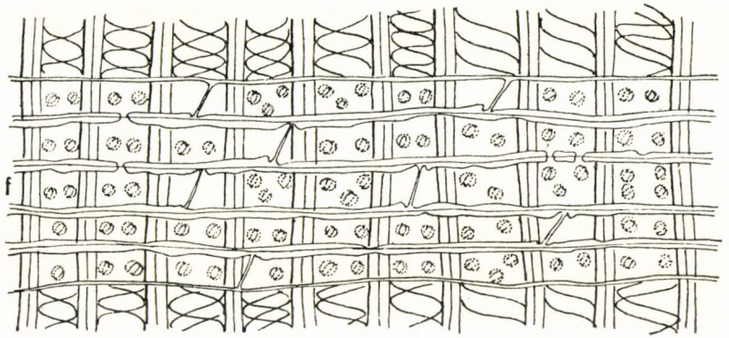


a



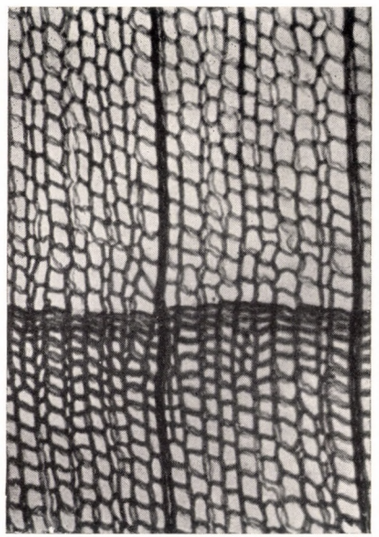
c

300 x



f

82. Taxus chinensis REHDER



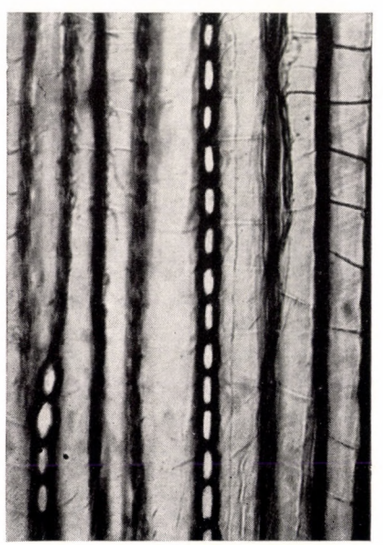
1. (100×)



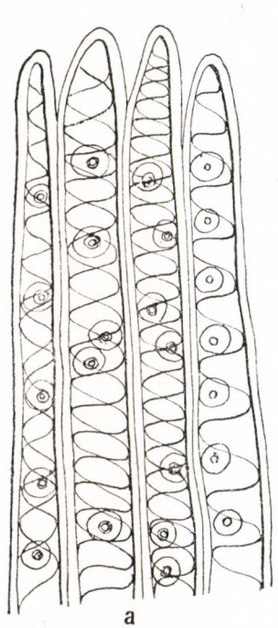
2. (100×)

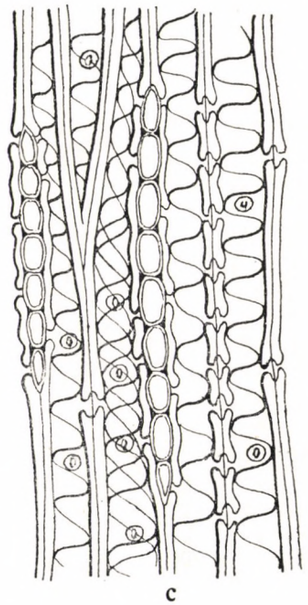


3. (300×)

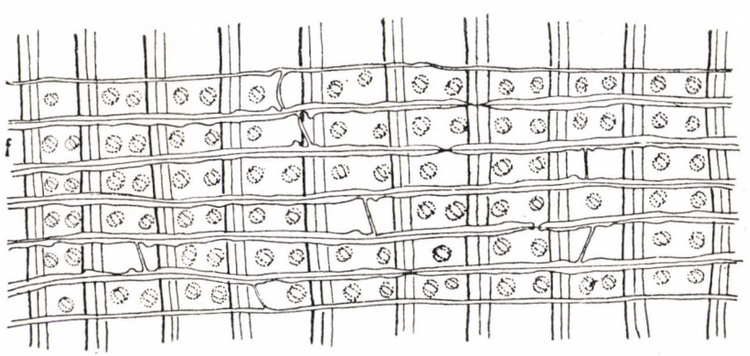


4. (300×)





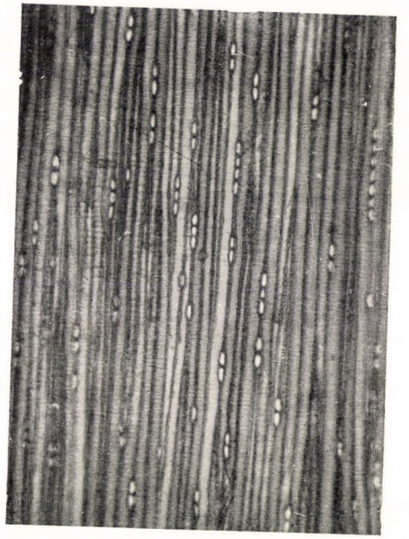
300 x



83. Taxus cuspidata SIEB. et ZUCC.



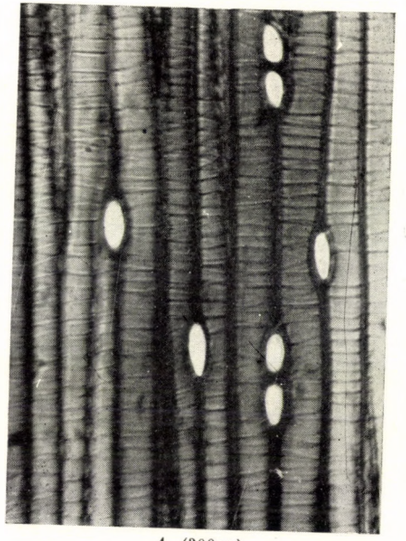
1. (100×)



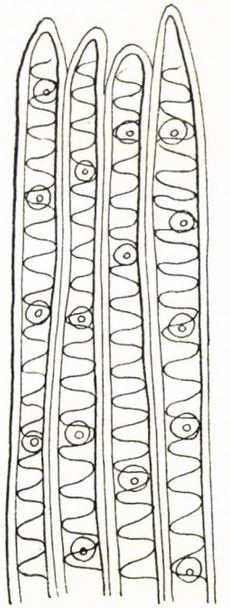
2. (100×)

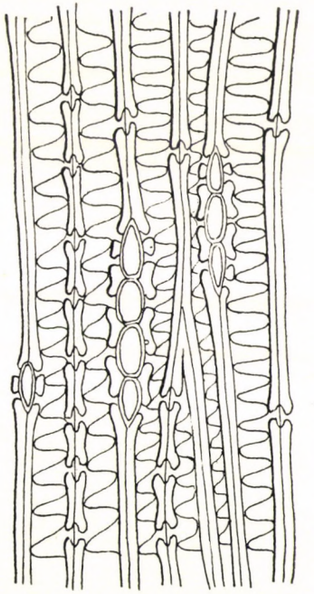


3. (300×)

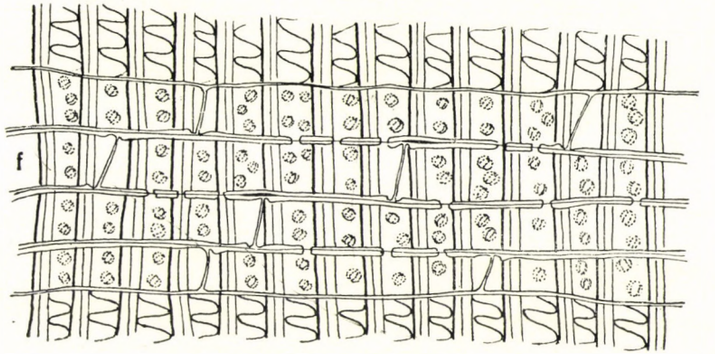


4. (300×)

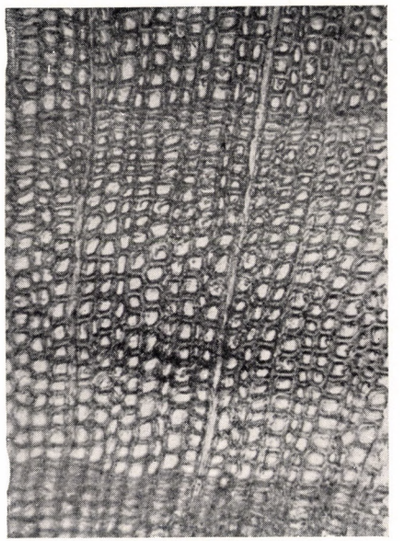




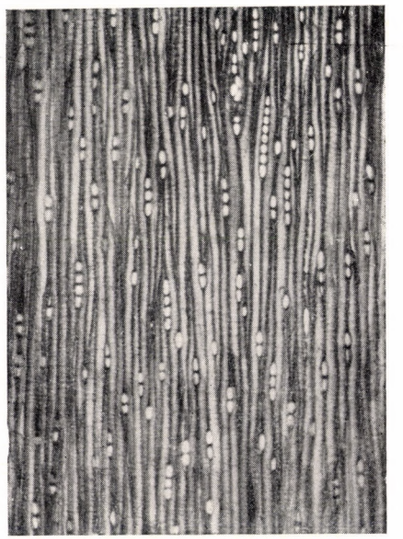
300 x



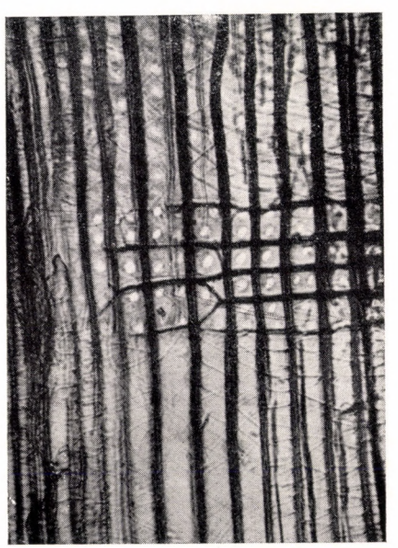
84. Taxus speciosa FLORIN



1. (100×)



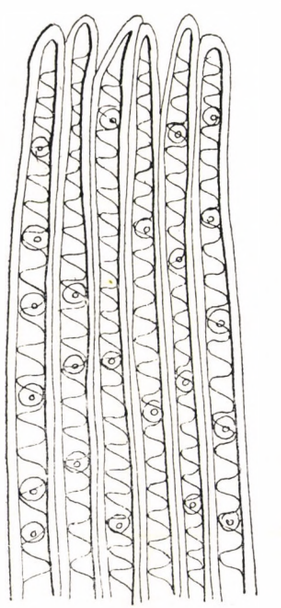
2. (100×)

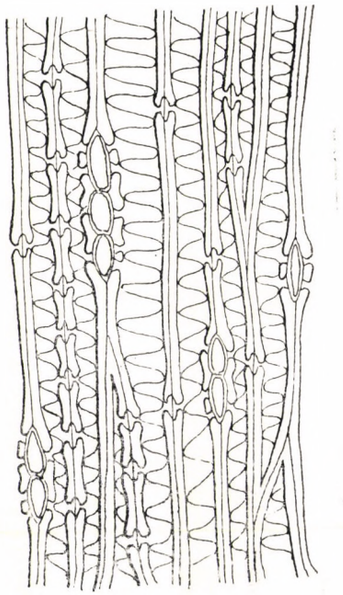


3. (300×)

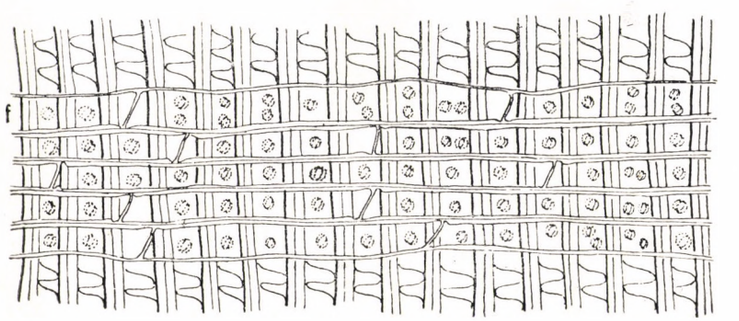


4. (300×)

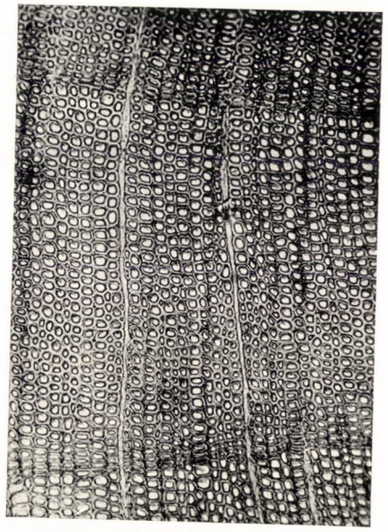




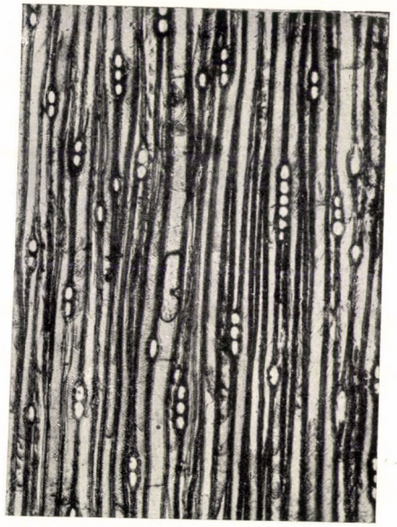
300 x



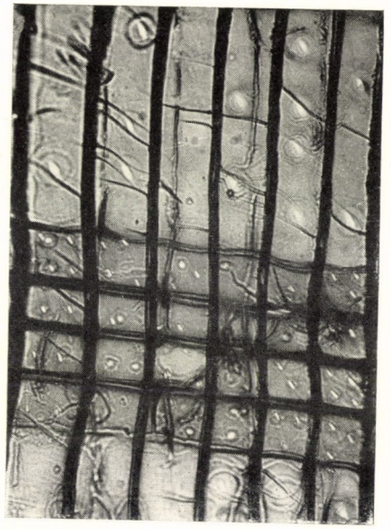
85. Taxus Wallichiana Zucc.



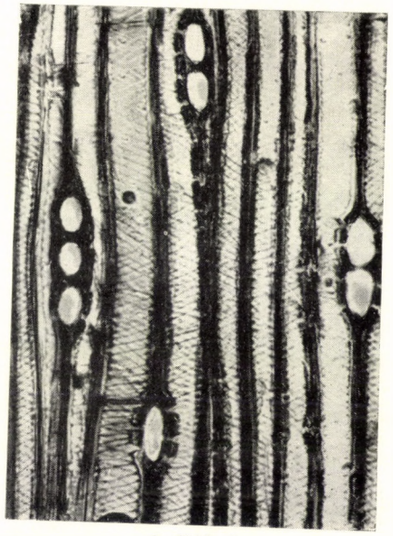
1. (100×)



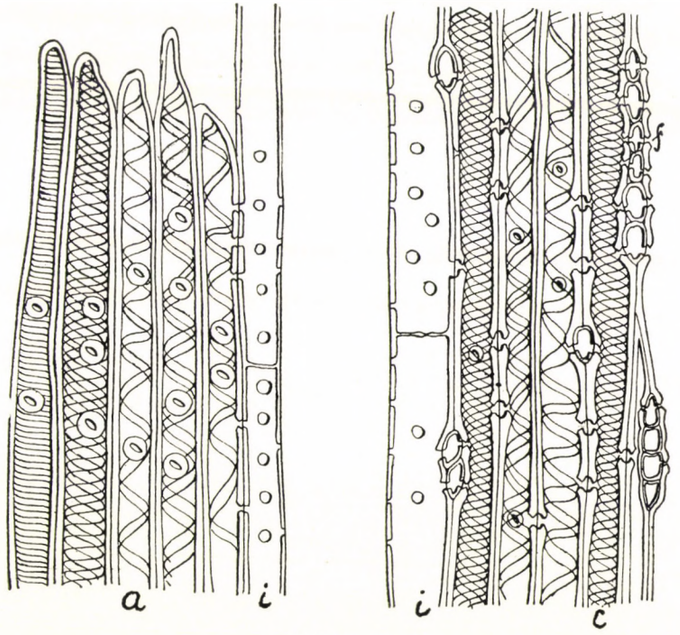
2. (100×)



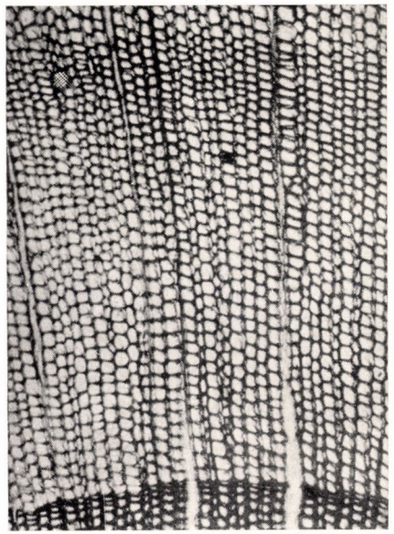
3. (300×)



4. (300×)



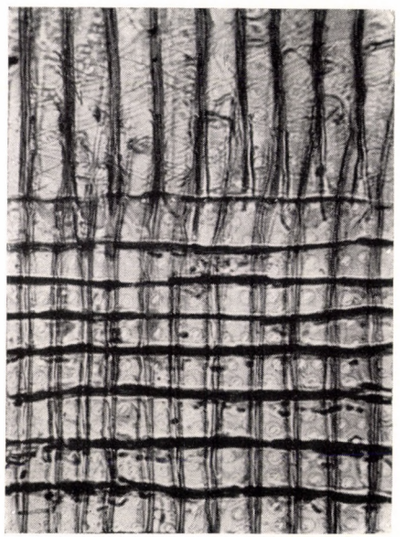
86. Torreya californica TORREY



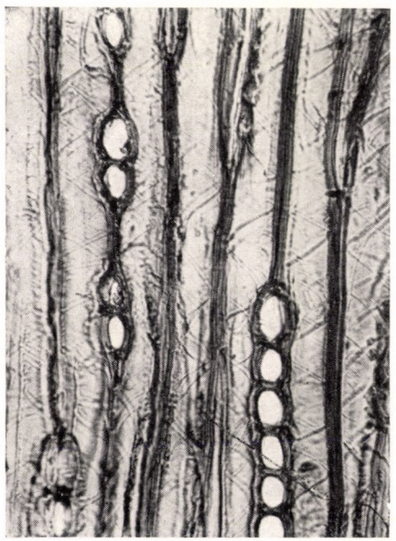
1. (100×)



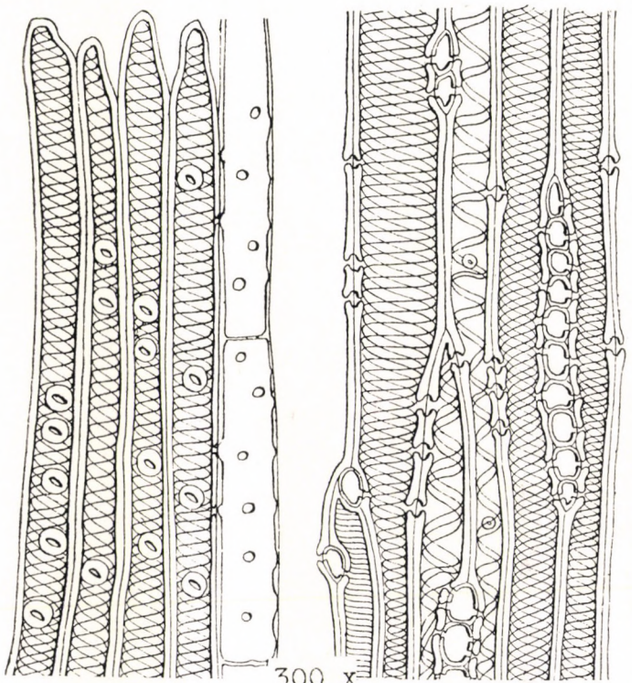
2. (100×)

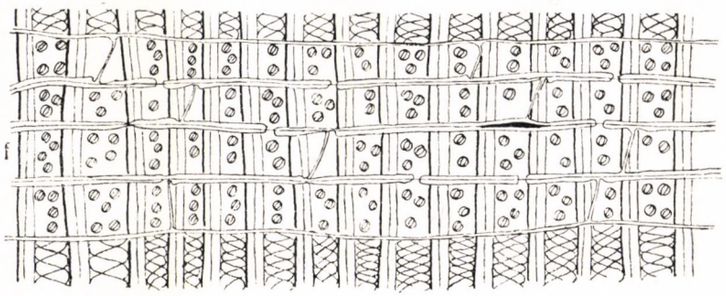


3. (300×)

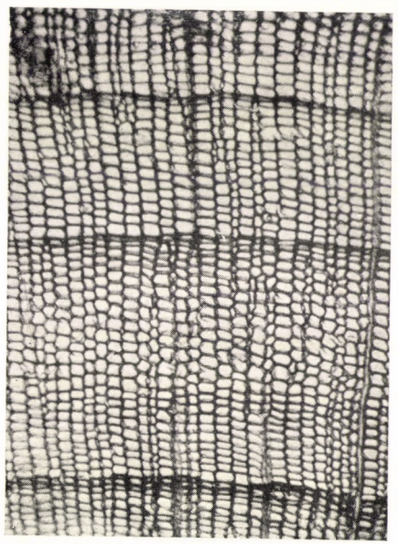


4. (300×)

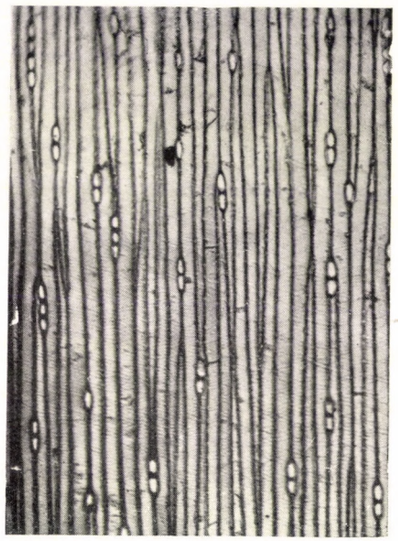




87. Torreya grandis FORTUNE



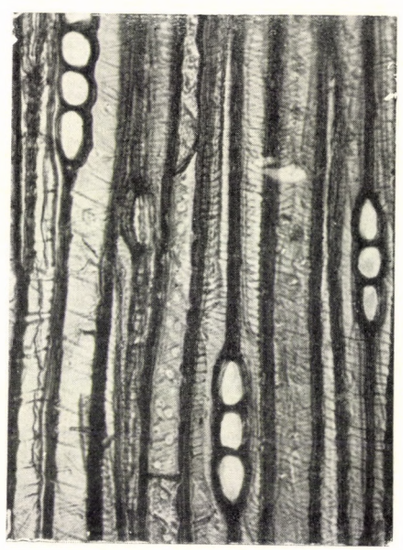
(1. 100×)



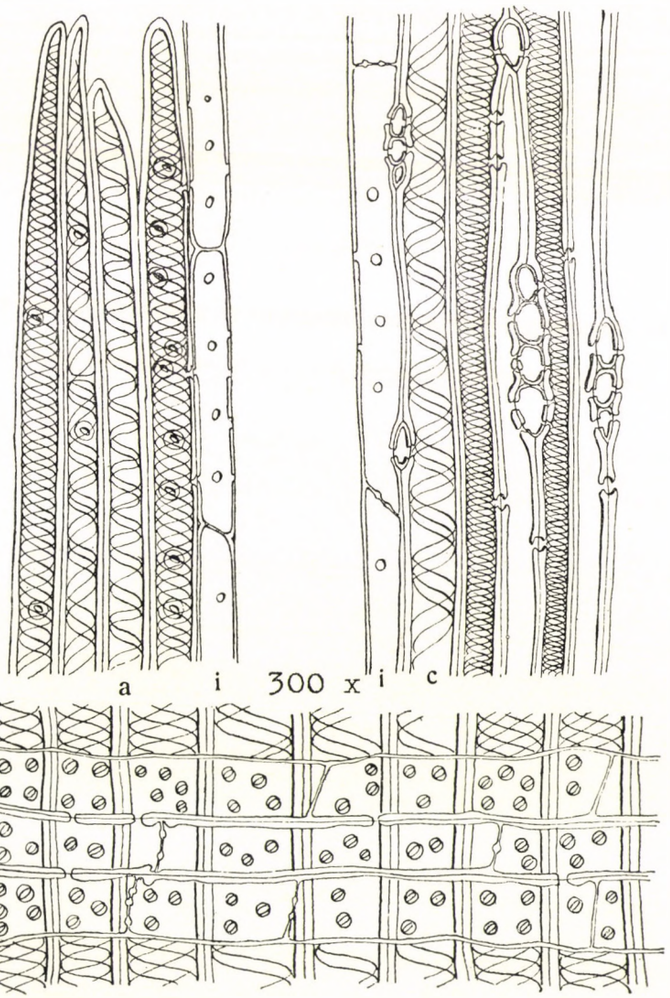
2. (100×)



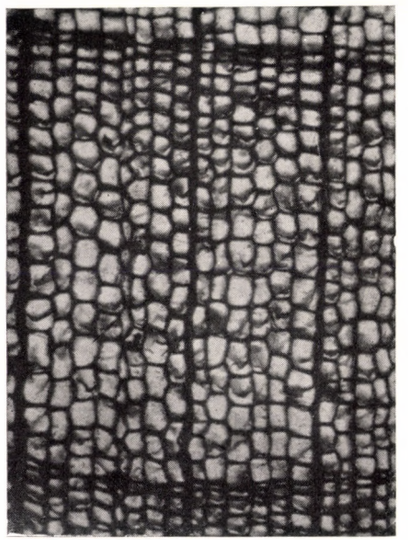
3. (300×)



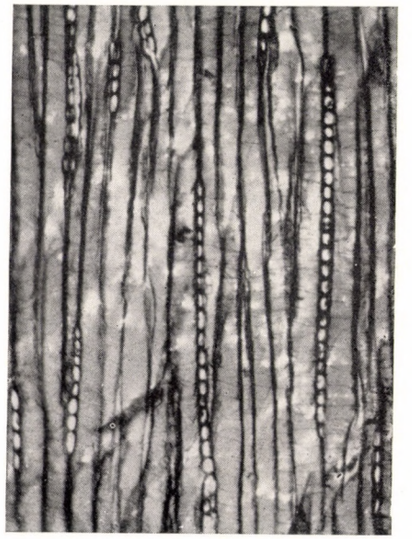
4. (300×)



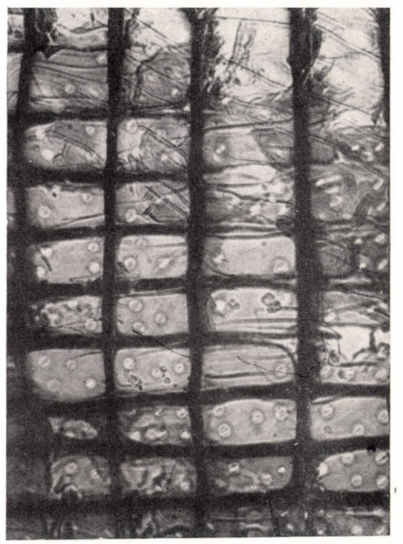
88. Torreya nucifera SIEB. et ZUCC.



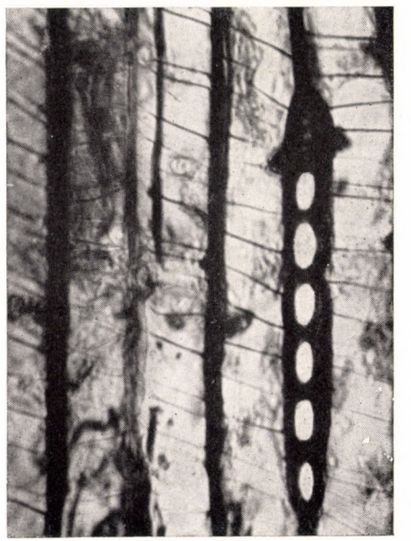
1. (100×)



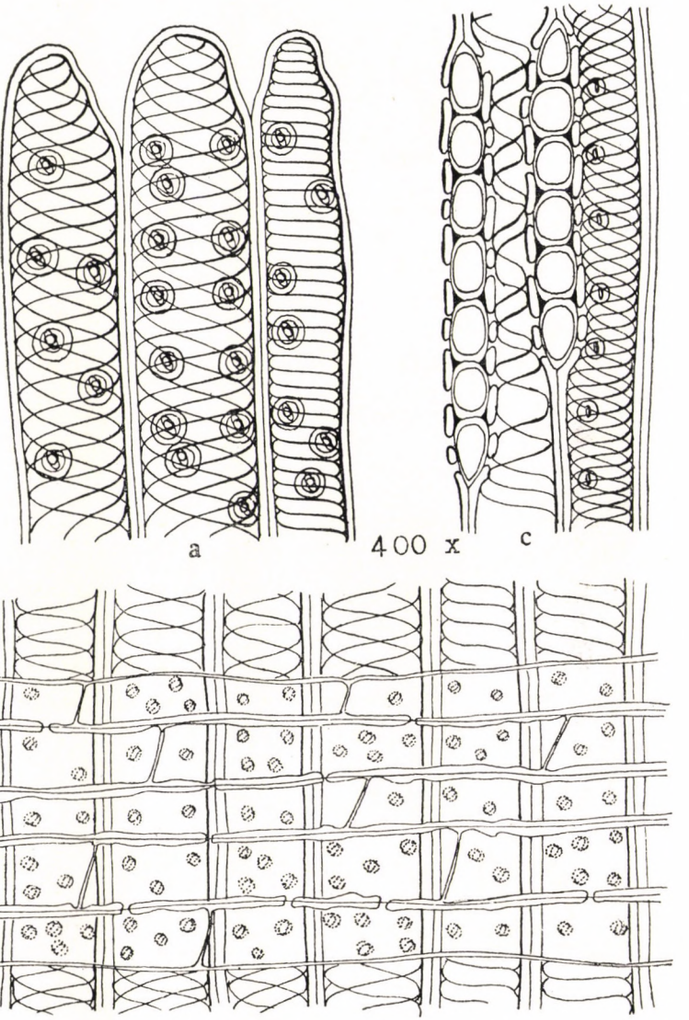
2. (100×)



3. (300×)



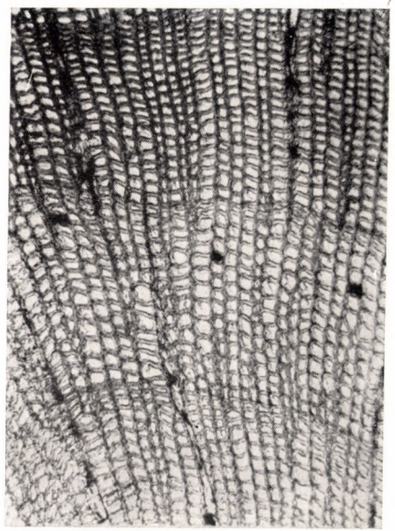
4. (300×)



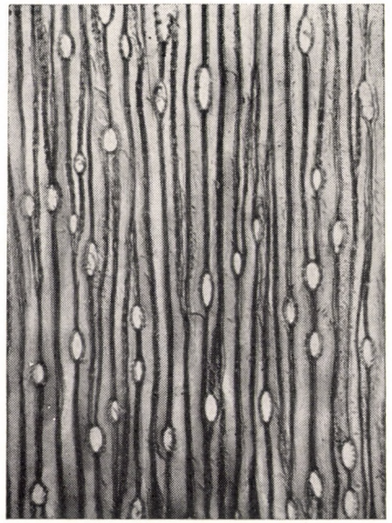
89. Torreya taxifolia ARNOTT

VI.

CUPRESSACEAE



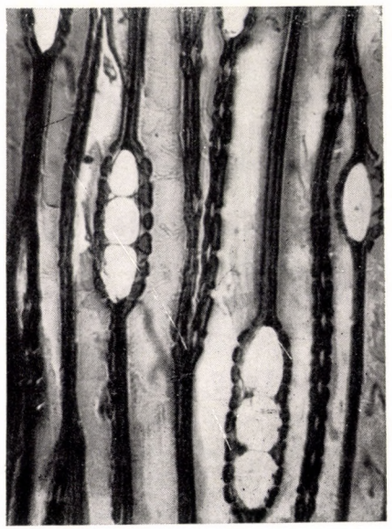
1. (100×)



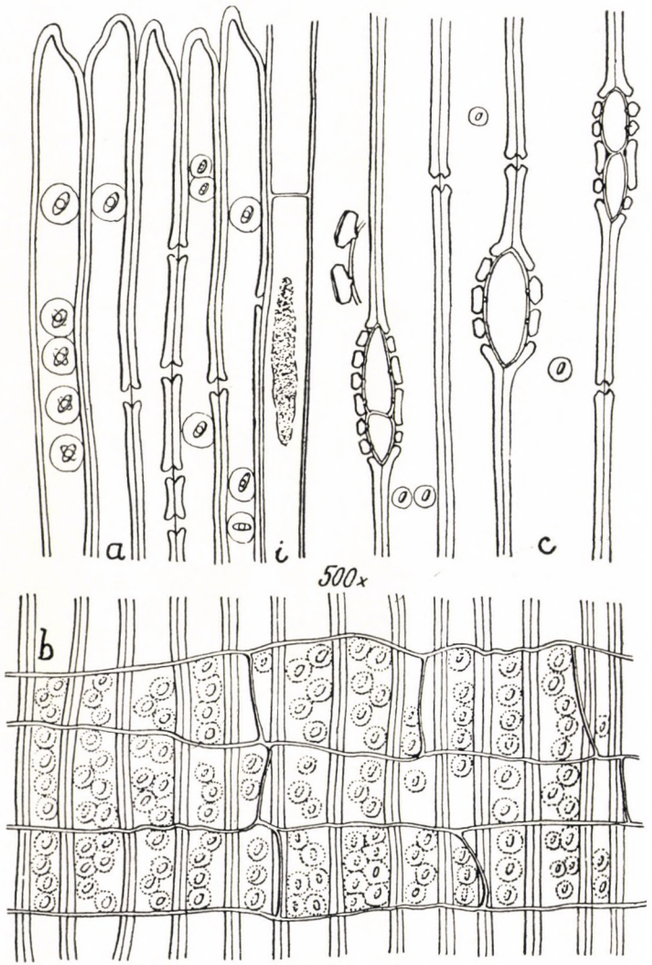
2. (100×)



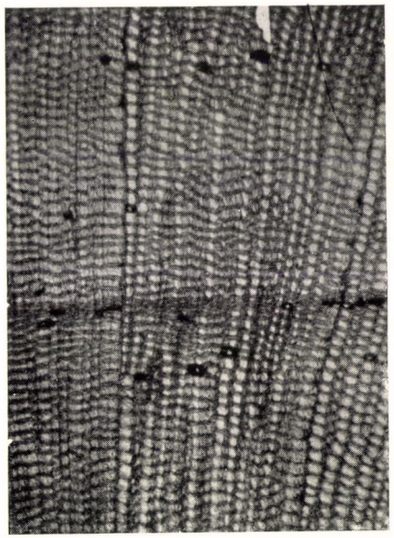
3. (300×)



4. (300×)



90. Actinostrobus acuminatus PARL.



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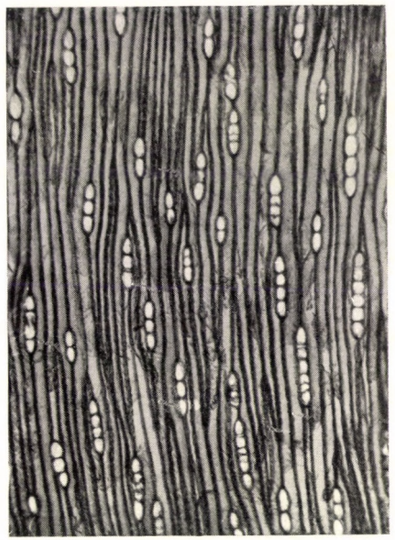
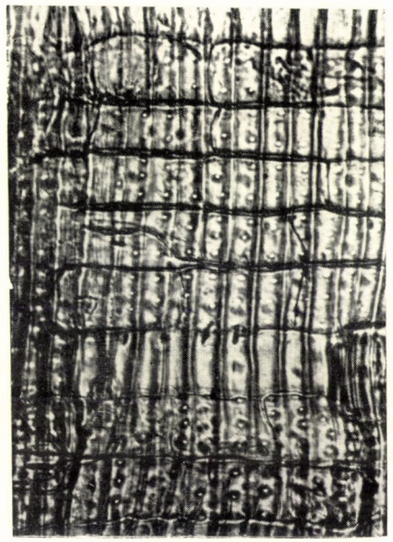
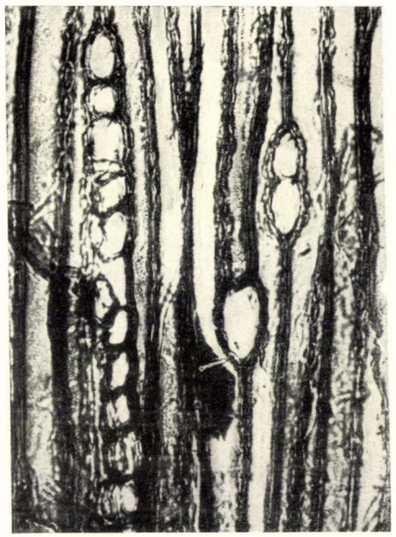


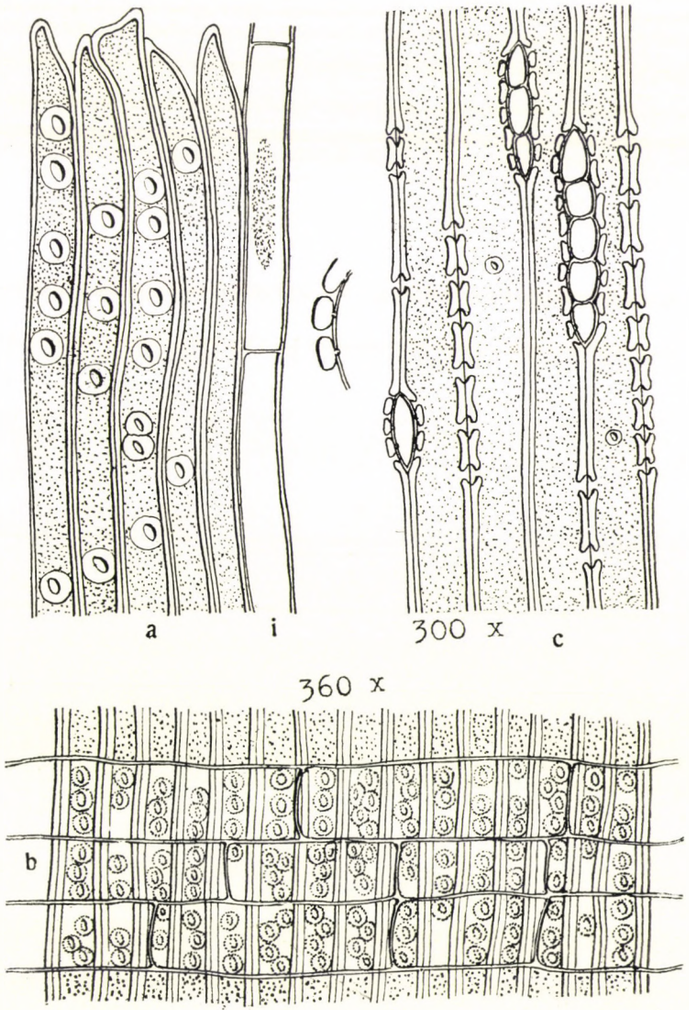
2. (100×)



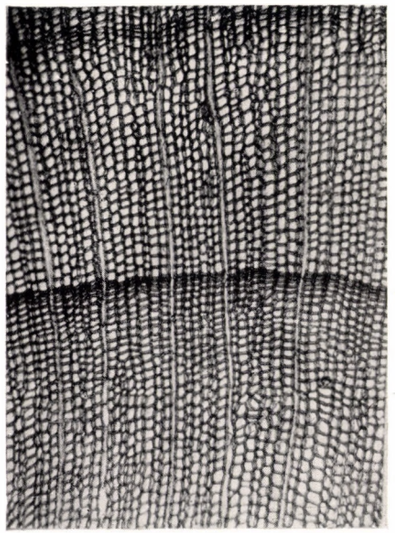
3. (300×)



4. (300×)



91. Actinostrobus pyramidalis MIQUEL



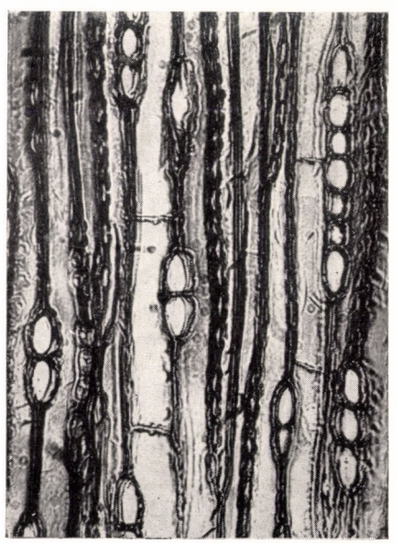
1. (100×)



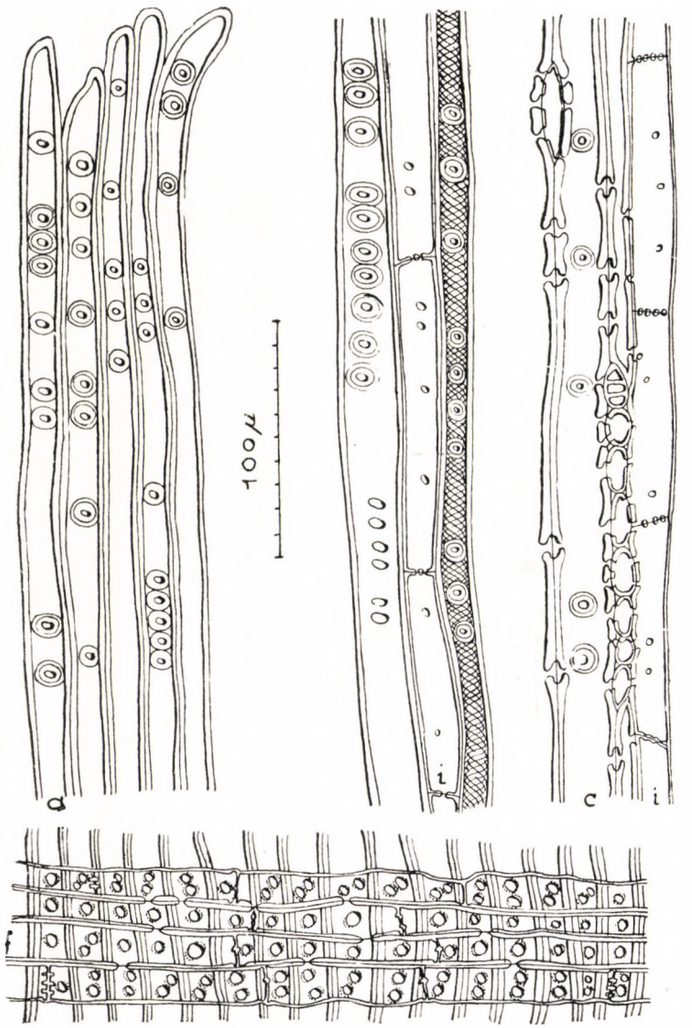
2. (100×)



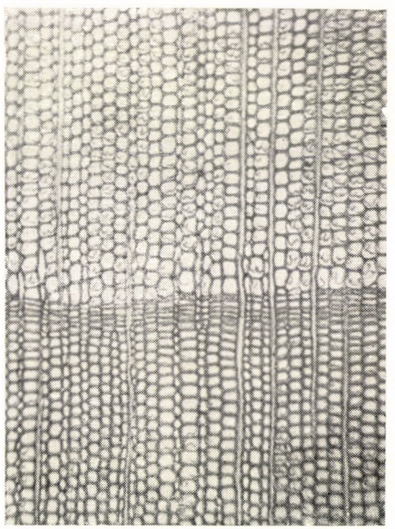
3. (300×)



4. (300×)



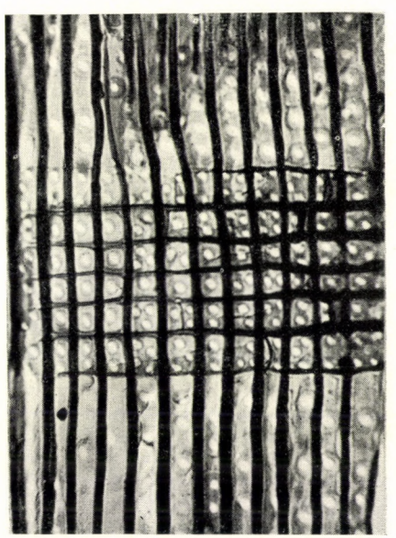
92. Arceuthos drupacea ANTOINE



1. (100×)



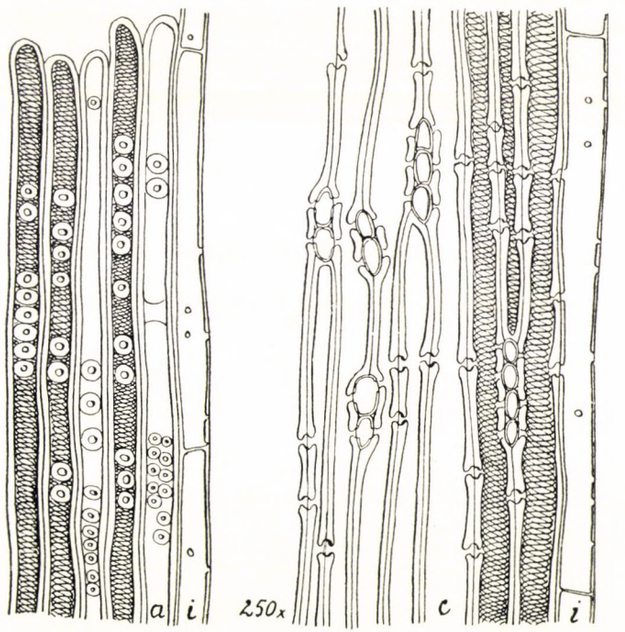
2. (100×)

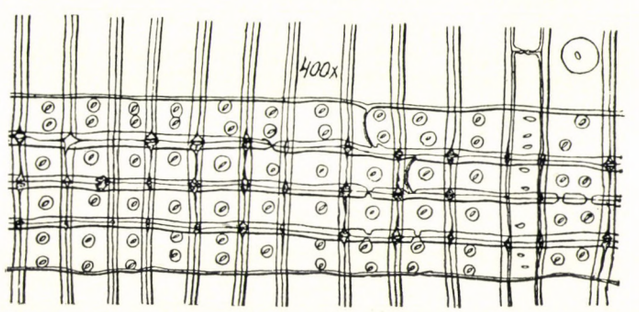


3. (300×)

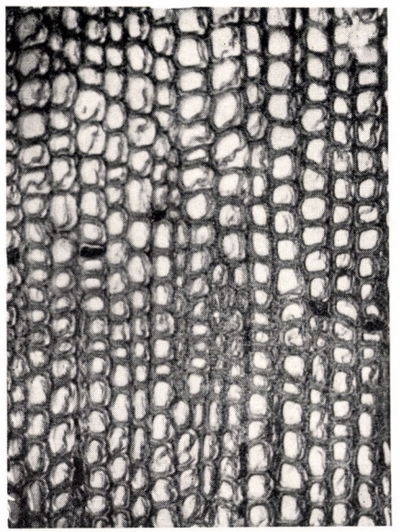


4. (300×)





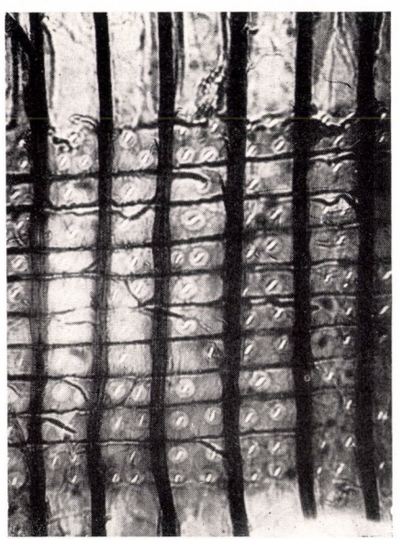
93. Biota orientalis ENDL.



1. (100×)



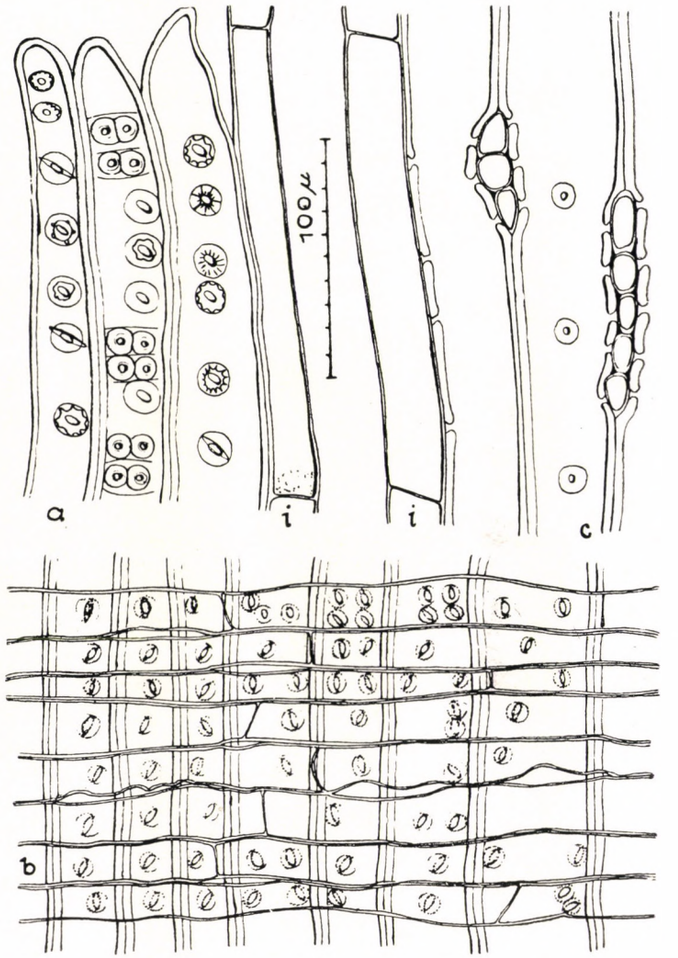
2. (100×)



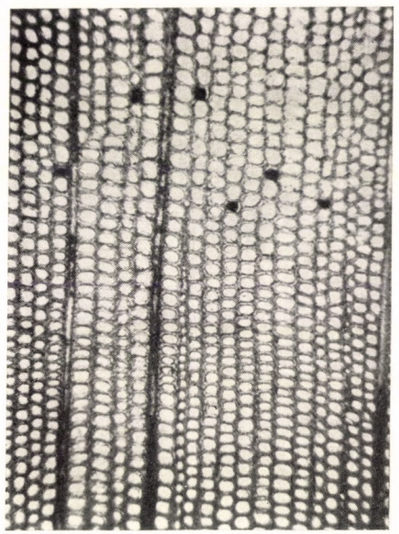
3. (300×)



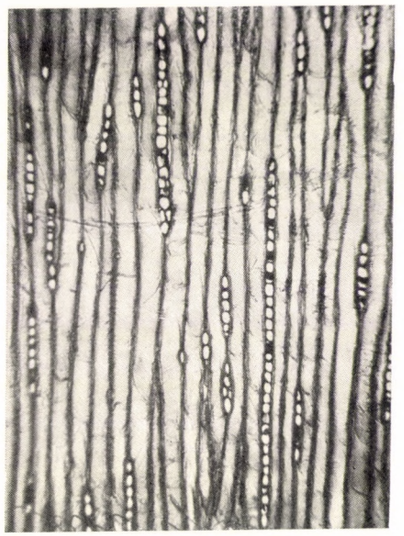
4. (300×)



94. Callitris cupressiformis VENTENAT



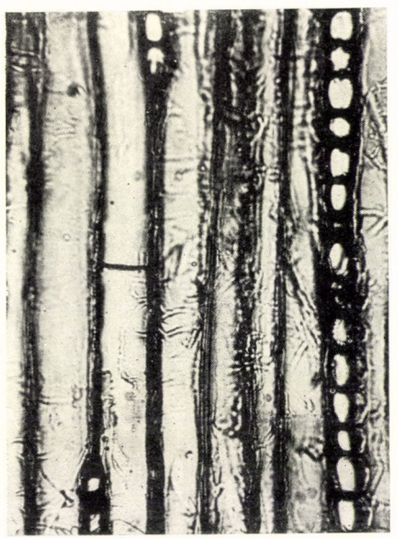
1. (100×)



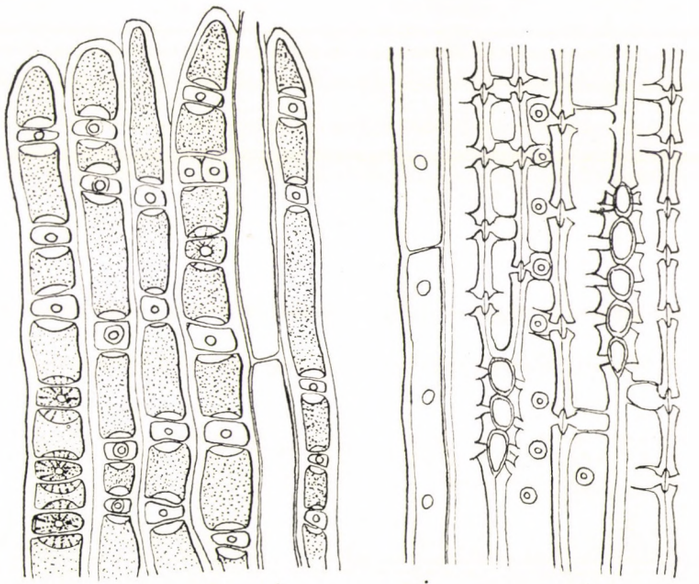
2. (100×)



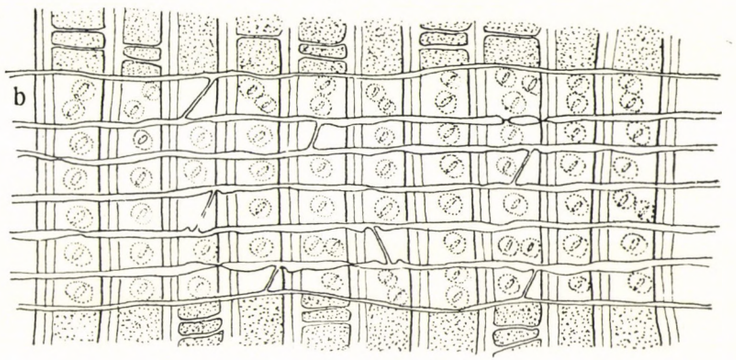
3. (300×)



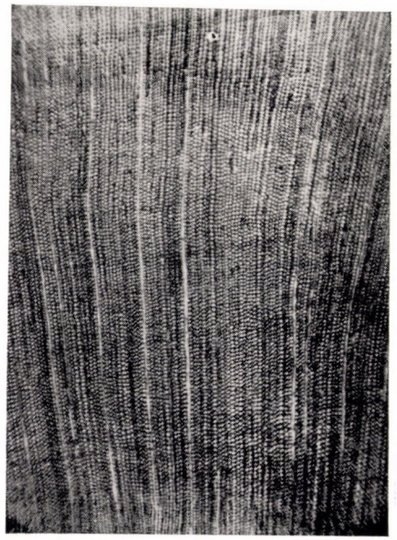
4. (300×)



300 x



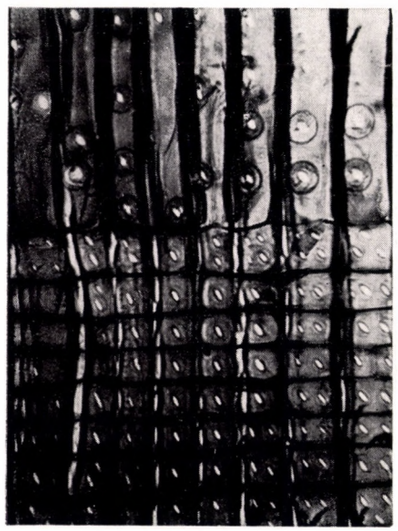
95. Callitris glauca R. Br.



1. (30×)



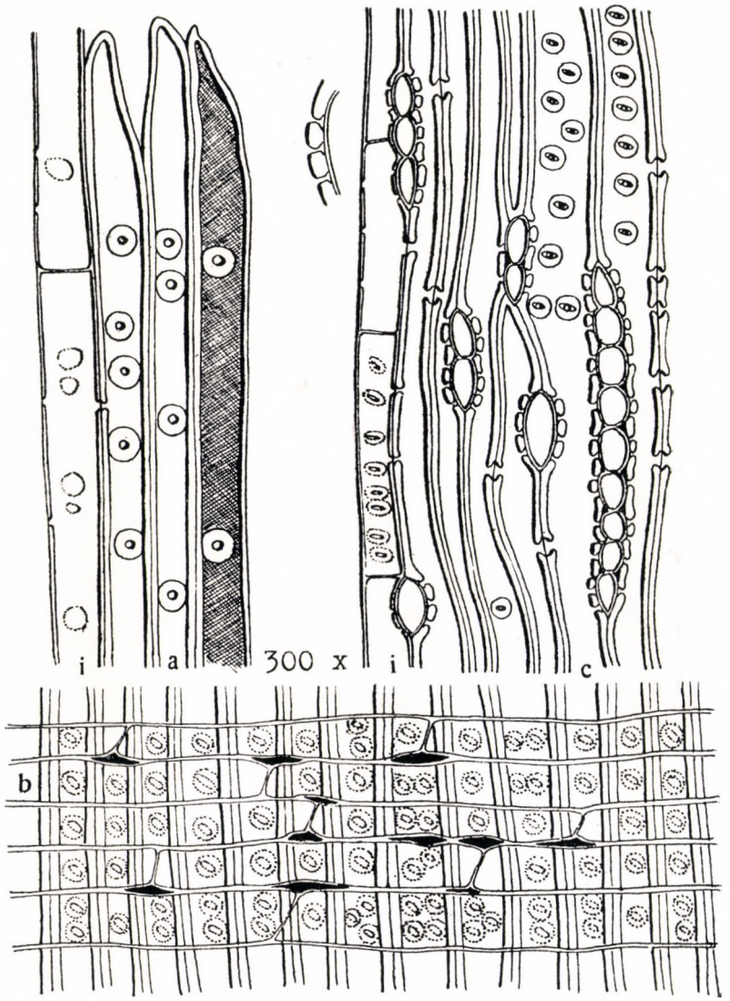
2. (100×)



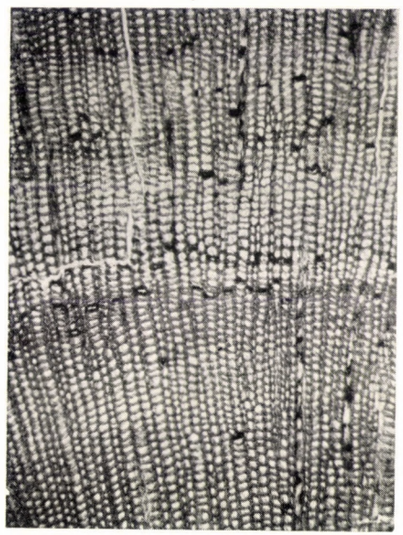
3. (300×)



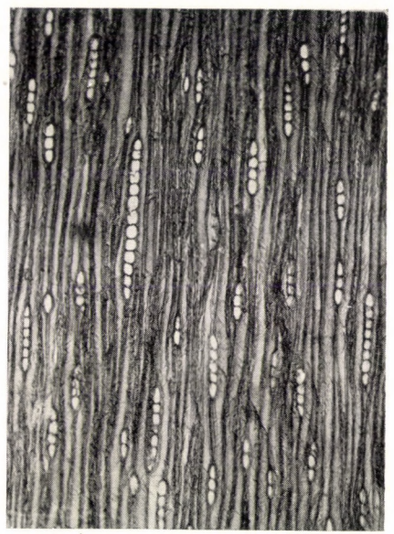
4. (300×)



96. Callitris intratropica Bent. et Hook.



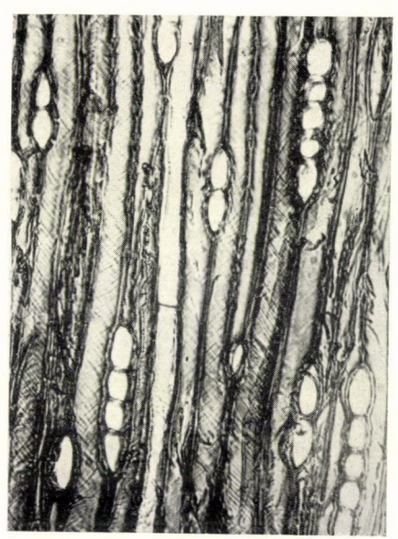
1. (100×)



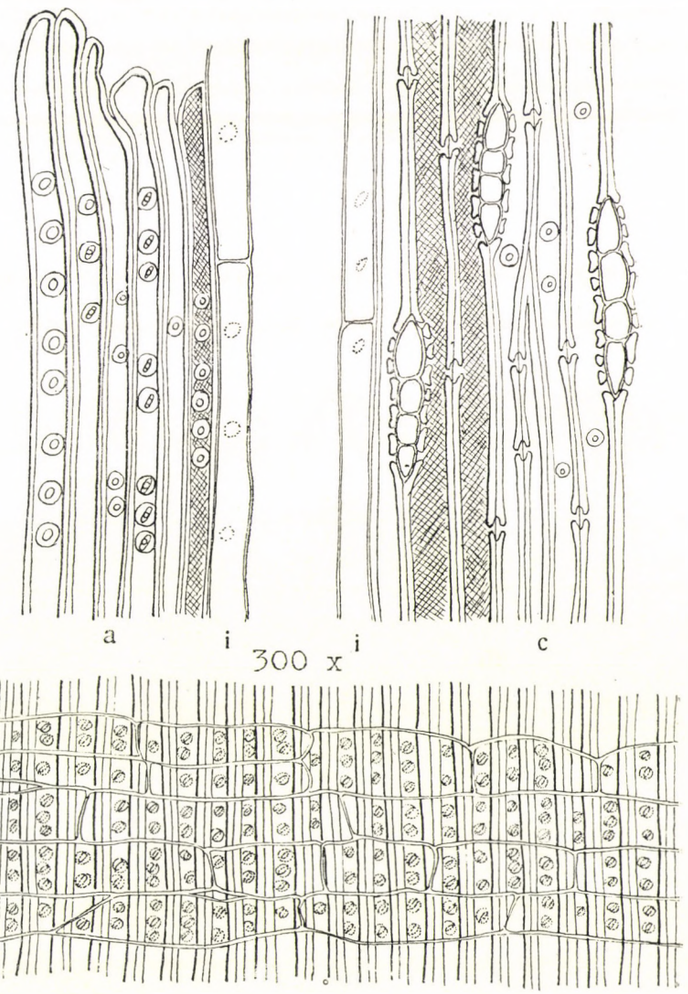
2. (100×)



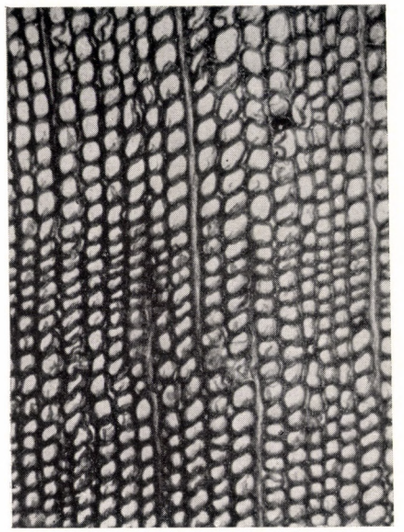
3. (300×)



4. (300×)



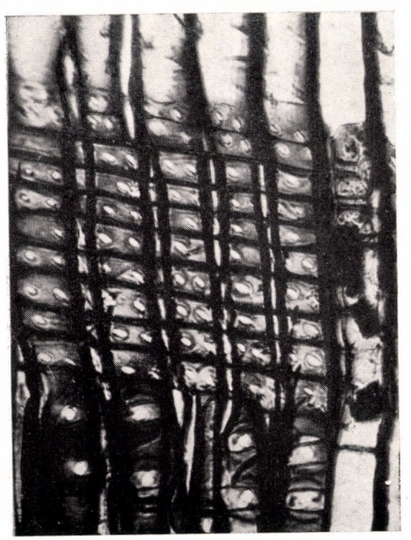
97. Callitris oblonga RICH.



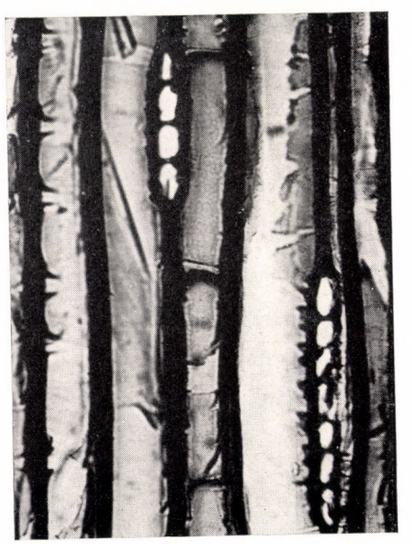
1. (100×)



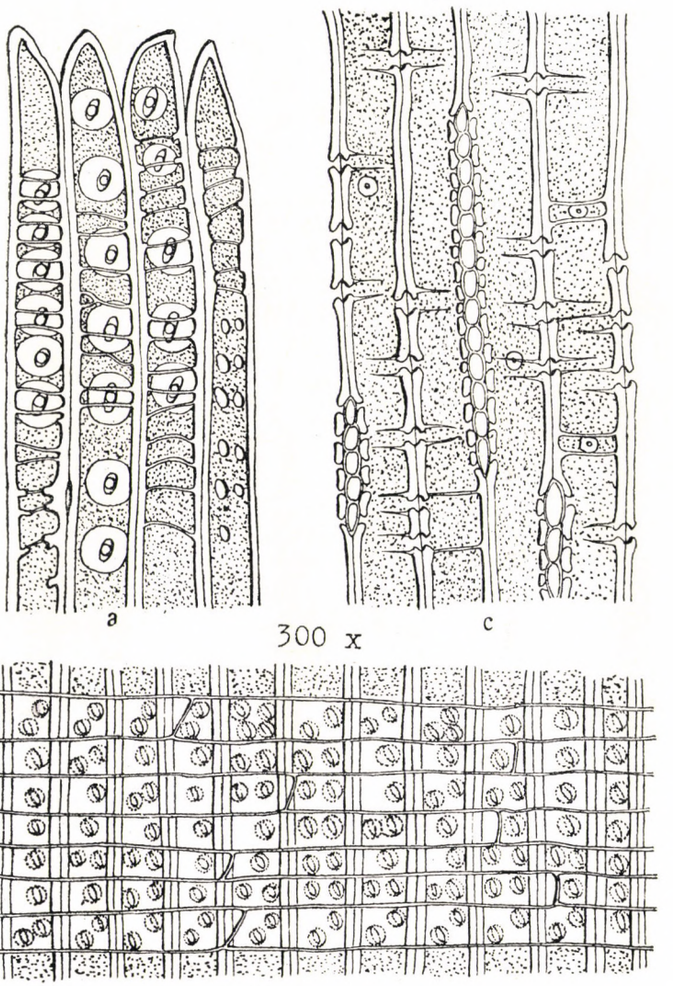
2. (100×)



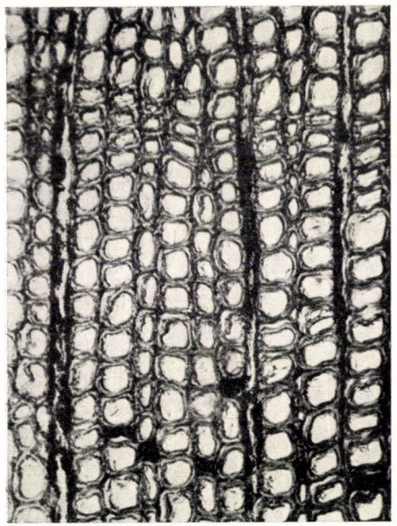
3. (300×)



4. (300×)



98. Callitris robusta R. Br.



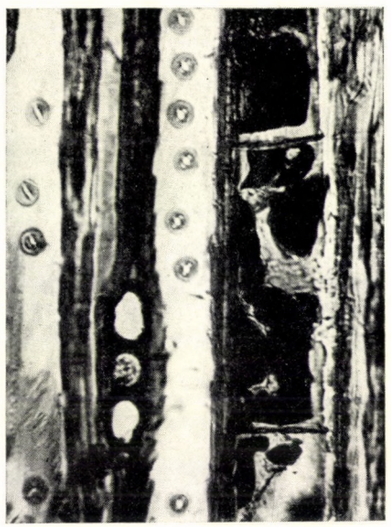
1. (100×)



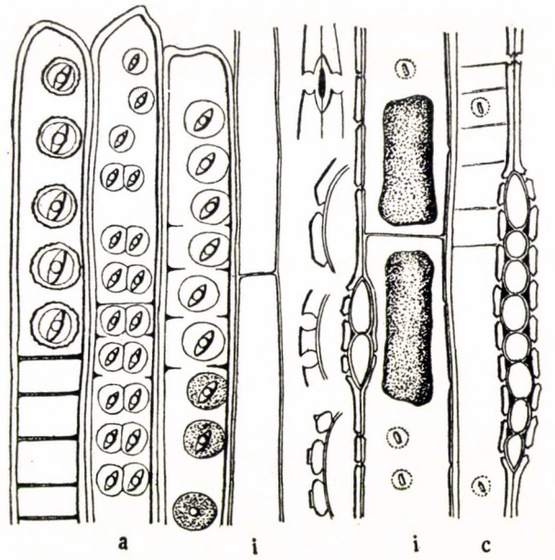
2. (100×)

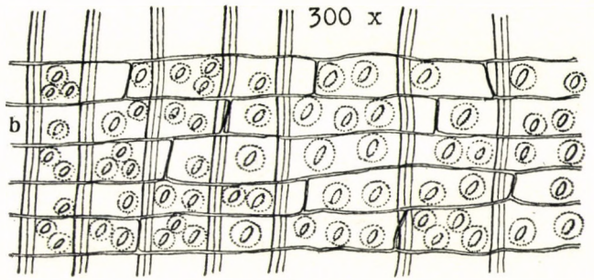


3. (300×)

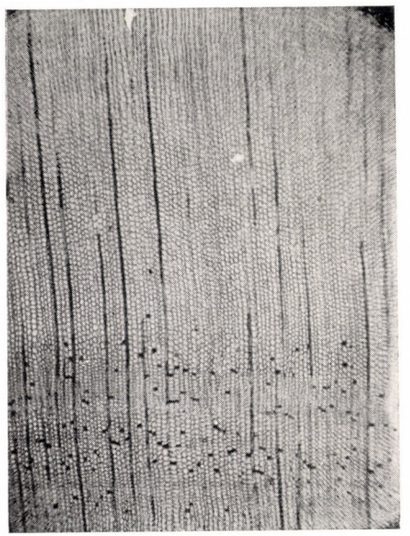


4. (300×)

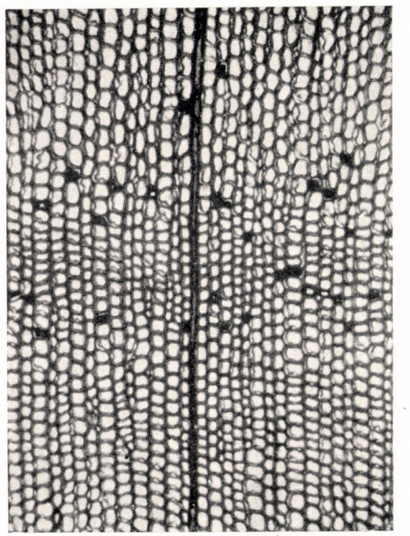




99. Callitris sulcata SCHLECHTER



1 (30×)



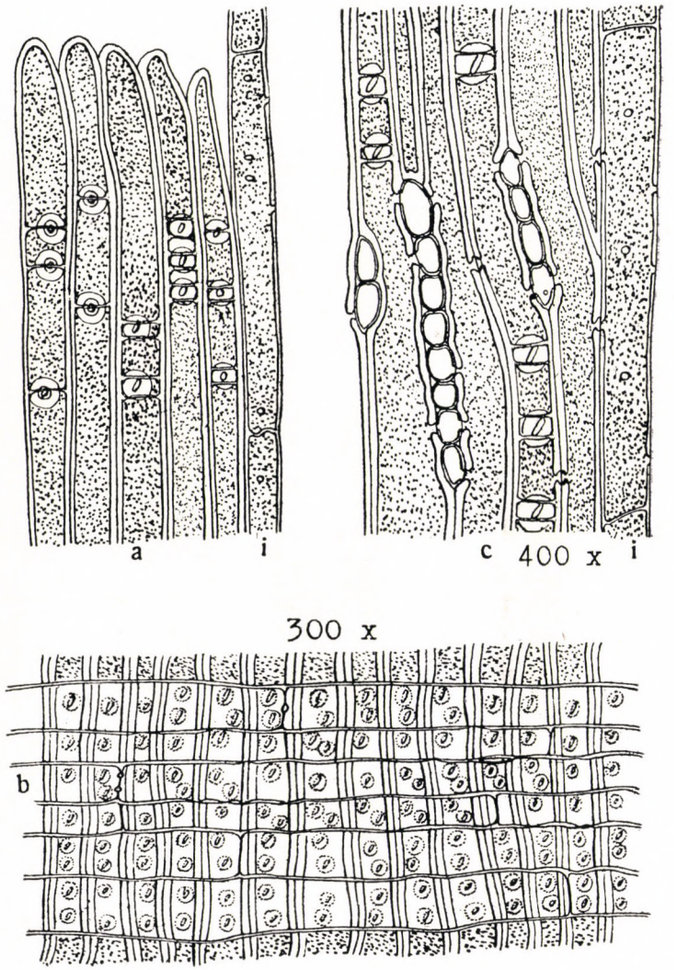
2. (100×)



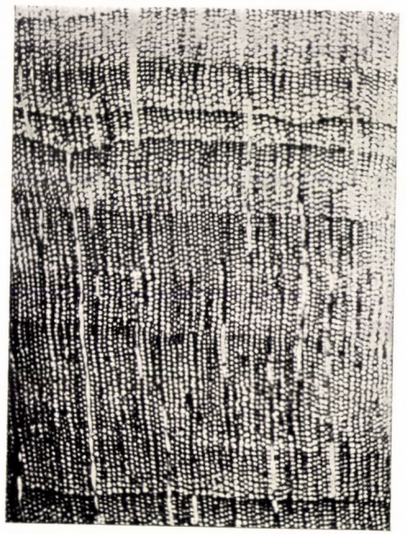
3 (300×)



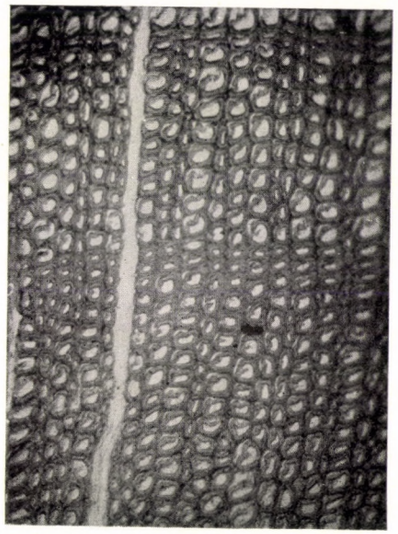
4. (100×)



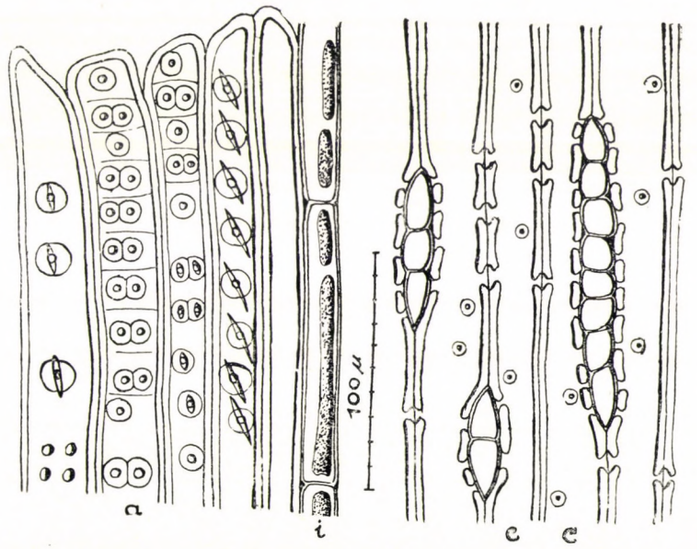
100. Callitris verrucosa R. Br.



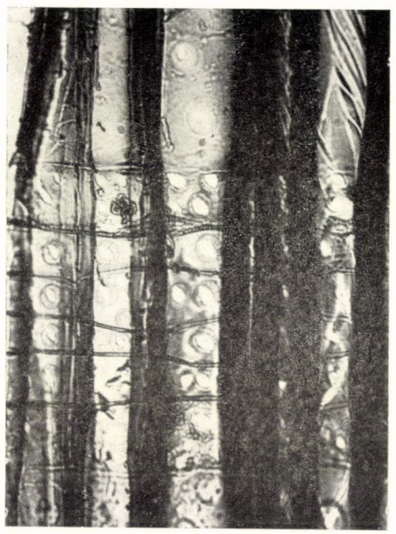
1. (30×)



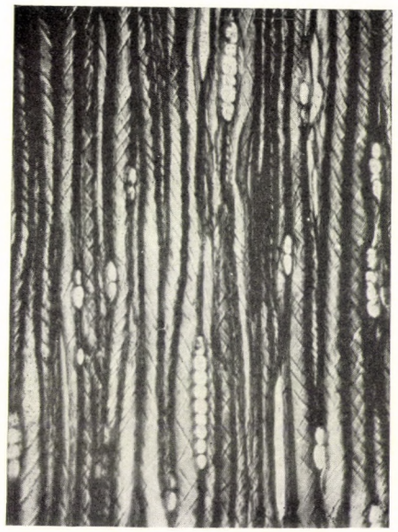
2. (100×)



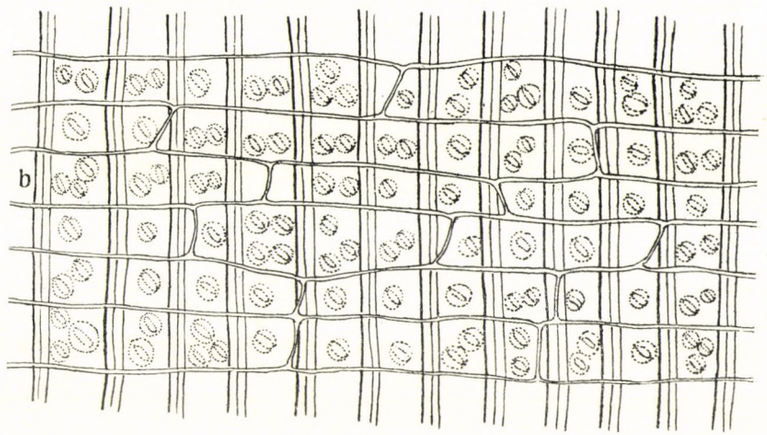
300 x



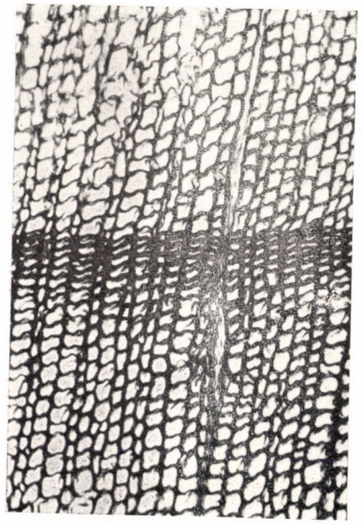
3. (300×)



4. (100×)



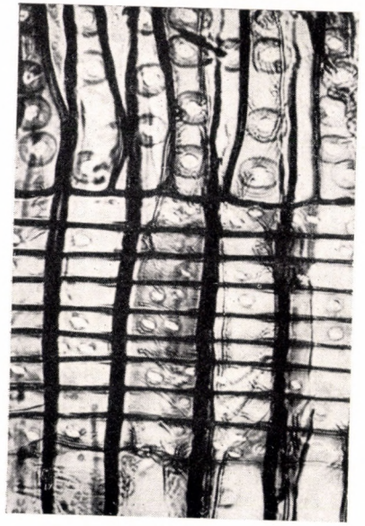
101. Callitropsis araucaroides COMPT.



1. (100×)



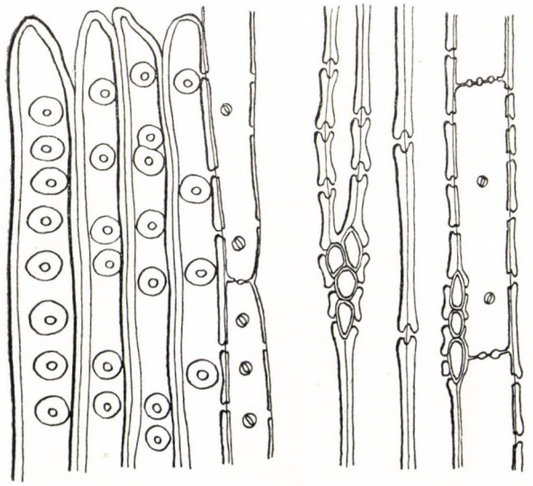
2. (100×)

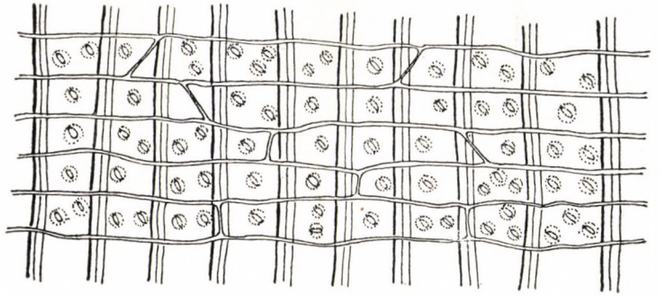


3. (300×)

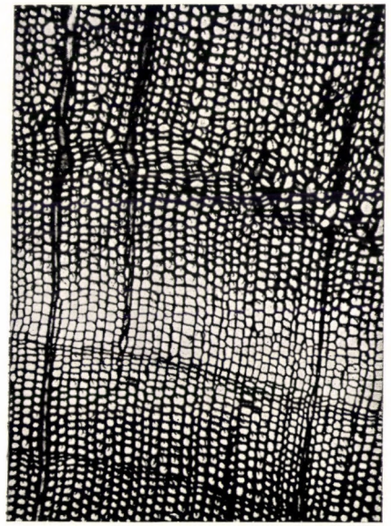


4. (300×)

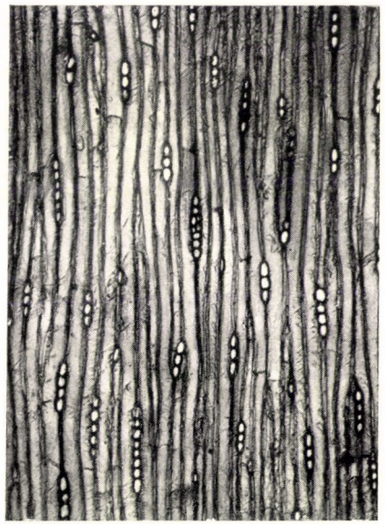




102. Chamaecyparis formosensis MATSUMURA



1. (100×)



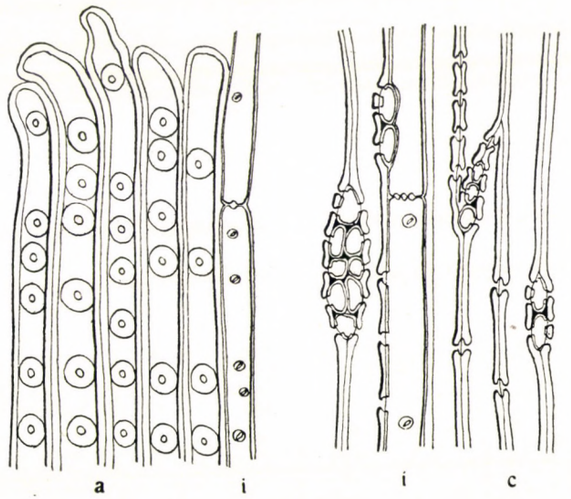
2. (100×)

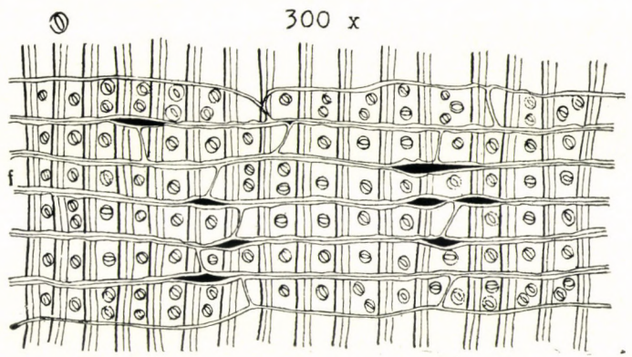


3. (300×)

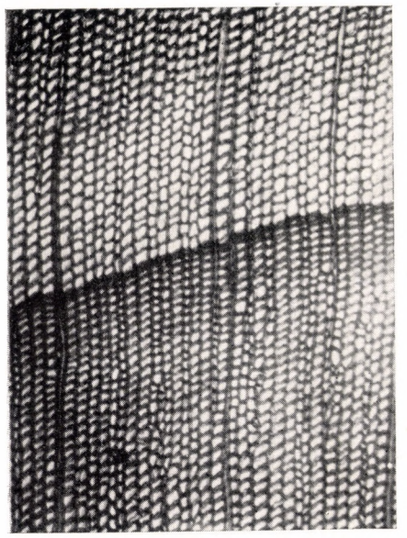


4. (300×)

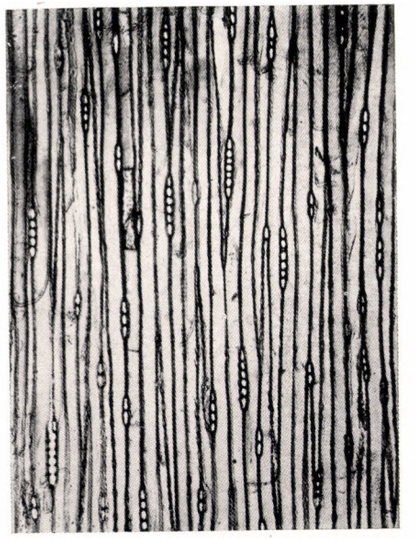




103. Chamaecyparis Lawsoniana (A. Murray) Parl.



1. (100×)



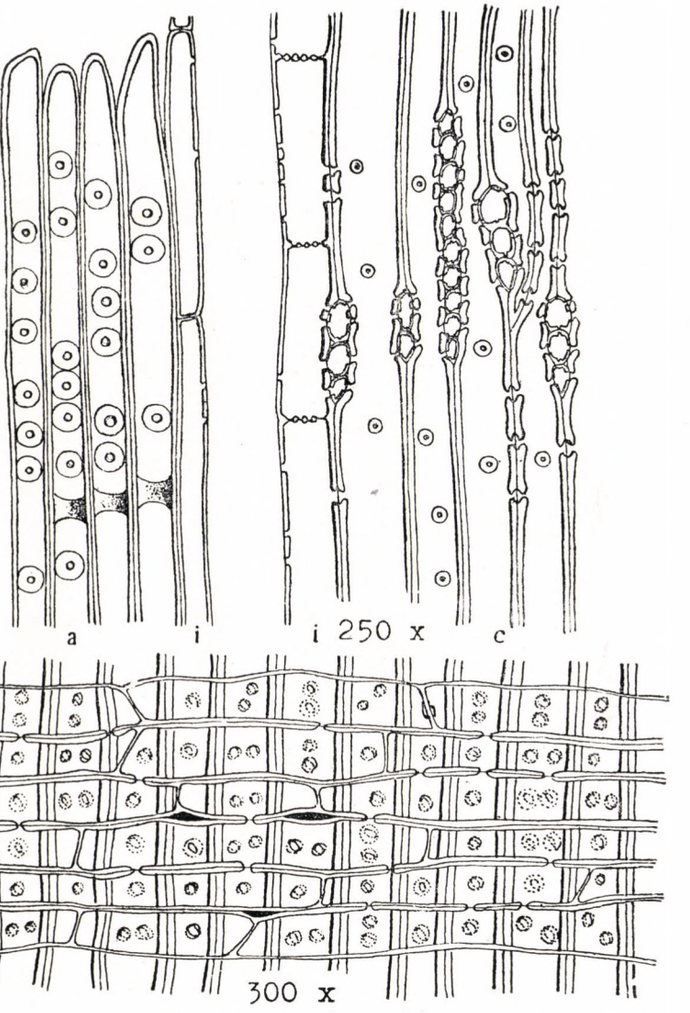
2. (100×)



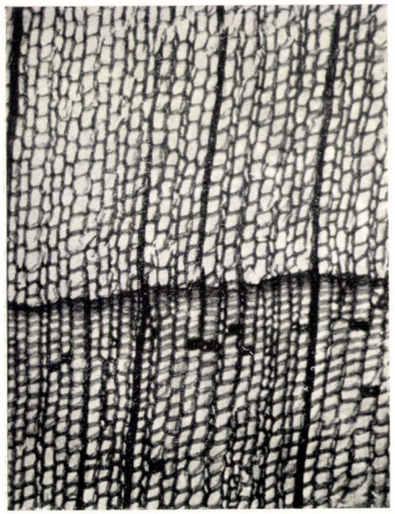
3. (300×)



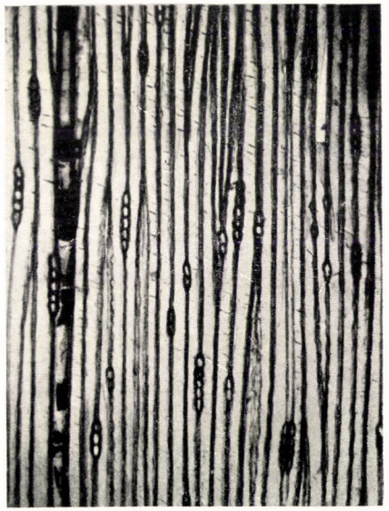
4. (300×)



104. Chamaecyparis nootkatensis (Lambert) SPACH



1. (100×)



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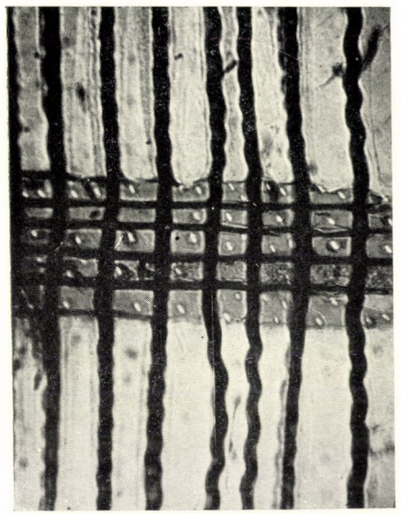
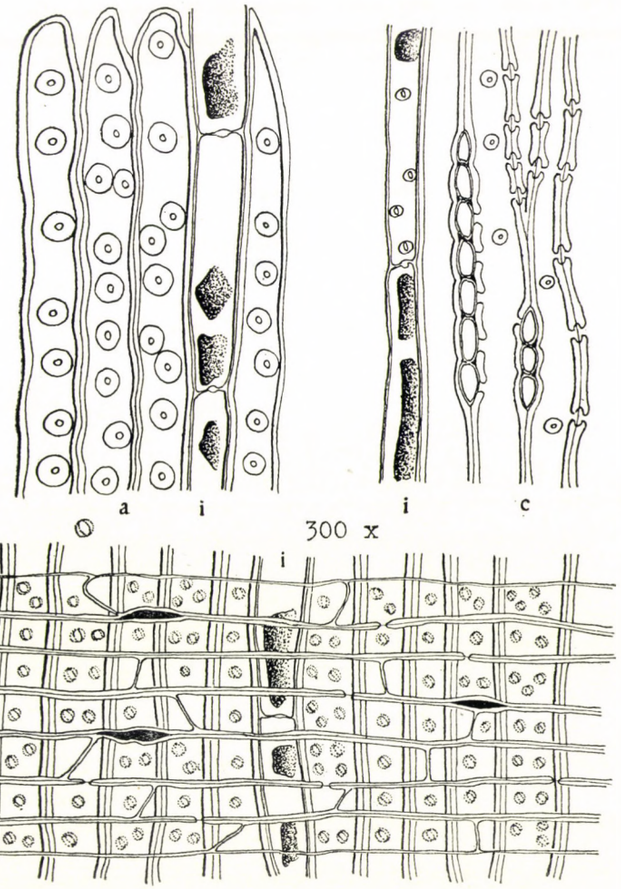


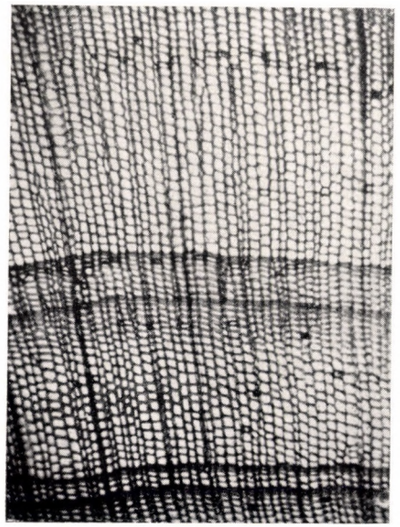
3. (300×)



4. (300×)



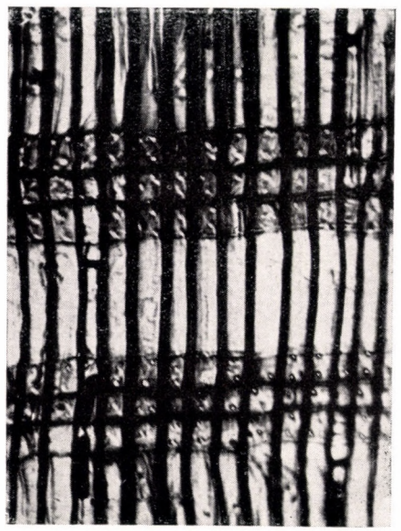
105. Chamaecyparis obtusa (Sieb. et Zucc.) ENDL.



1. (100×)



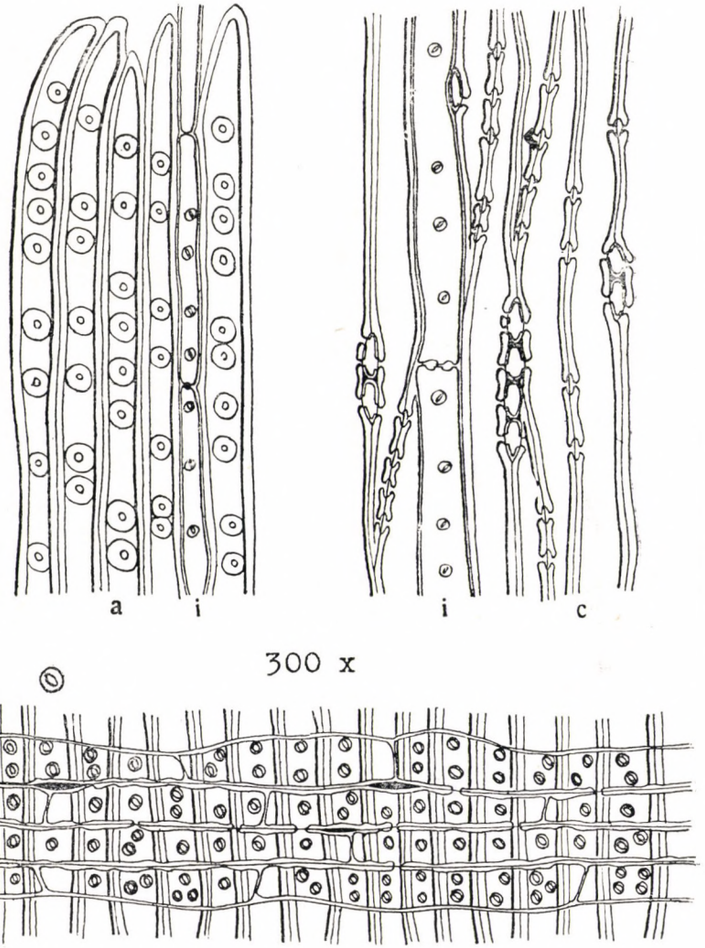
2. (100×)



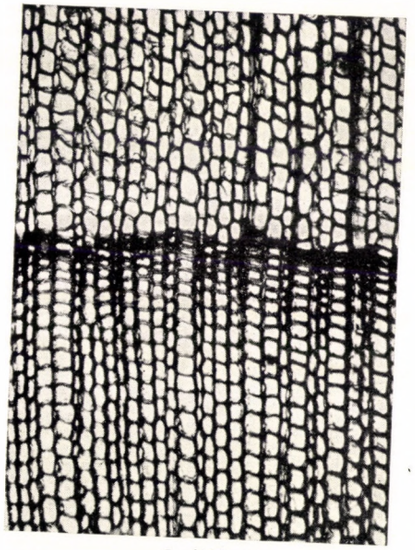
3. (300×)



4. (300×)



106. Chamaecyparis pisifera (Sieb. et Zucc.) ENDL.



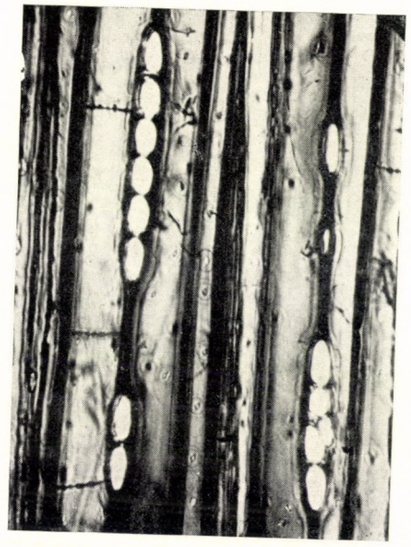
1. (100×)



2. (100×)



3. (300×)



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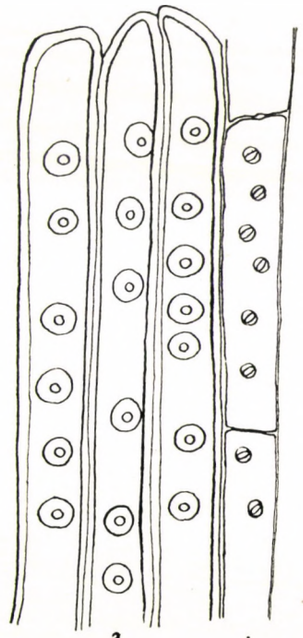
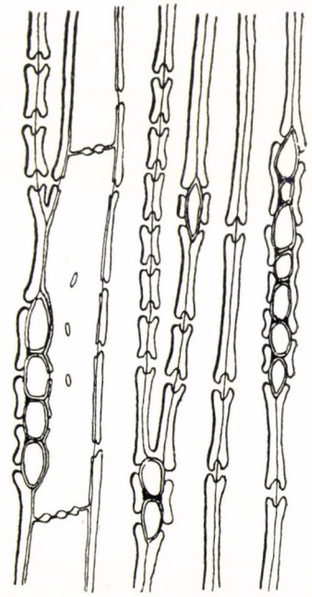
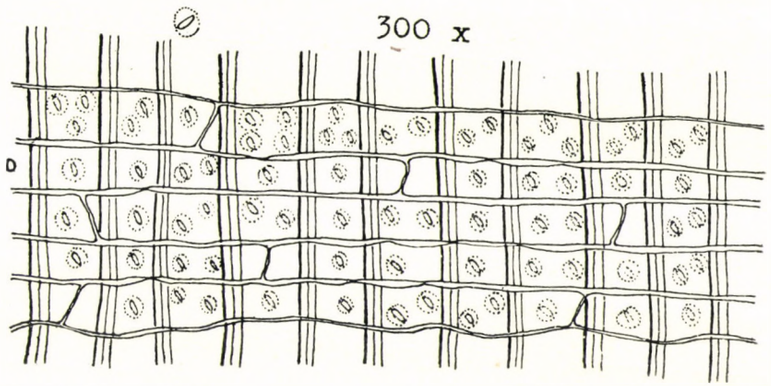
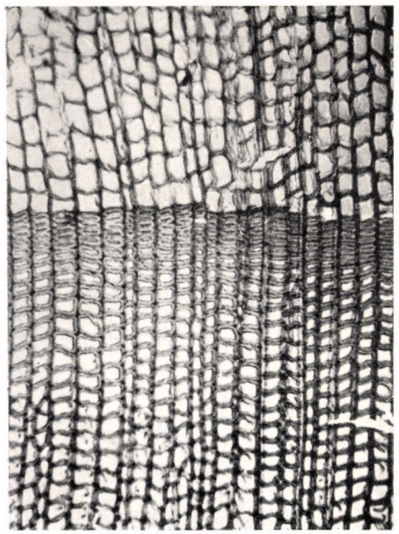


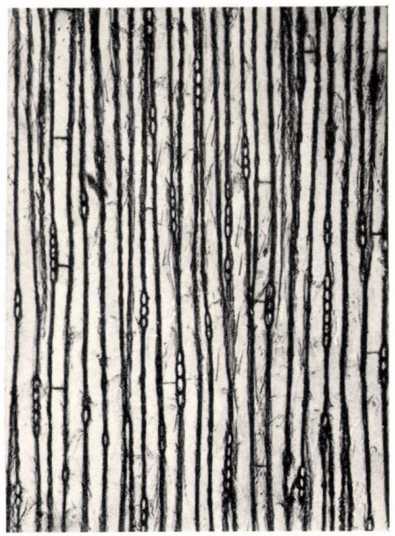




107. Chamaecyparis taiwanensis MASAMUNE et SUFUKI



1. (100×)



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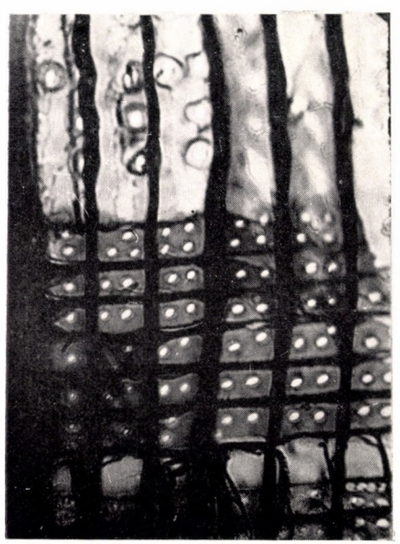

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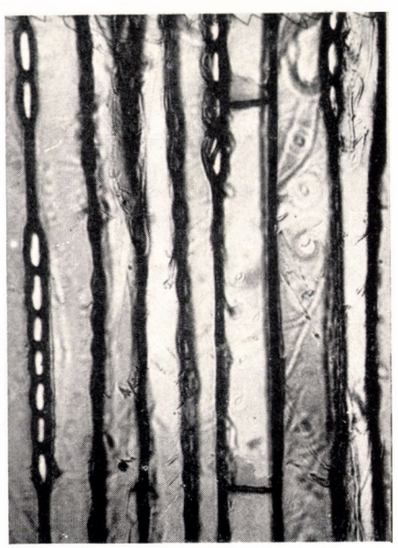
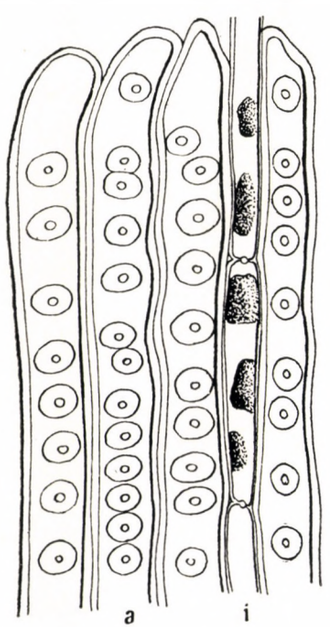
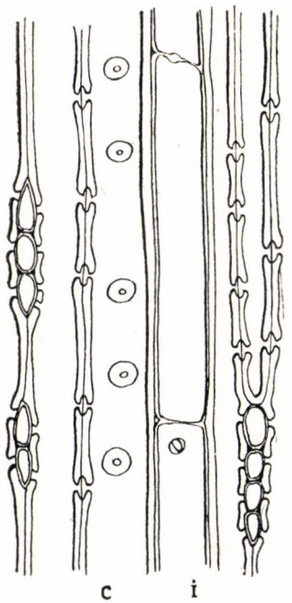
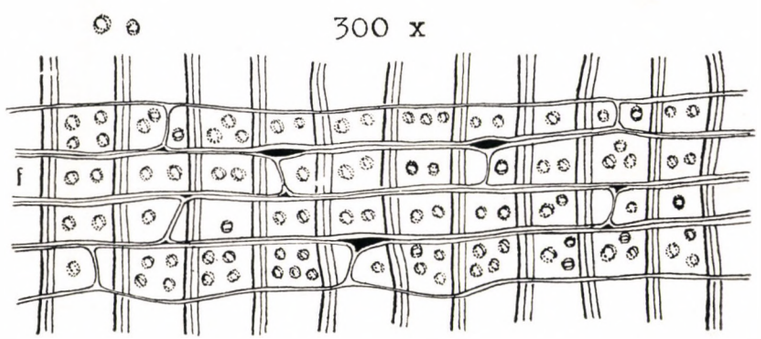


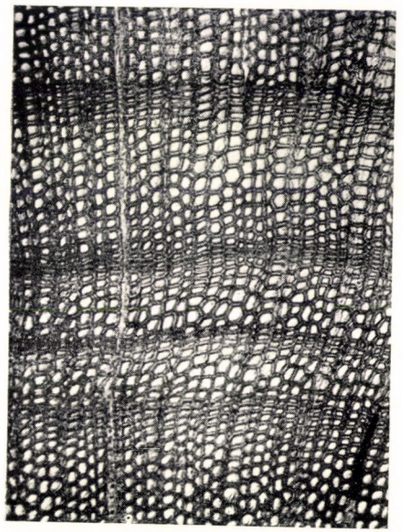
4. (300×)



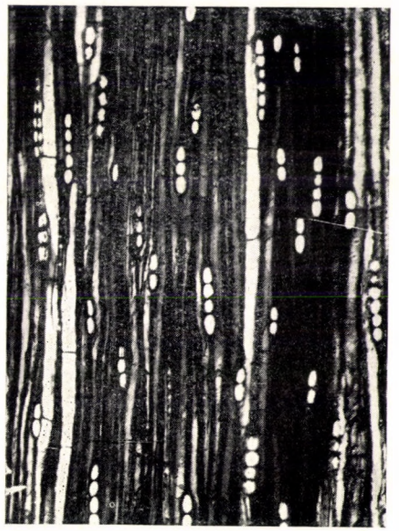




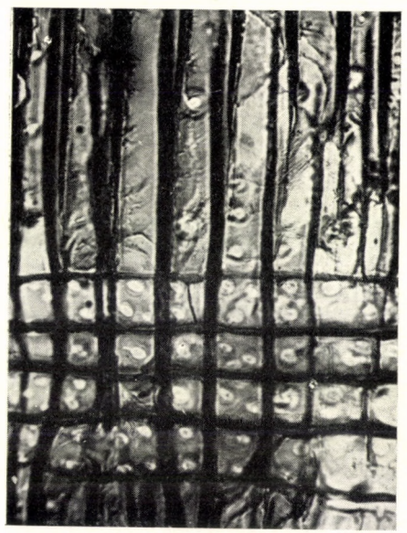
108. Chamaecyparis Thyoides I. Britton



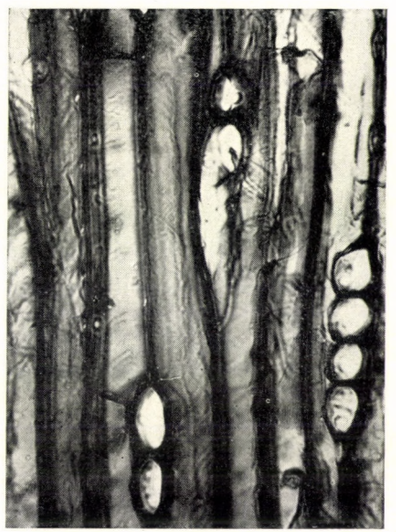
1. (100×)



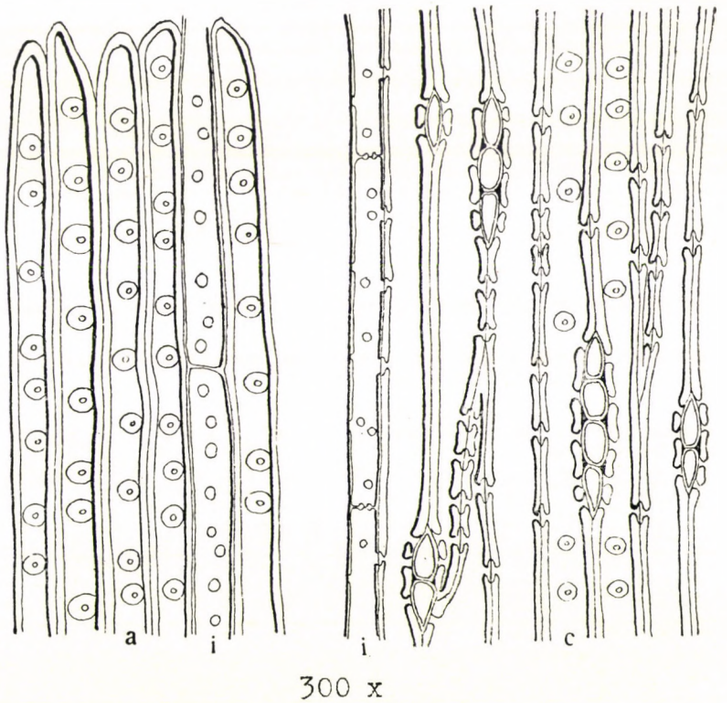
2. (100×)



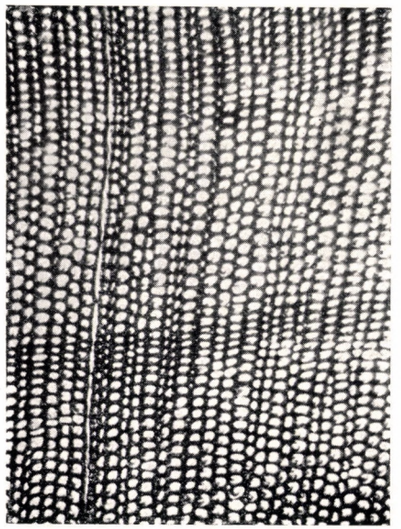
3. (300×)



4. (300×)



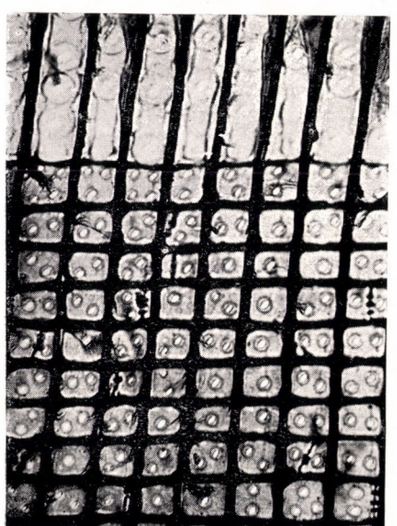
109. Cupressocyparis Leylandii (Jackson et Dallimore) DALLIMORE



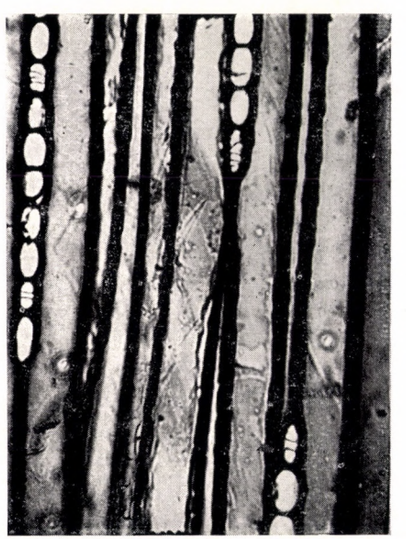
1. (100×)



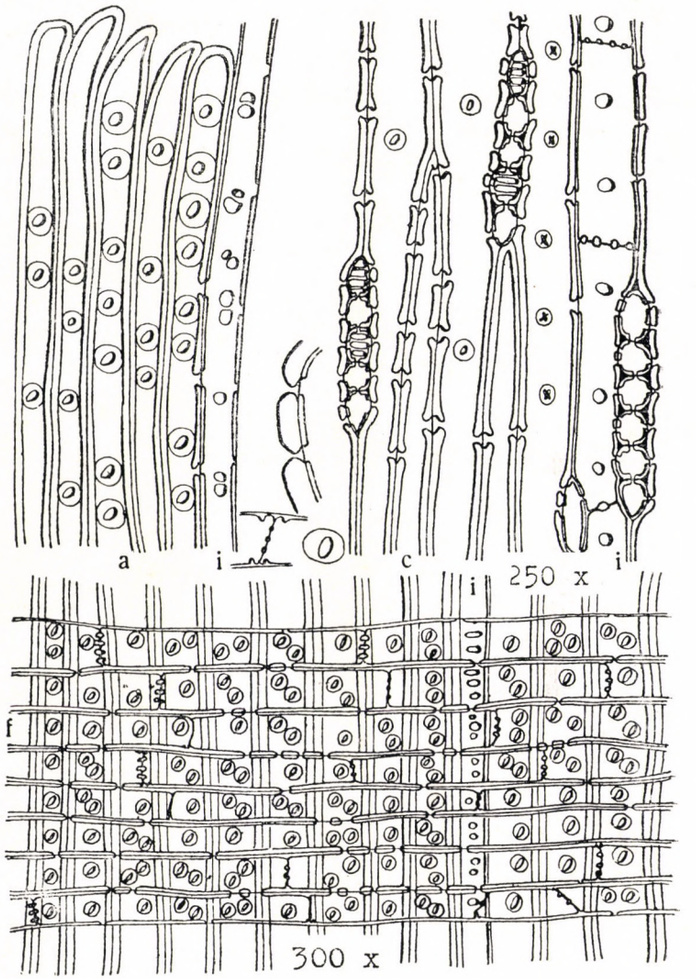
2. (100×)



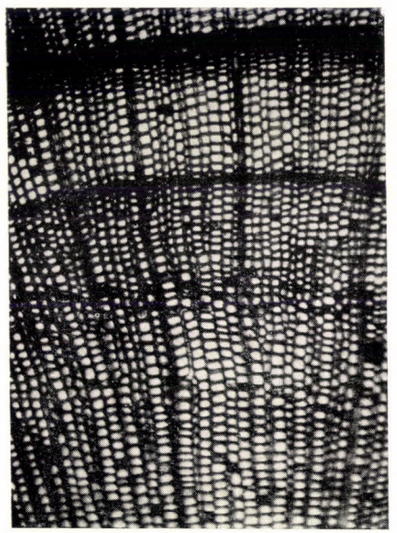
3. (300×)



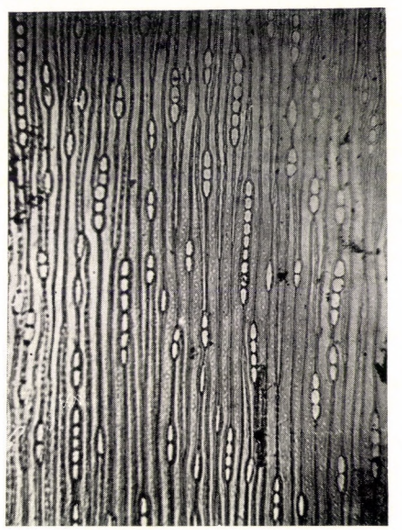
4. (300×)



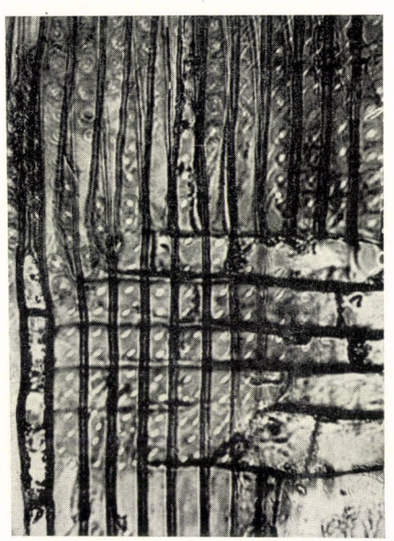
110. Cupressus arizonica GREENE



1. (100×)



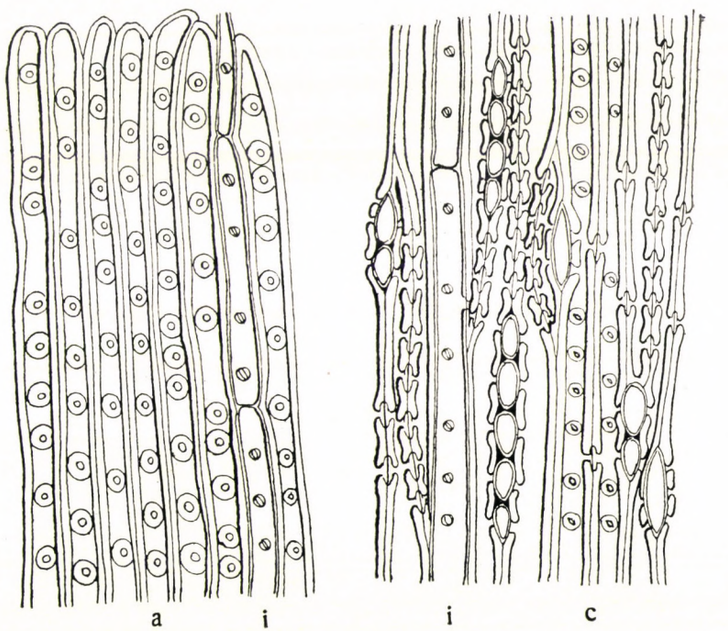
2. (100×)

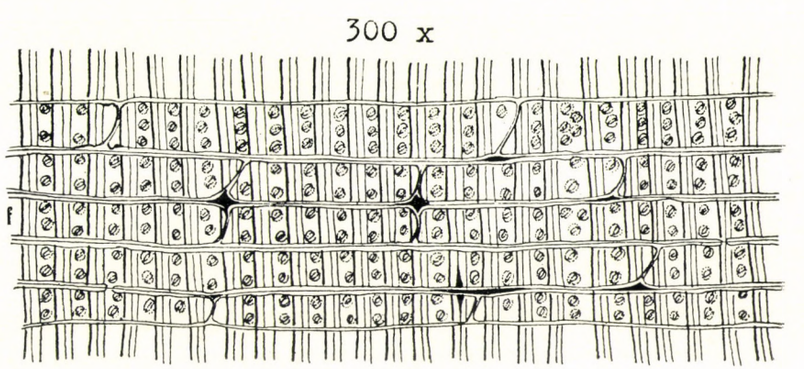


3. (300×)

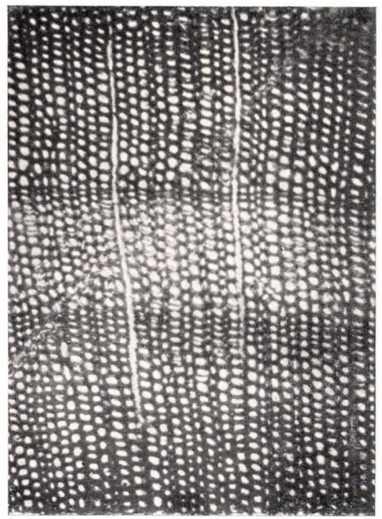


4. (300×)





111. Cupressus Duclouxiana Hickel



1. (100×)



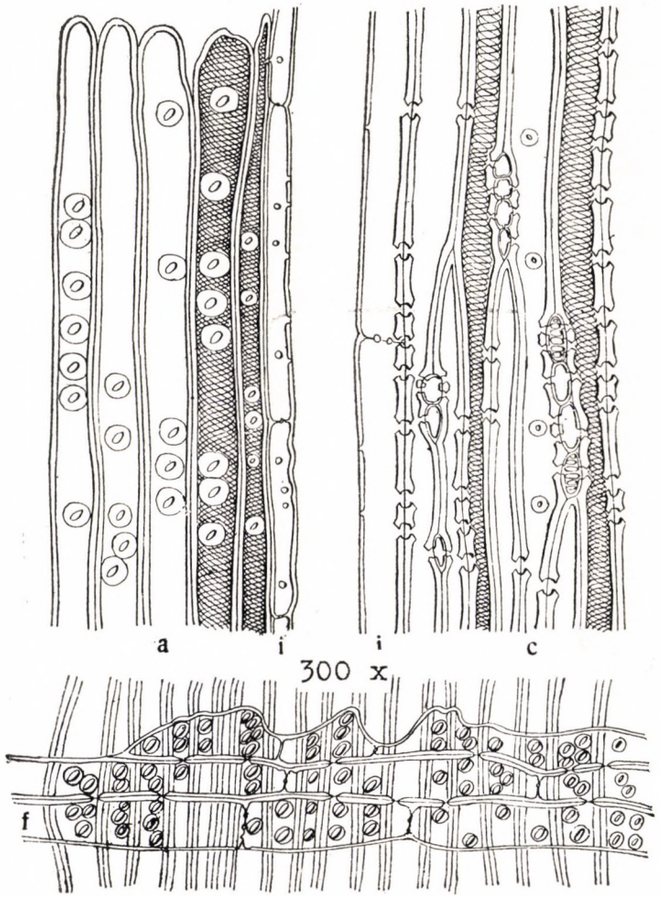
2. (100×)



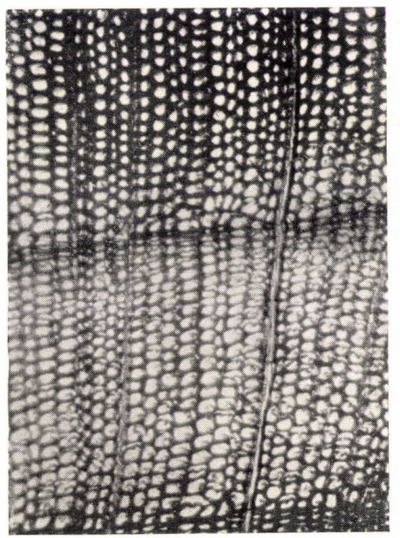
3. (300×)



4. (300×)



112. Cupressus funebris ENDL.



1. (100×)



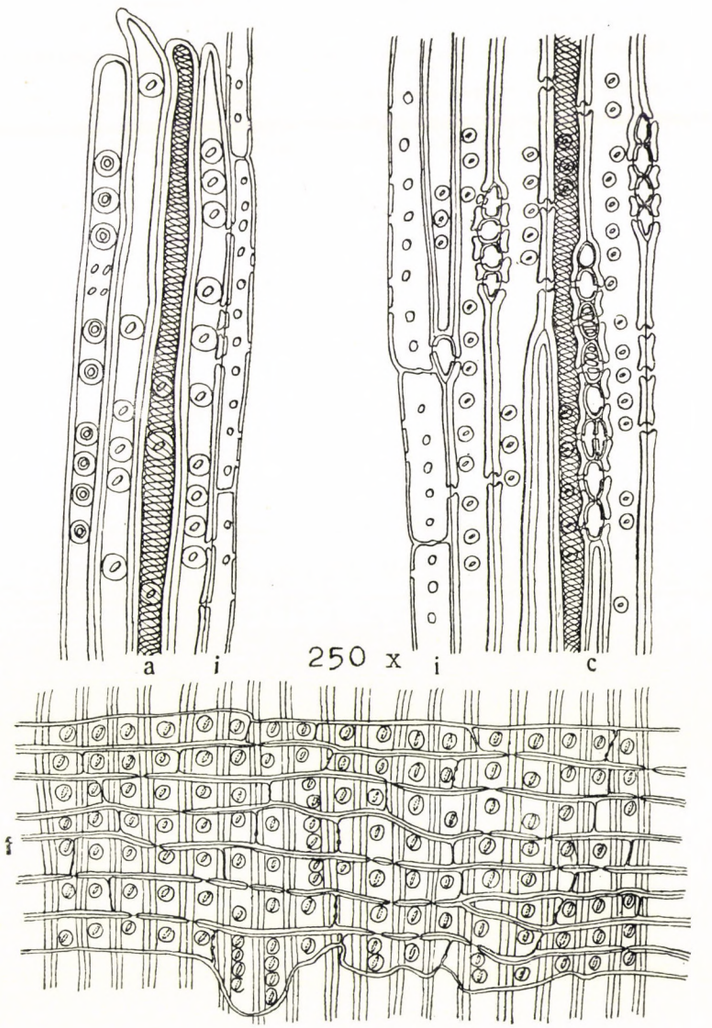
2. (100×)



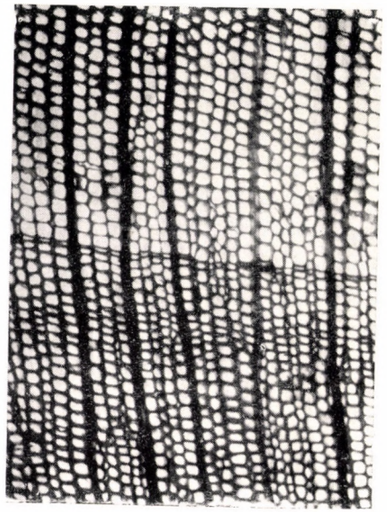
3. (300×)



4. (300×)



113. Cupressus Goveniana Gordon



1. (100×)



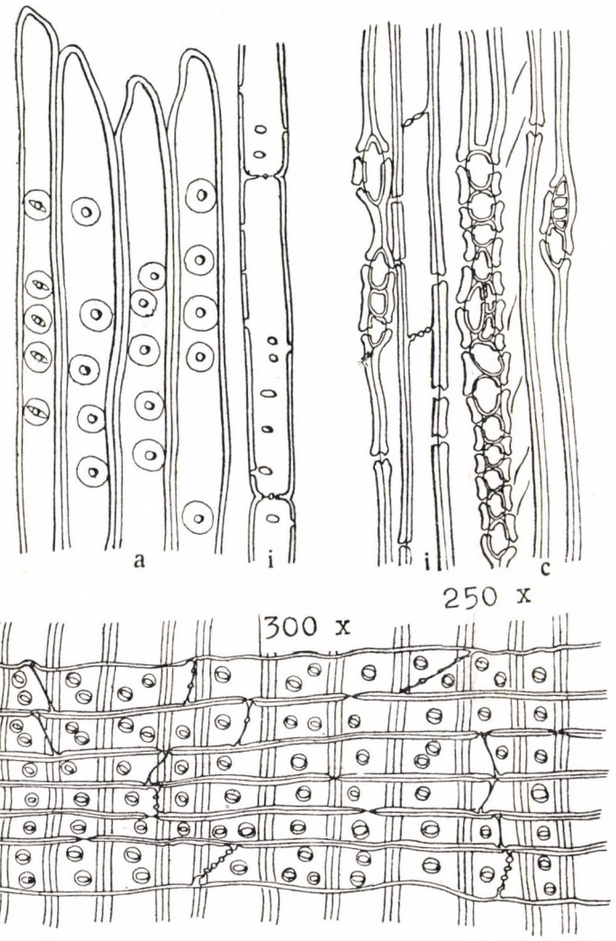
2. (100×)



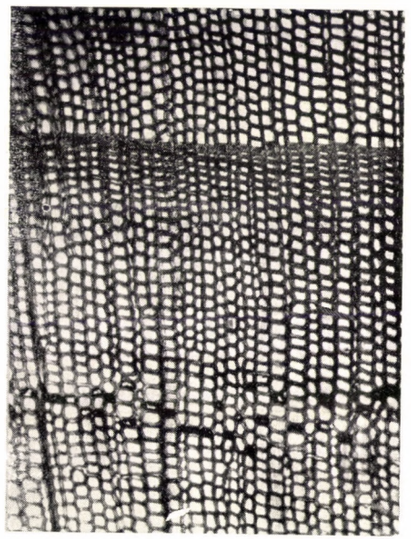
3. (300×)



4. (300×)



114. Cupressus lusitanica v. Benthamii CARR.



1. (100×)



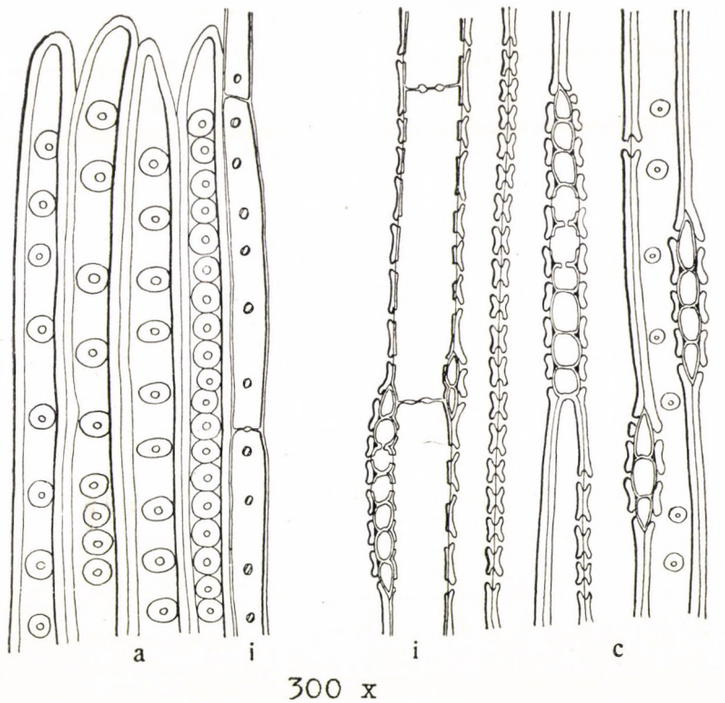
2. (100×)

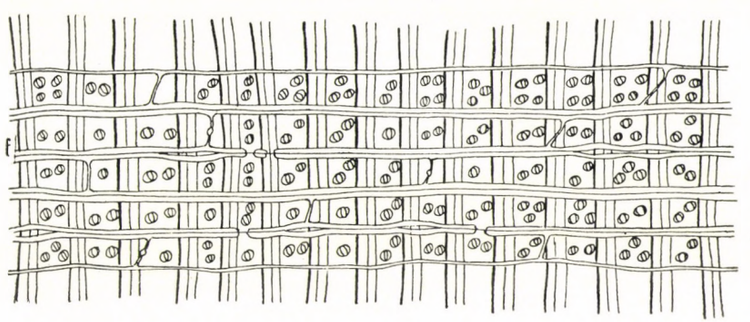


3. (300×)

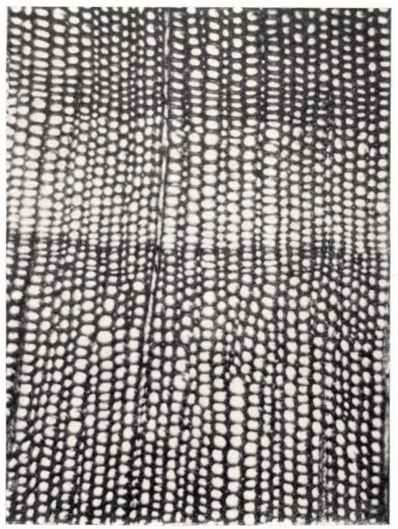


4. (300×)

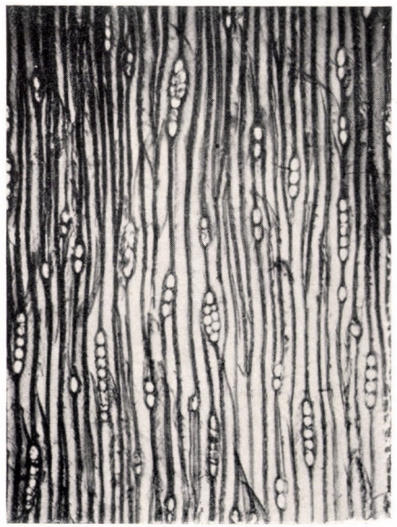




115. Cupressus Macnabiana MURR.



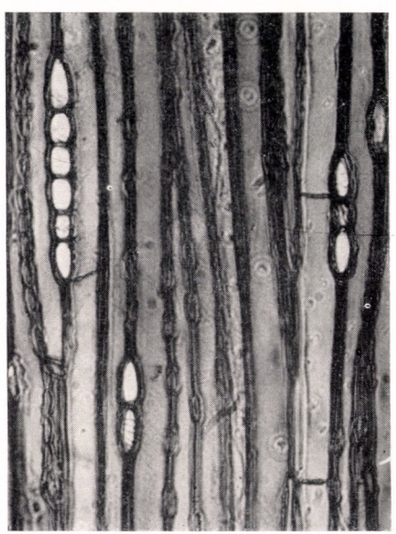
1. (100×)



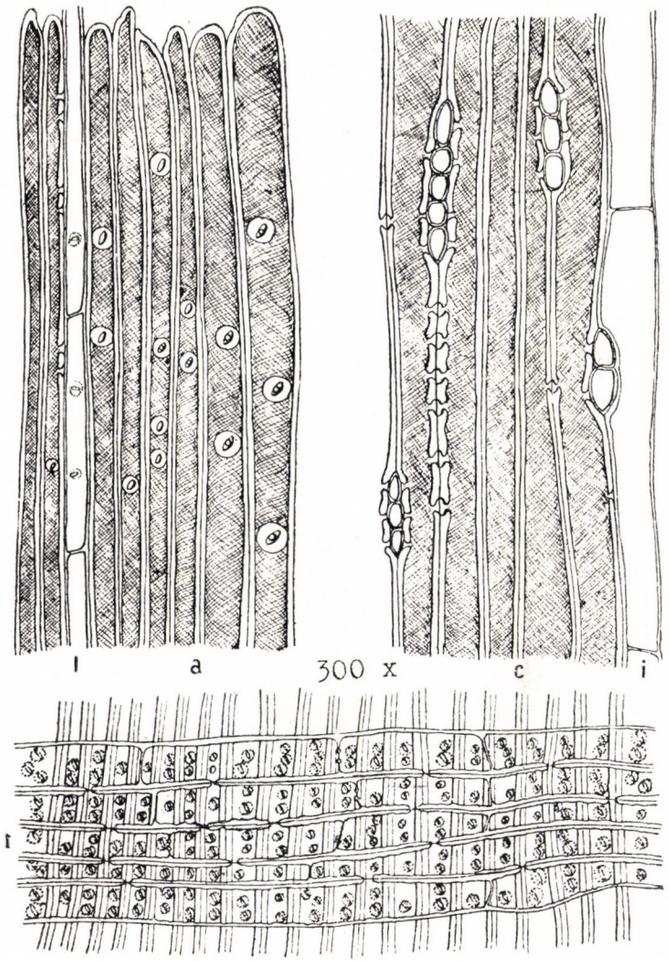
2. (100×)



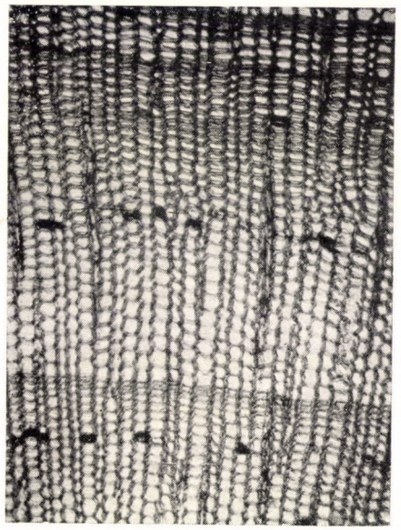
3. (300×)



4. (300×)



116. Cupressus macrocarpa HARTWEG



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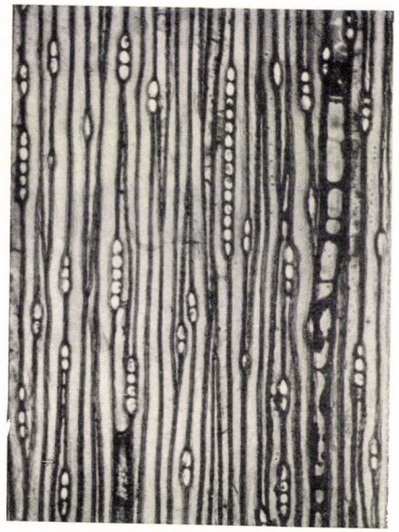


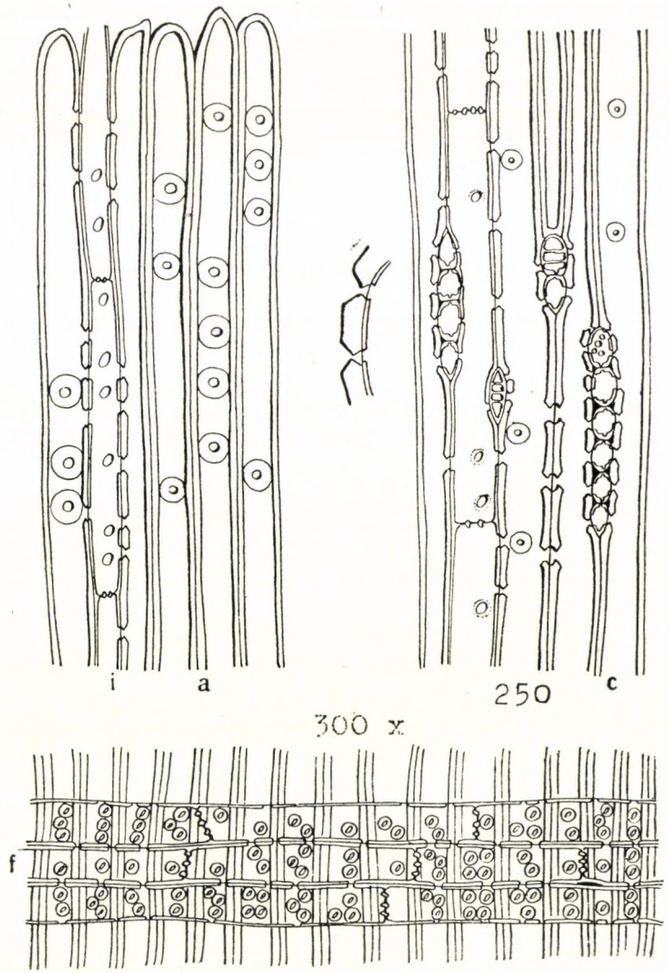
2. (100×)



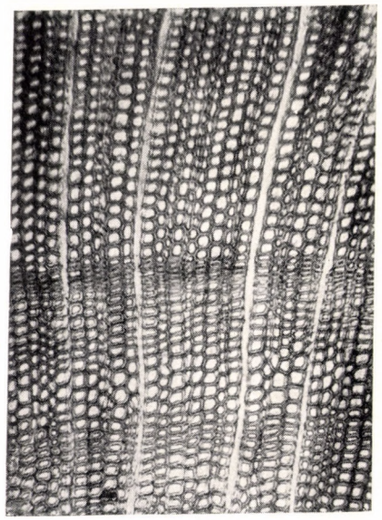
3. (300×)



4. (300×)



117. Cupressus macrocarpa v. guadalupensis MAST.



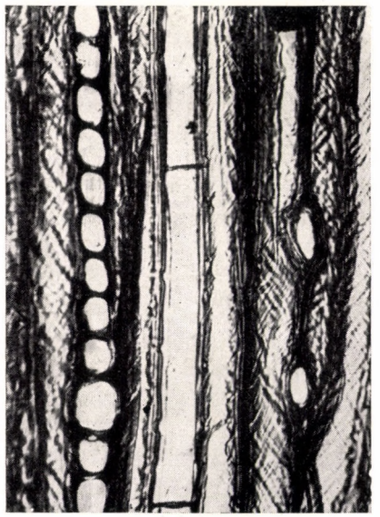
1. (100×)



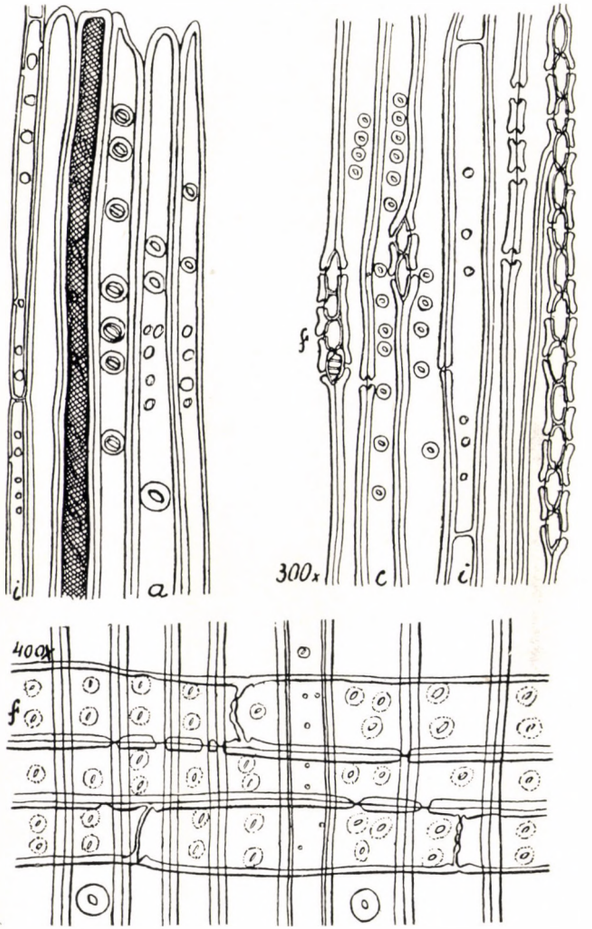
2. (100×)



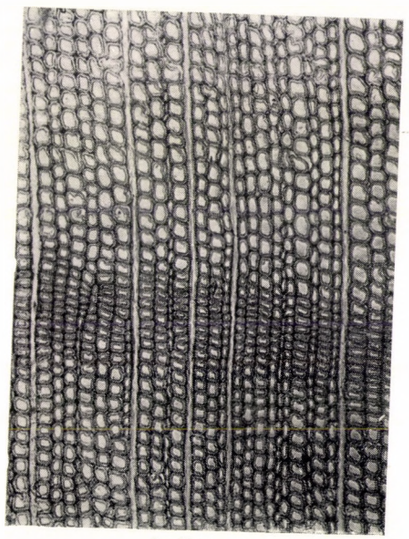
3. (300×)



4. (300×)



118. Cupressus sempervirens L.



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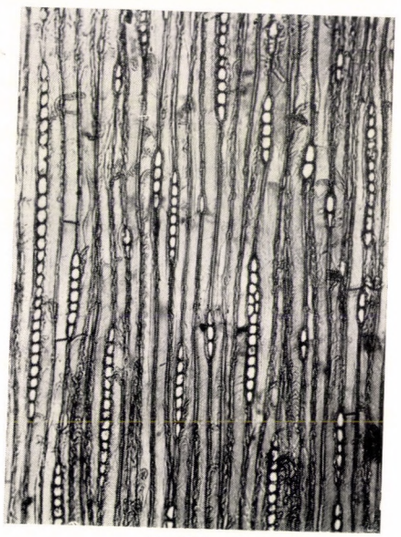
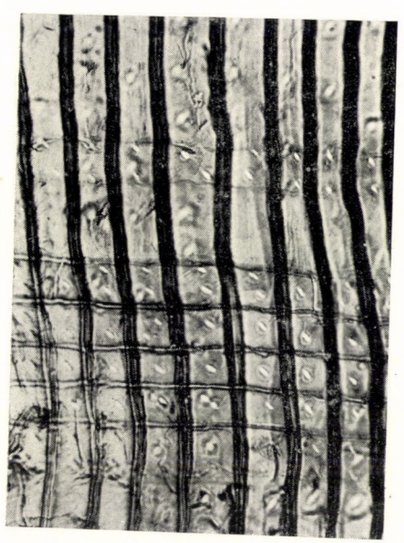


2. (100×)



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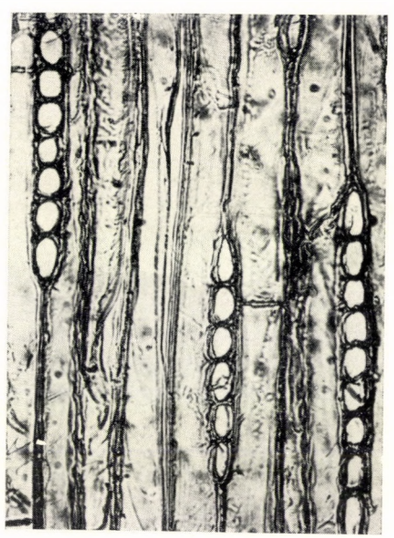

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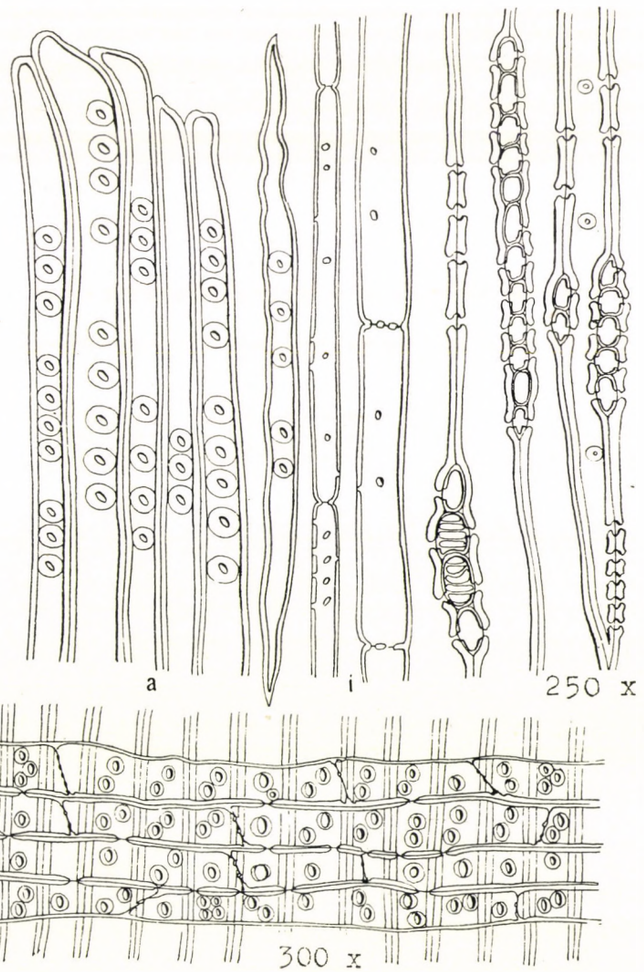
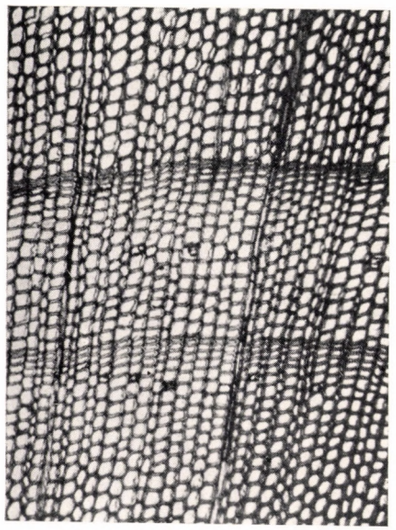


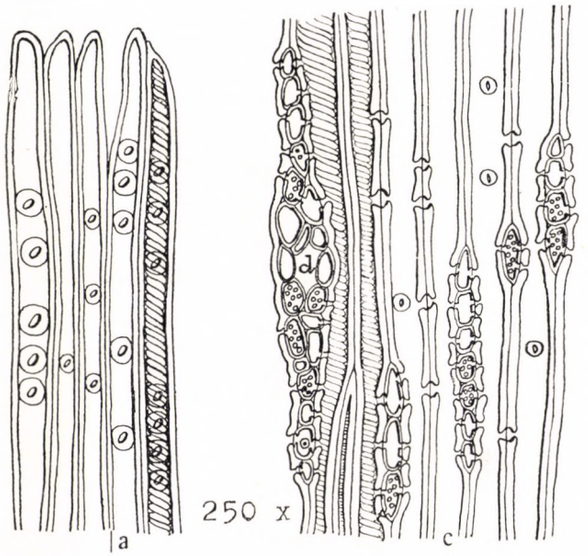
119. Cupressus torulosa Don.



1. (100×)



2. (100×)

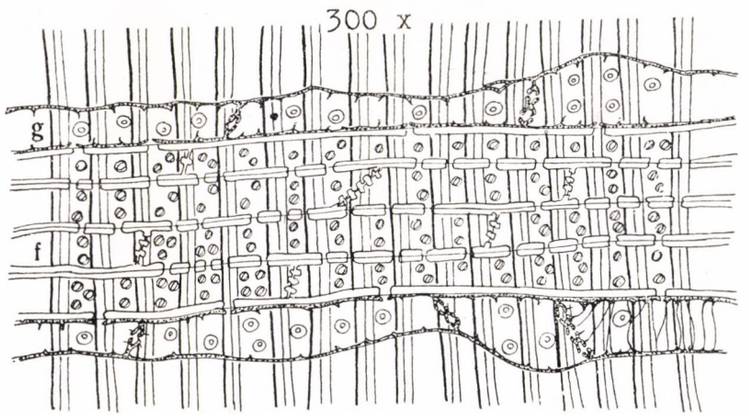




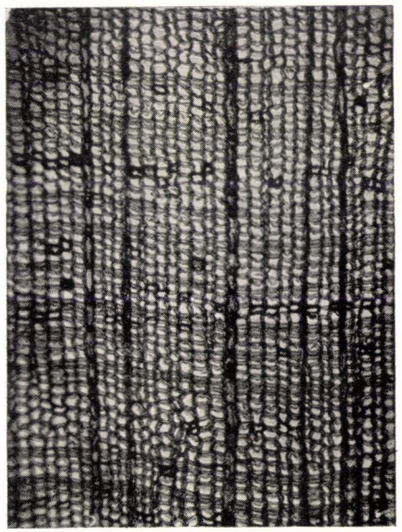
3. (300×)



4. (300×)



120. Cupressus Whytleyana CARR.



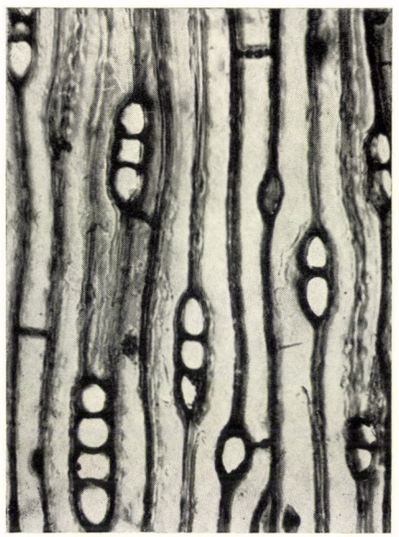
1. (100×)



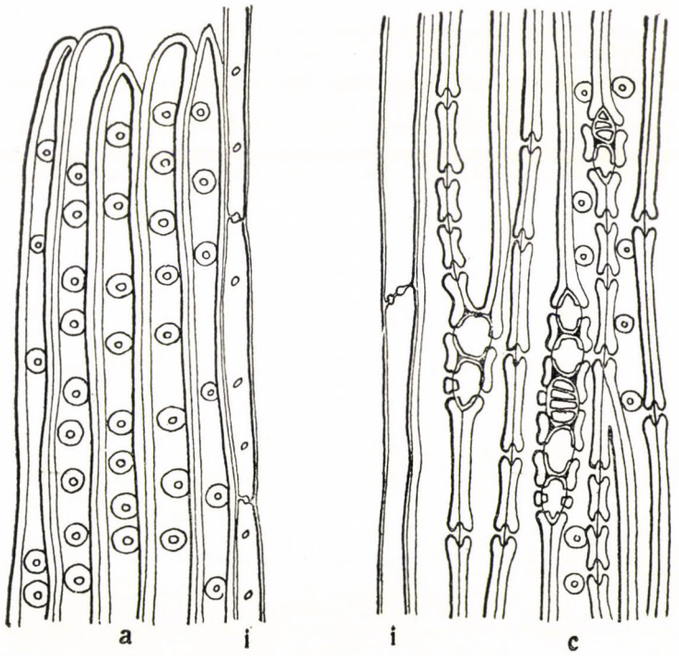
2. (100×)



3. (300×)



4. (300×)



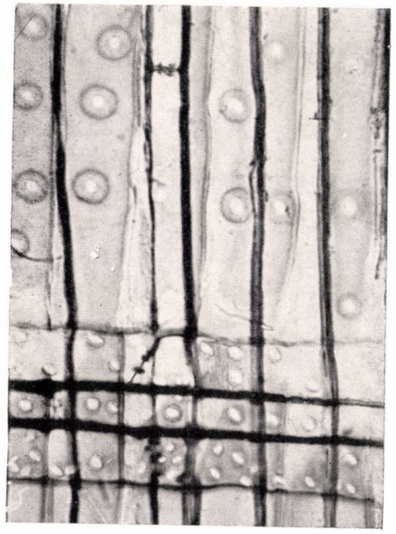
121. Diselma Archeri Hook.



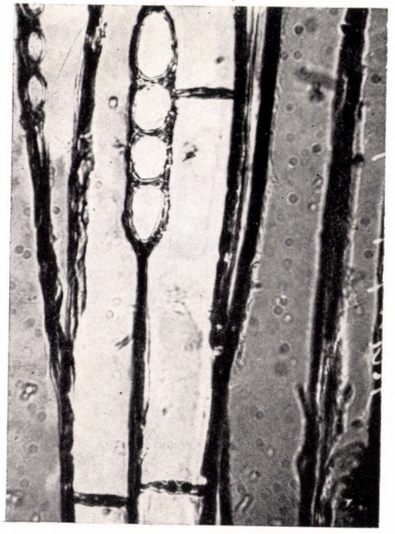
1. (100×)



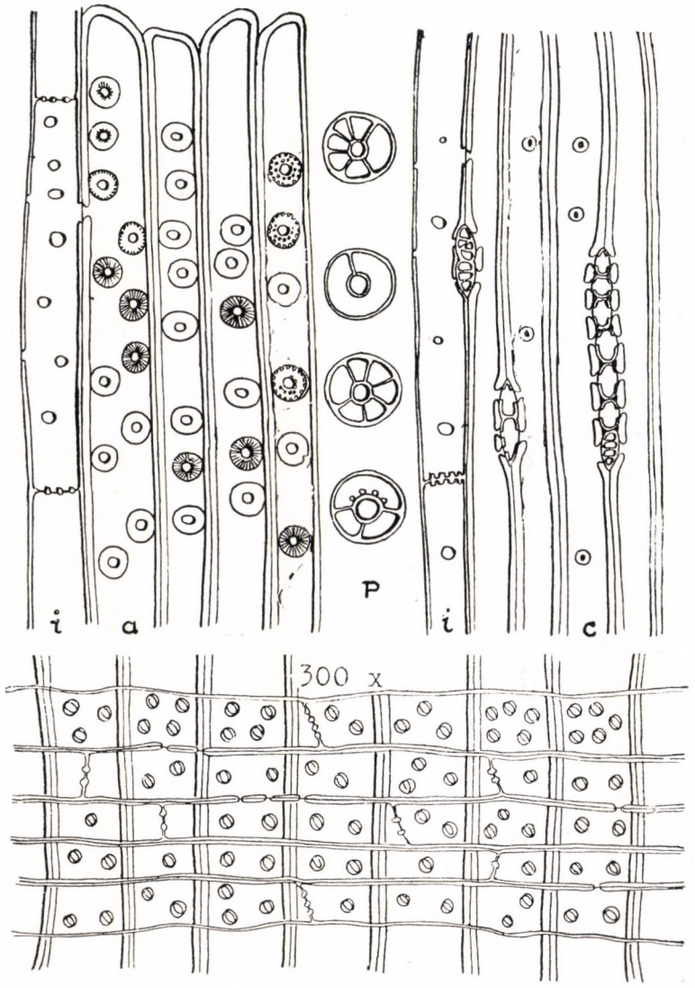
2. (100×)



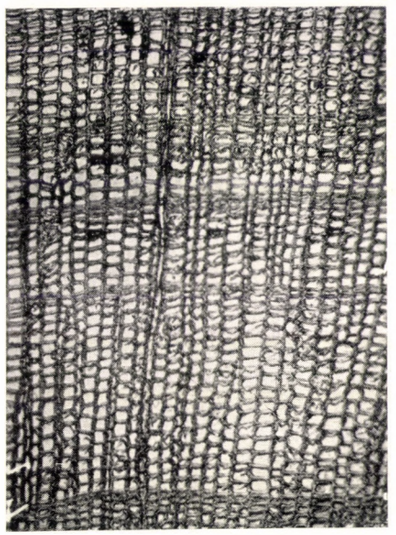
3. (300×)



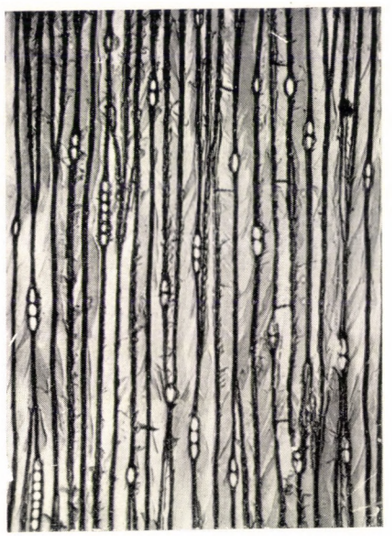
4. (100×)



122. Fitzroya cupressoides (Molina) JOHNSTON



1. (100×)



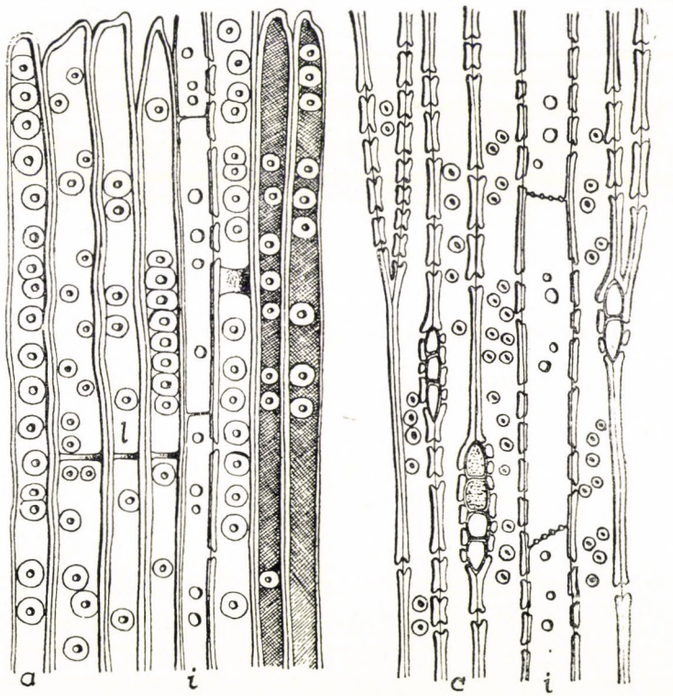
2. (100×)

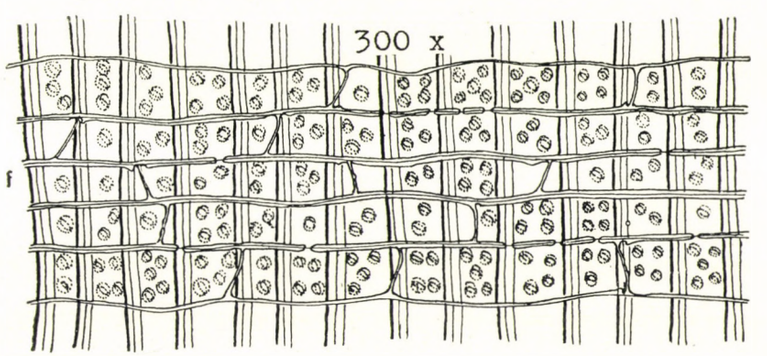


3. (300×)

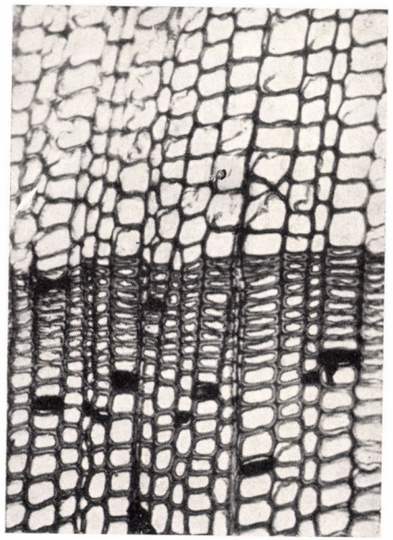


4. (300×)





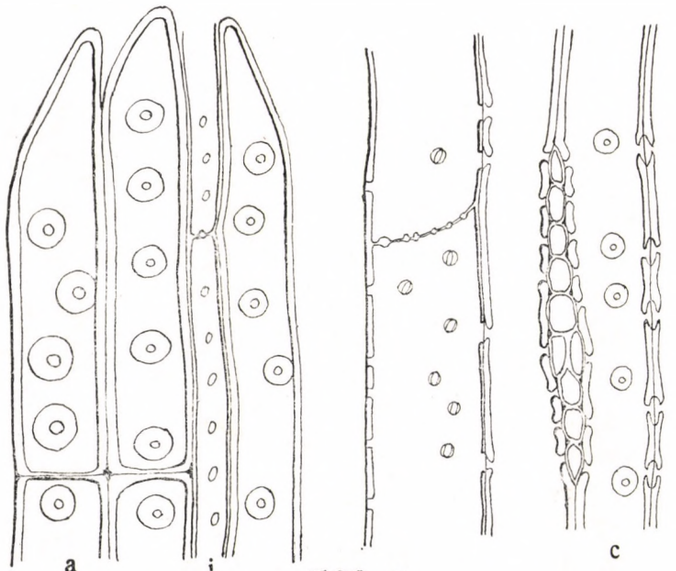
123. Fokienia Hoodginsii HENRY et THOMAS



1. (100×)



2. (100×)

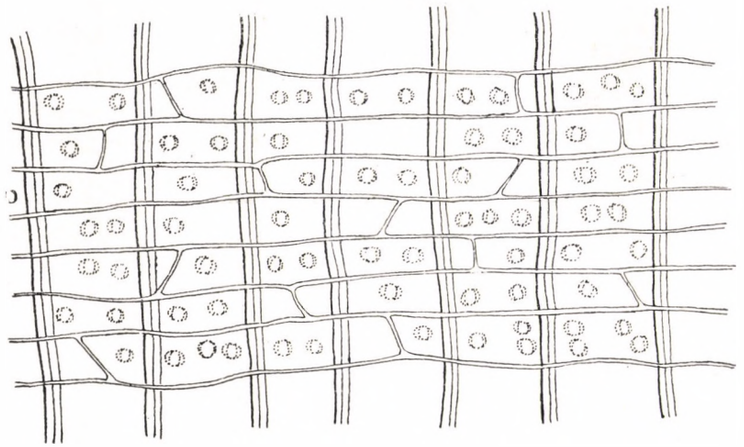




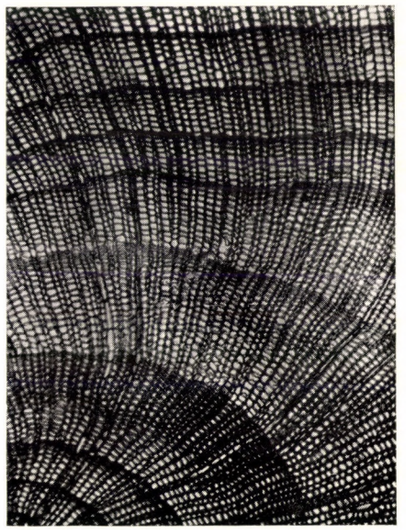
3. (300×)



4. (300×)



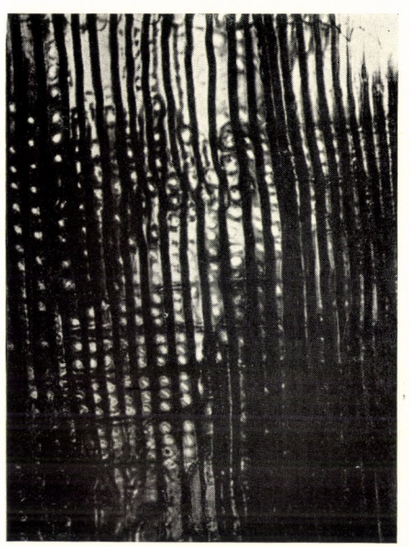
124. Fokienia Kawai HAYATA



1. (100×)



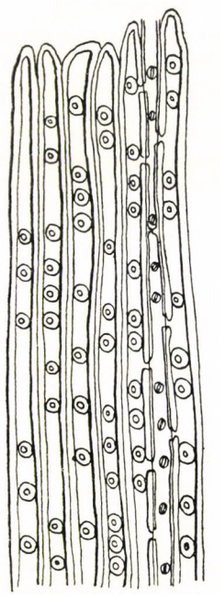
2. (100×)

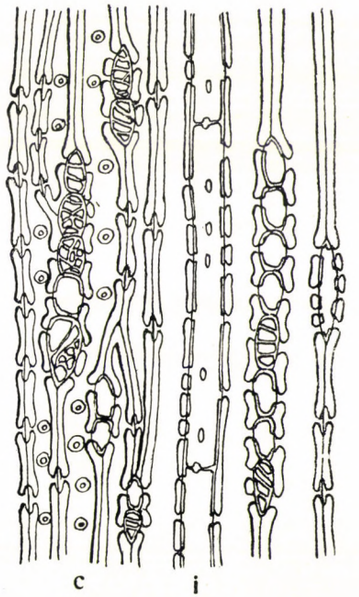


3. (300×)

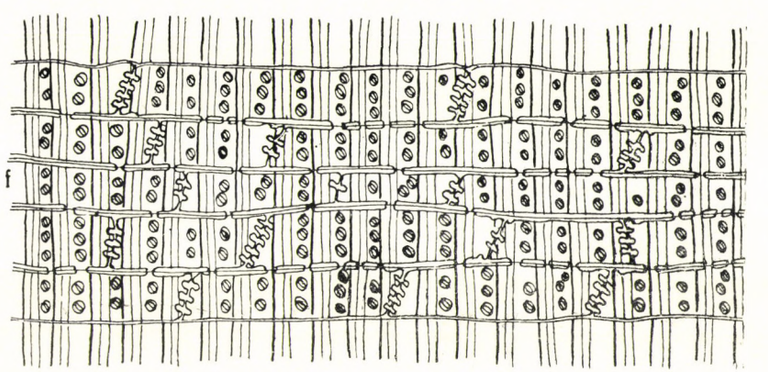


4. (300×)

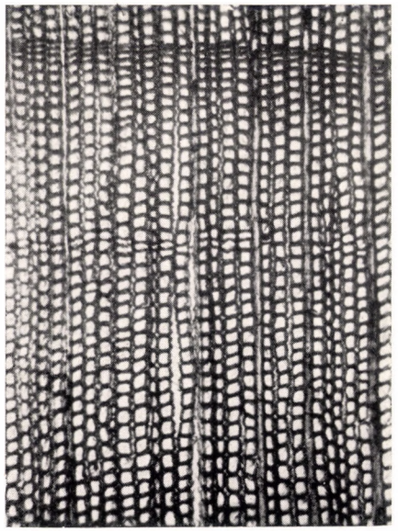




300 x



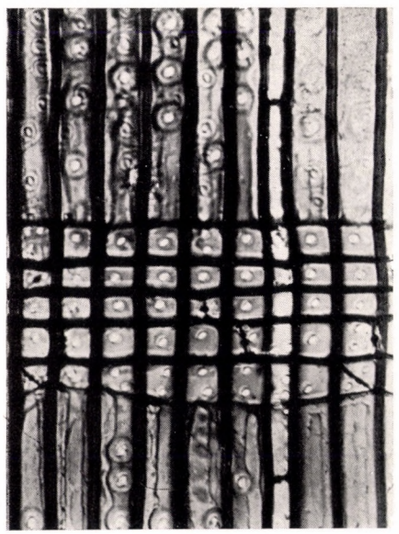
125. Juniperus arenaria (Wils.) FLORIN



1. (100×)



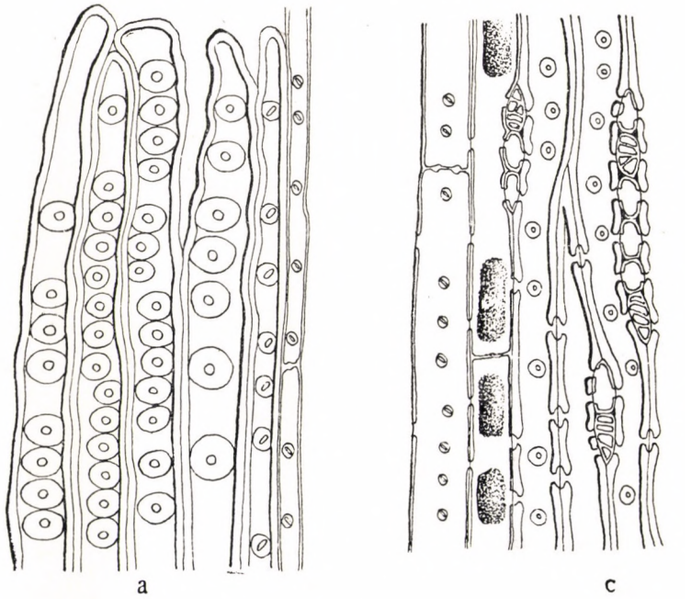
2. (100×)



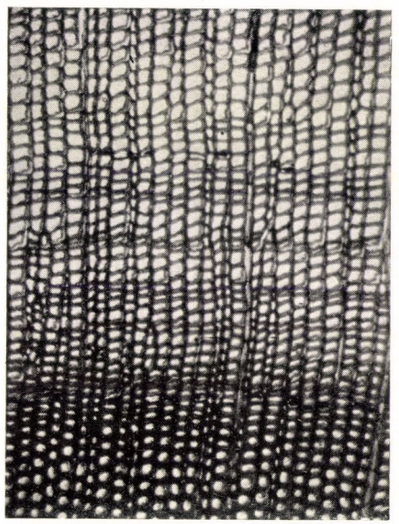
3. (300×)



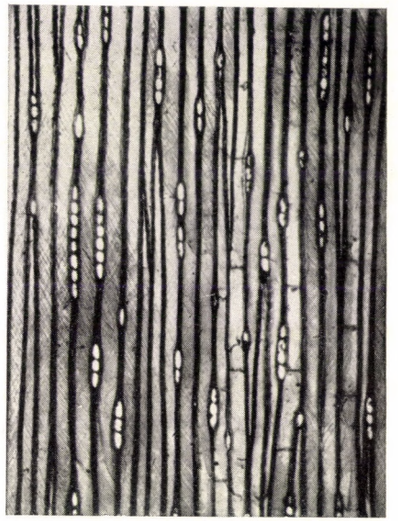
4. (300×)



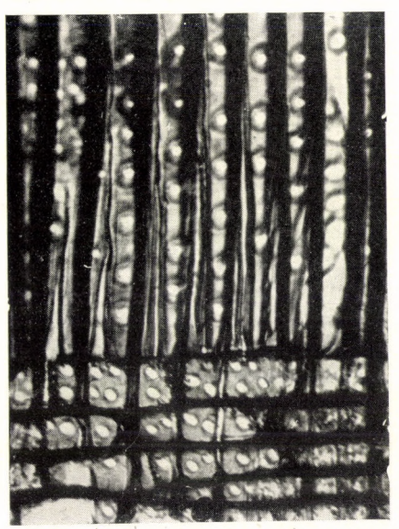
126. Juniperus Ashei BUCHH.



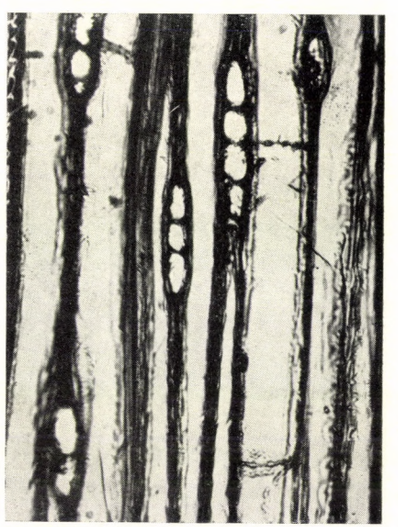
1. (100×)



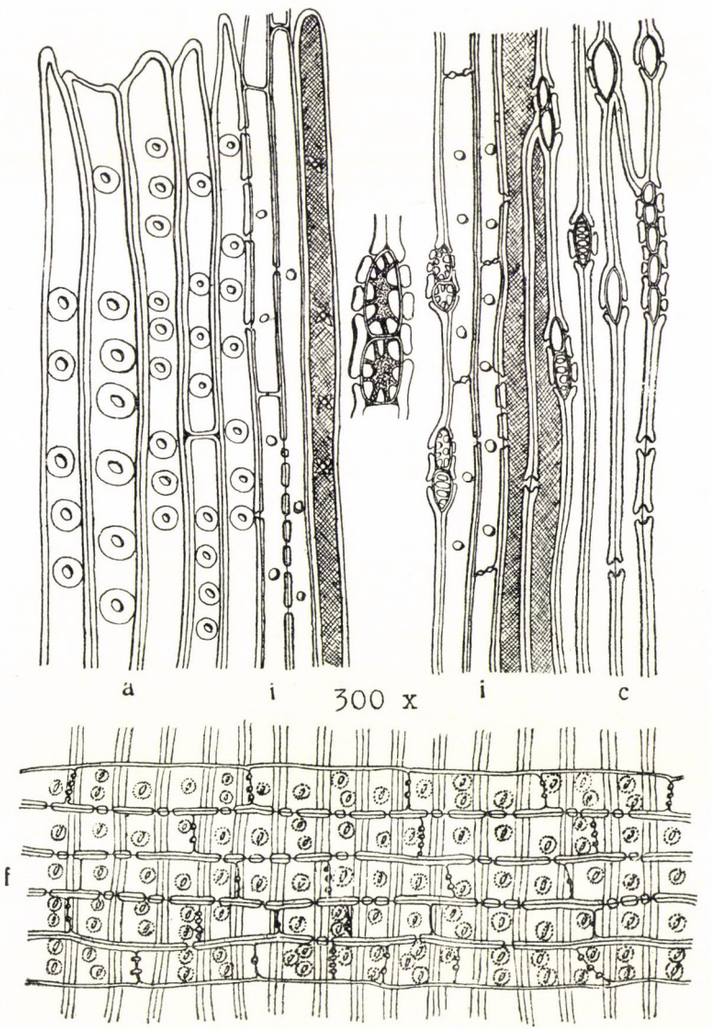
2. (100×)



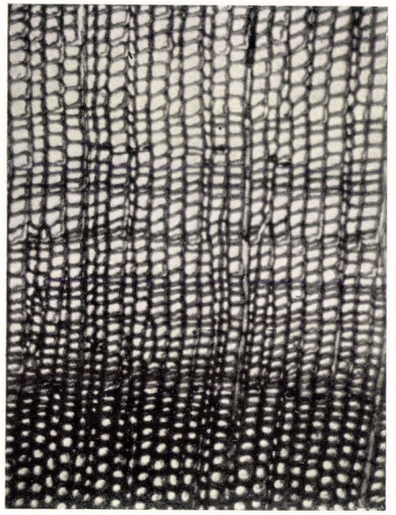
3. (300×)



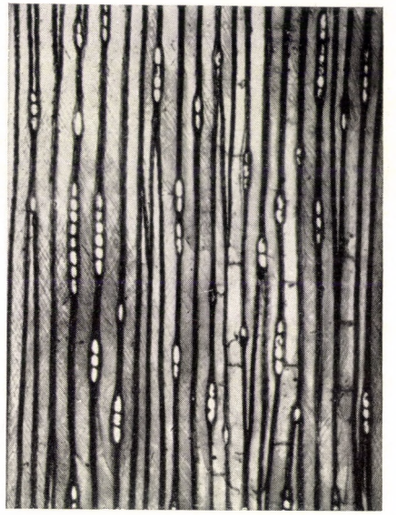
4. (300×)



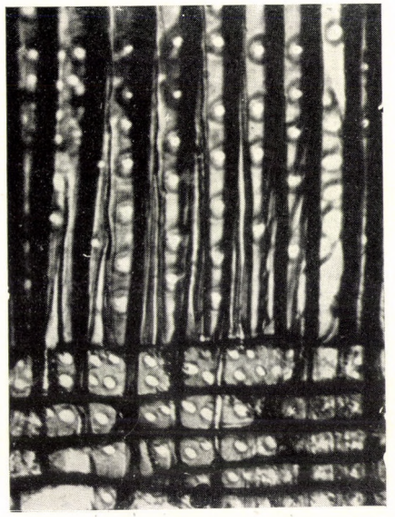
127. Juniperus bermudiana L.



1. (100×)



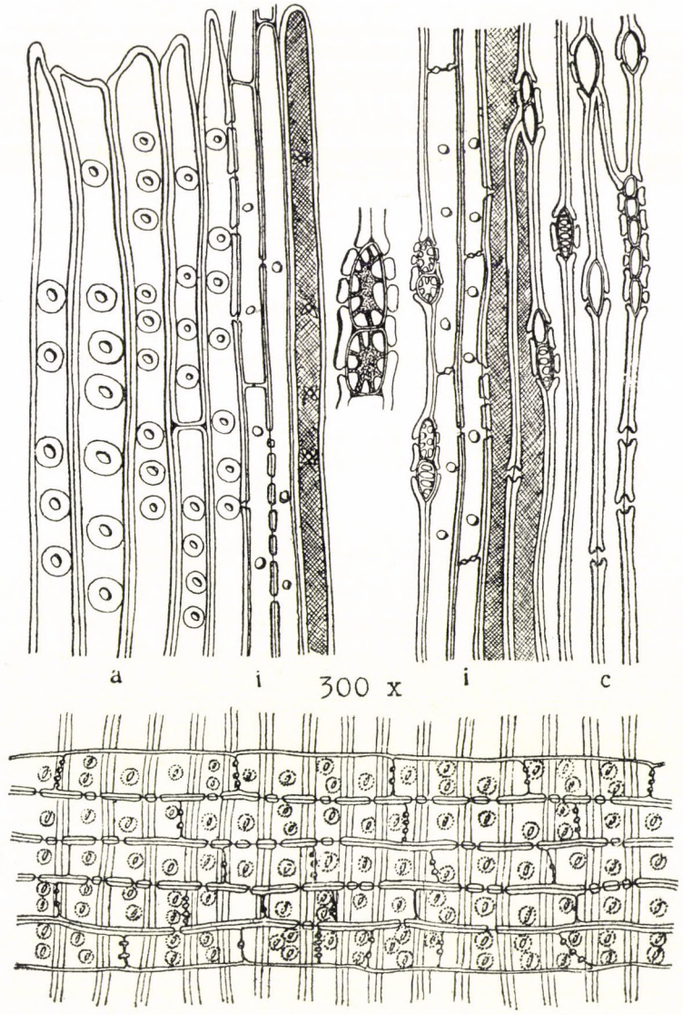
2. (100×)



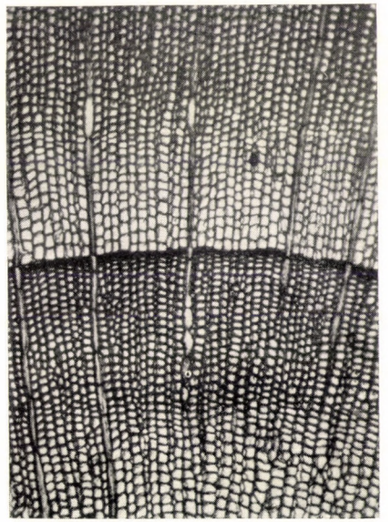
3. (300×)



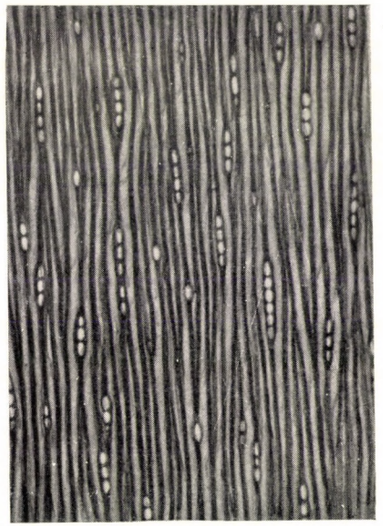
4. (300×)



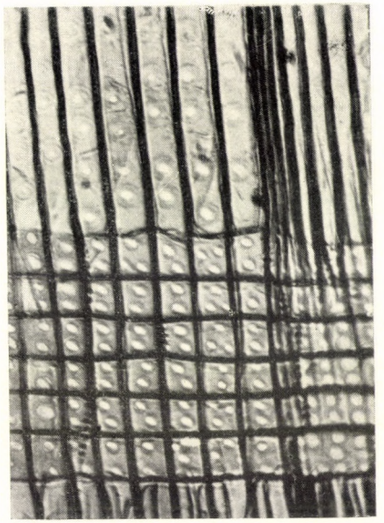
127. Juniperus bermudiana L.



1. (100×)



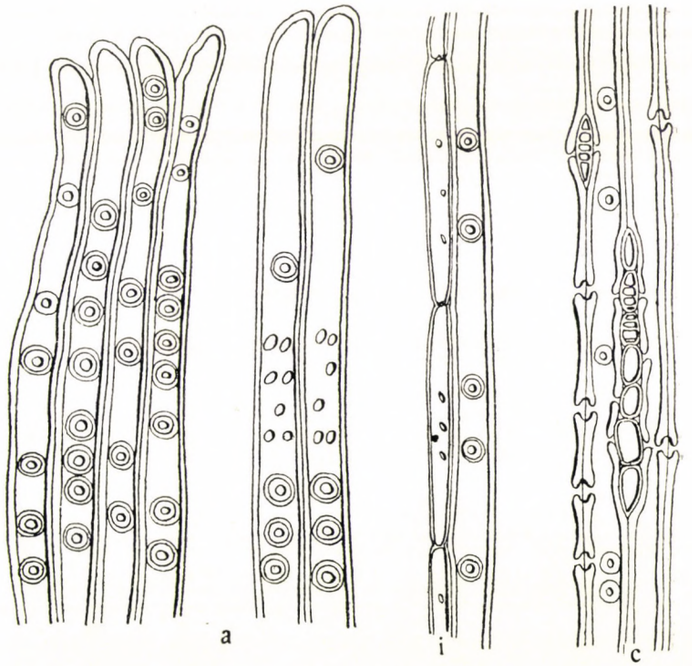
2. (100×)



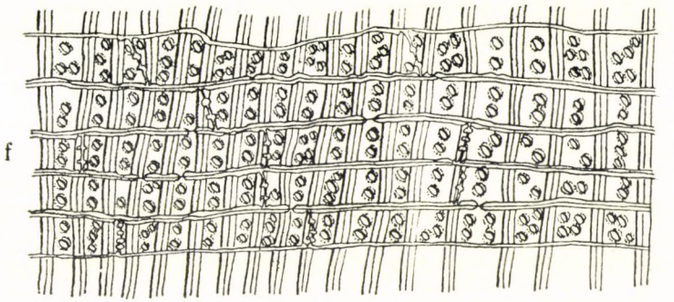
3. (300×)



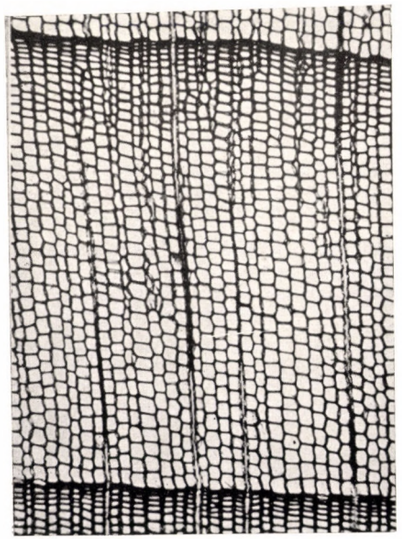
4. (300×)



300 x



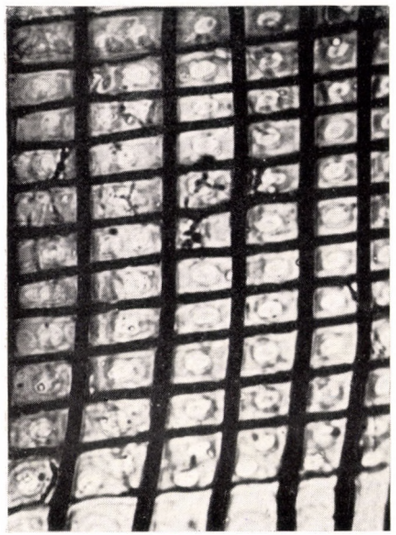
129. Juniperus chinensis L.



1. (100×)



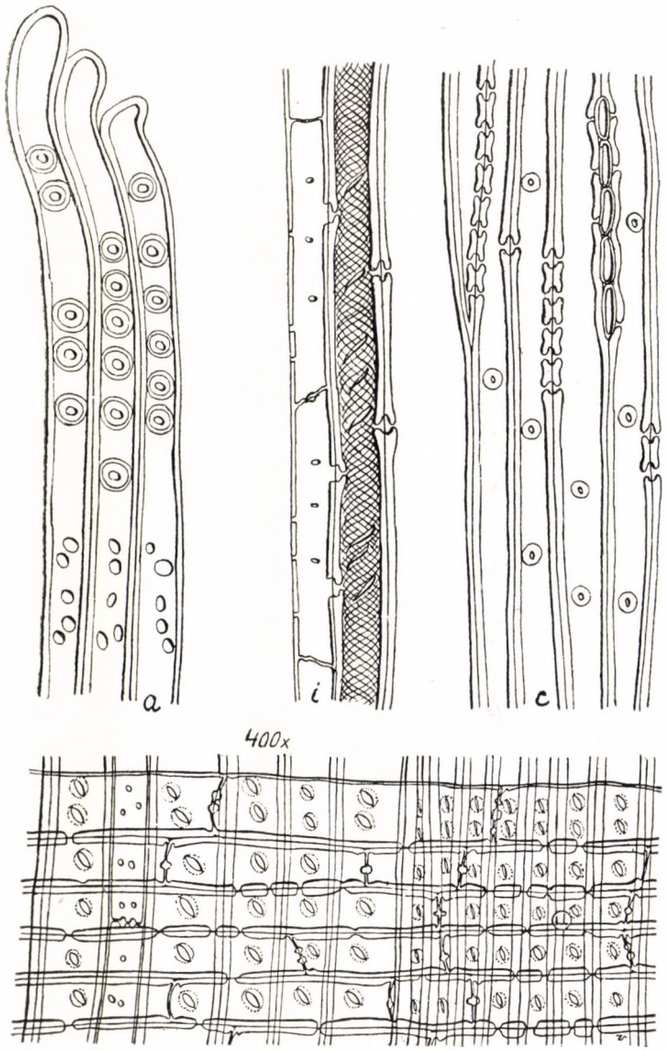
2. (100×)



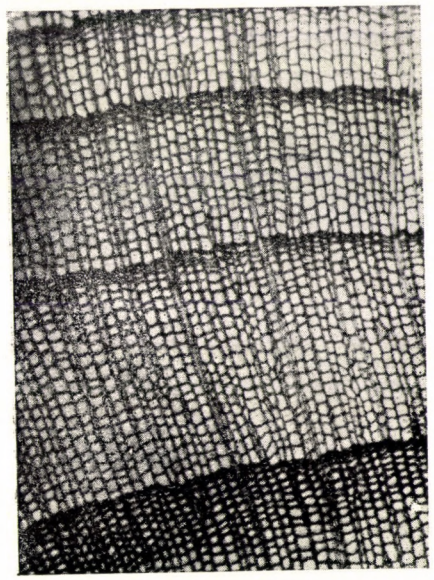
3. (300×)



4. (300×)



130. Juniperus communis L.



1. (100×)



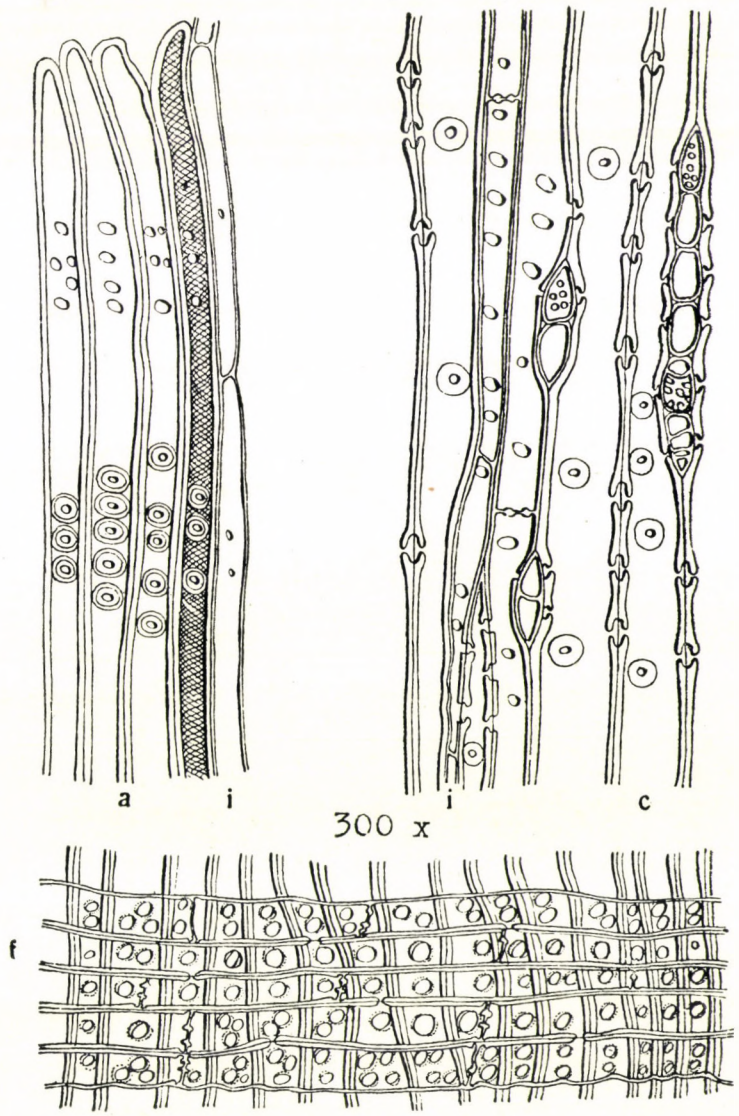
2. (100×)



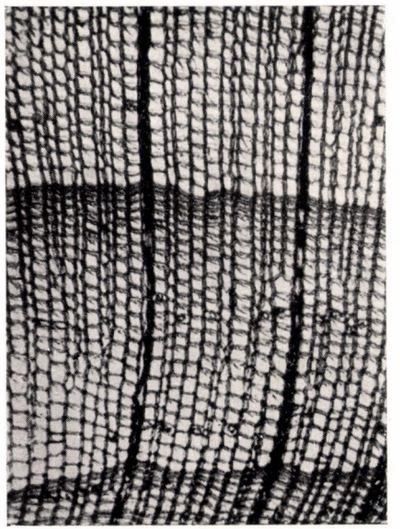
3. (300×)



4. (300×)



131. Juniperus communis var. saxatilis PALLAS



1. (100×)



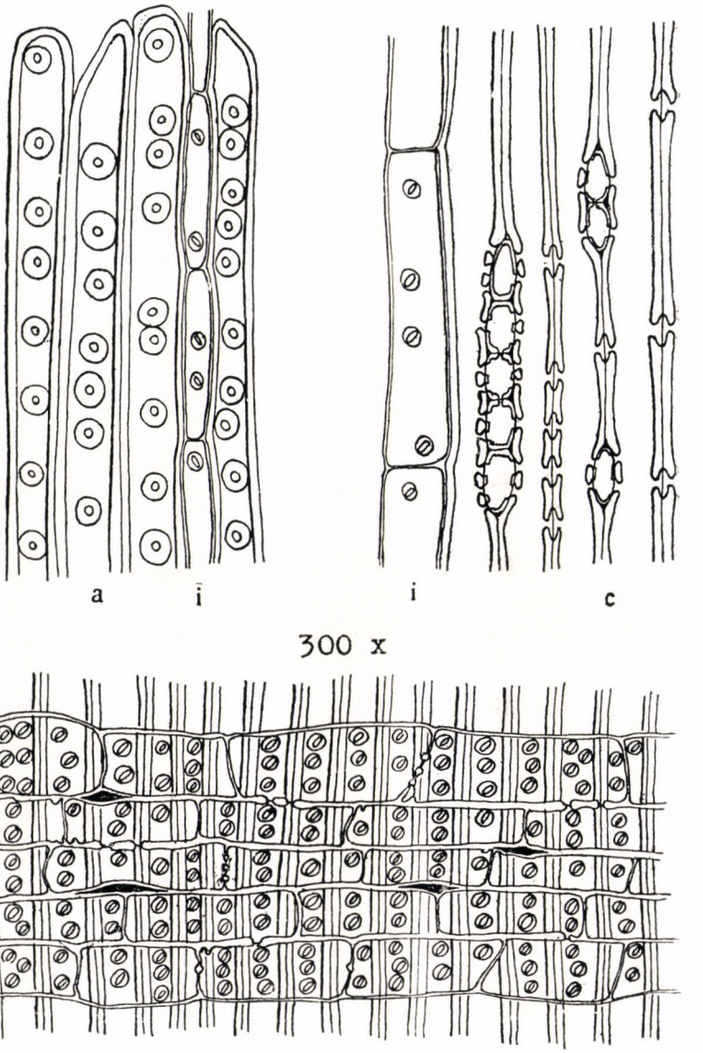
2. (100×)



3. (300×)



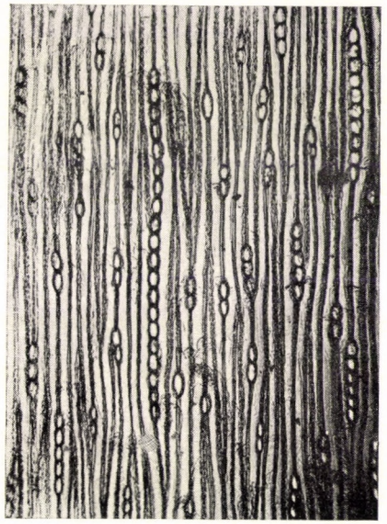
4. (300×)



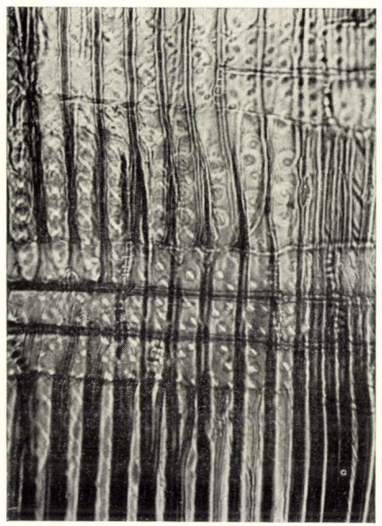
132. Juniperus conferta PARL.



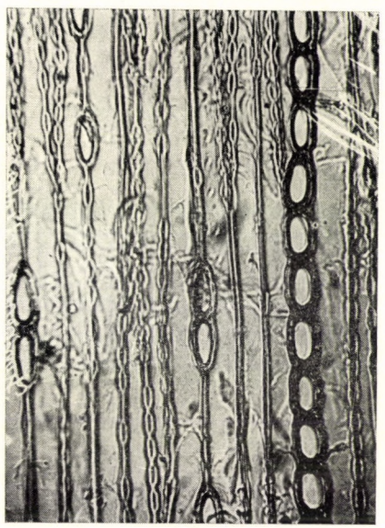
1. (100×)



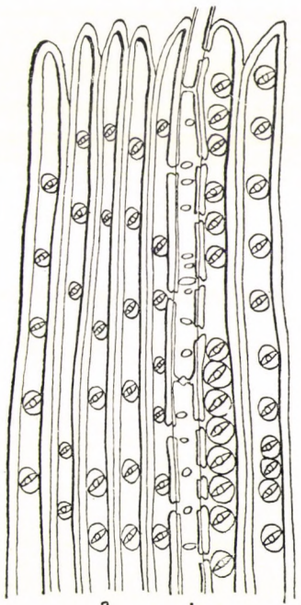
2. (100×)

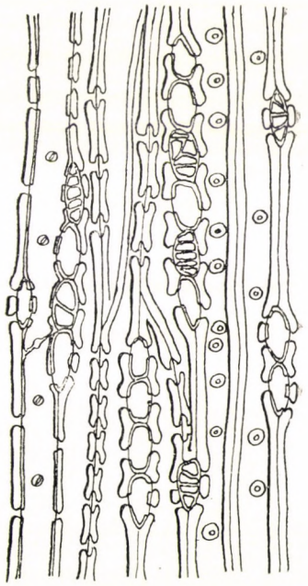


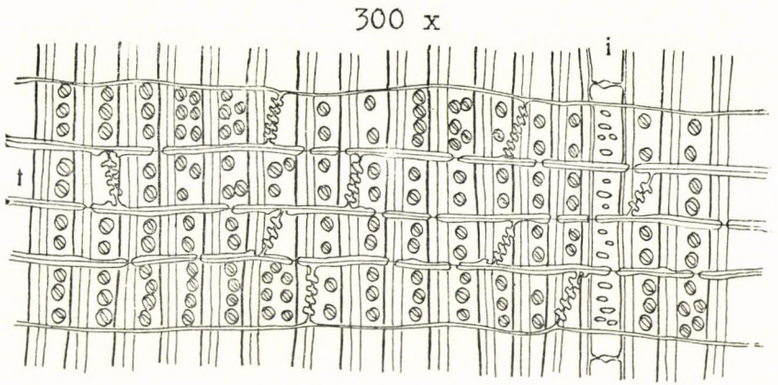
3. (300×)



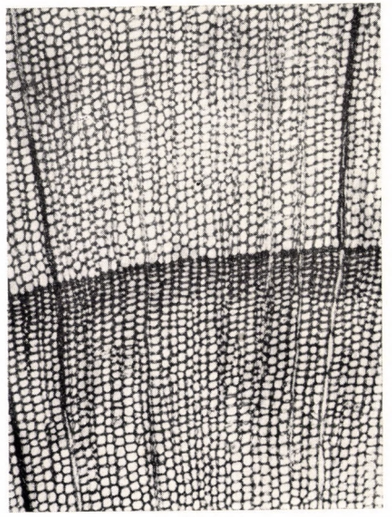
4. (300×)



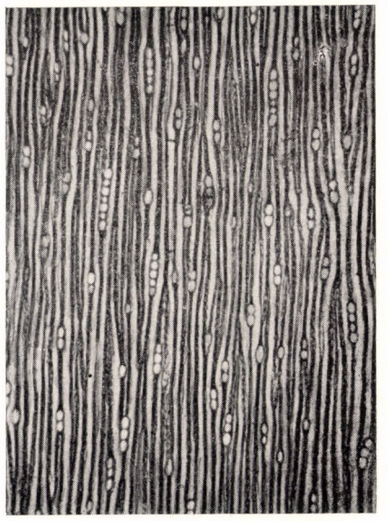




133. Juniperus distans FLORIN



1. (100×)



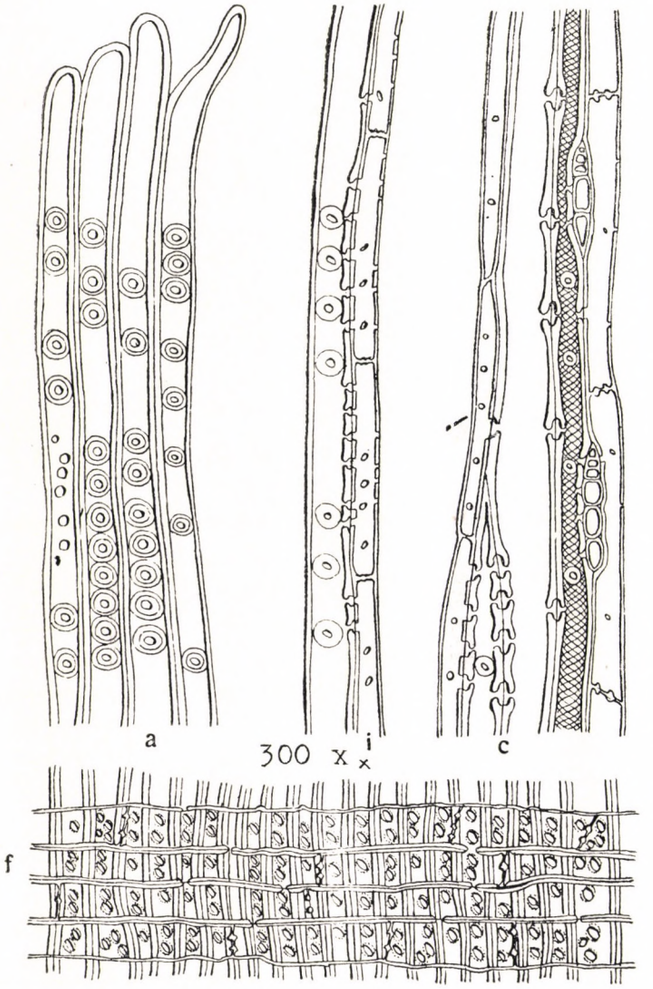
2. (100×)



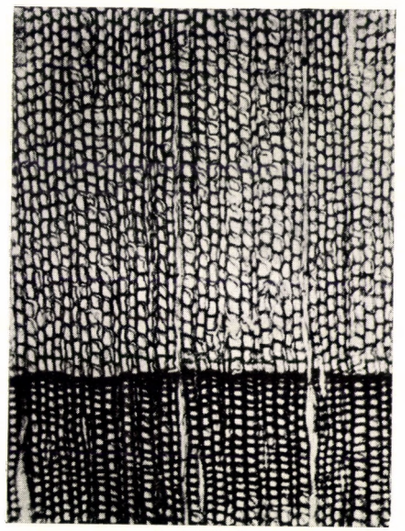
3. (300×)



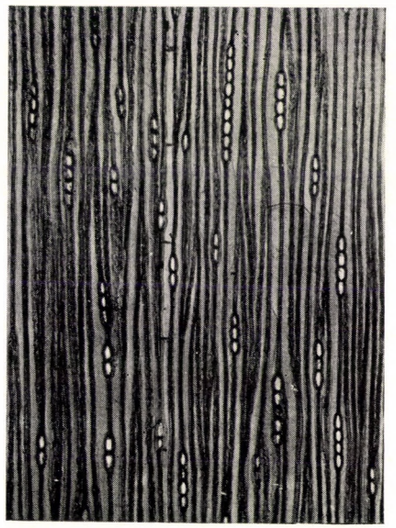
4. (300×)



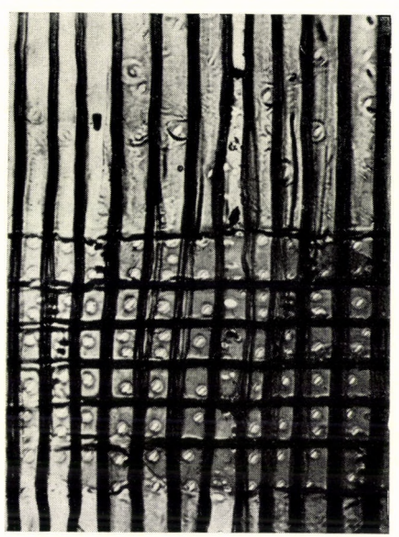
134. Juniperus exelsa BIEBERSTEIN



1. (100×)



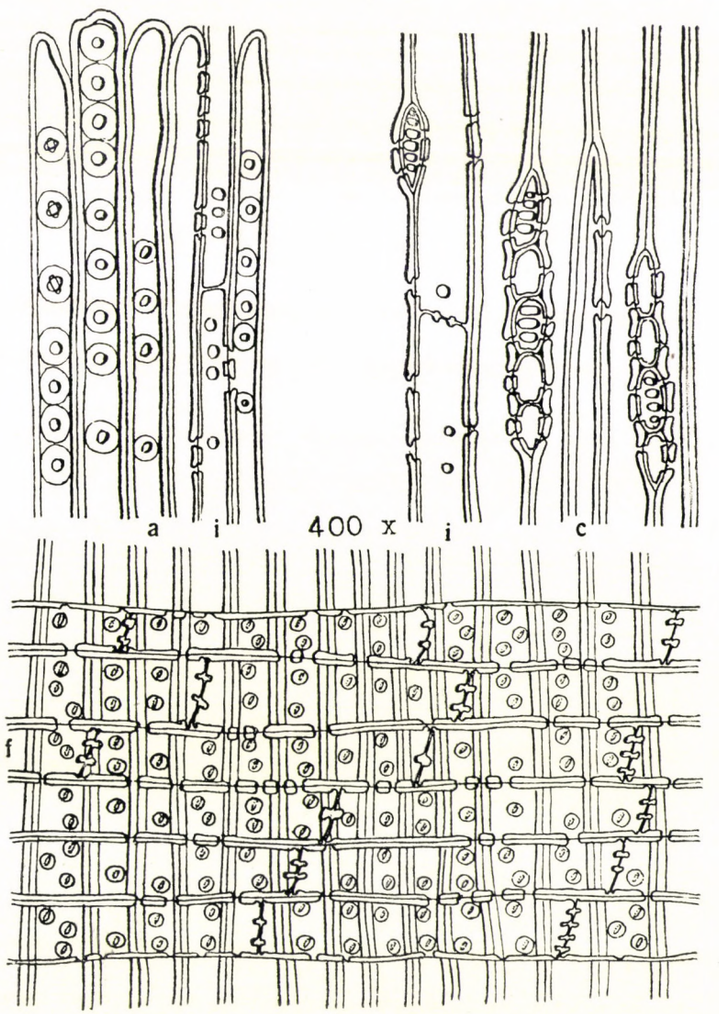
2. (100×)



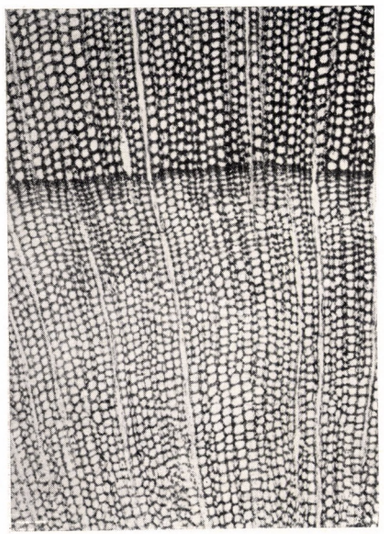
3. (300×)



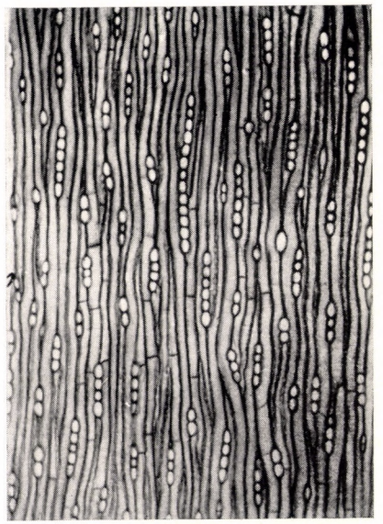
4. (300×)



135. Juniperus formosana HAYATA



1. (100×)



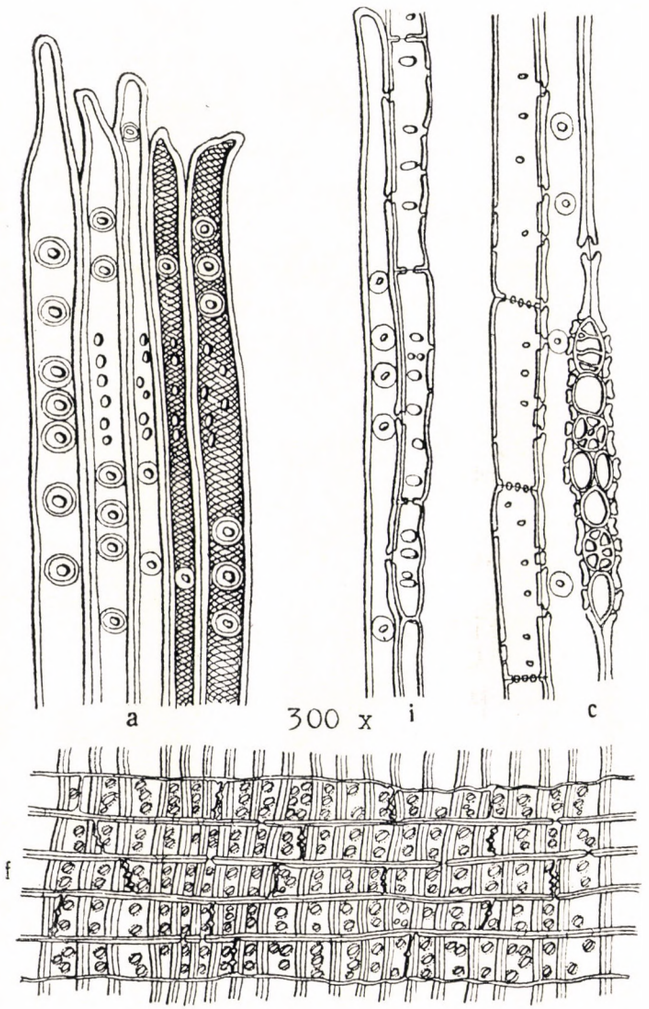
2. (100×)



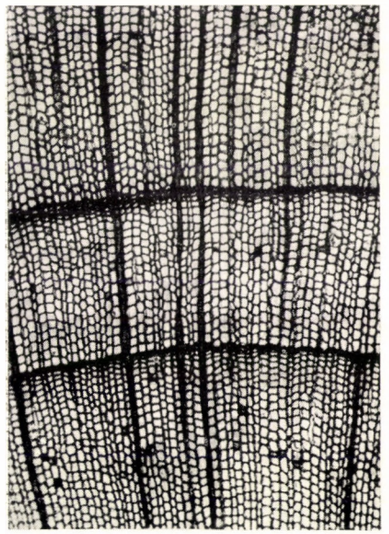
3. (300×)



4. (300×)



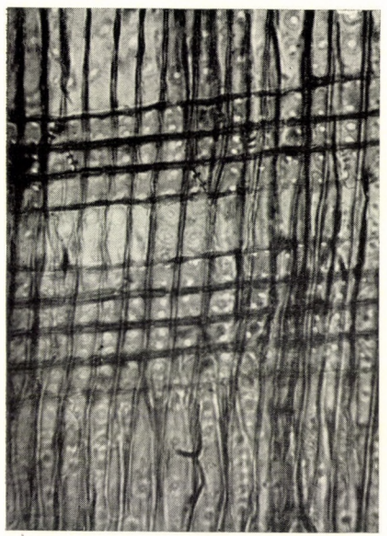
136. Juniperus foetidissima WILL.



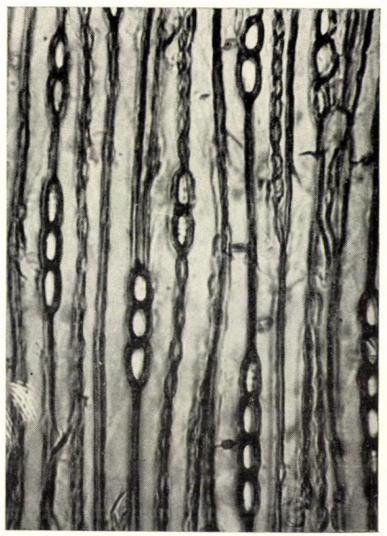
1. (100×)



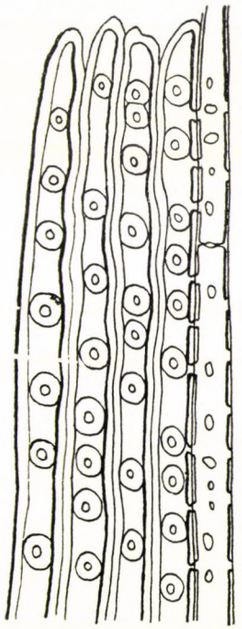
2. (100×)

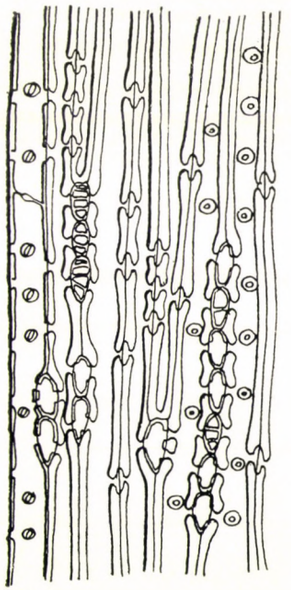


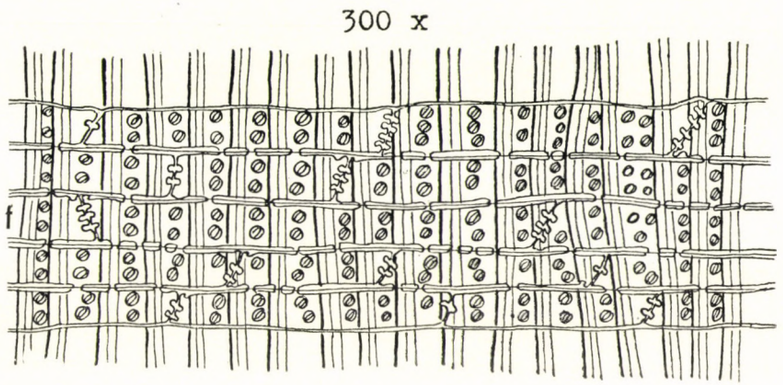
3. (300×)



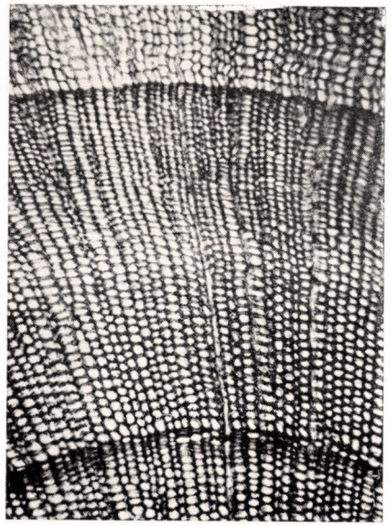
4. (300×)







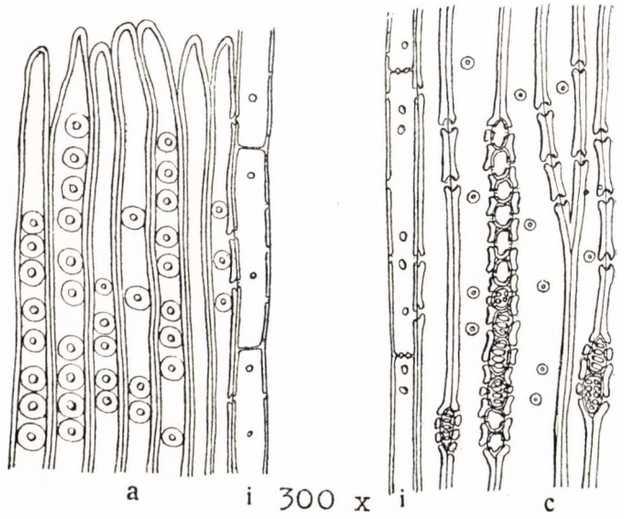
137. Juniperus glaucescens FLORIN



1. (100×)

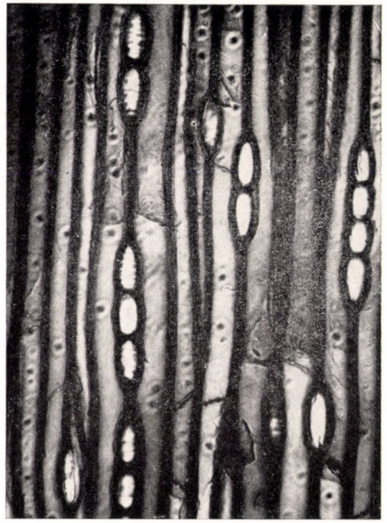


2. (100×)

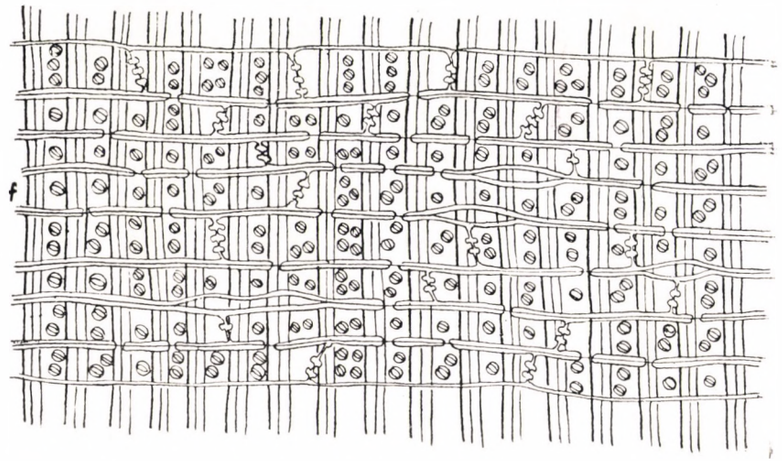




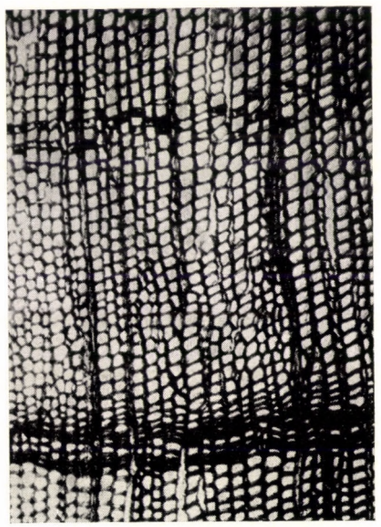
3. (300×)



4. (300×)



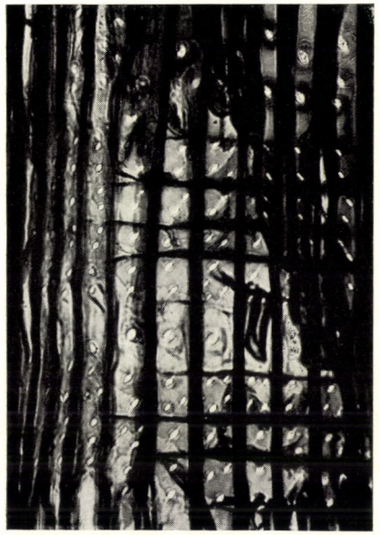
138. Juniperus horizontalis MOENCH



1. (100×)



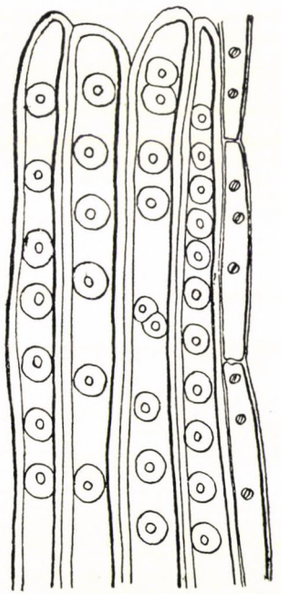
2. (100×)

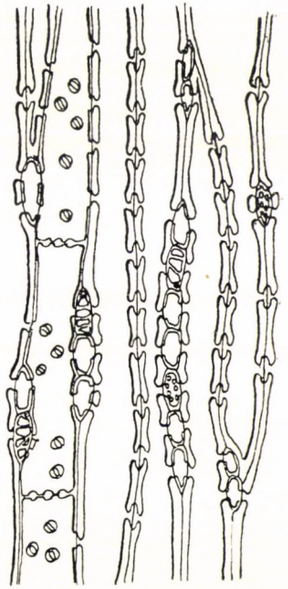


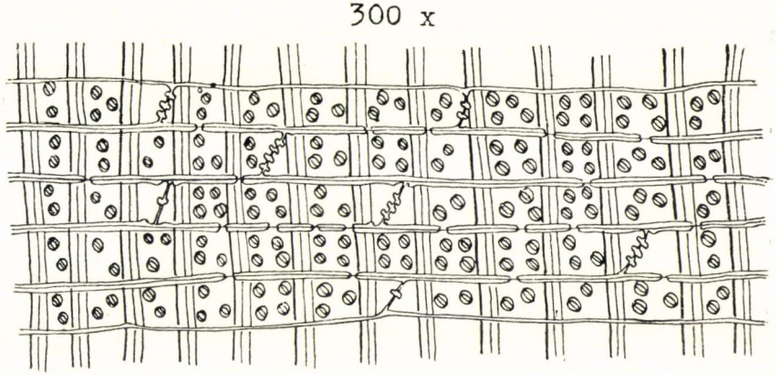
3. (300×)



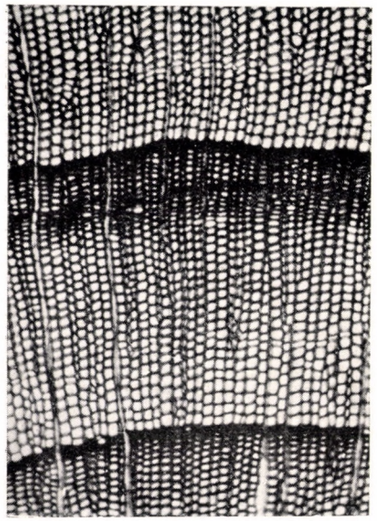
4. (300×)



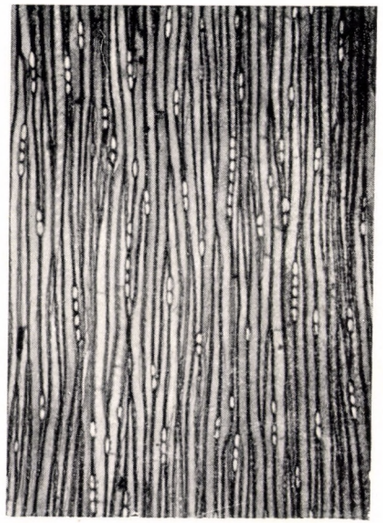




139. Juniperus Lemeeana Lev. et Blin



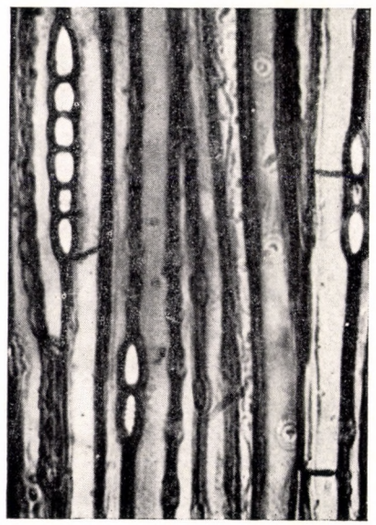
1. (100×)



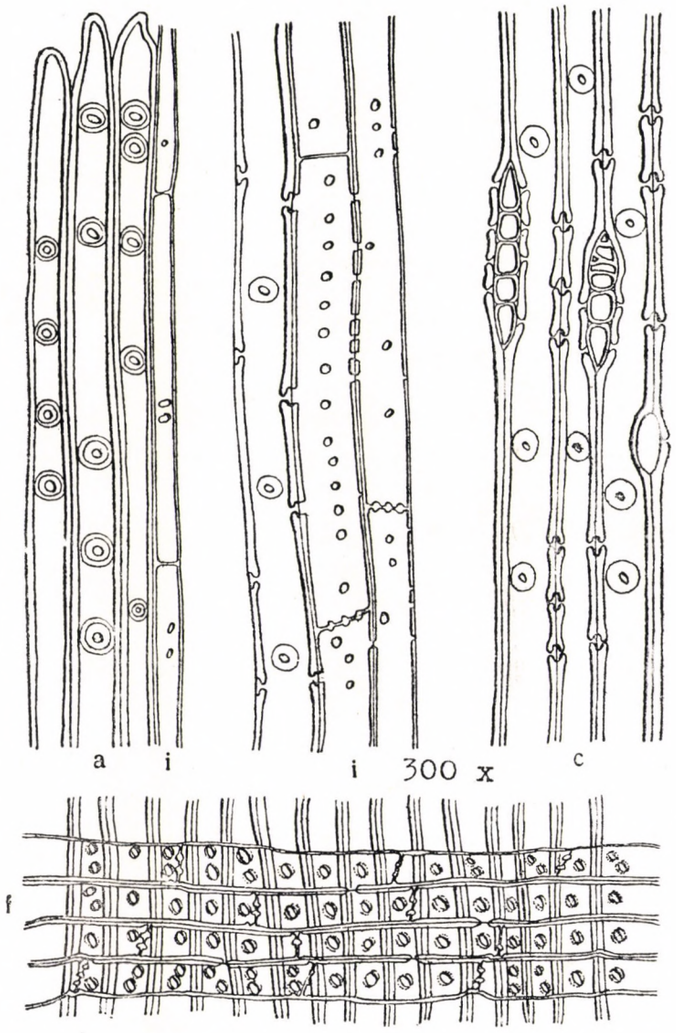
2. (100×)



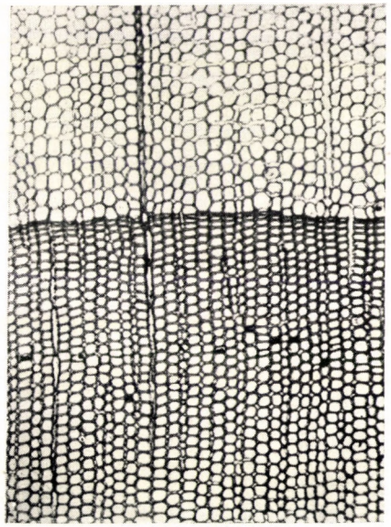
3. (300×)



4. (300×)



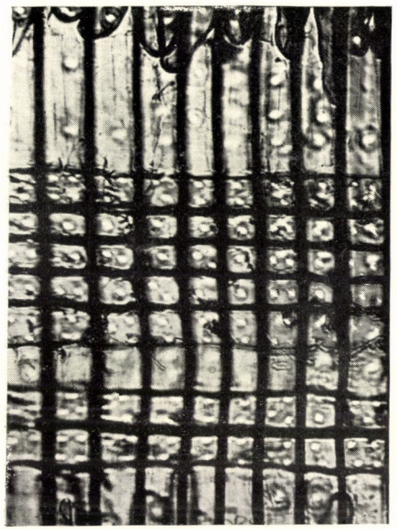
140. Juniperus macrocarpa SIBTHORP et SMITH



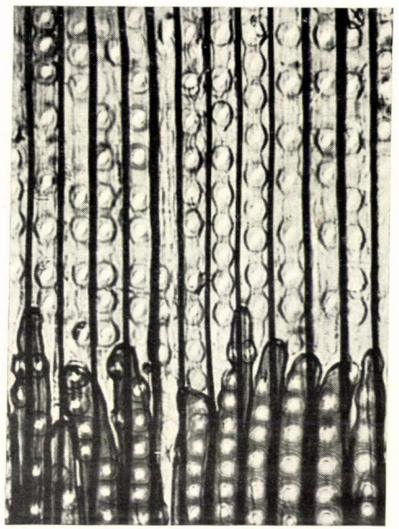
1. (100×)



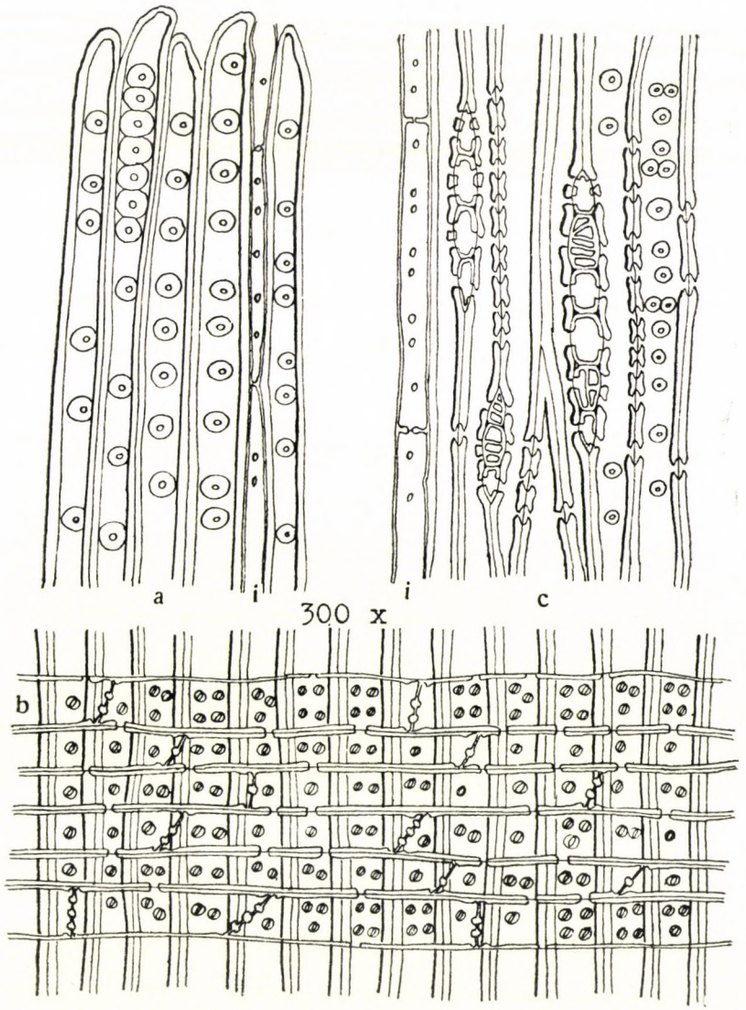
2. (100×)



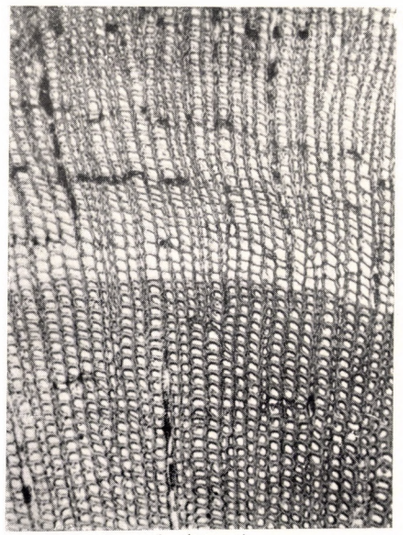
3. (300×)



4. (300×)



141. Juniperus macropoda Boiss



1. (100×)



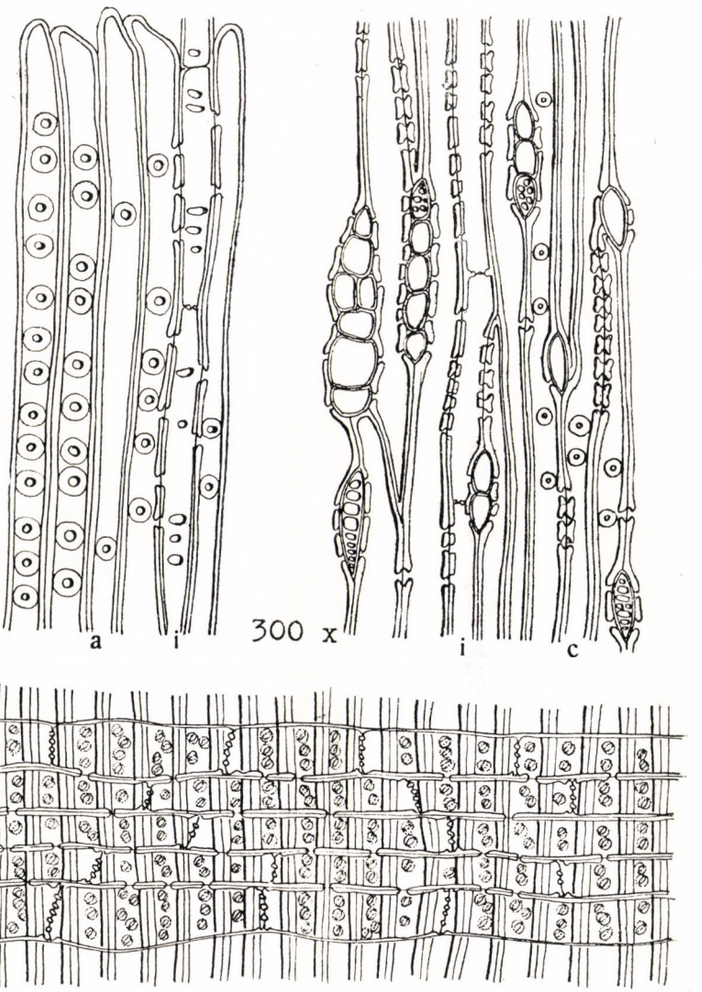
2. (100×)



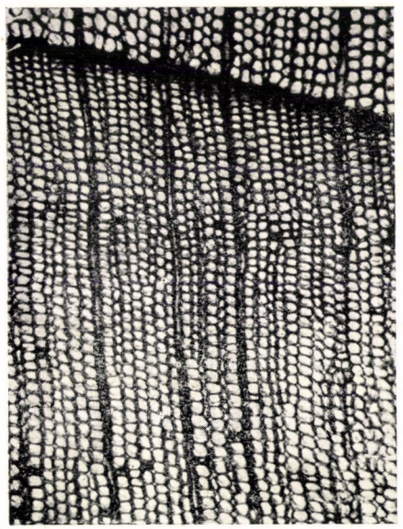
3. (300×)



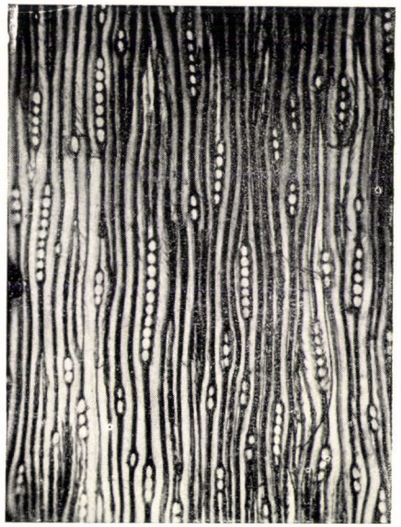
4. (300×)



142. Juniperus mexicana SCHLECHTENDAL



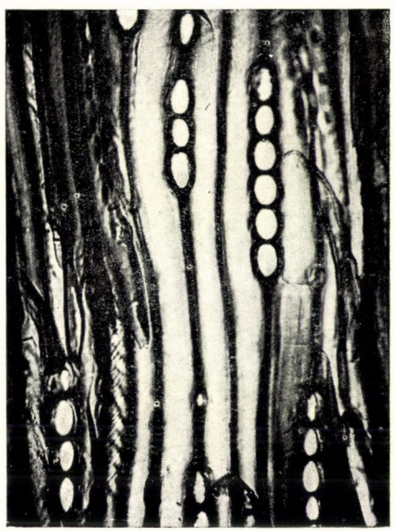
1. (100×)



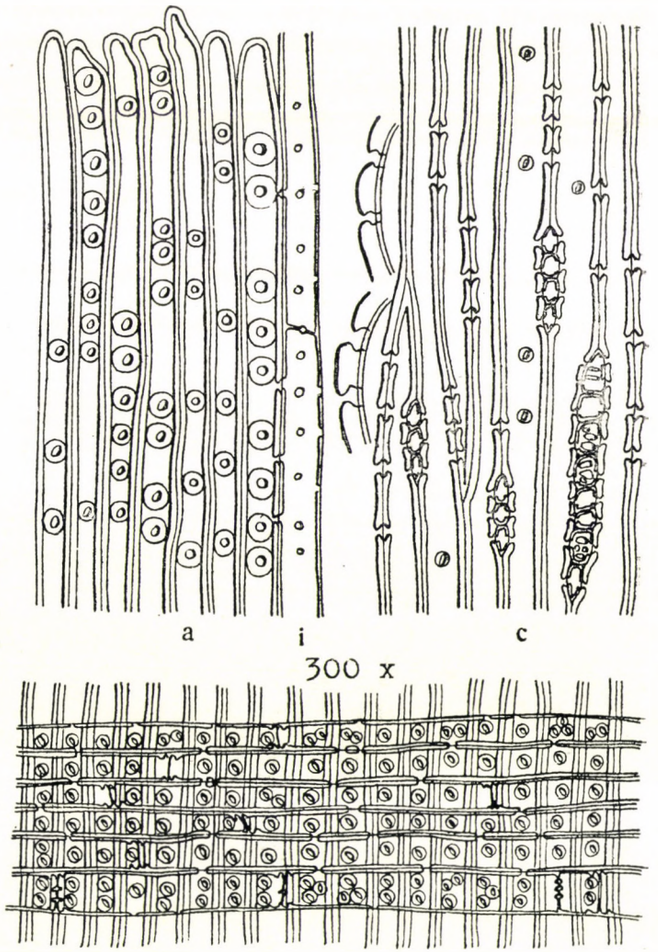
2. (100×)



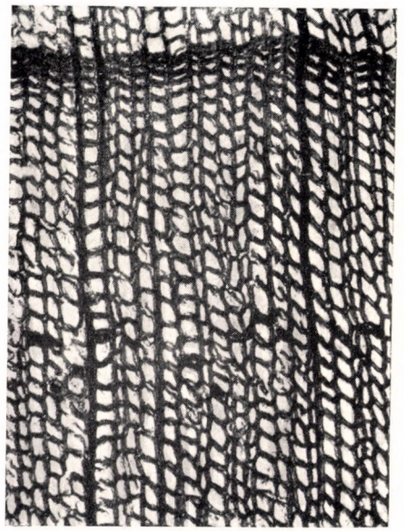
3. (300×)



4. (300×)



143. Juniperus monosperma (Engelmann) Sarg.



1. (100×)



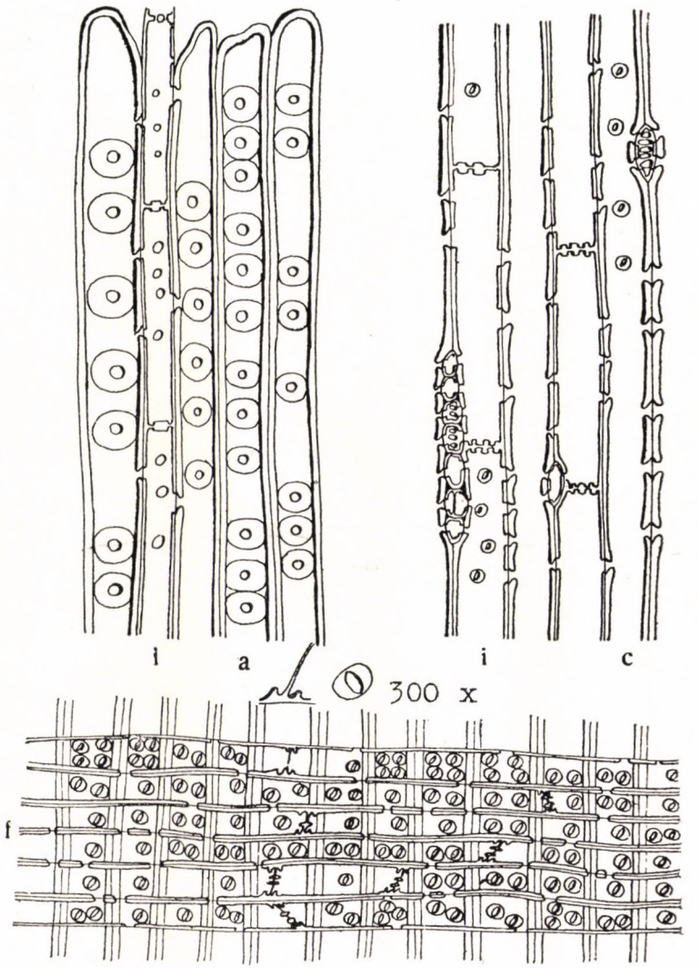
2. (100×)



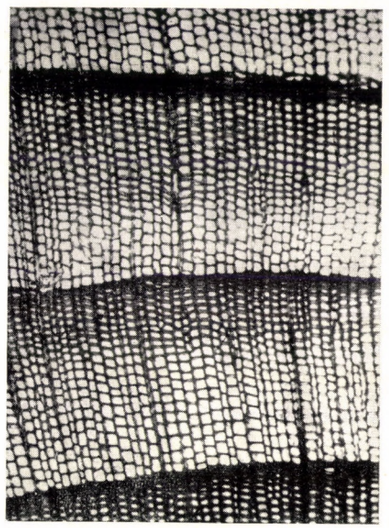
3. (300×)



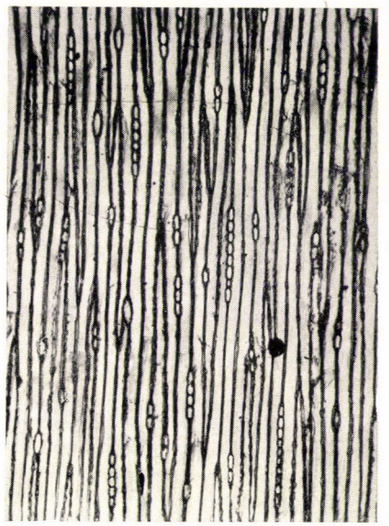
4. (300×)



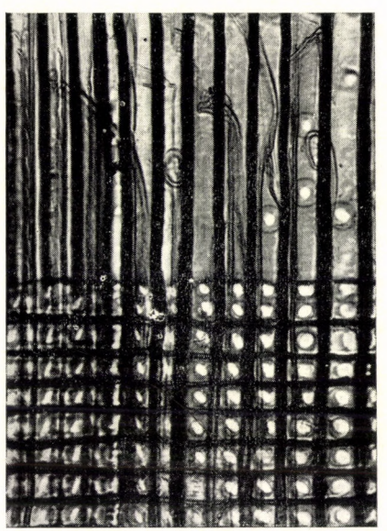
144. Juniperus occidentalis Hook.



1. (100×)



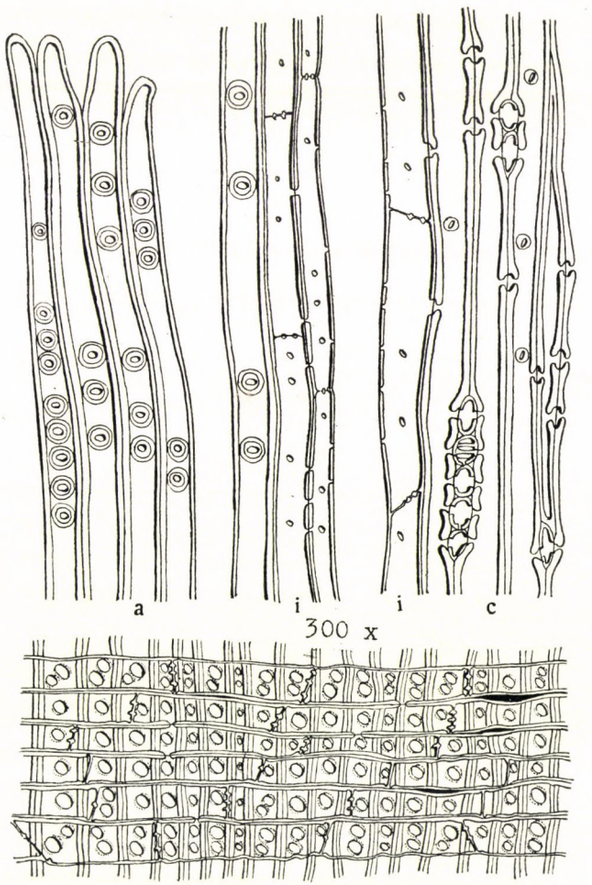
2. (100×)



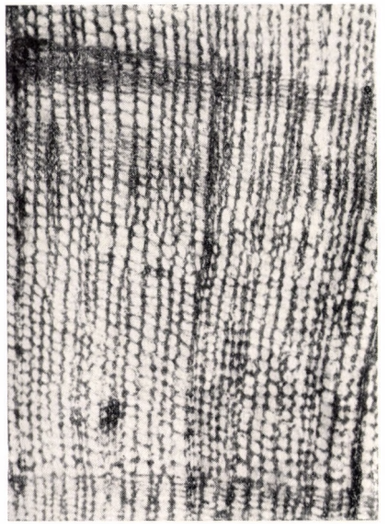
3. (300×)



4. (300×)



145. Juniperus Oxycedrus L.



1. (100×)



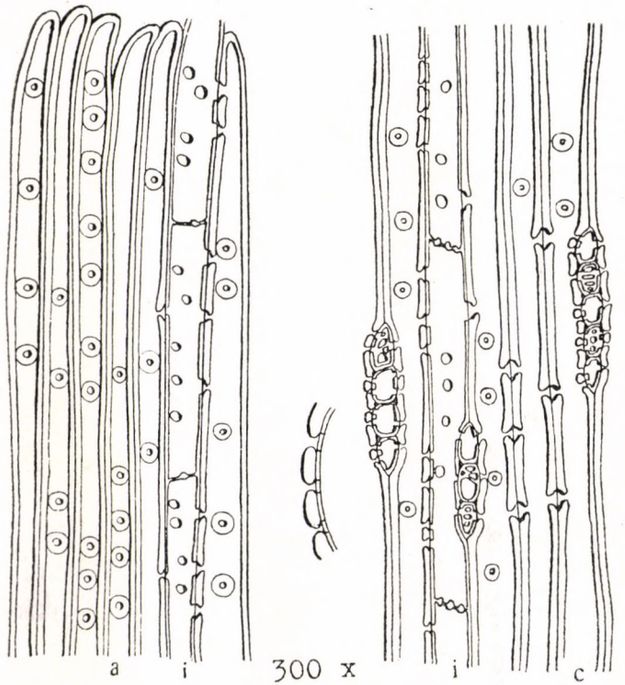
2. (100×)

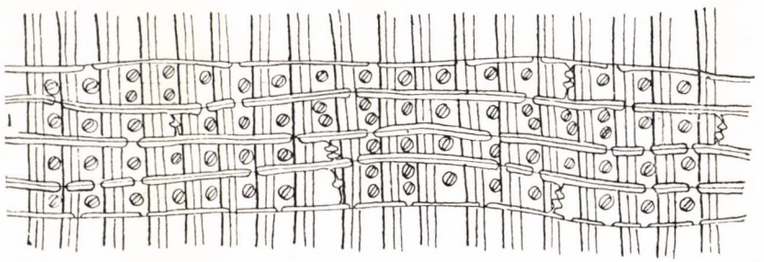


3. (300×)

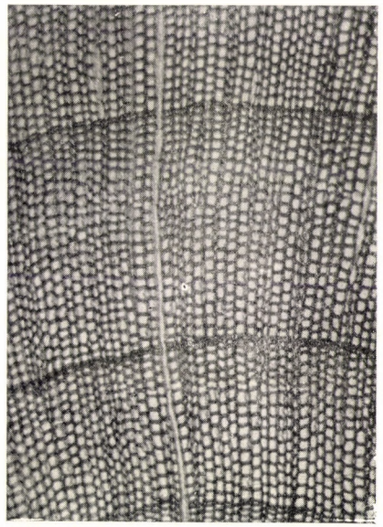


4. (300×)





146. Juniperus pachyphloea TORREY.



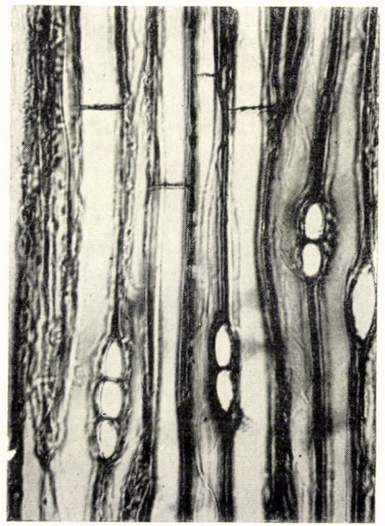
1. (100×)



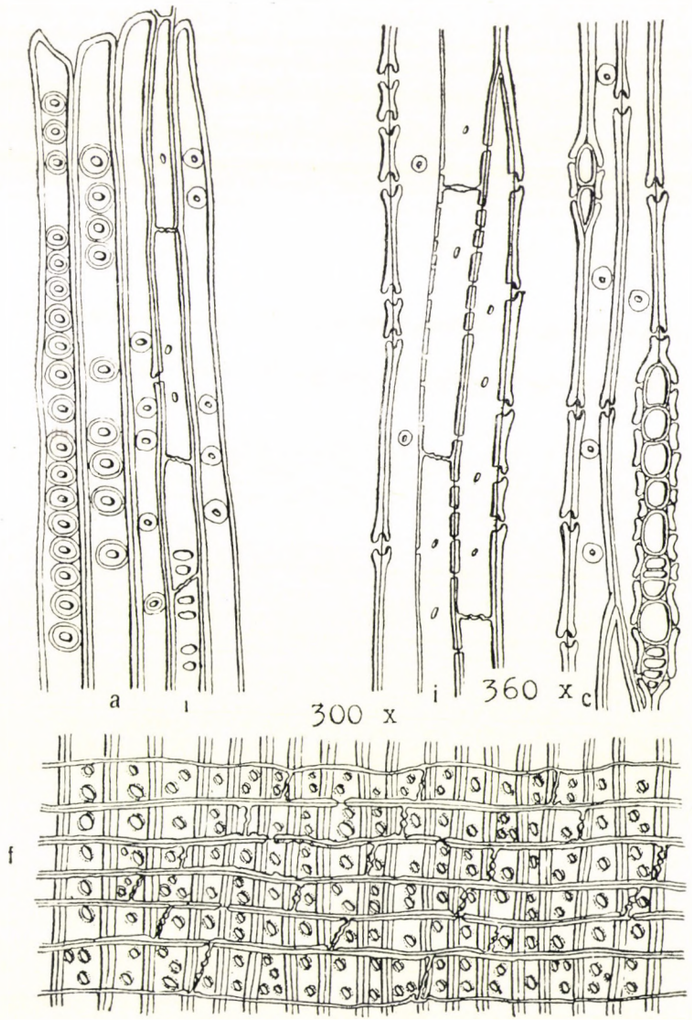
2. (100×)



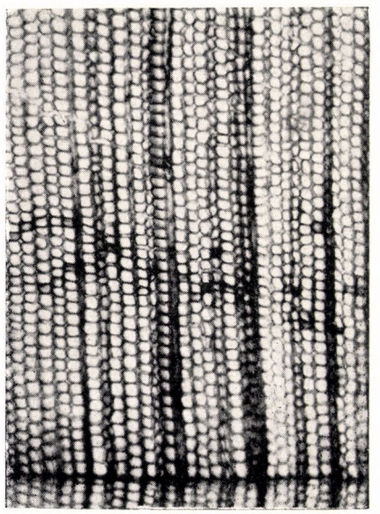
3. (300×)



4. (300×)



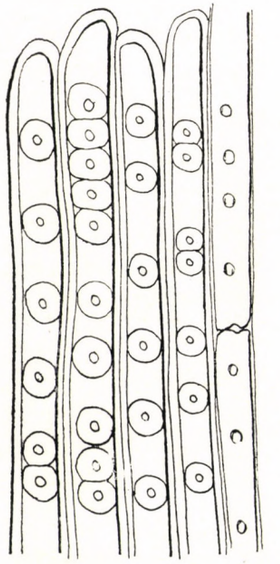
147. Juniperus phoenicea L.

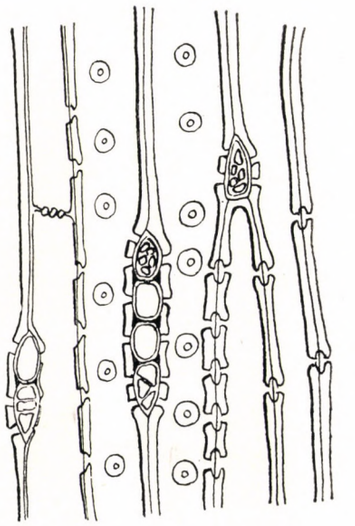


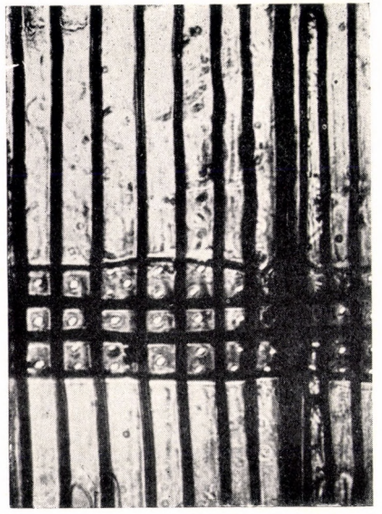
1. (100×)



2. (100×)



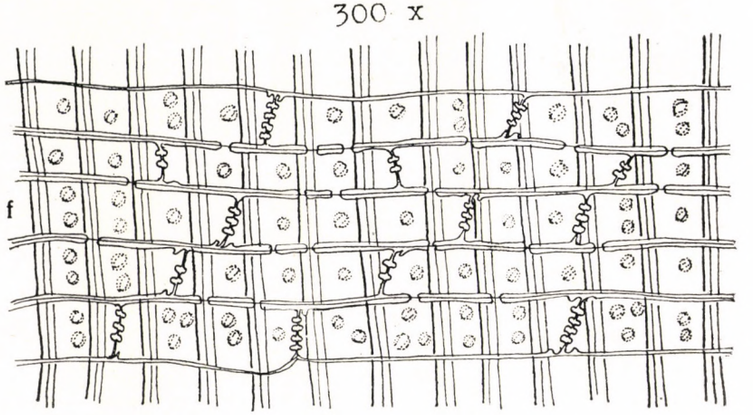




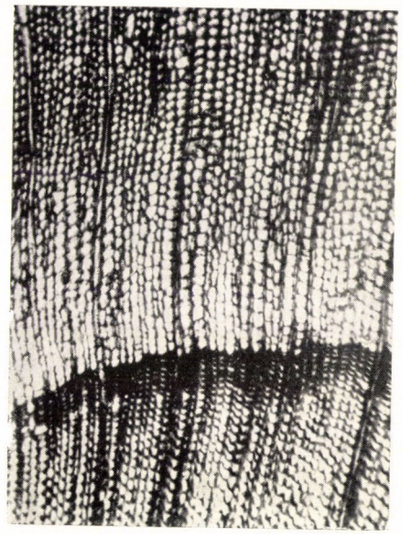
3. (300×)



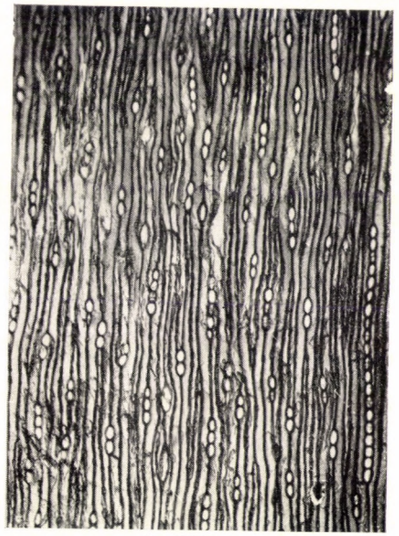
4. (300×)



148. Juniperus Pinchoti SUDWORTH



1. (100×)



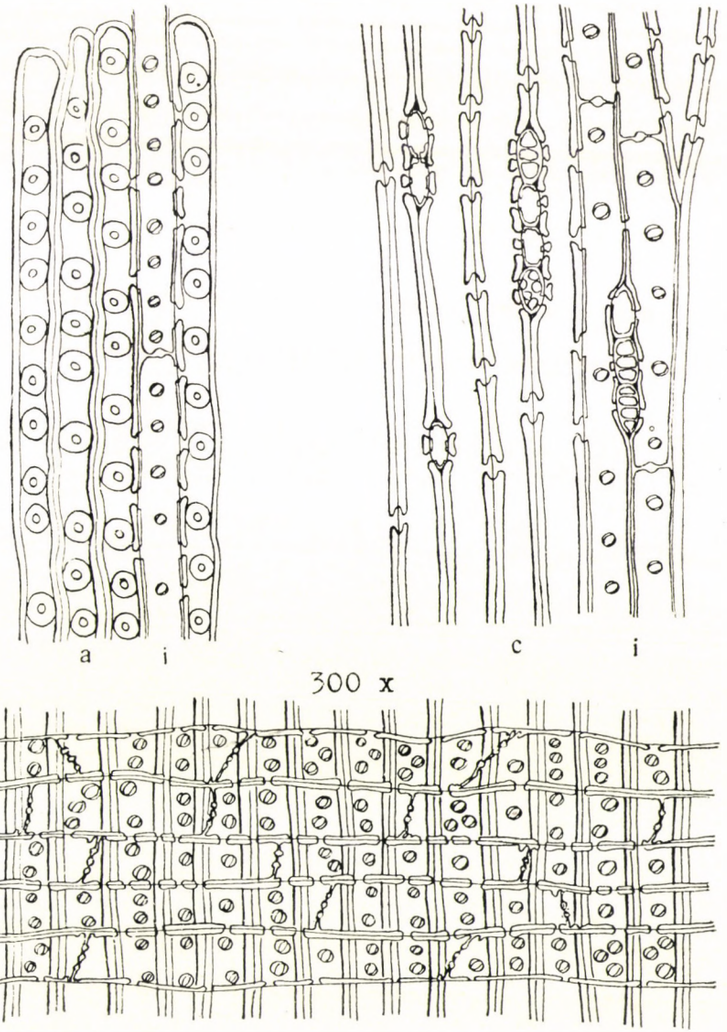
2. (100×)



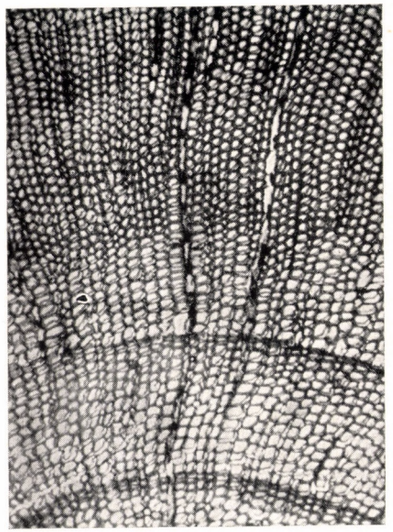
3. (300×)



4. (300×)



149. Juniperus Pingii CHENG



1. (100×)



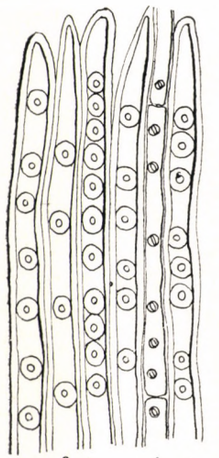
2. (100×)

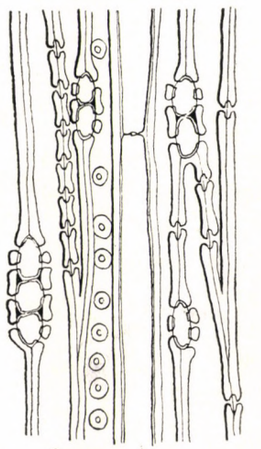


3. (300×)

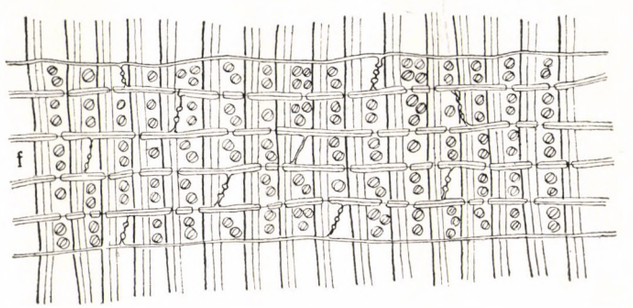


4. (300×)

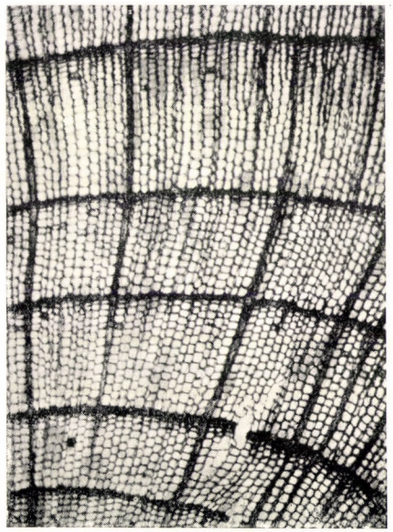




300 x



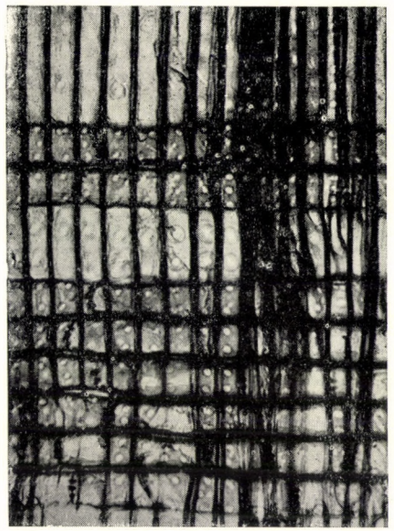
150. Juniperus procera HOCHST.



1. (100×)



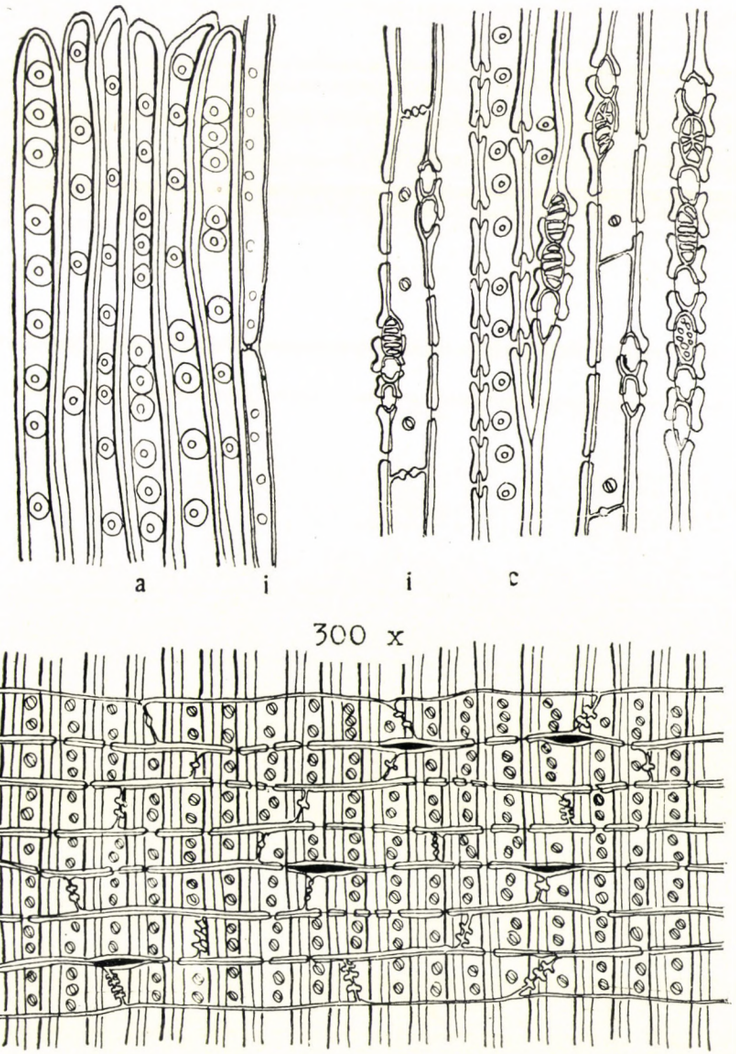
2. (100×)



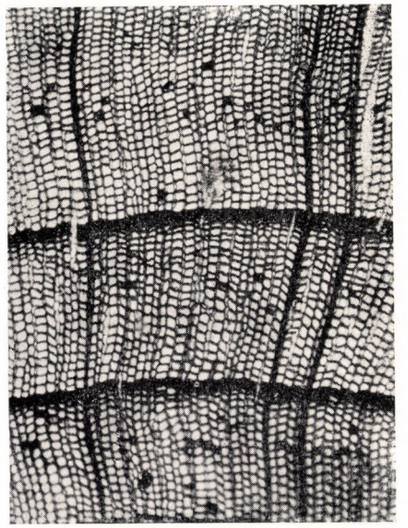
3. (300×)



4. (300×)



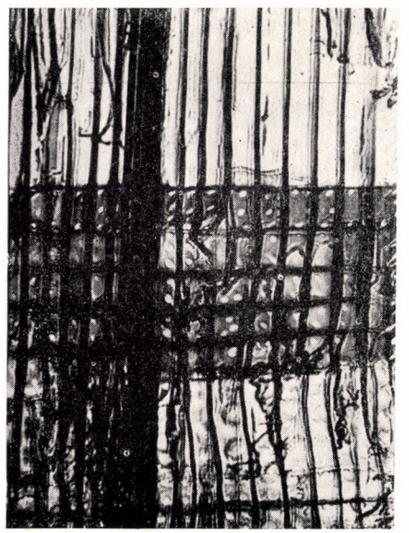
151. Juniperus Przewalskii KOMAROV



1. (100×)



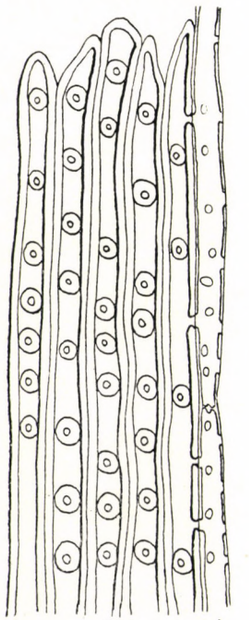
2. (100×)

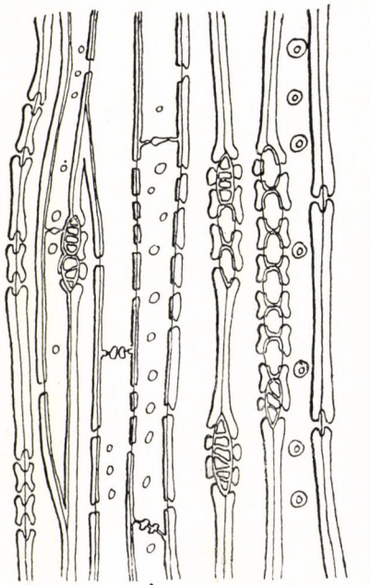


3. (300×)

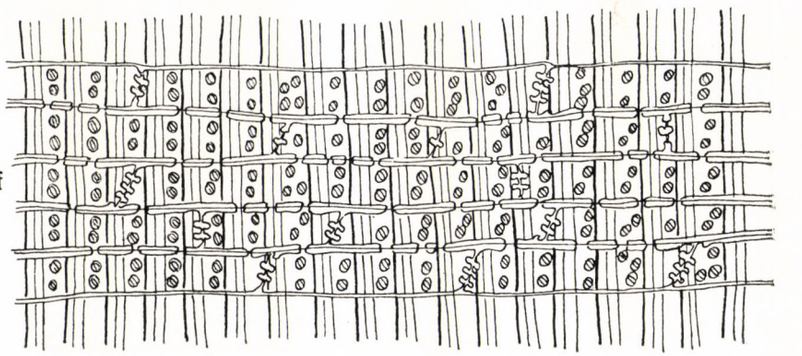


4. (300×)

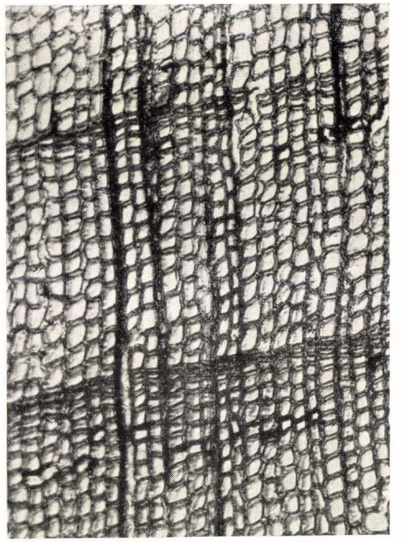




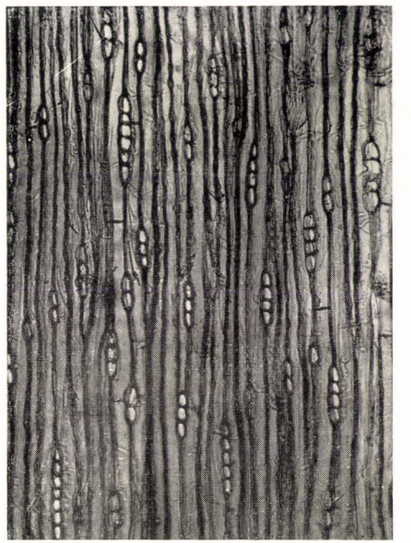
300 x



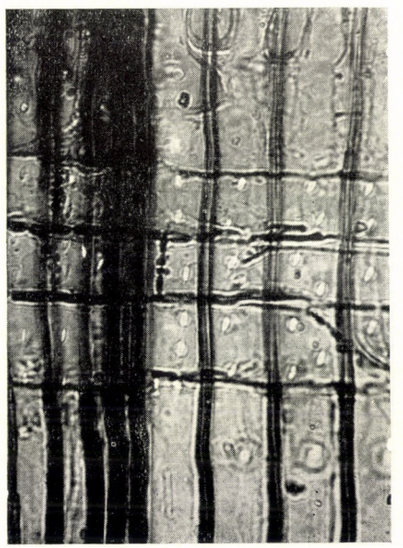
152. Juniperus ramulosa FLORIN



1. (100×)



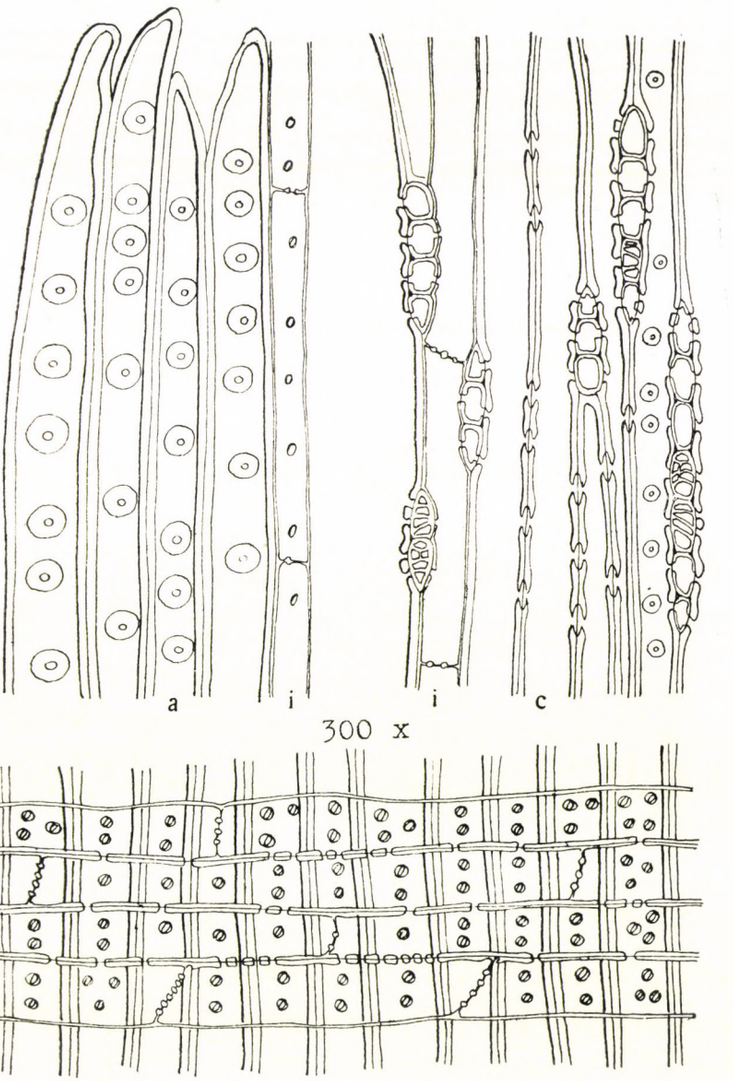
2. (100×)



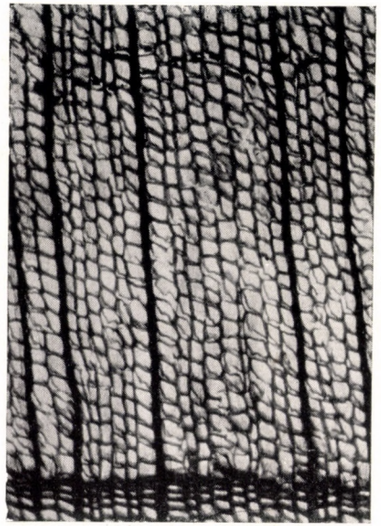
3. (300×)



4. (300×)



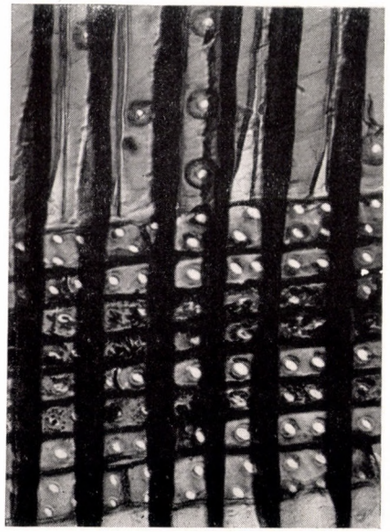
153. Juniperus recurva BUCH-HAM.



1. (100×)



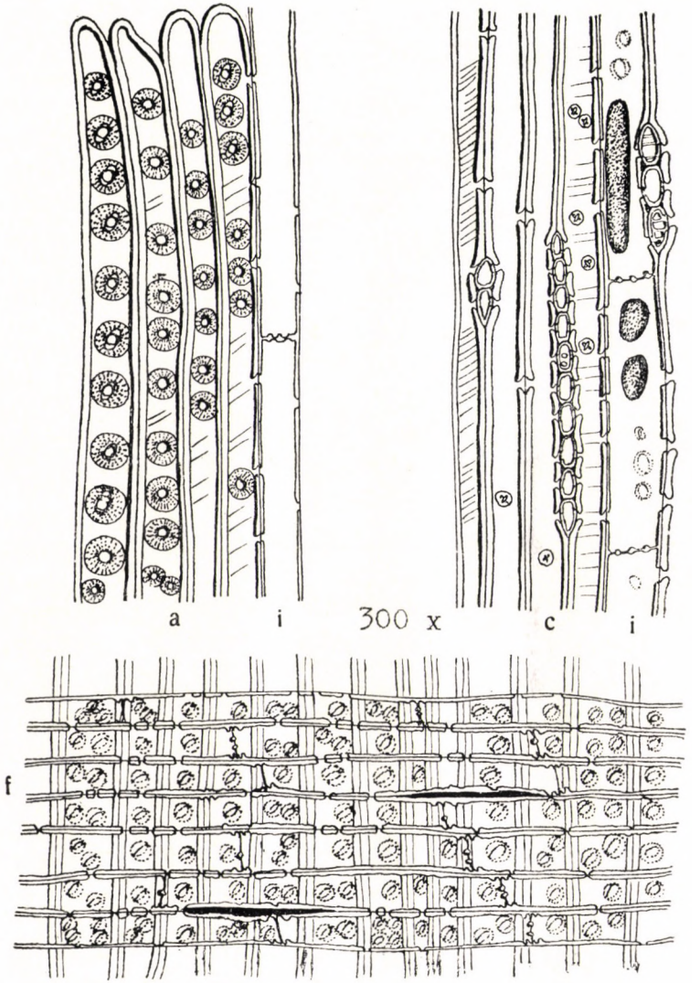
2. (100×)



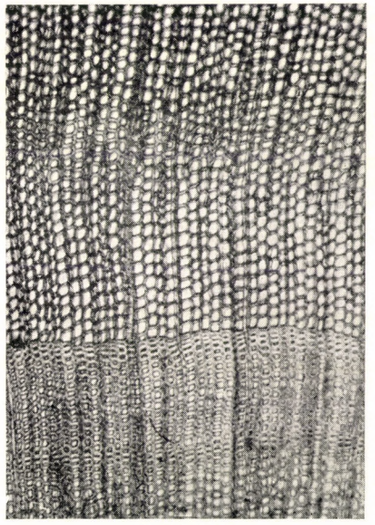
3. (300×)



4. (300×)



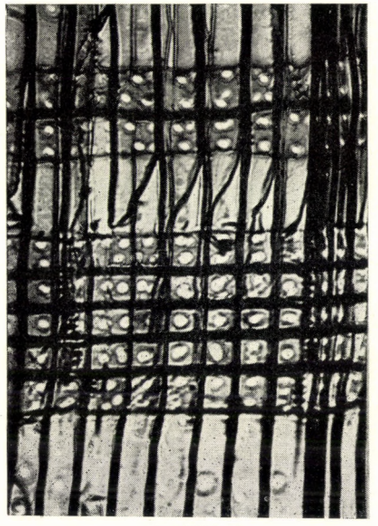
154. Juniperus rigida SIEB. et ZUCC.



1. (100×)



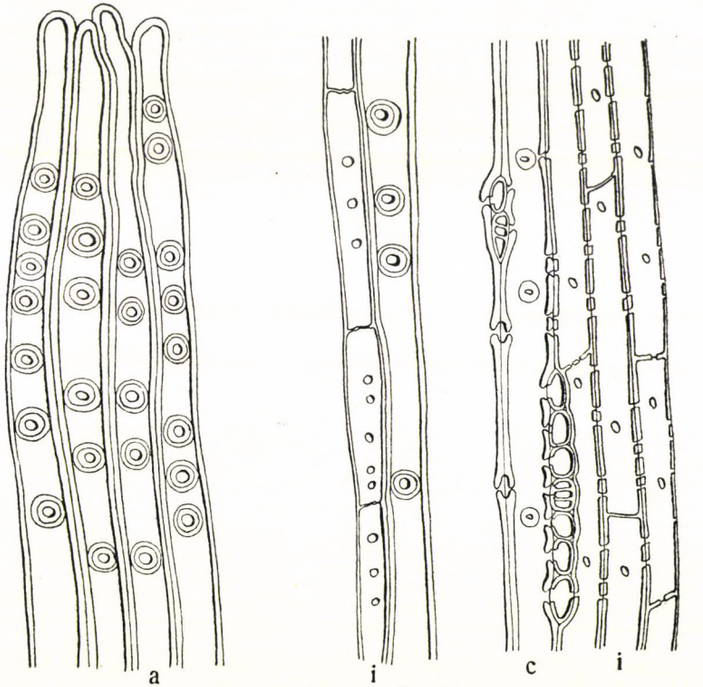
2. (100×)



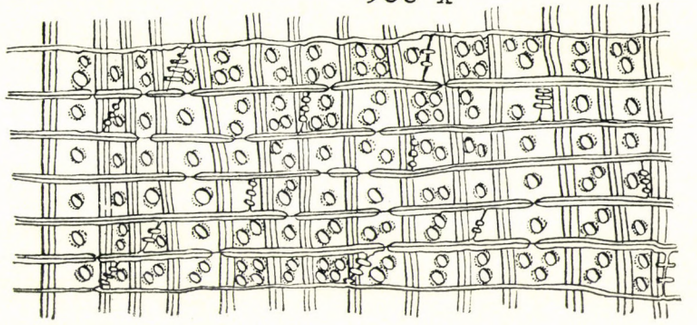
3. (300×)



4. (300×)



300 x



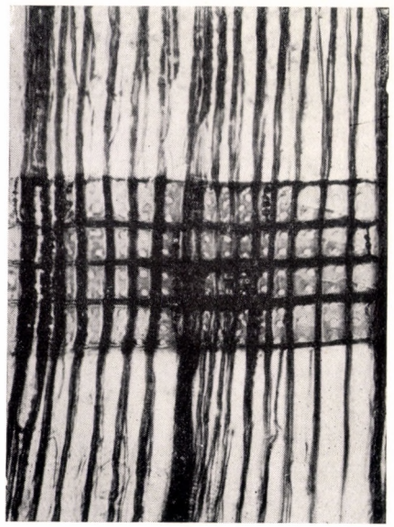
155. Juniperus Sabina L.



1. (100×)



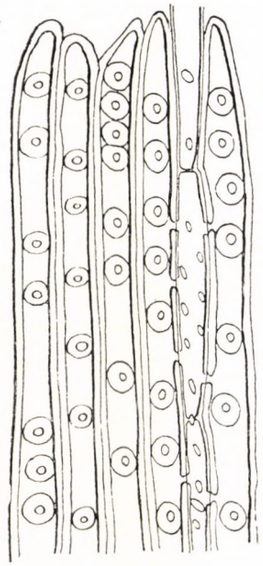
2. (100×)

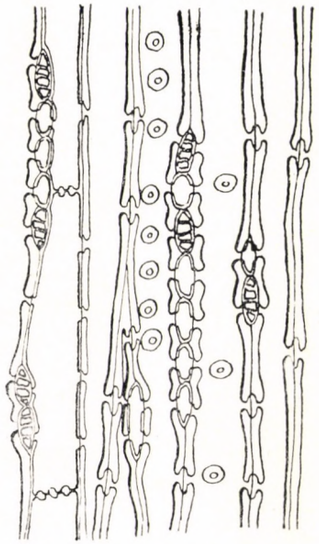


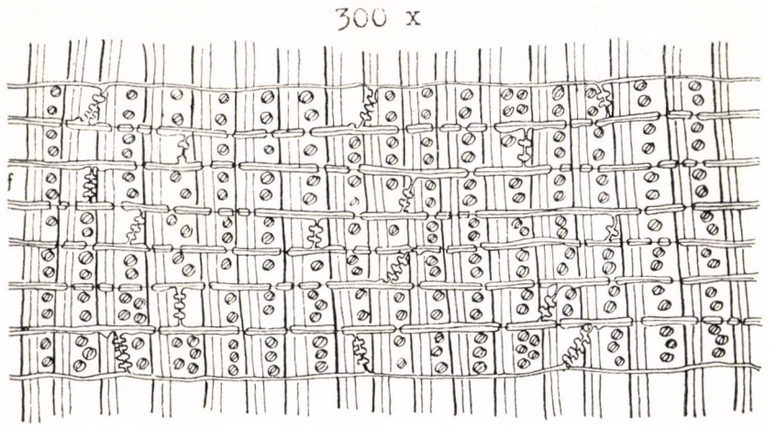
3. (300×)



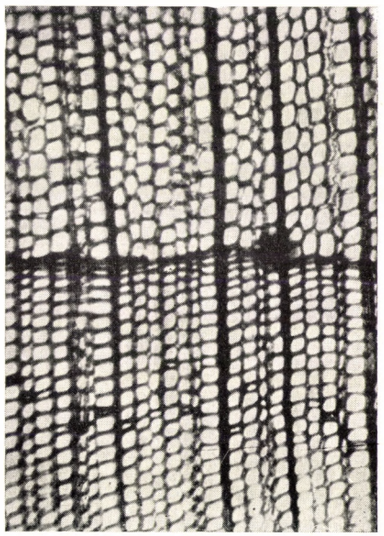
4. (300×)







156. Juniperus saltuaria REHDER et WILSON



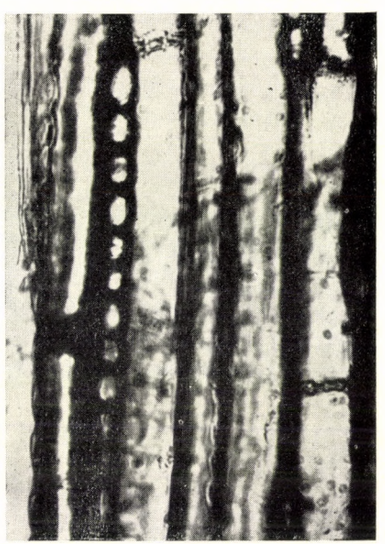
1. (100×)



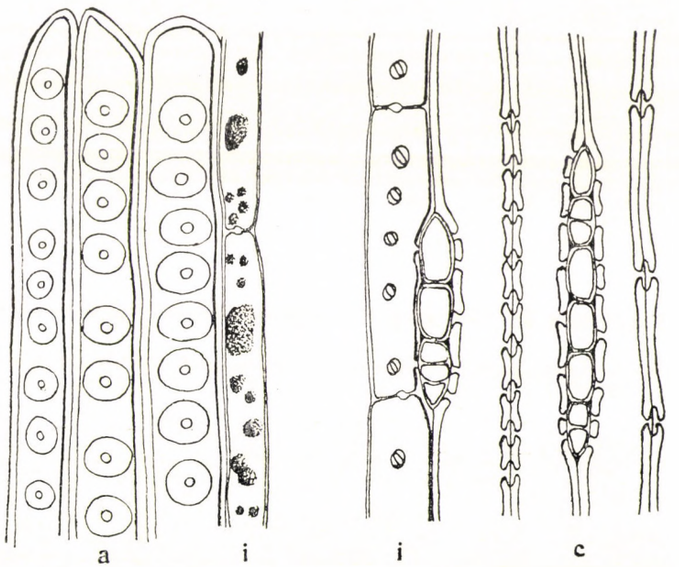
2. (100×)

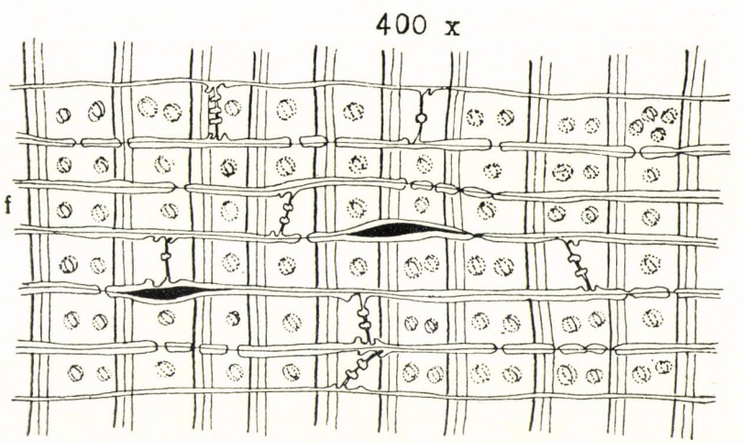


3. (300×)

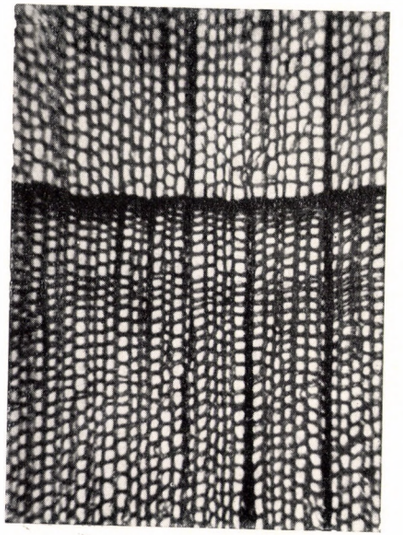


4. (300×)





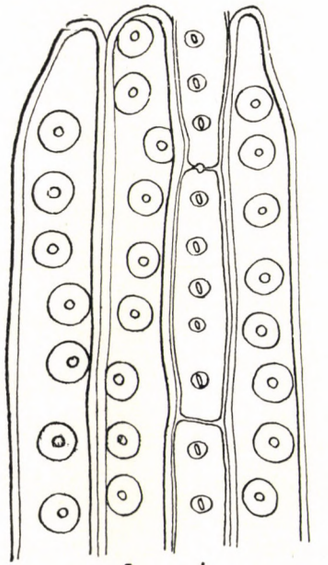
157. Juniperus scopulorum SARG.

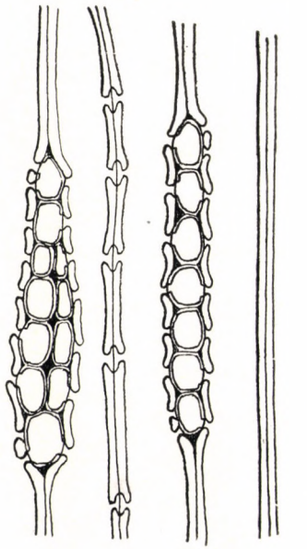


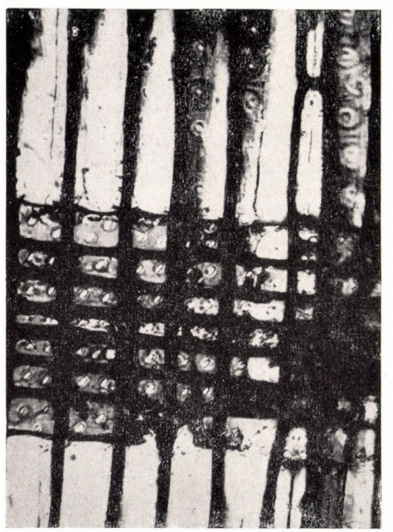
1. (100×)



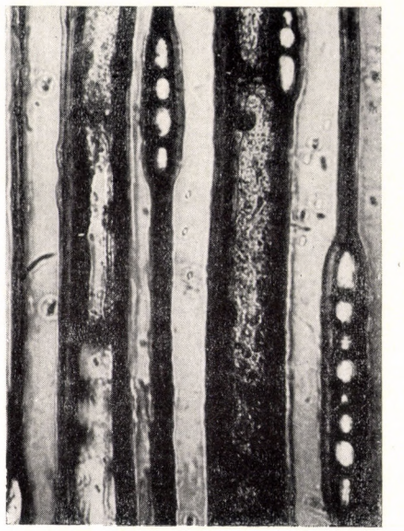
2. (100×)



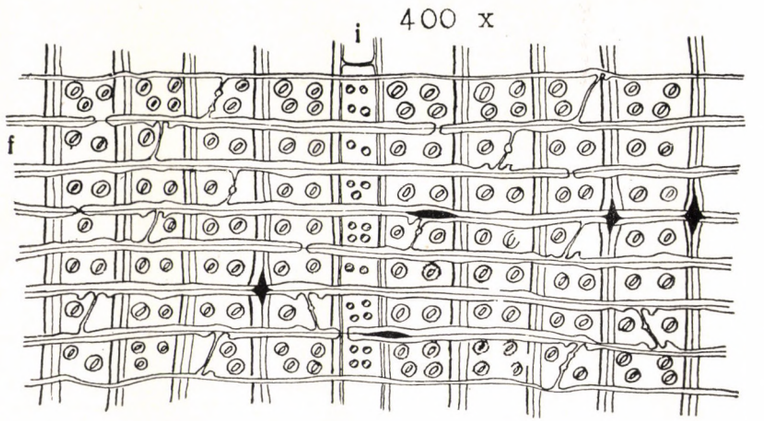




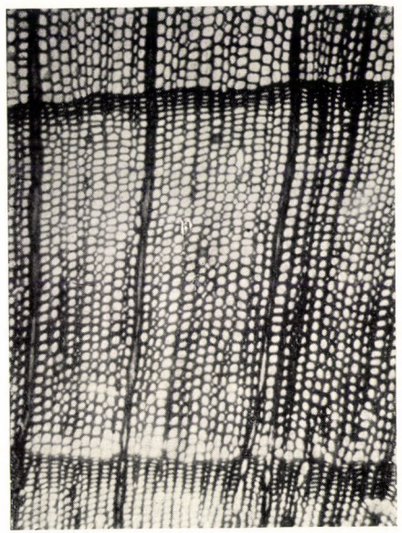
3. (300×)



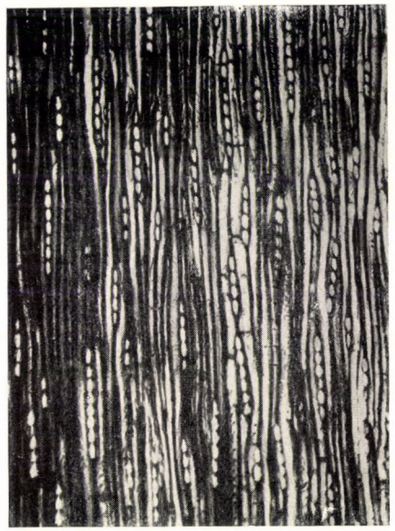
4. (300 ×)



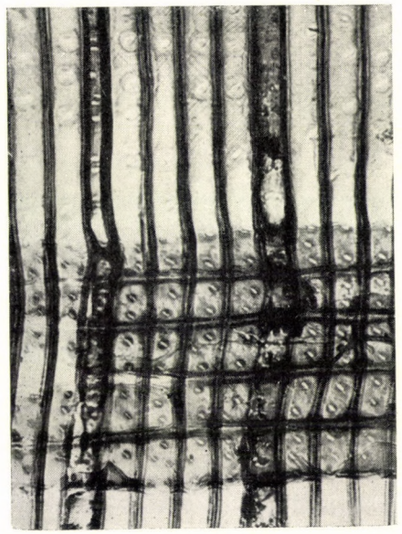
158. Juniperus silicicola (Small) Bailey



1. (100×)



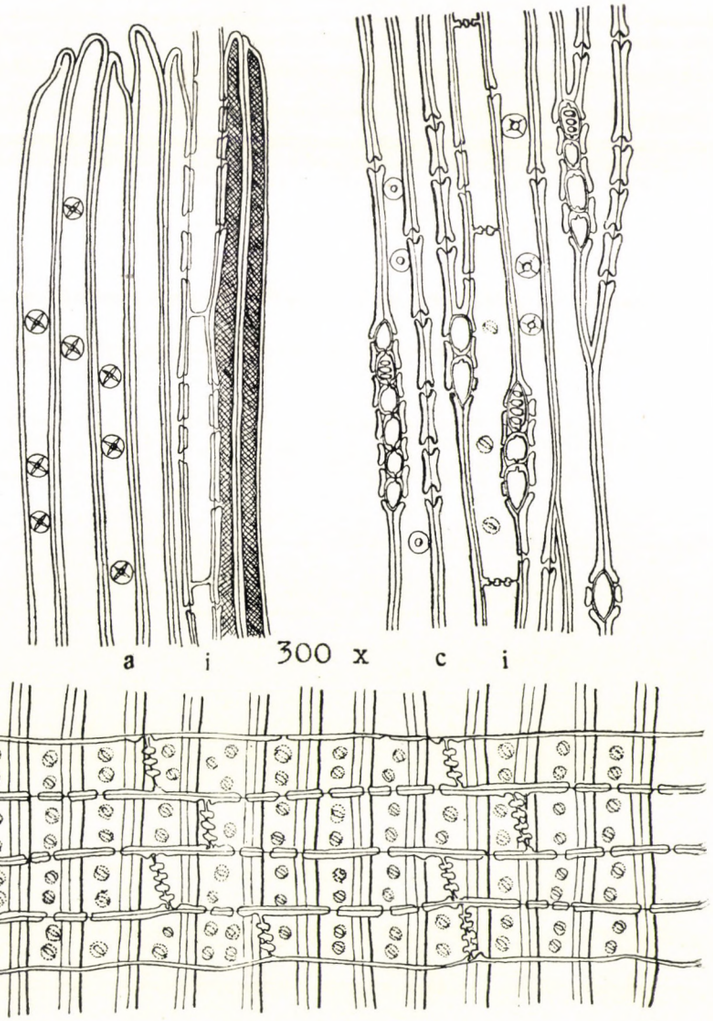
2. (100×)



3. (300×)



4. (300×)



159. Juniperus squamata Buch.—Ham.



1. (100×)



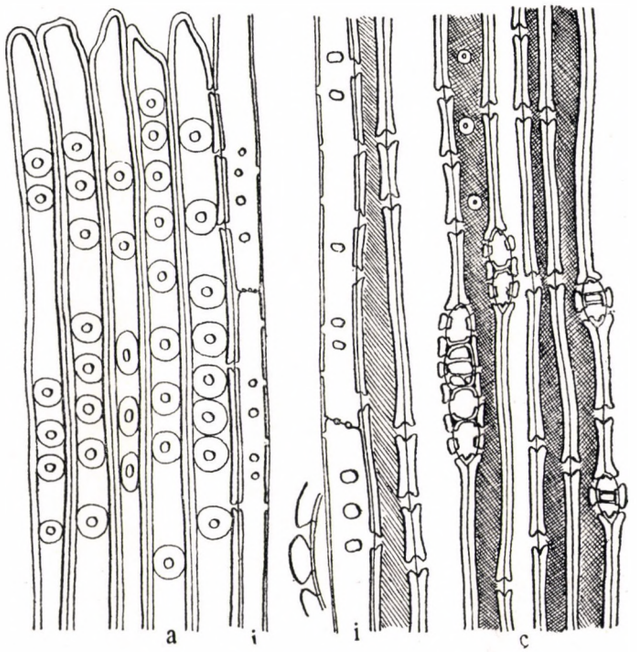
2. (100×)



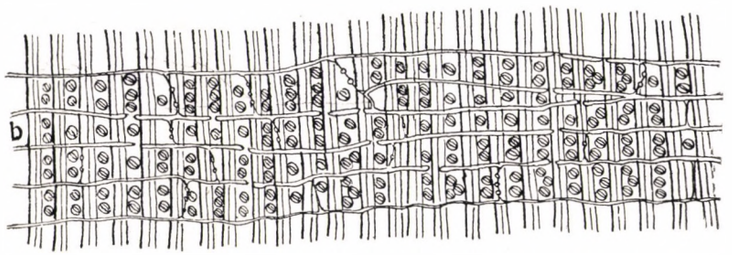
3. (300×)



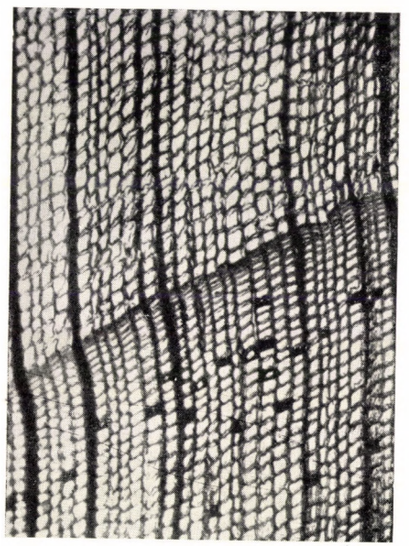
4. (300×)



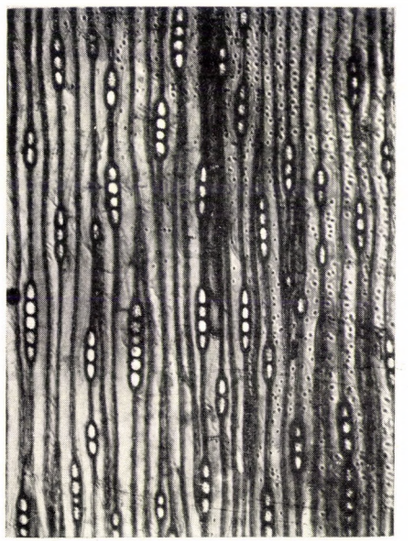
300 x



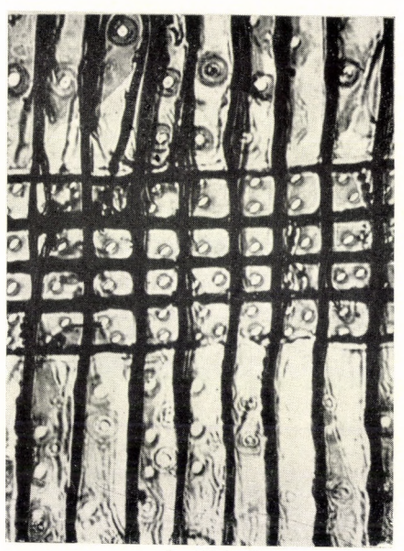
160. Juniperus thurifera L.



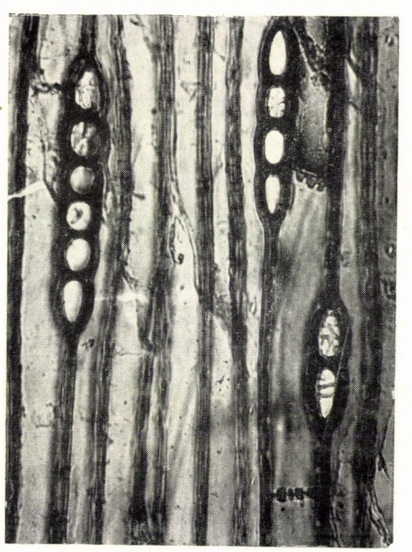
1. (100×)



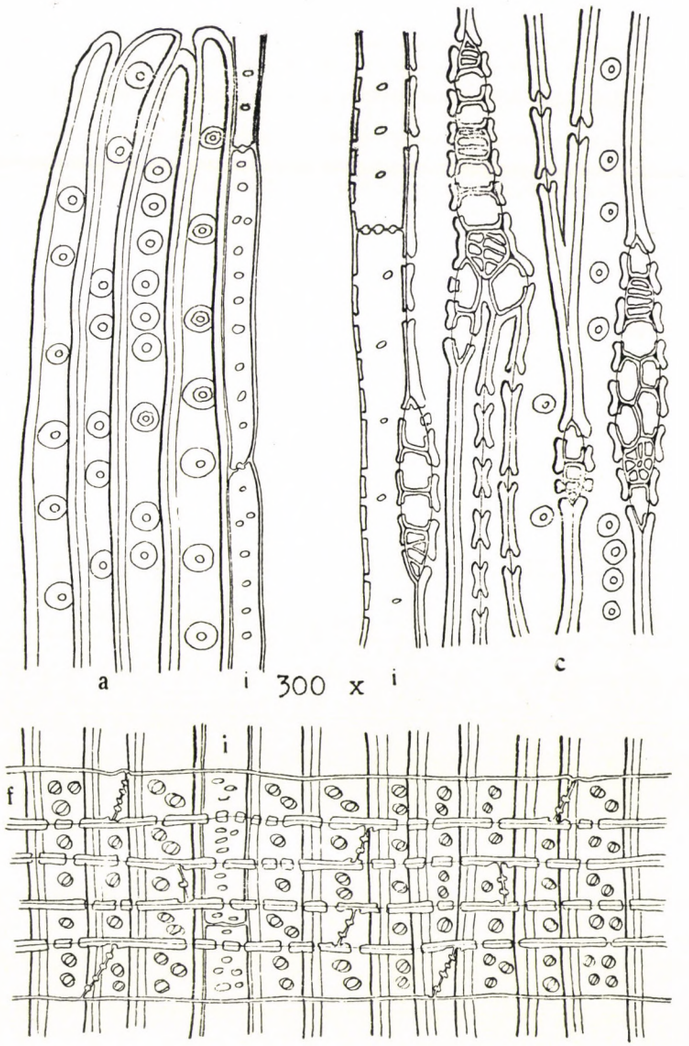
2. (100×)



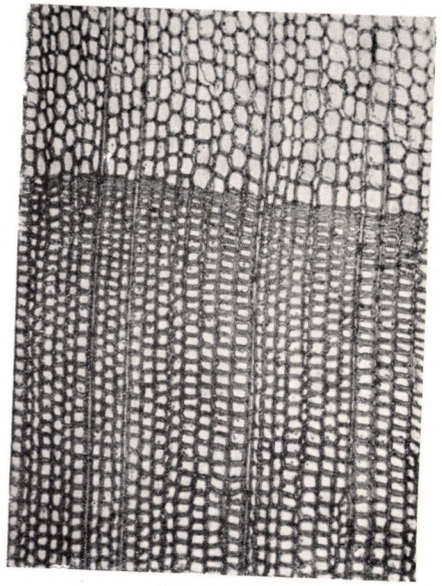
3. (300×)



4. (300×)



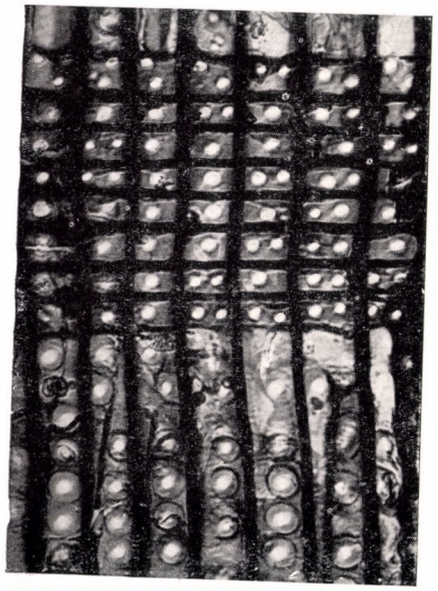
160a Juniperus tibetica KOMAROV



1. (100×)



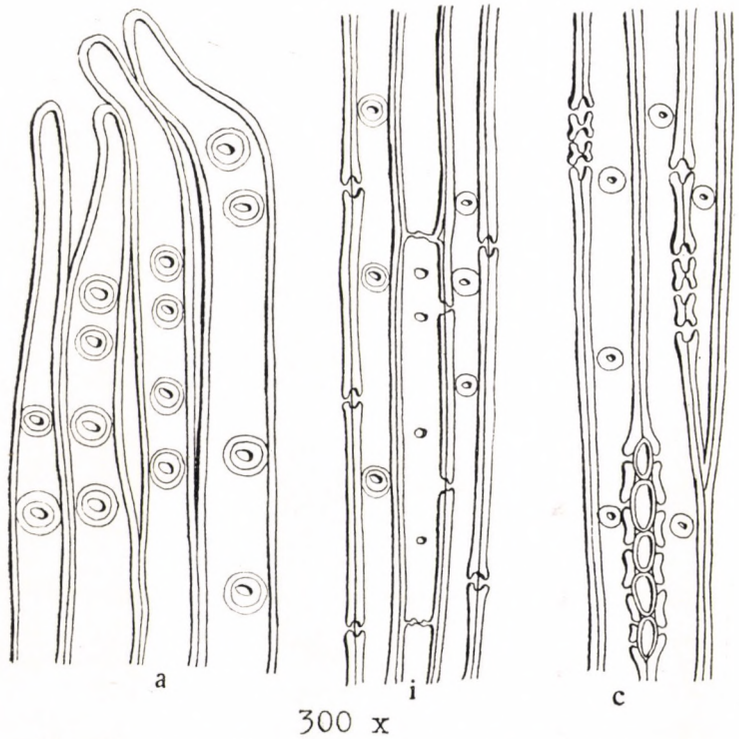
2. (100×)



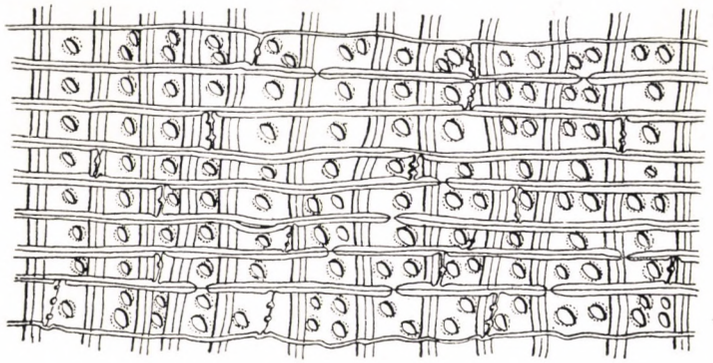
3. (300×)



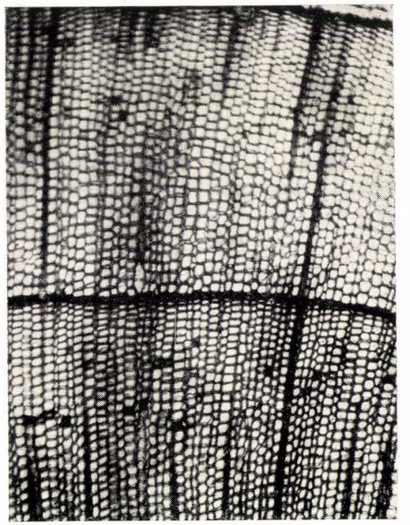
4. (300×)



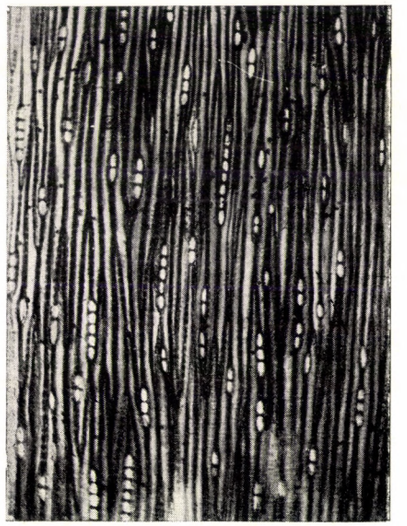
300 x



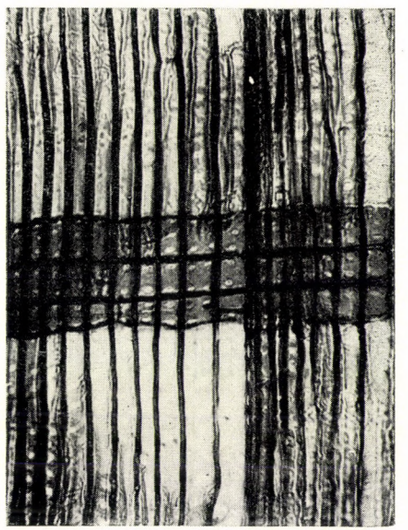
161. Juniperus virginiana L.



1. (100×)



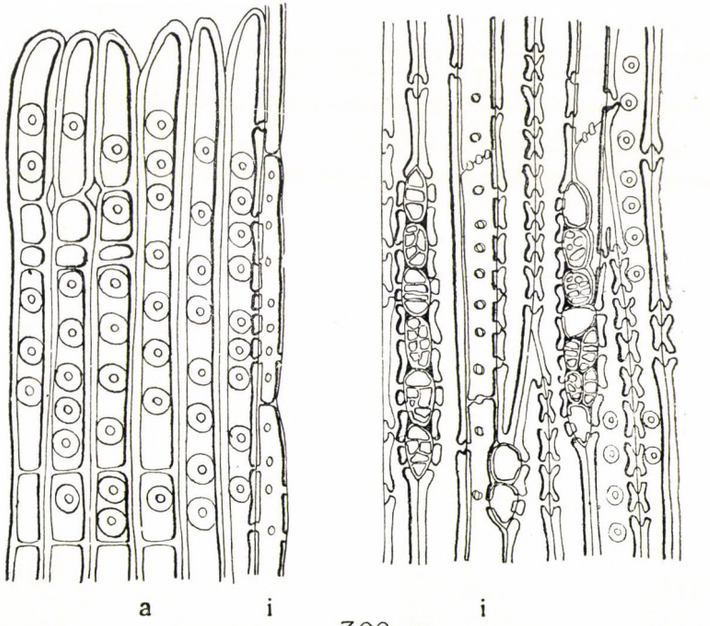
2. (100×)

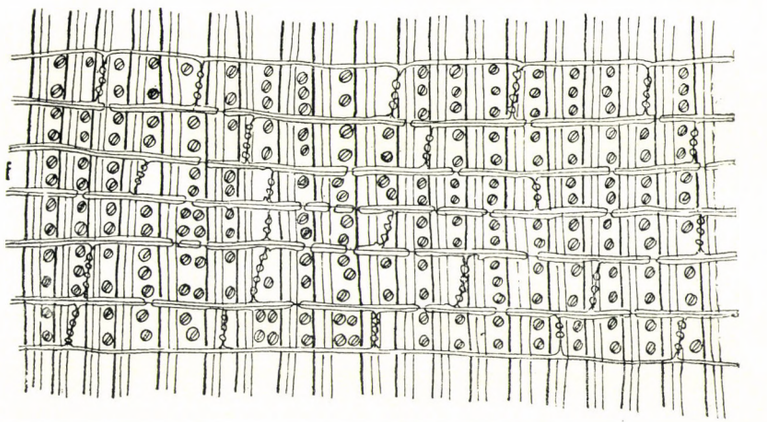


3. (300×)

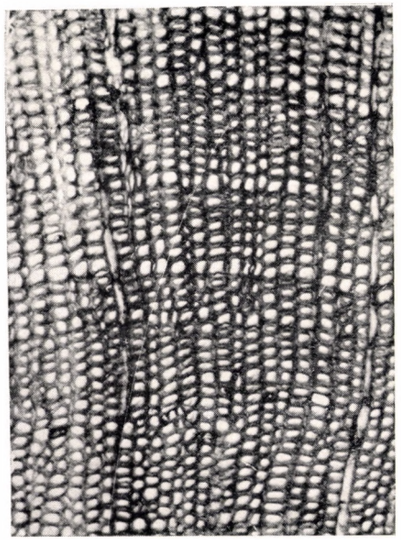


4. (300×)

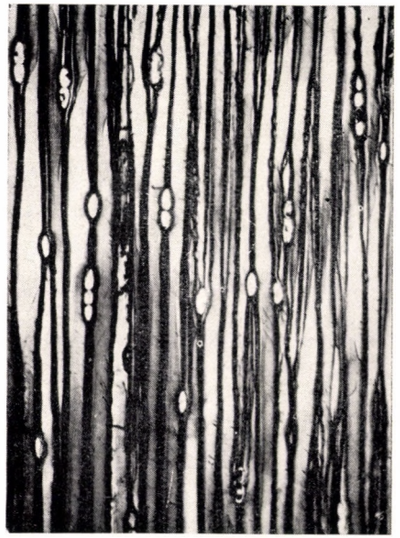




162. Juniperus zoidamensis KOMAROV



1. (100×)



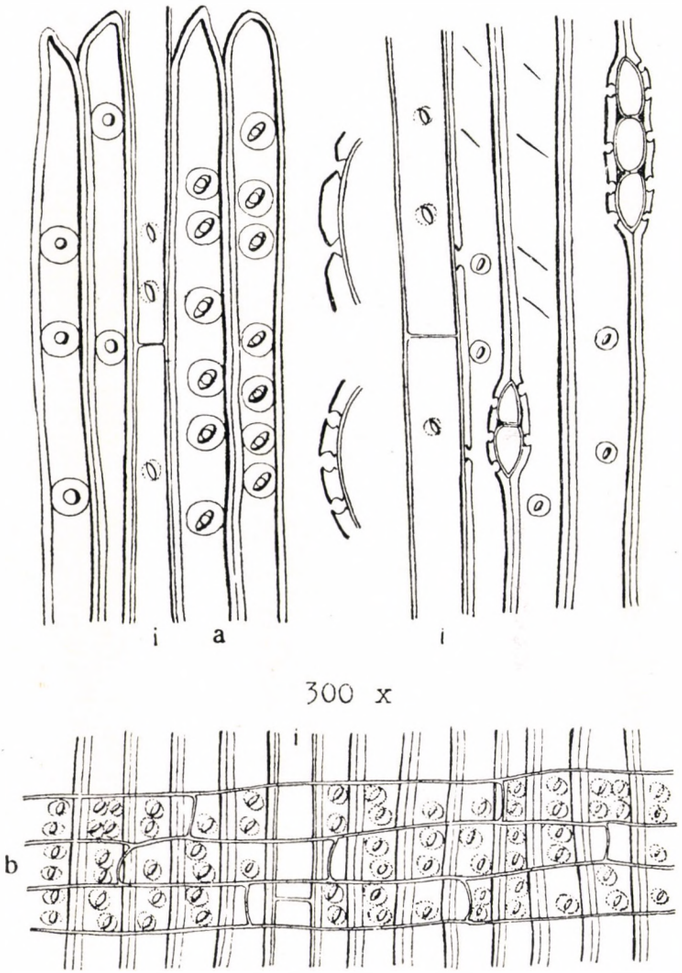
2. (100×)



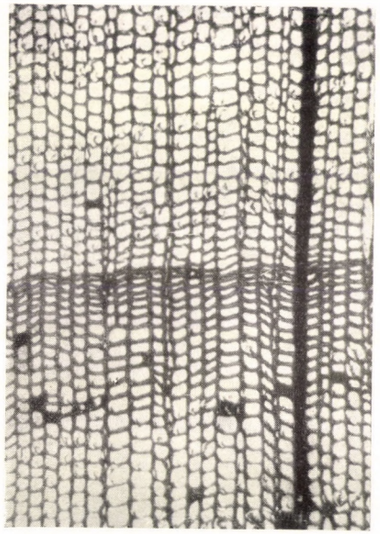
3. (300×)



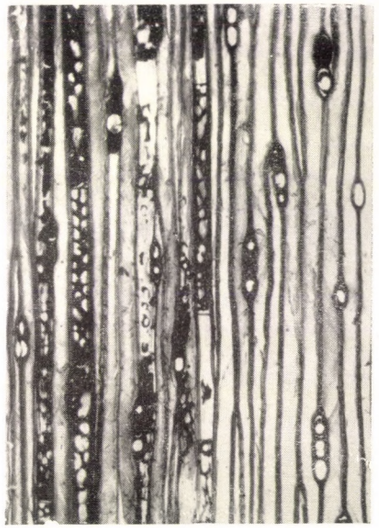
4. (300×)



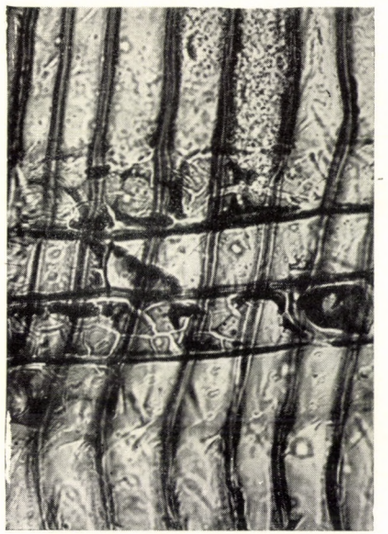
163. Libocedrus austro-caledonica Br. et Gr.



1. (100×)



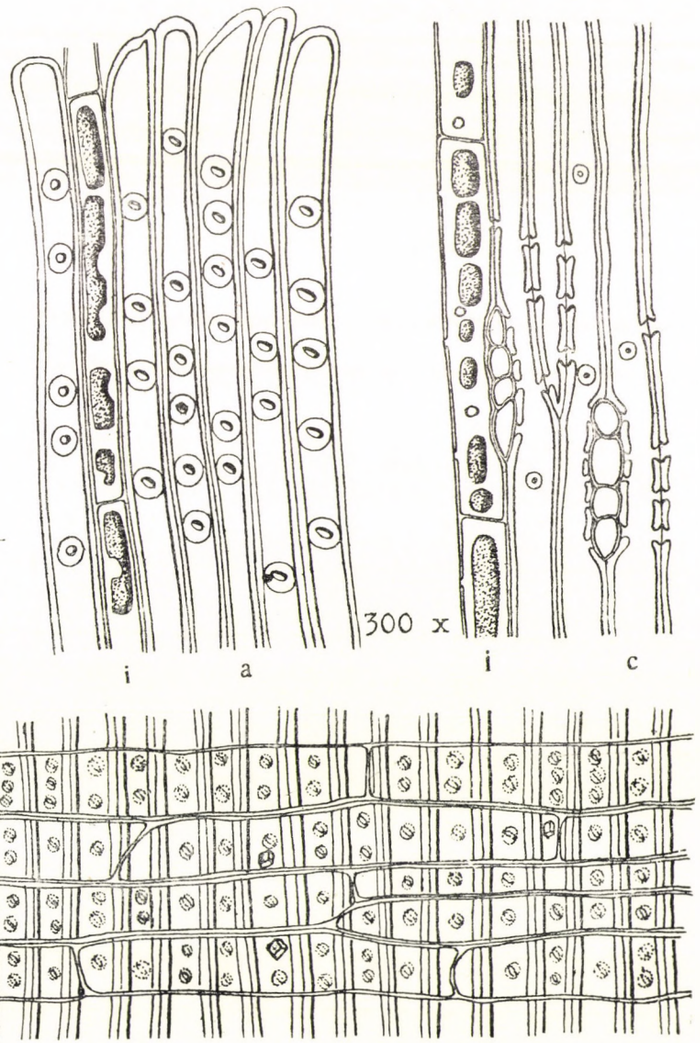
2. (100×)



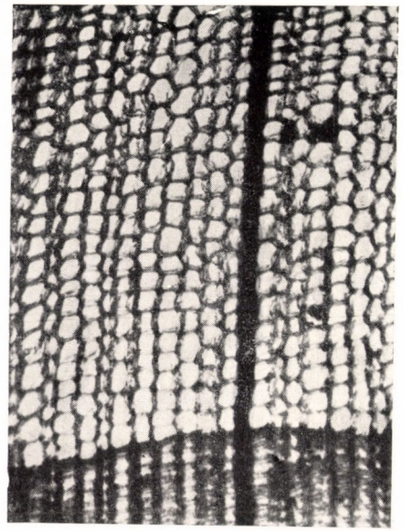
3. (300×)



4. (300×)



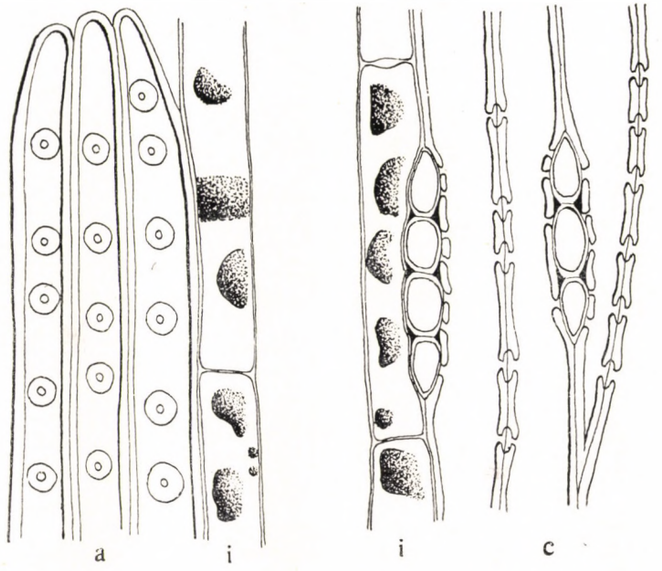
164. Libocedrus Bidwillii Hook.



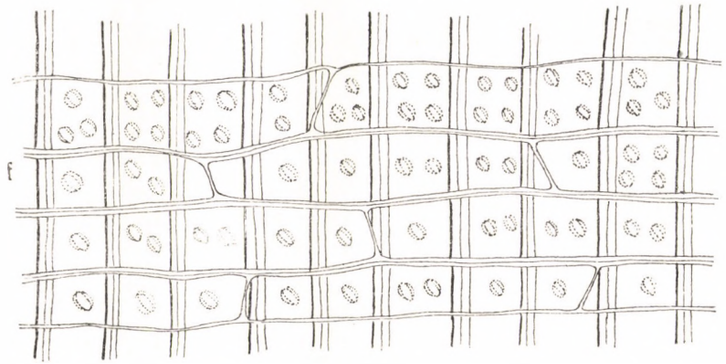
1. (100×)



2. (100×)



400 x



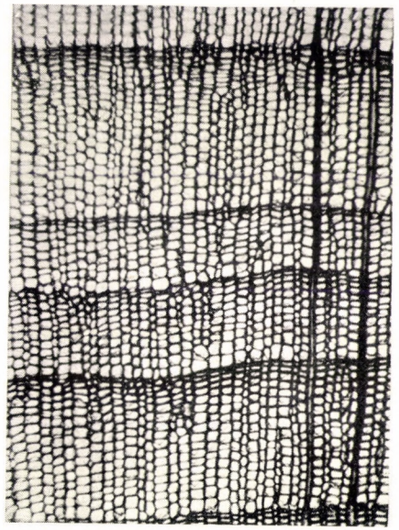


3. (300×)



4. (300×)

165. Libocedrus chilensis (D. Don) ENDLICHER



1. (100×)



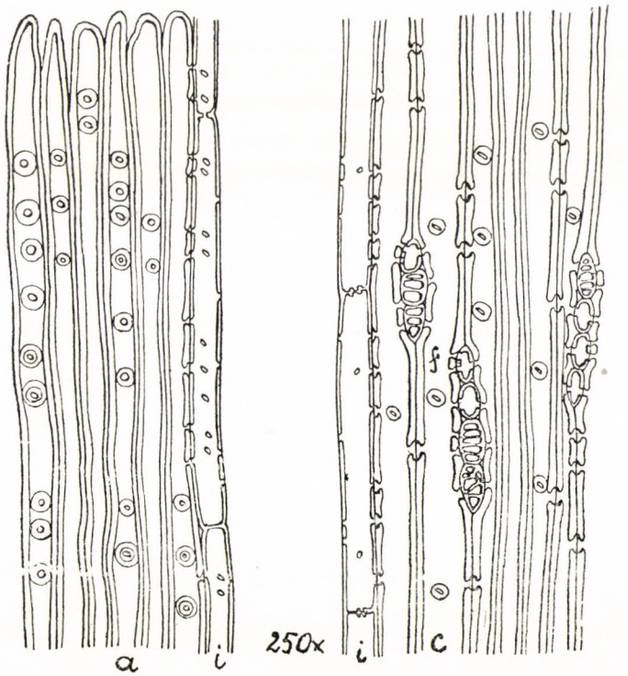
2. (100×)

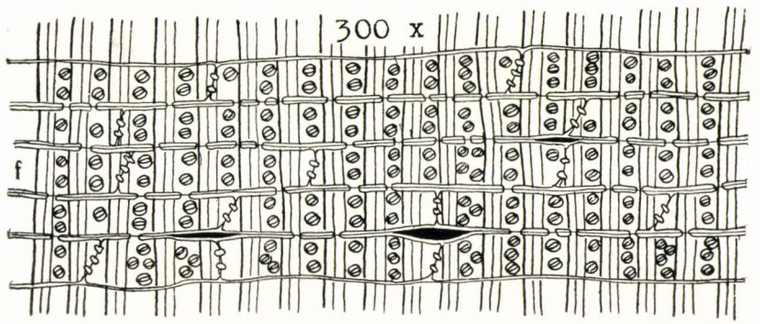


3. (300×)

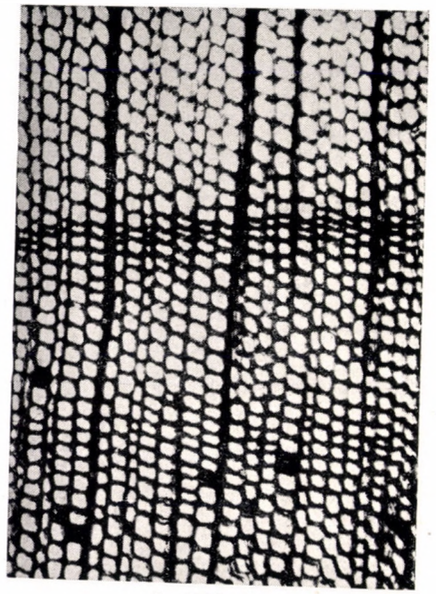


4. (300×)





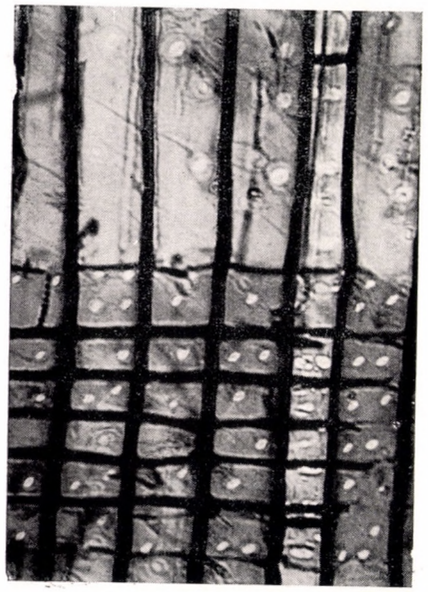
166. Libocedrus decurrens TORREY



1. (100×)



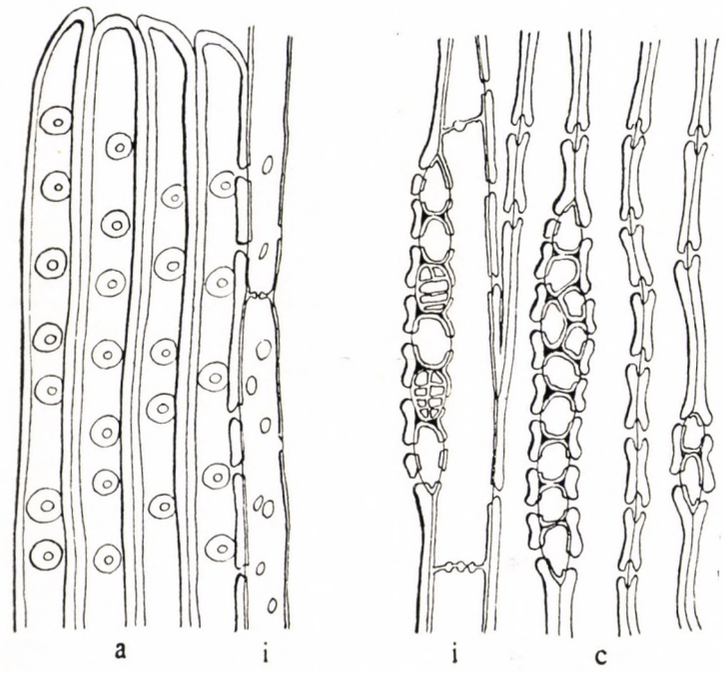
2. (100×)

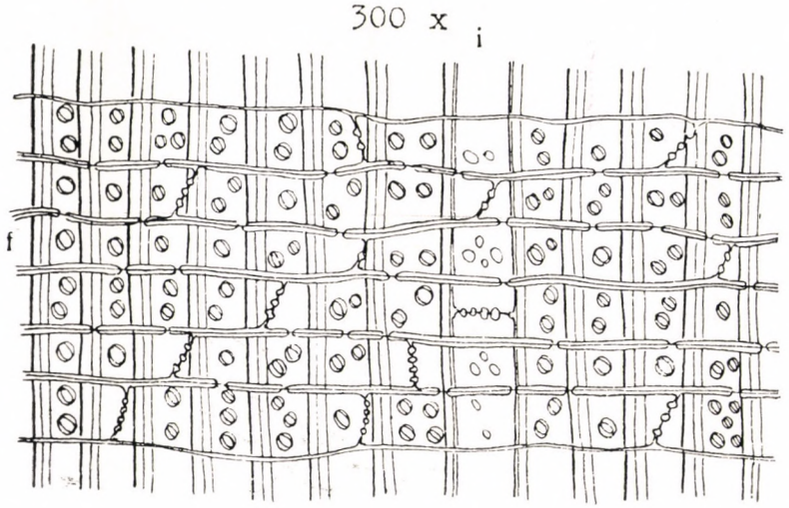


3. (300×)

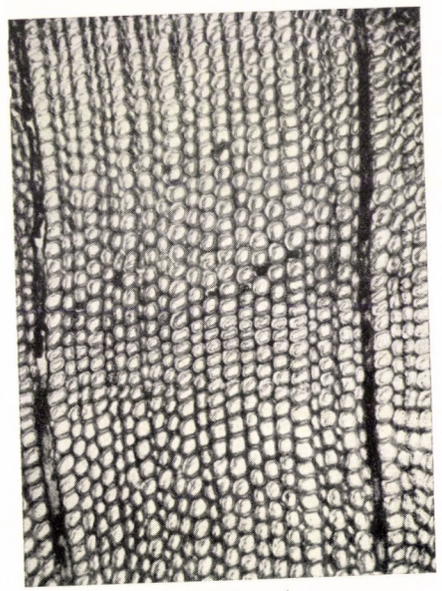


4. (300×)





167. Libocedrus formosana FLORIN



1. (100×)



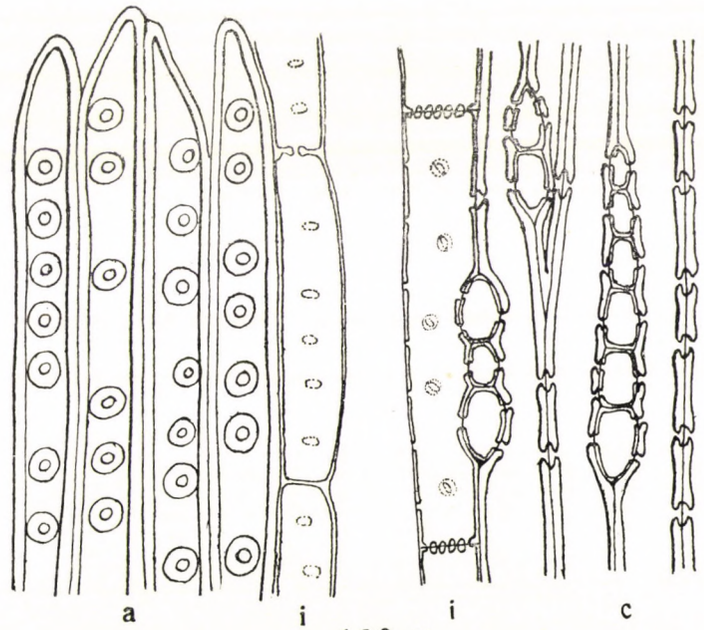
2. (100×)

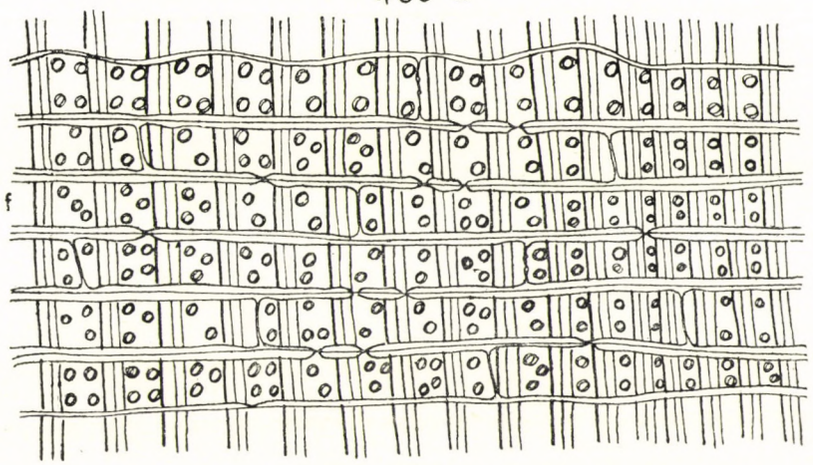


3. (300×)

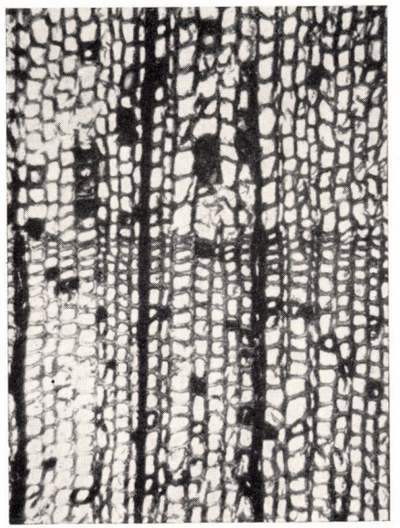


4. (300×)

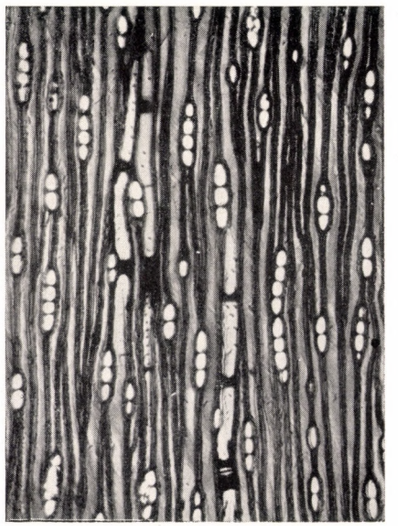




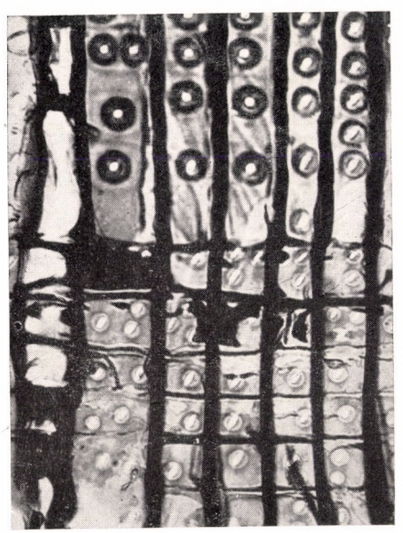
168. Libocedrus macrolepis (Kurz) Benth. et Hook.



1. (100×)



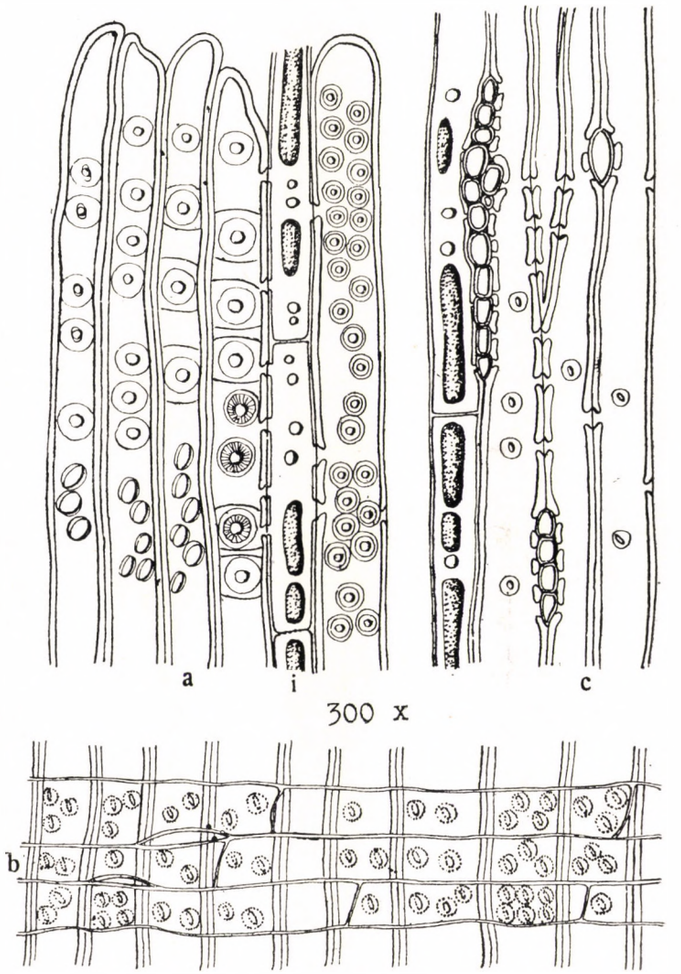
2. (100×)



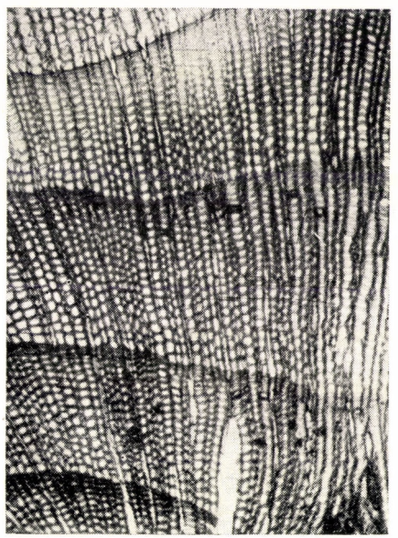
3. (300×)



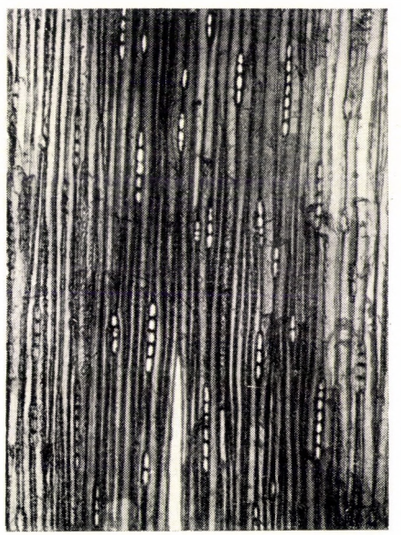
4. (300×)



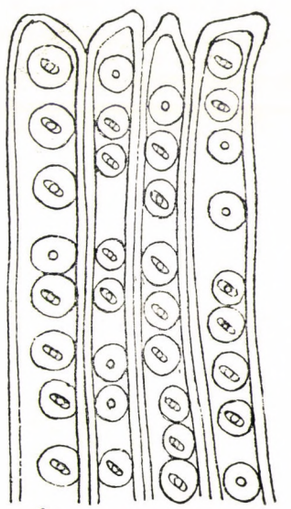
169. Libocedrus plumosa (D. Don) Druce.

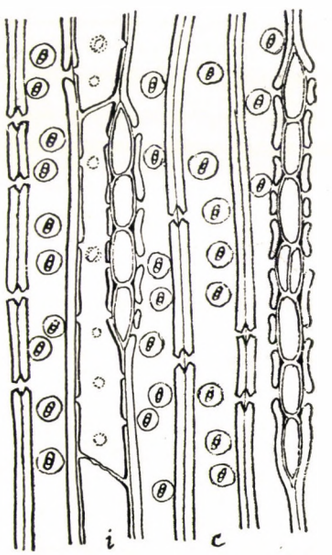


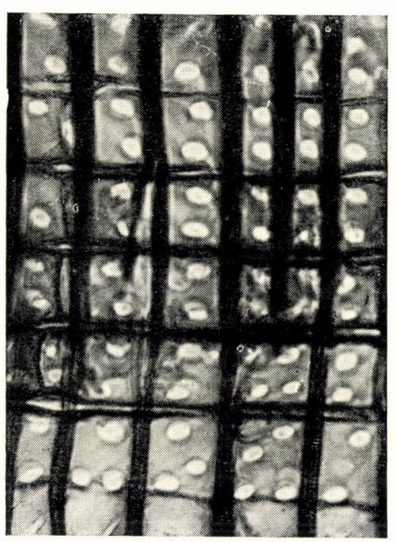
1. (100×)



2. (100×)



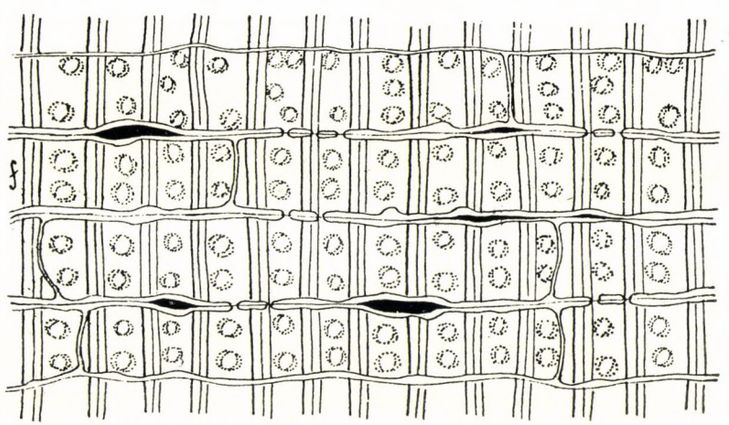




3. (500×)



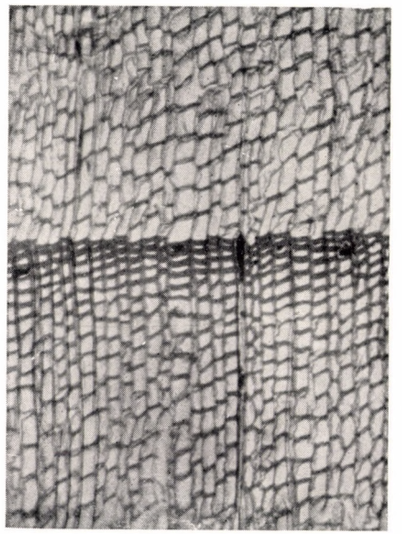
4. (300×)



170. Microbiota decussata KOMAROV



1. (30×)



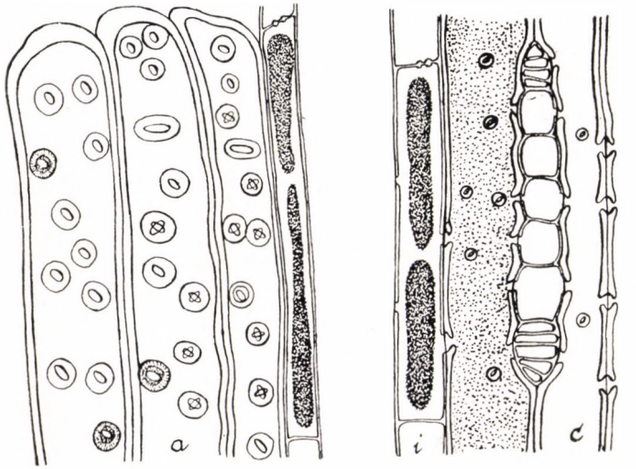
2. (100×)

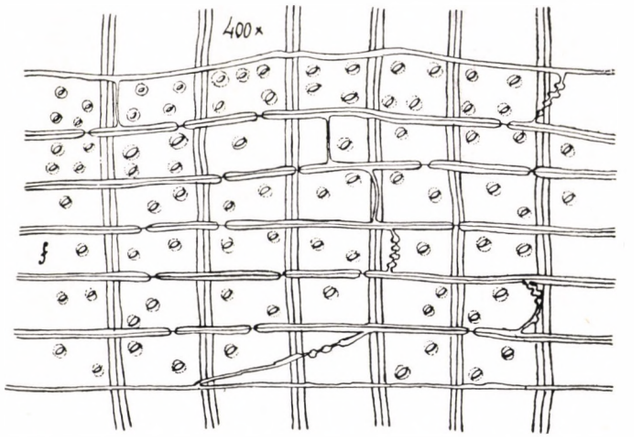


3. (300×)

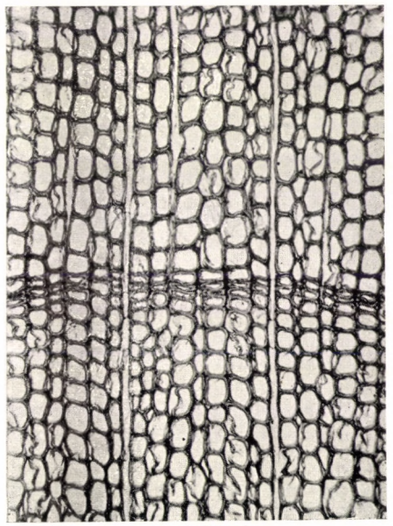


4. (100×)





171. Pilgerodendron uviferum FLORIN



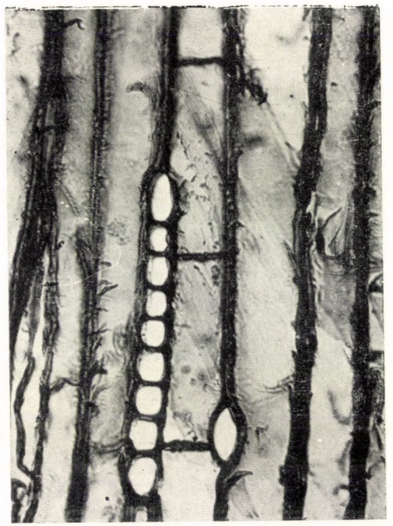
1. (100×)



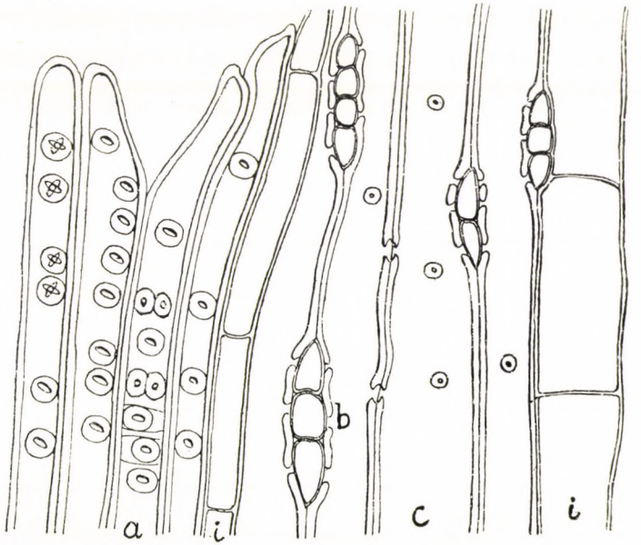
2. (100×)

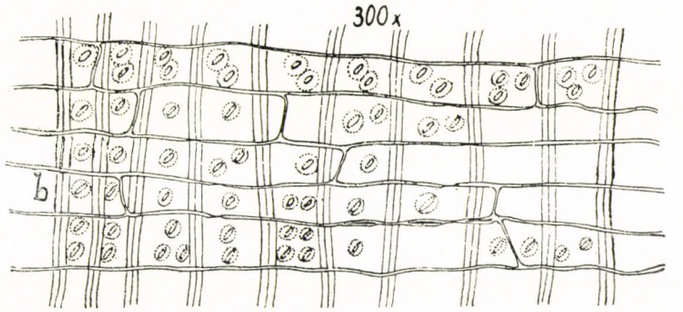


3. (300×)

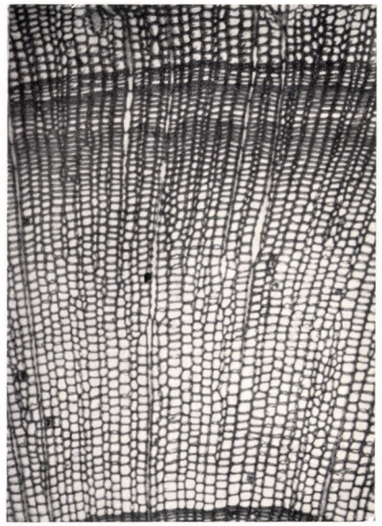


4. (300×)





172. Tetraclinis articulata (Vahl) MAST.



1. (100×)



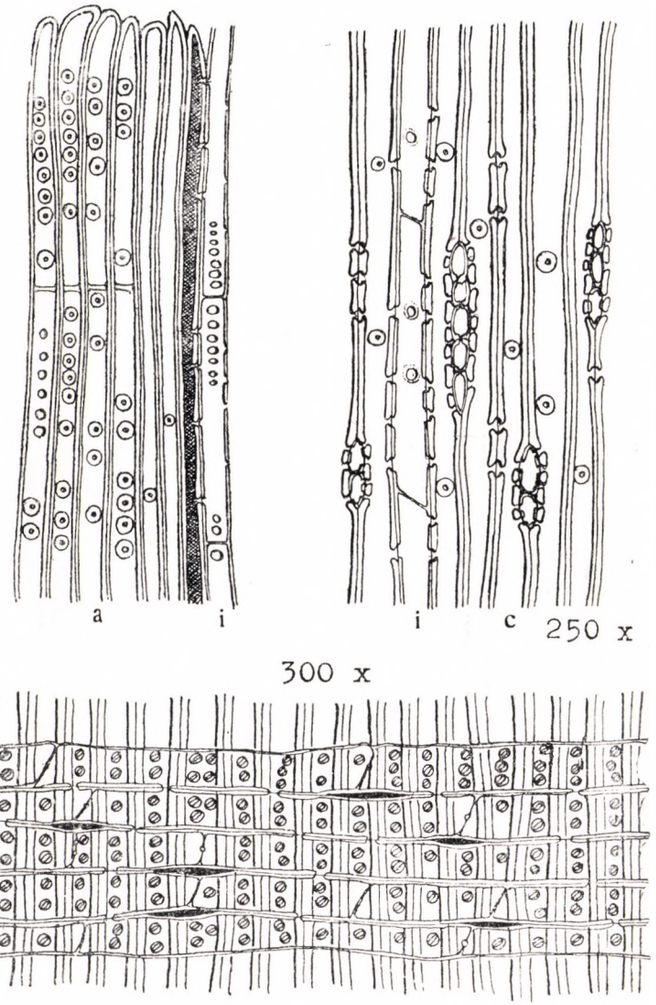
2. (100×)



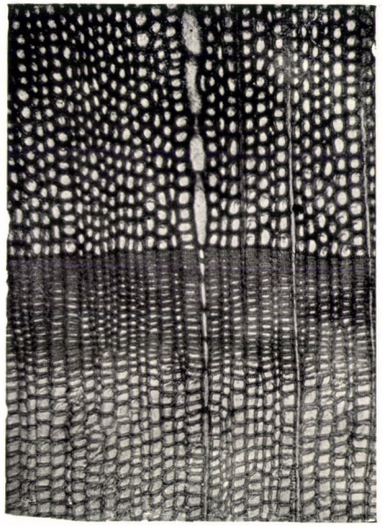
3. (300×)



4. (300×)



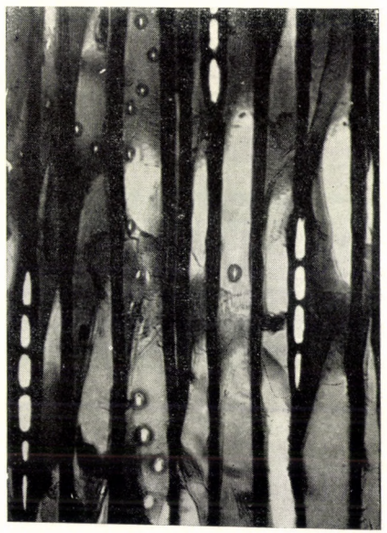
173. Thuja koraiensis NAKAI



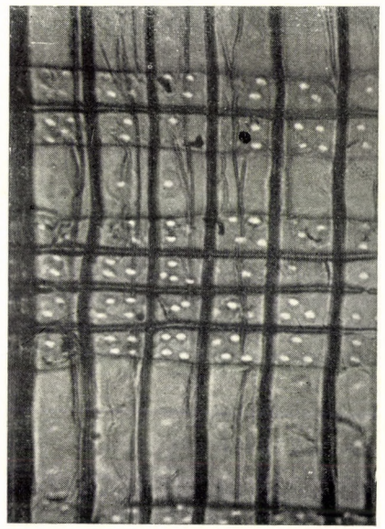
1. (100×)



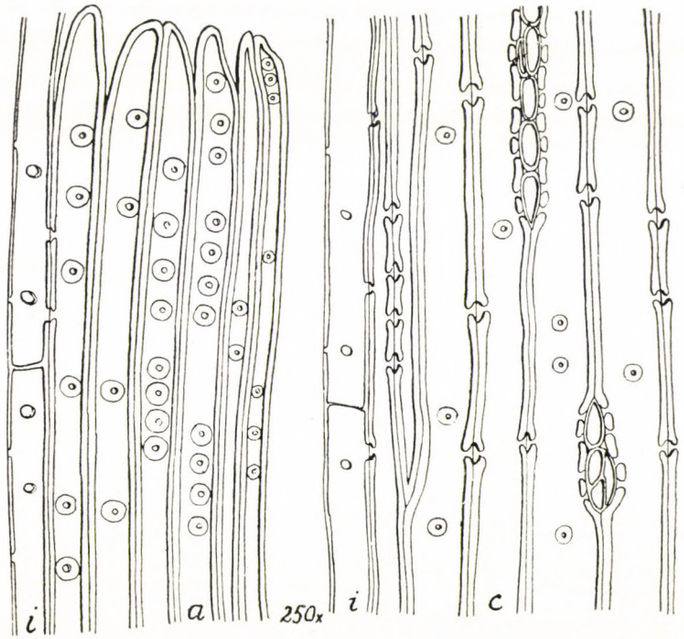
2. (100×)

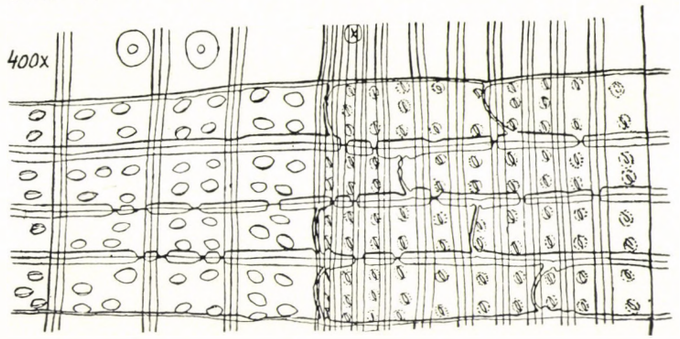


3. (300×)

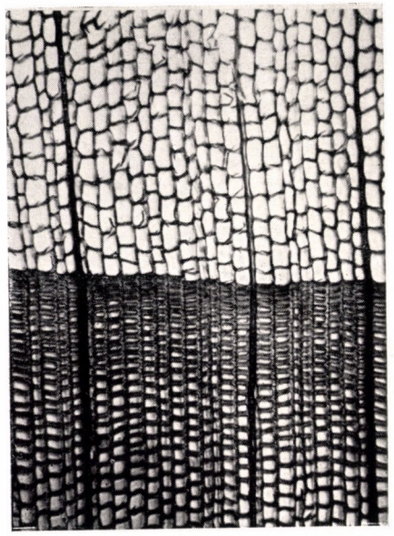


4. (300×)





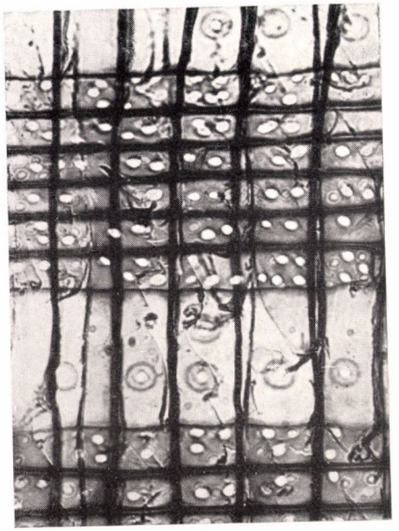
174. Thuja occidentalis L.



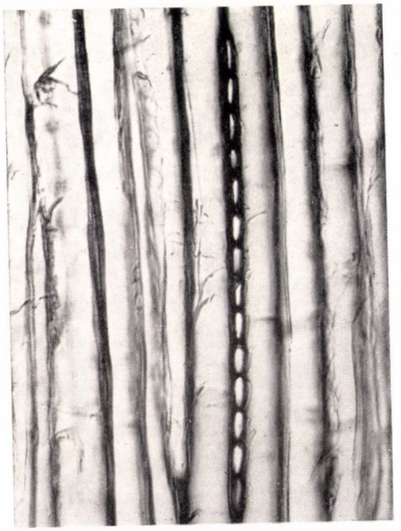
1. (100×)



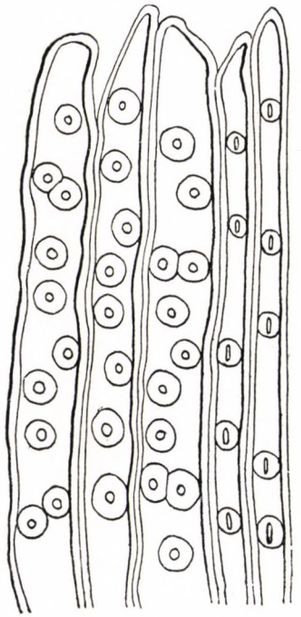
2. (100×)

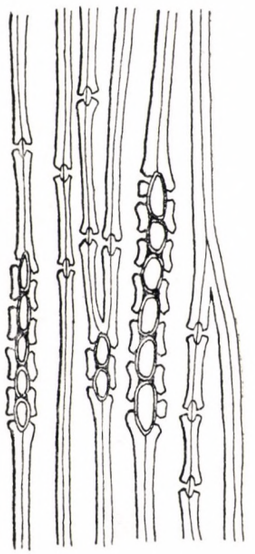


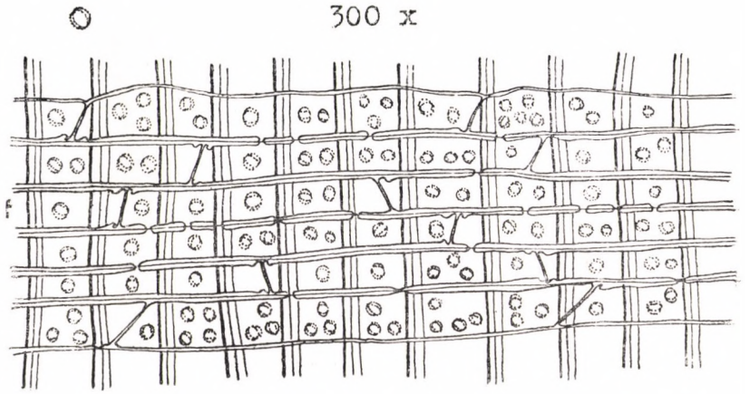
3. (300×)



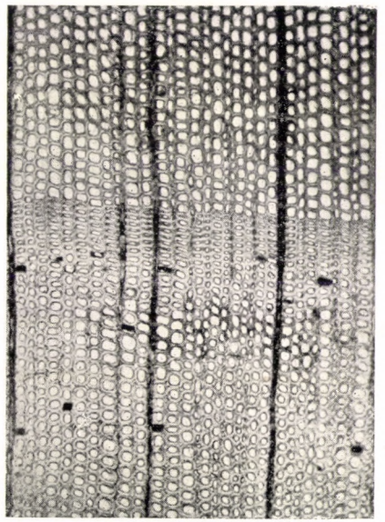
4. (300×)







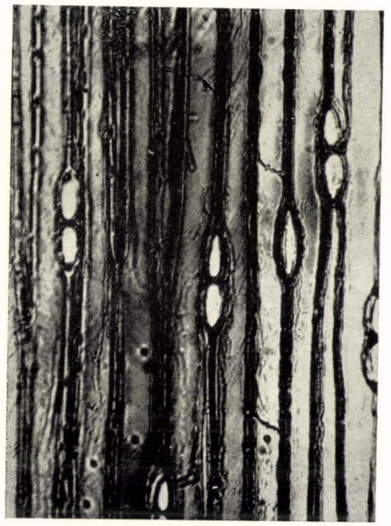
175. Thuja plicata D. Don



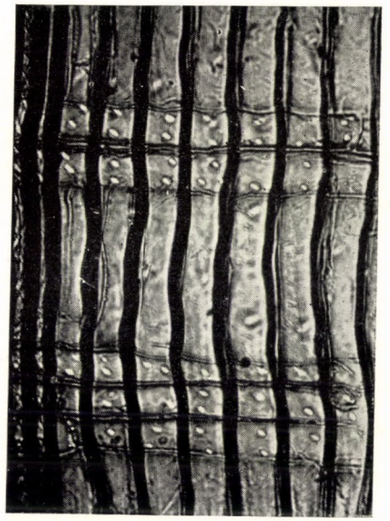
1. (100×)



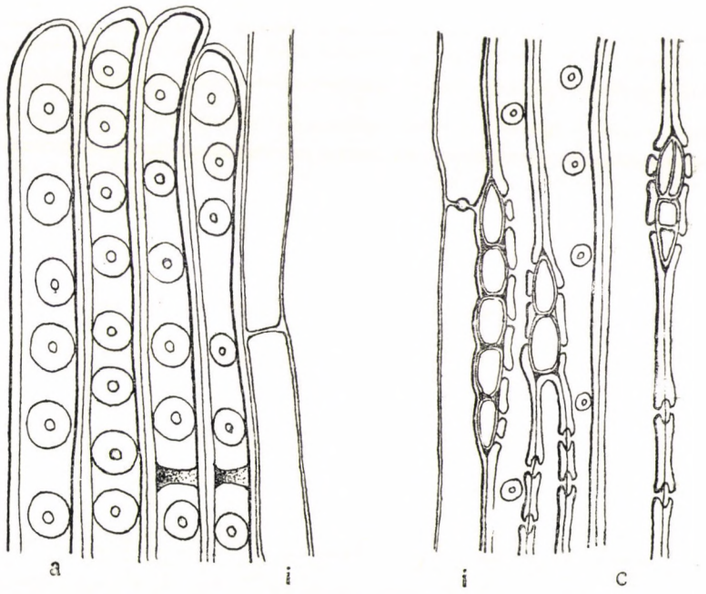
2. (100×)

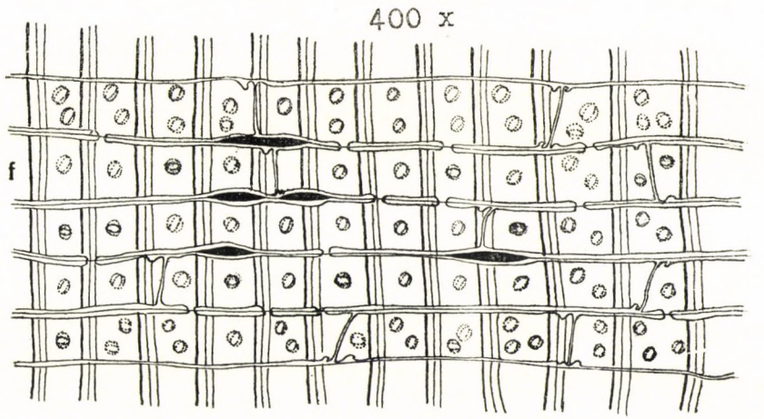


3. (300×)

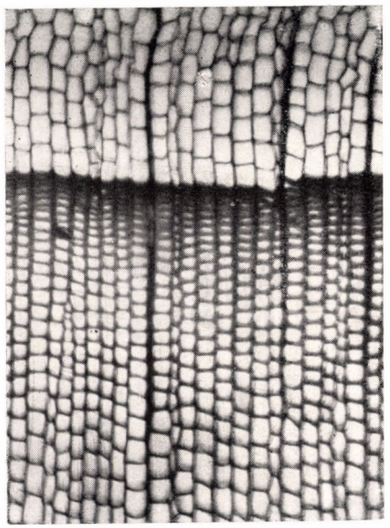


4. (300×)

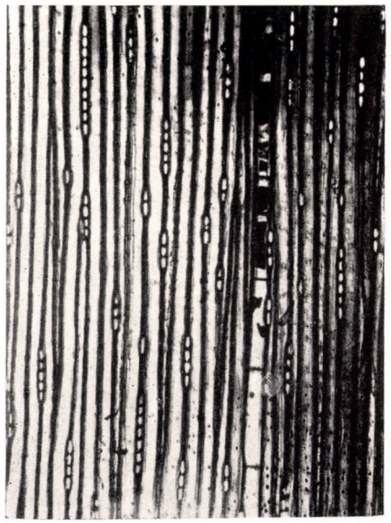




176. Thujopsis dolobrata (L.) Sieb. et Zucc.



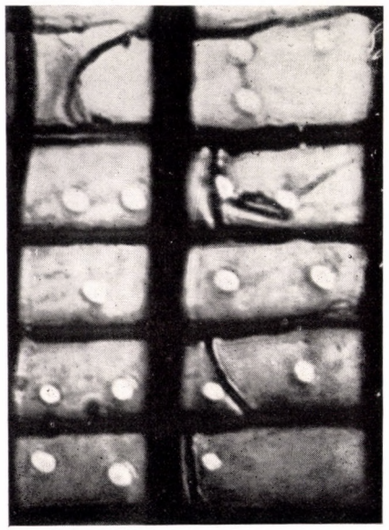
1. (100×)



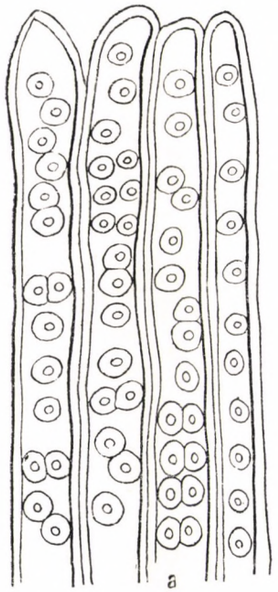
2. (100×)

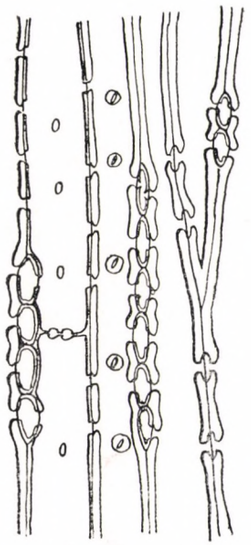


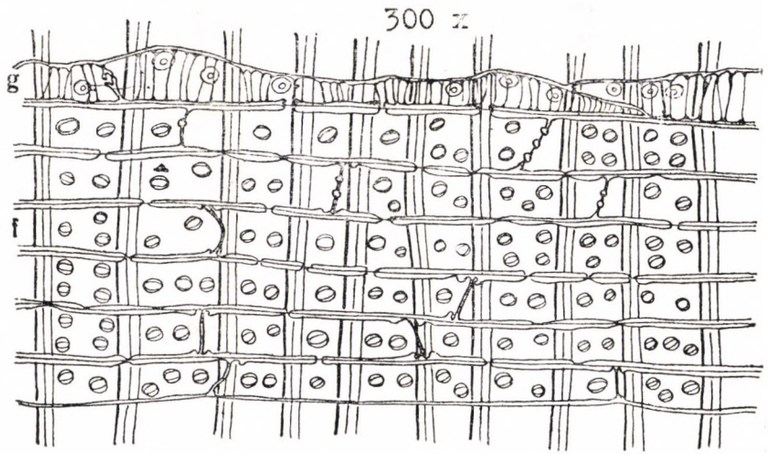
3. (300×)



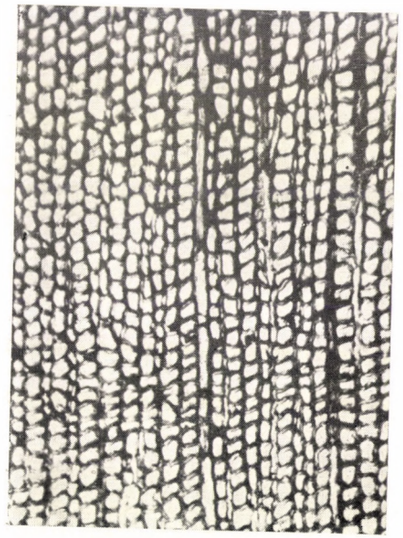
4. (600×)







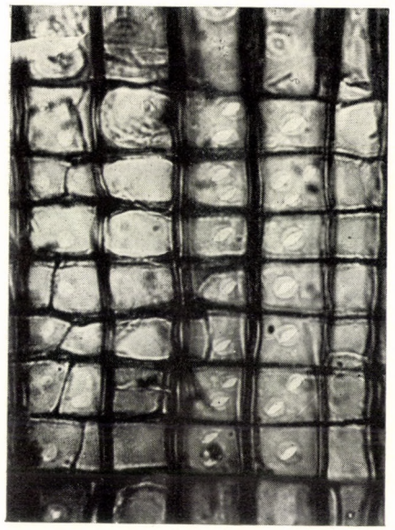
177. Thuja Standishii (Gordon) Carr.



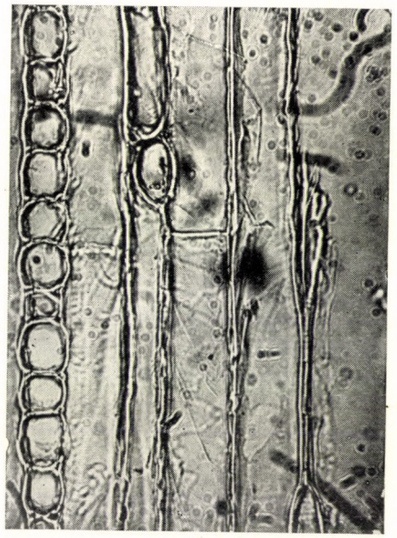
1. (100×)



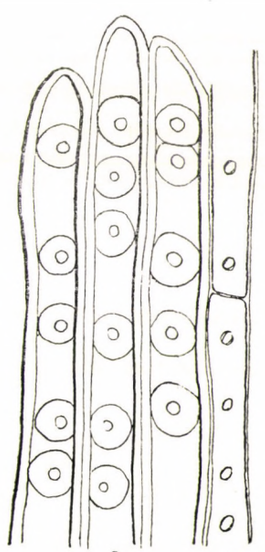
2. (100×)

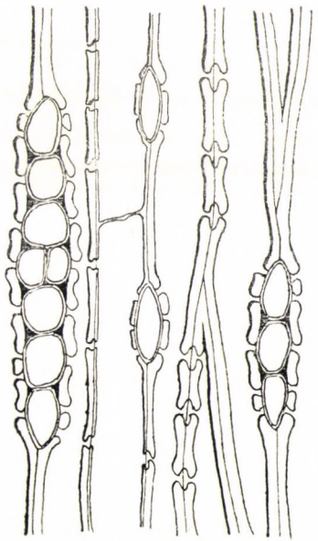


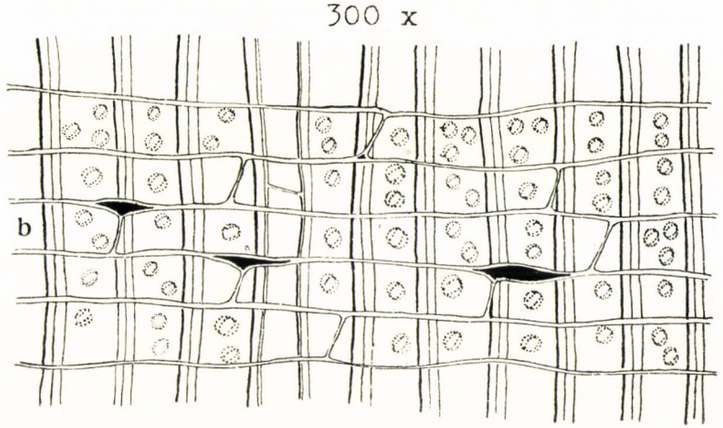
3. (300×)



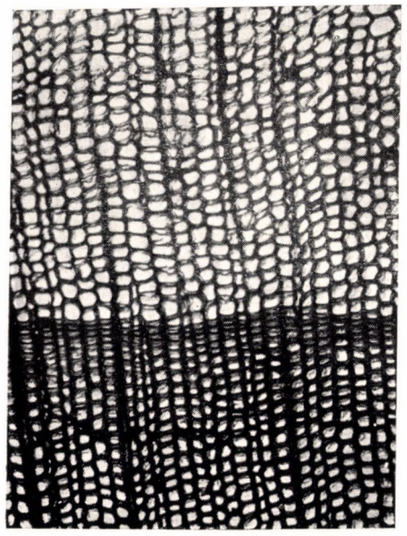
4. (300×)







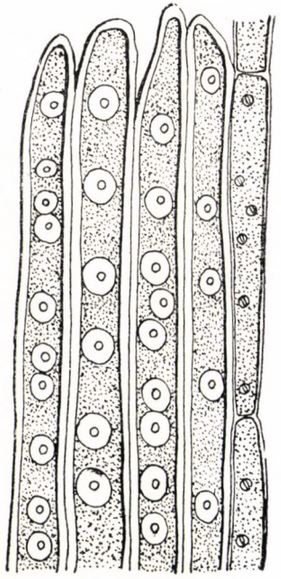
178. Widdringtonia cupressoides (L.) Endl.

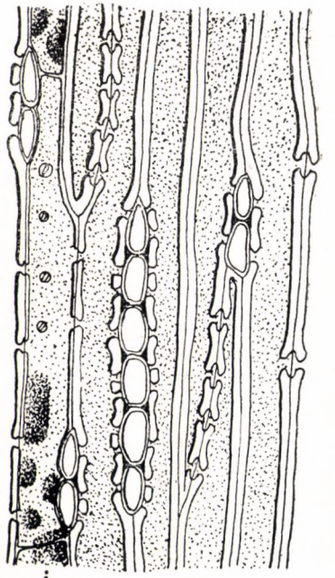


1. (100×)



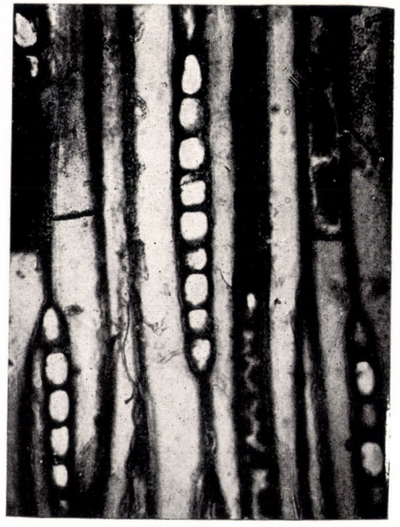
2. (100×)



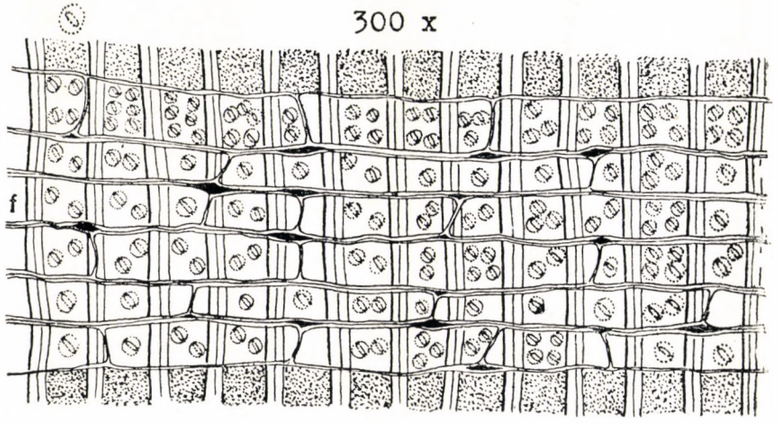




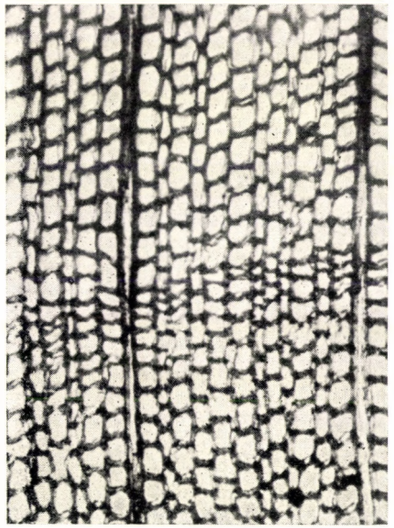
3. (300×)



4. (300×)



179. Widdringtonia dracomontana STAPF



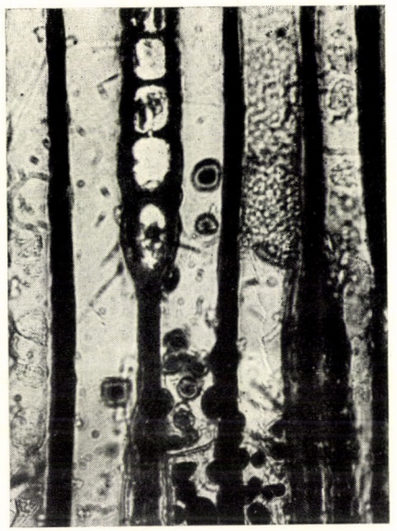
1. (100×)



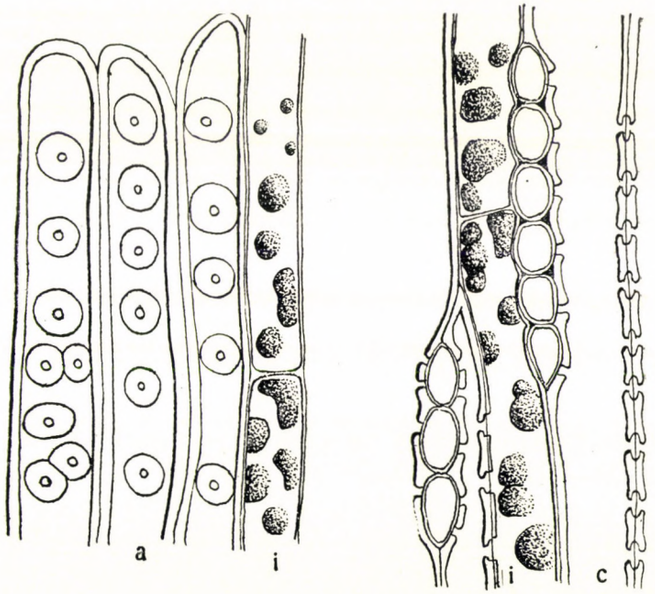
2. (100×)



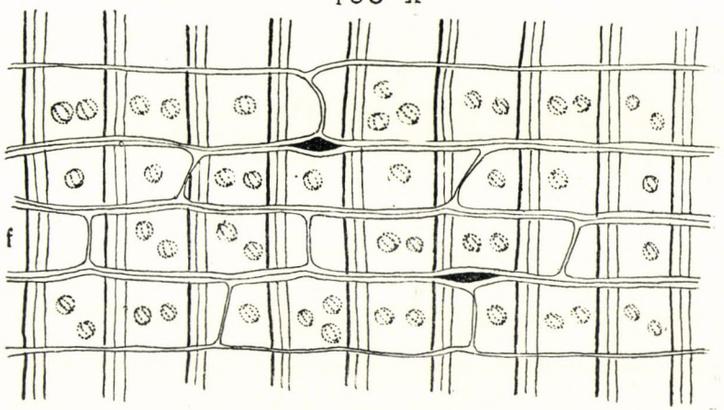
3. (300×)



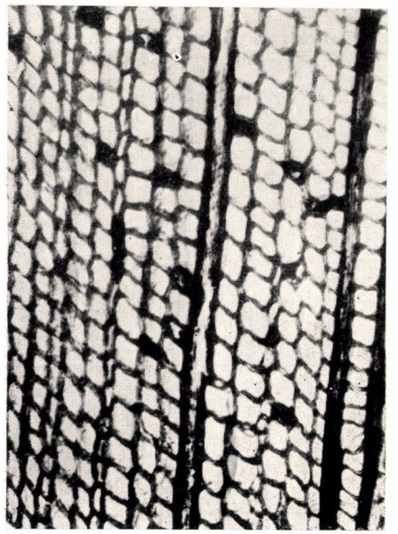
4. (300×)



400 x



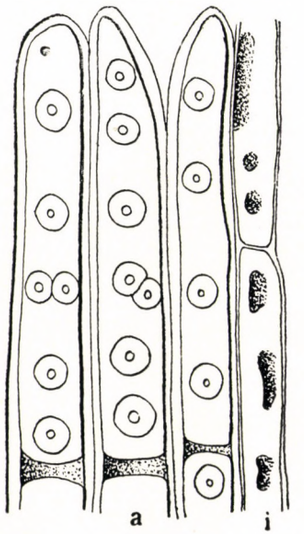
180. Widdringtonia juniperoides (L.) Endl.

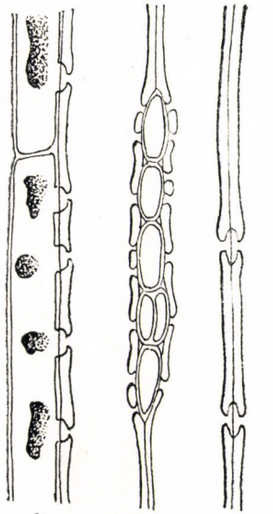


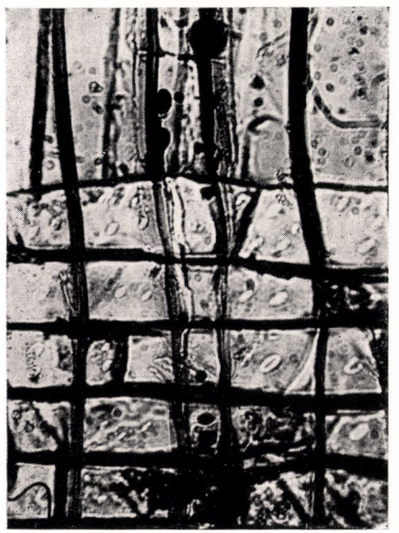
1. (100×)



2. (100×)



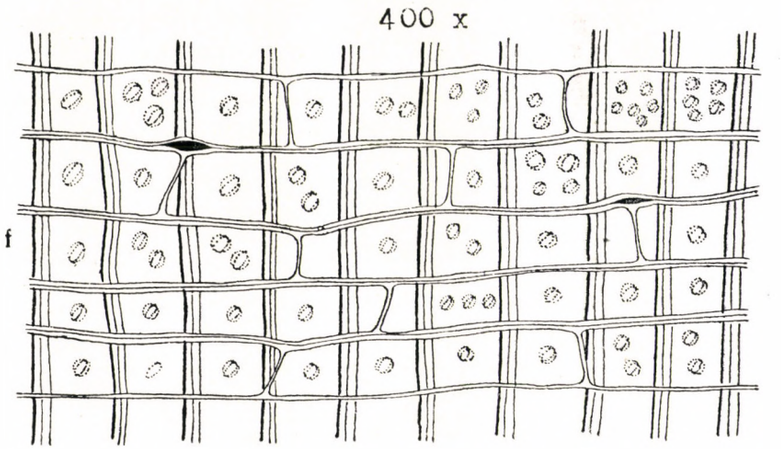




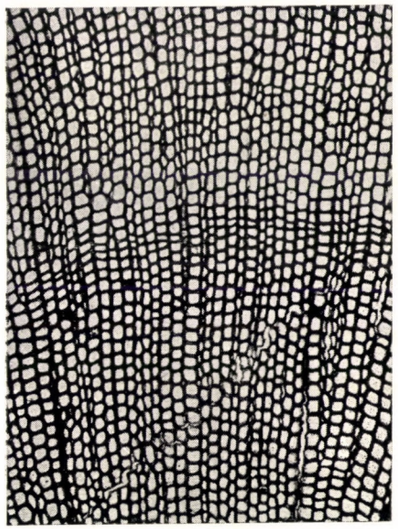
3. (300×)



4. (300×)



181. Widdringtonia Schwarzii MARLOTH



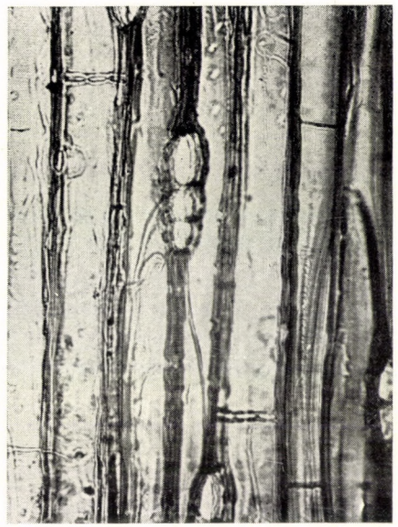
1. (100×)



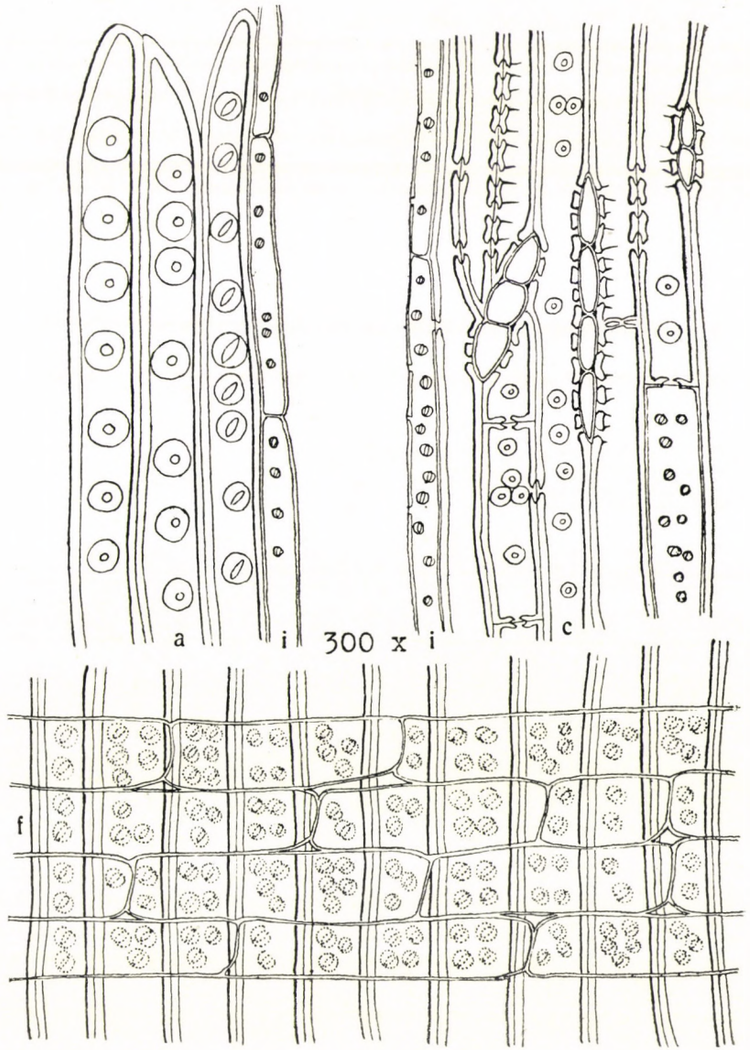
2. (100×)



3. (300×)



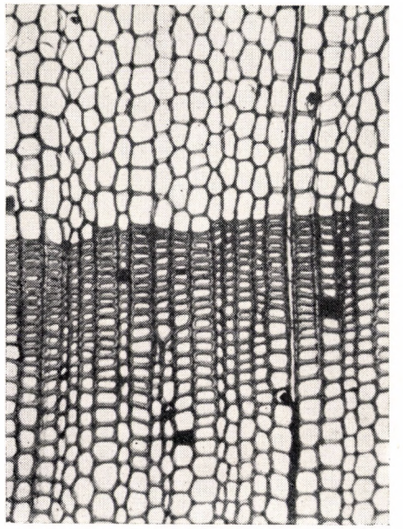
4. (300×)



182. Widdingtonia Whytei RENDLE

VII.

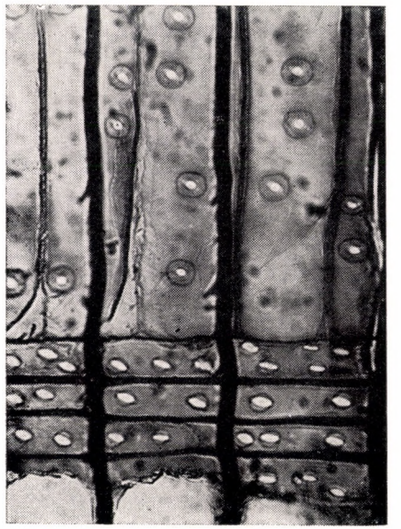
TAXODIACEAE



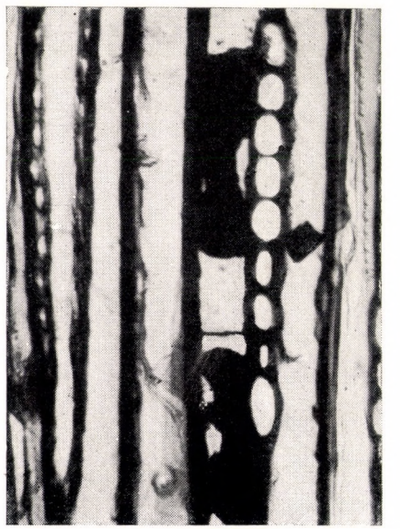
1. (100×)



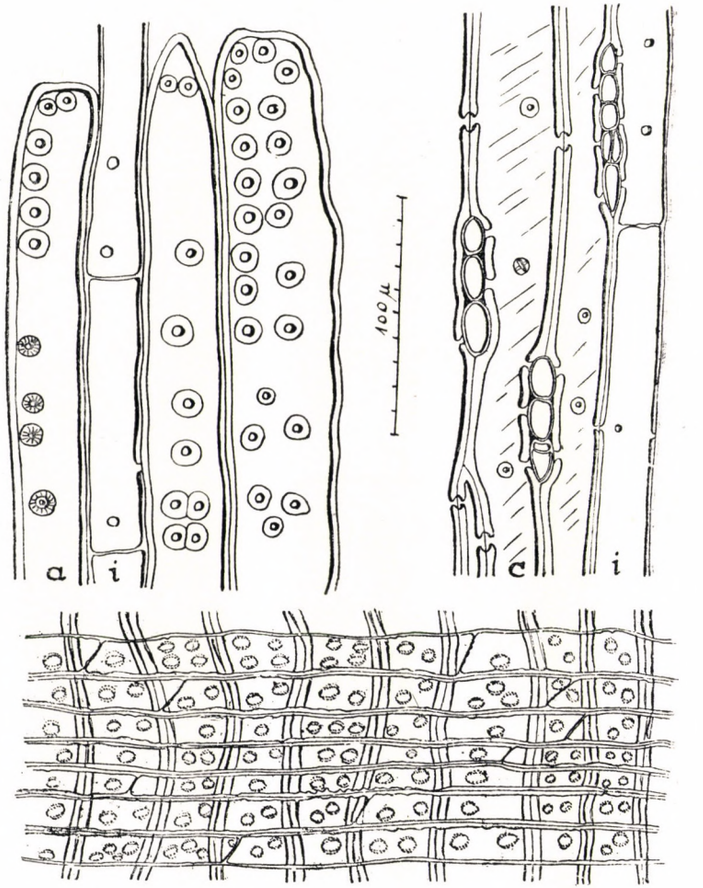
2. (100×)



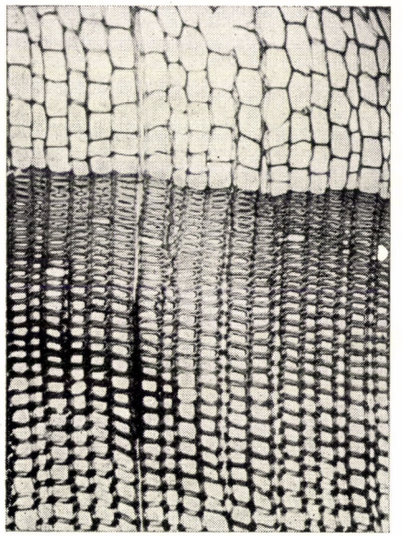
3. (300×)



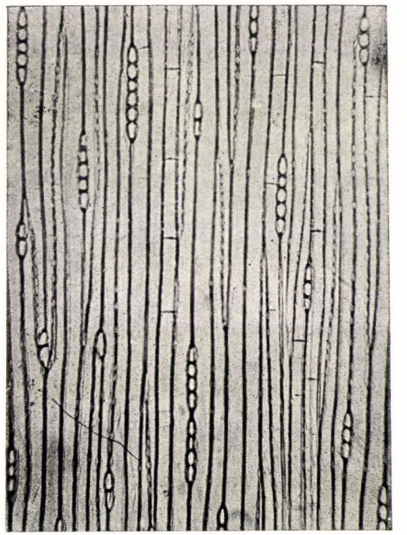
4. (300×)



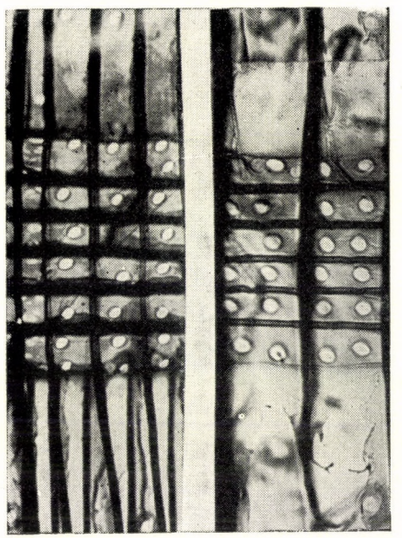
183. Athrotaxis selaginoides Don



1. (100×)



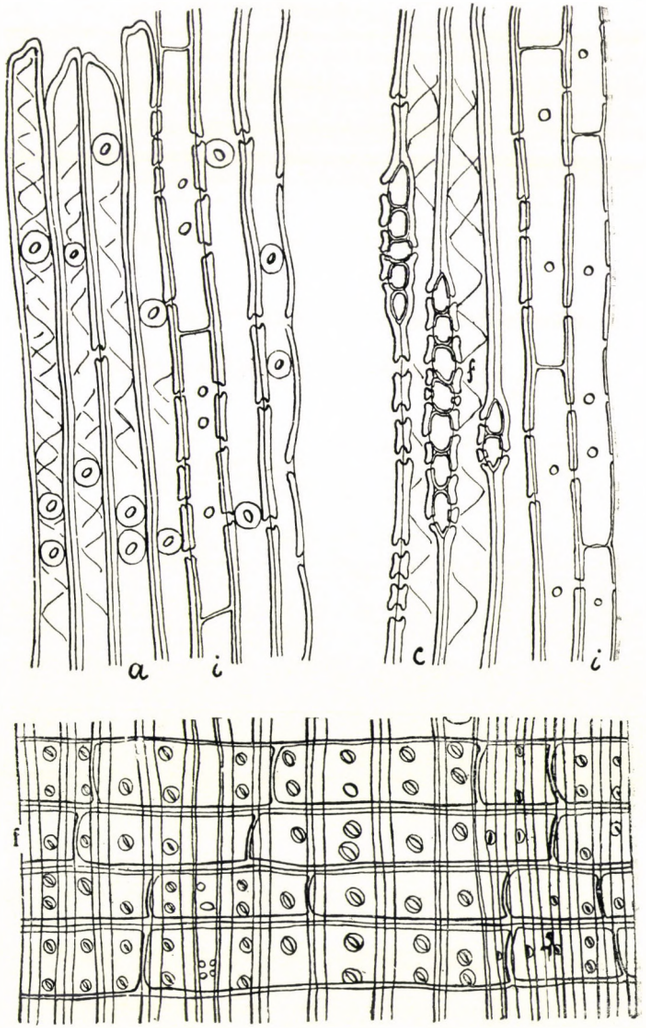
2. (100×)



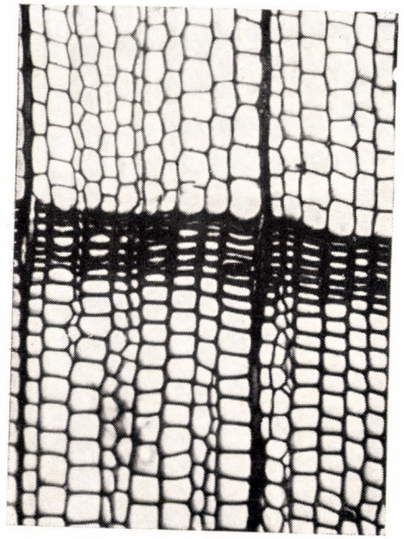
3. (300×)



4. (300×)



184. Cryptomeria japonica (L.) Don



1. (100×)



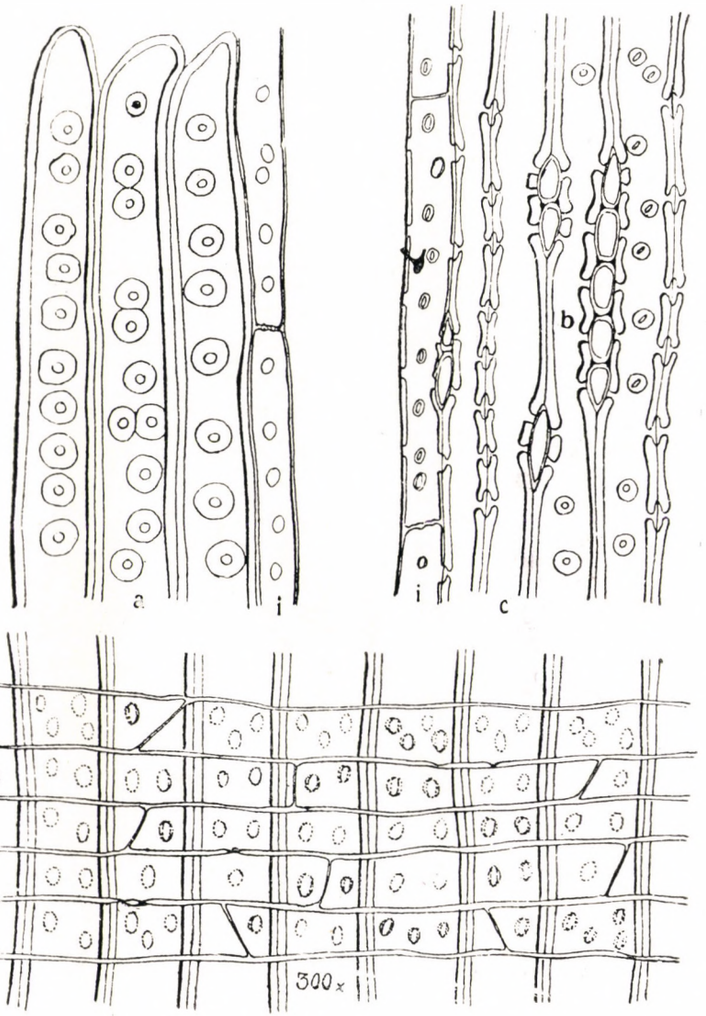
2. (100×)



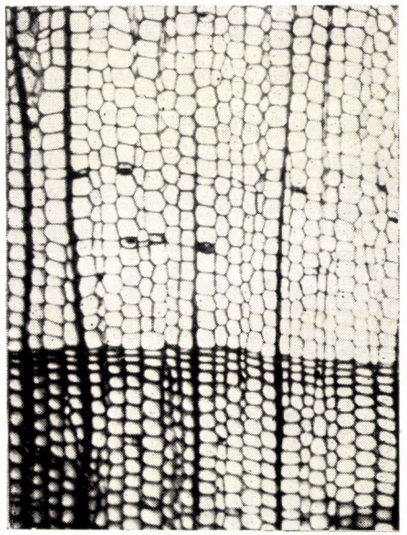
3. (300×)



4. (300×)



185. Cunninghamia lanceolata (Lambert) Hook.



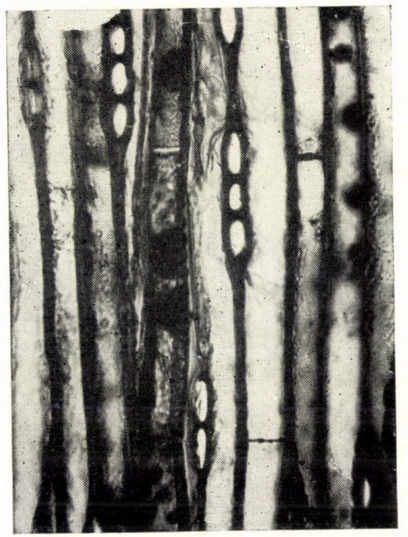
1. (100×)



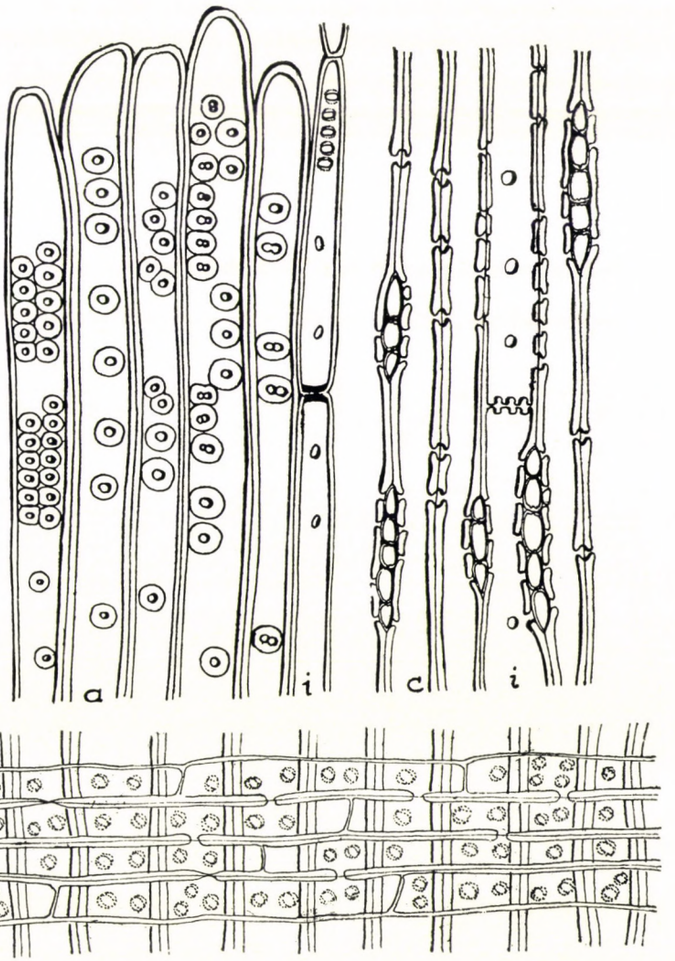
2. (100×)



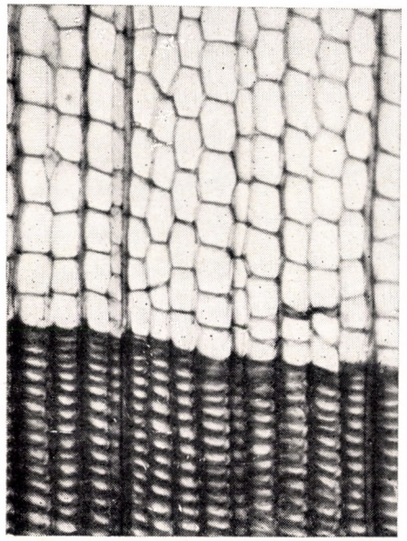
3. (300×)



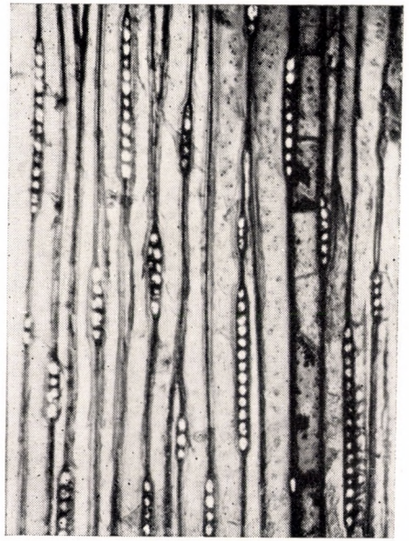
4. (300×)



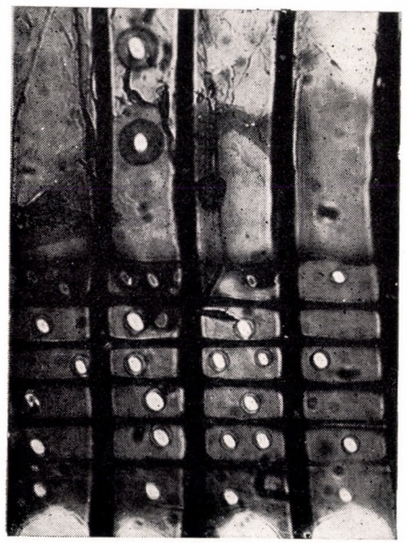
186. Glyptostrobus pensilis (Saunton) K. Koch



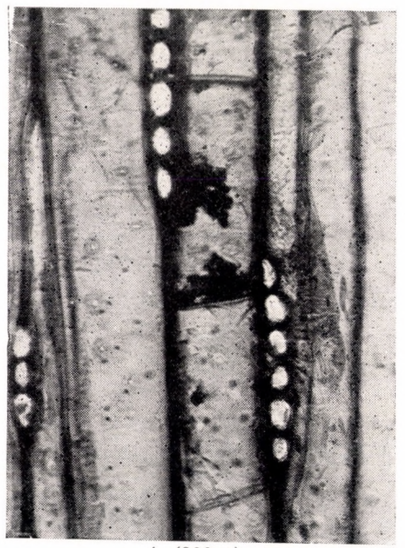
1. (100×)



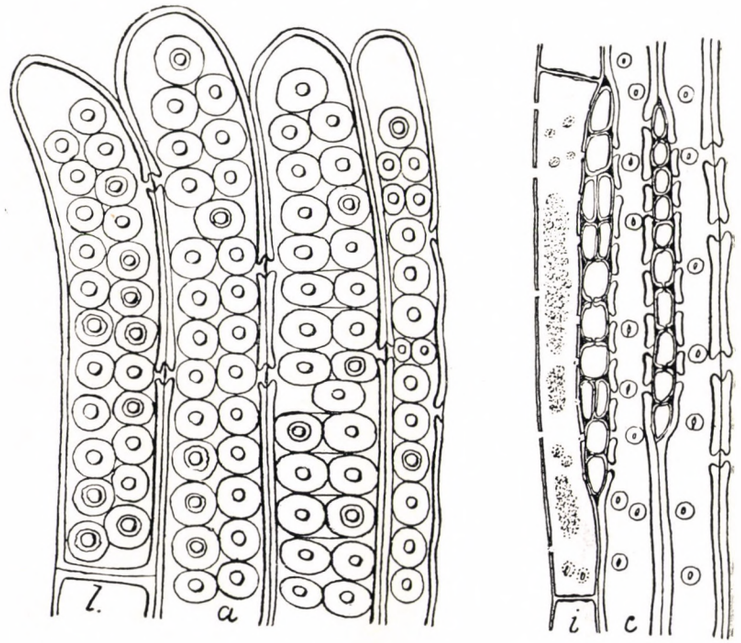
2. (100×)



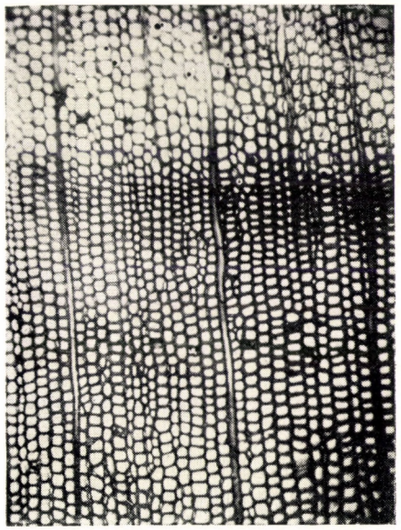
3. (300×)



4. (300×)



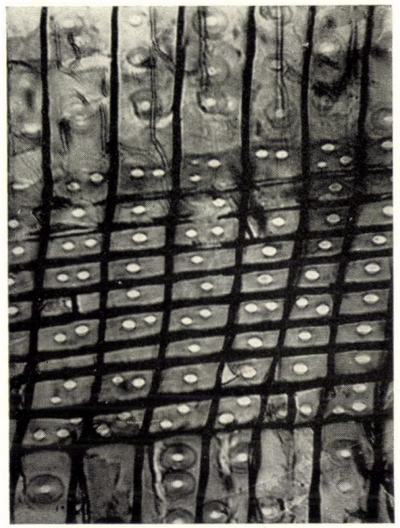
187. Metasequoia glyptostroboides Hu et Cheng



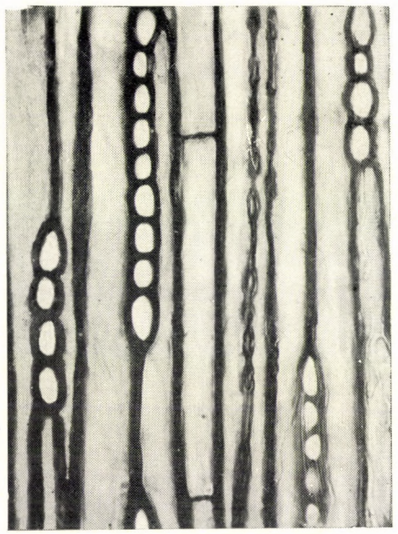
1. (100×)



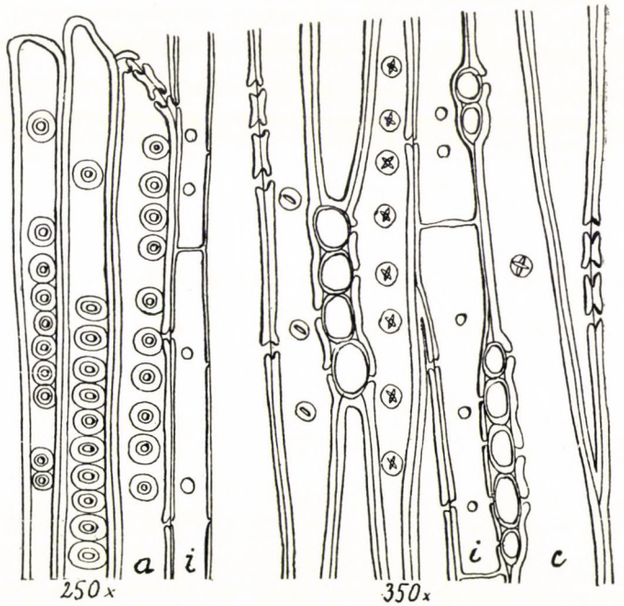
2. (100×)

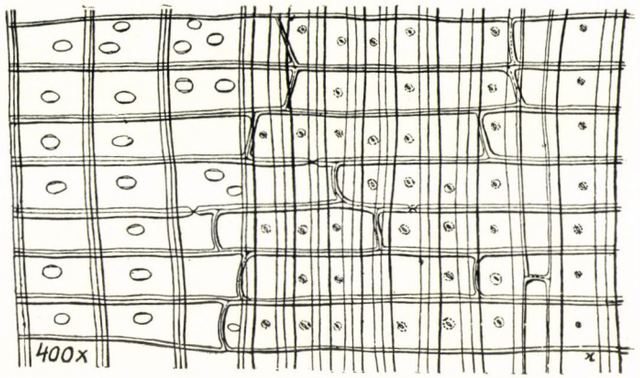


3. (300×)

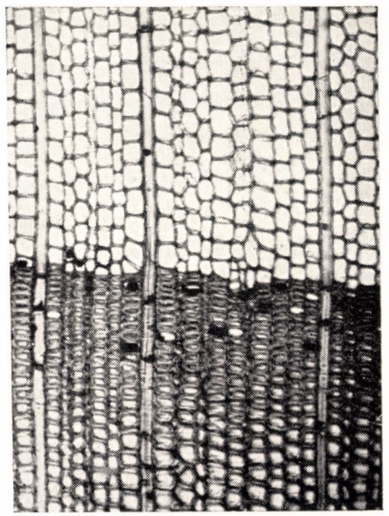


4. (300×)

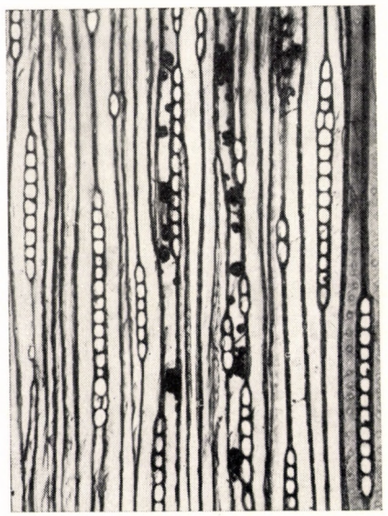




188. Sequoia gigantea TORREY



1. (100×)



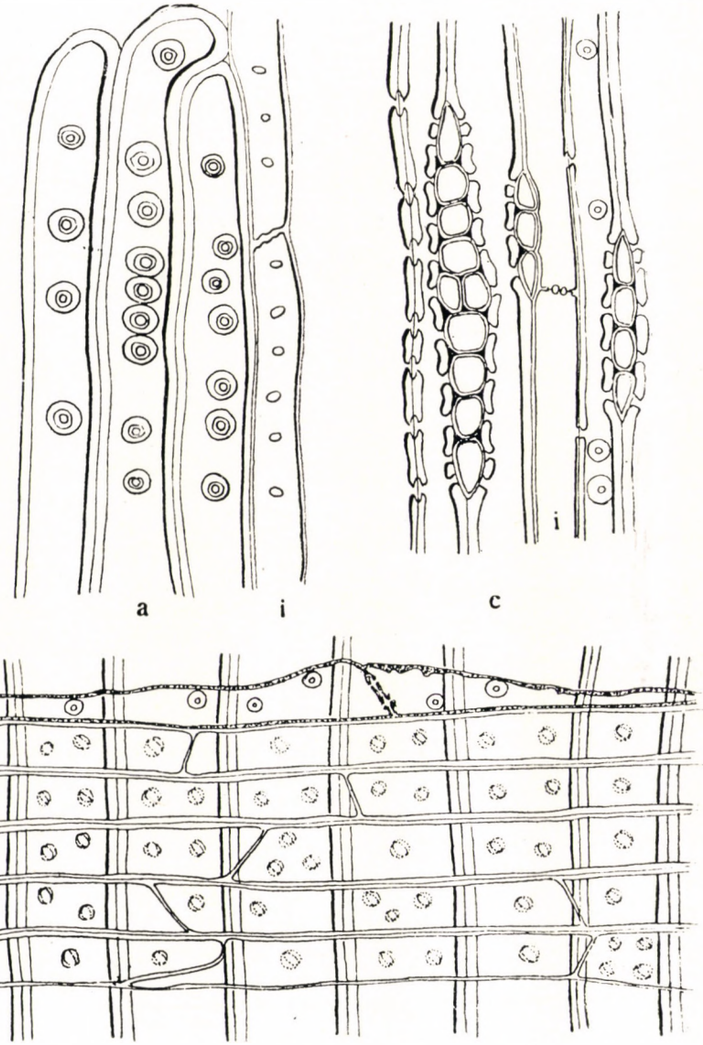
2. (100×)



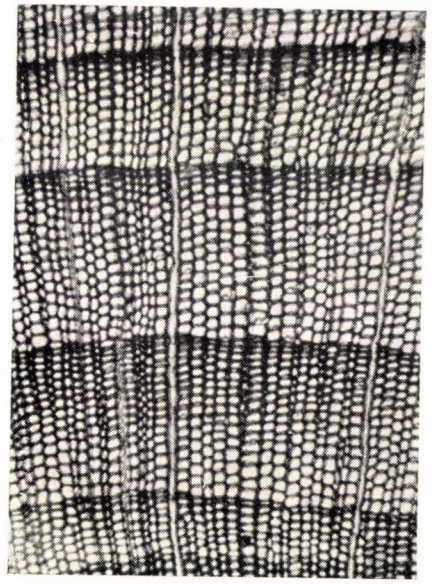
3. (300×)



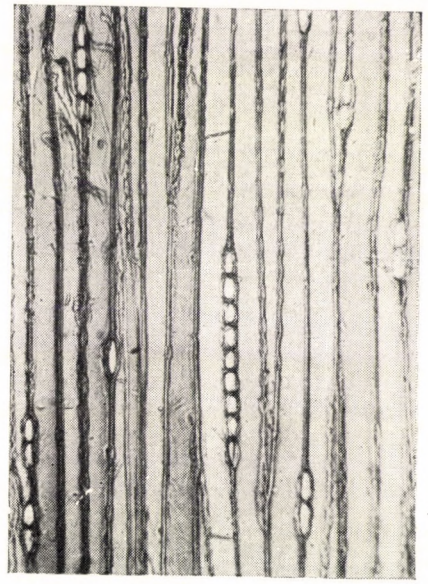
4. (300×)



189. Sequoia sempervirens (Lambert) Endl.



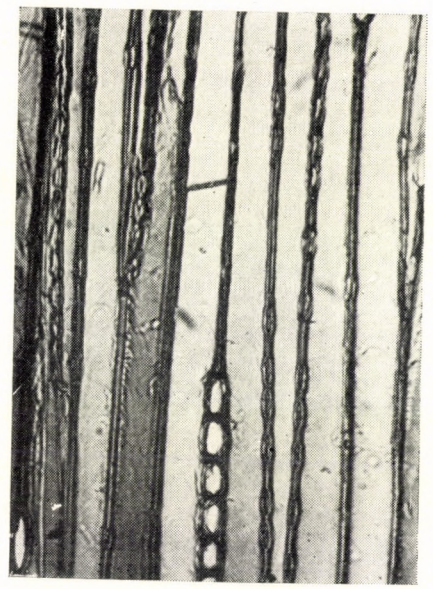
1. (100×)



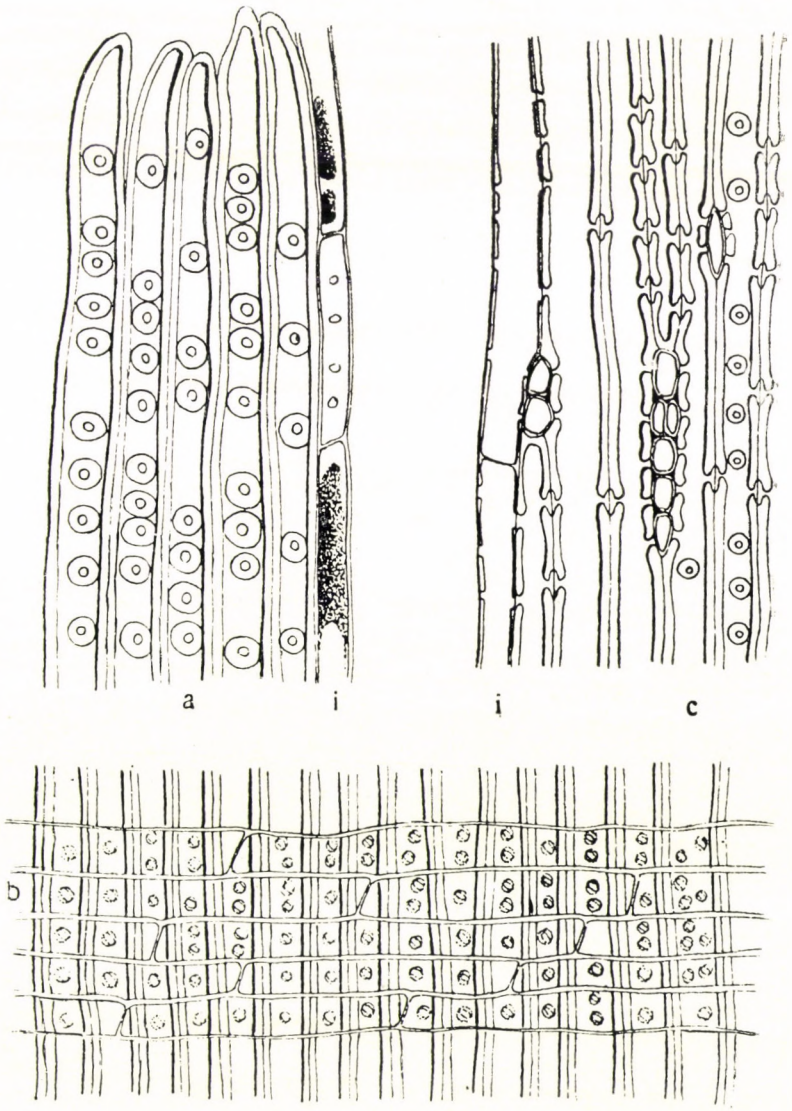
2. (100×)



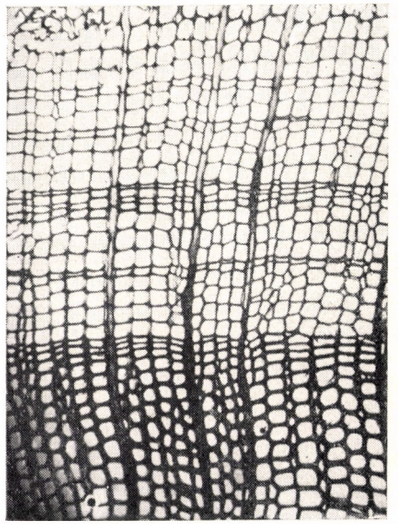
3. (600×)



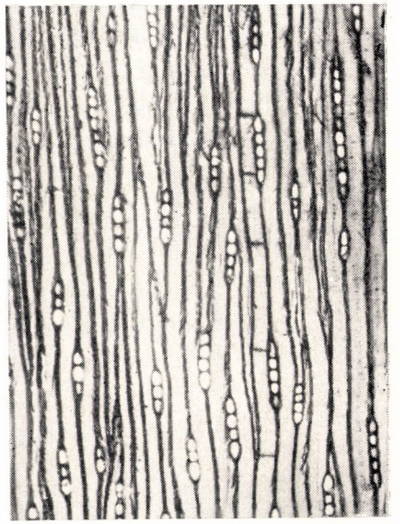
4. (300×)



190. Taiwania cryptomerioides HAYATA



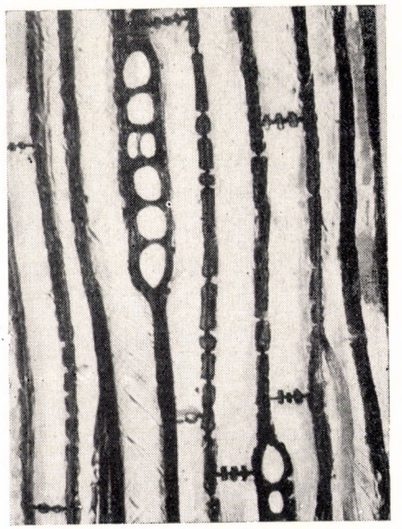
1. (100×)



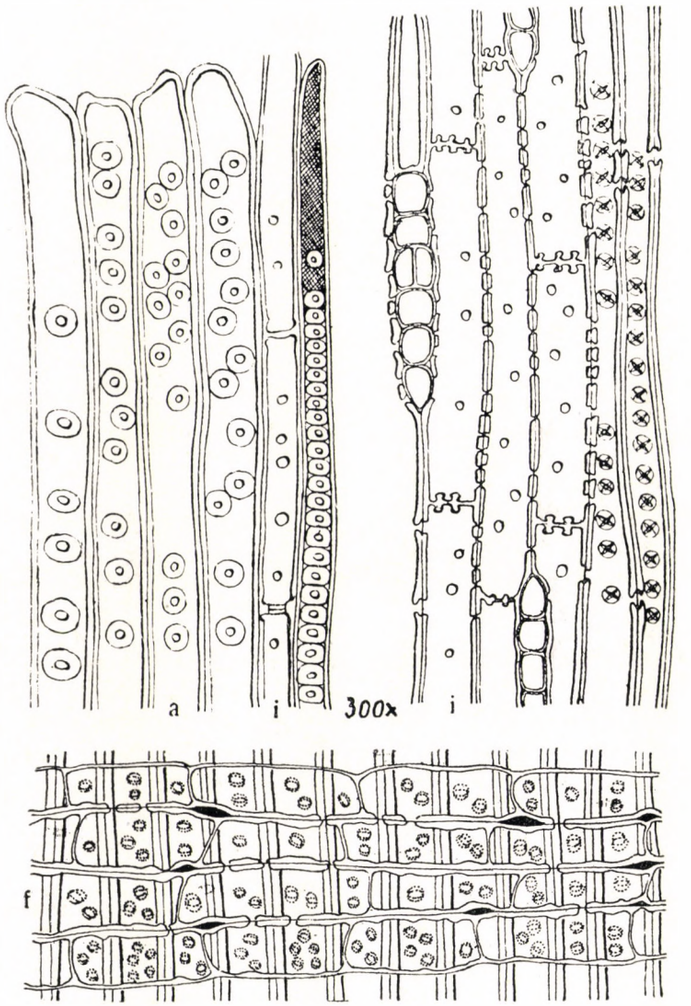
2. (100×)



3. (300×)



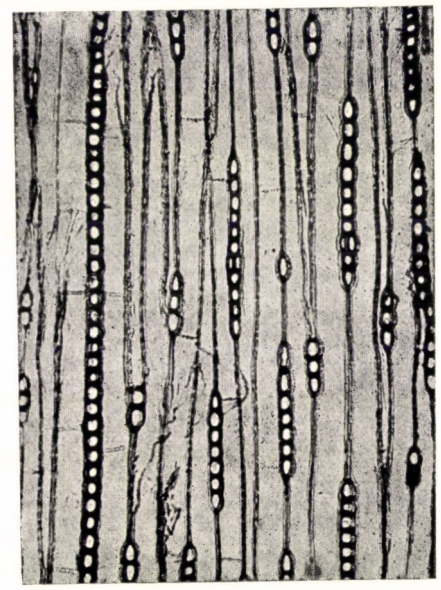
4. (300×)



191. Taxodium ascendens BRONGN.



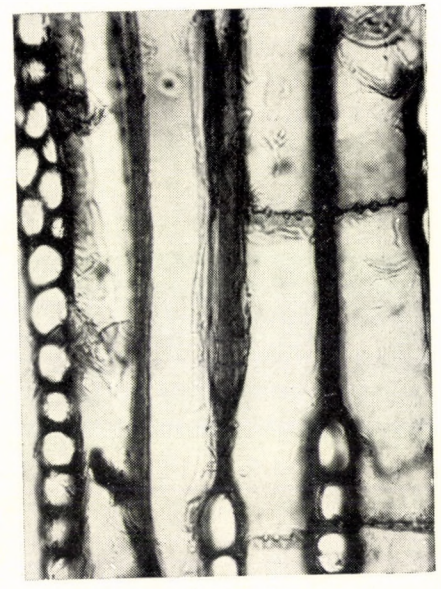
1. (100×)



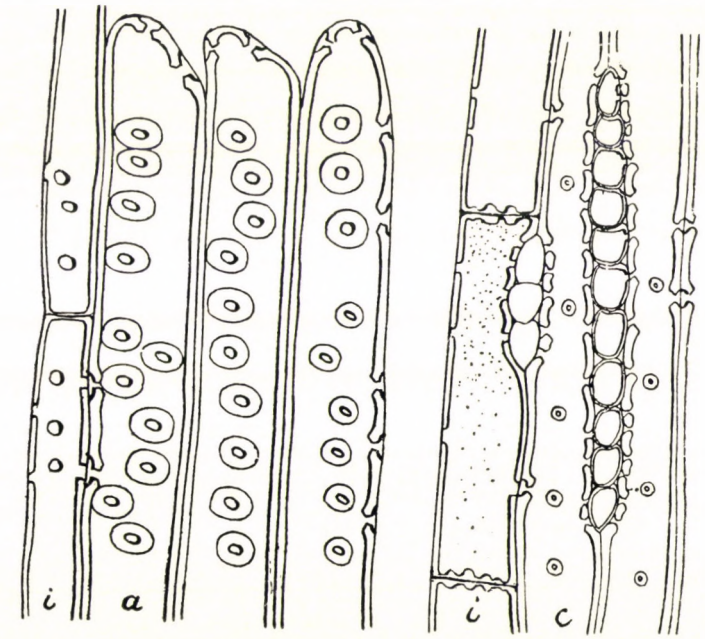
2. (100×)

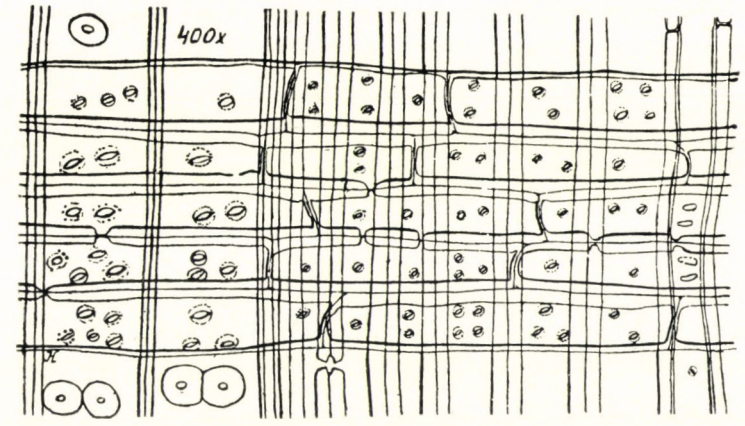


3. (300×)

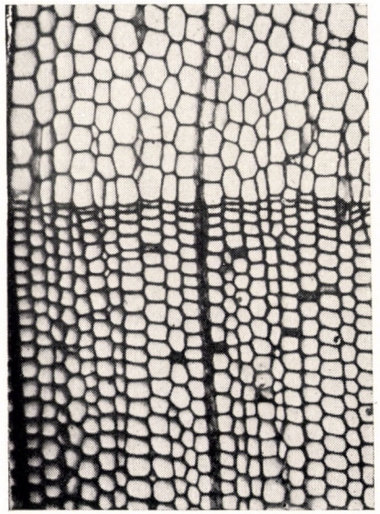


4. (300×)





192. Taxodium distichum RICH.



1. (100×)



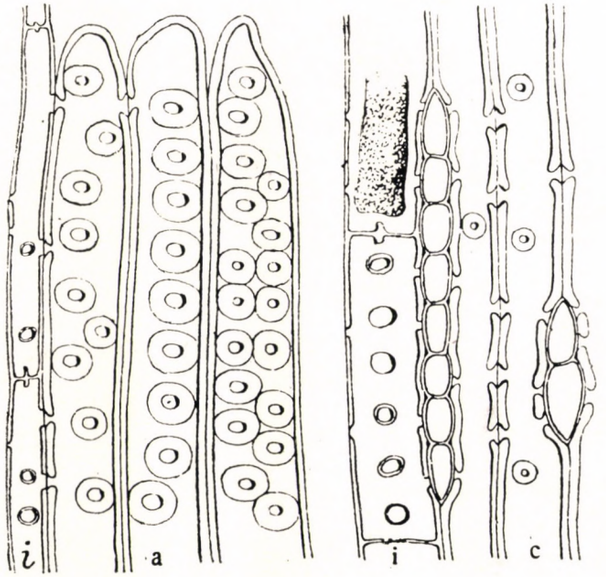
2. (100×)

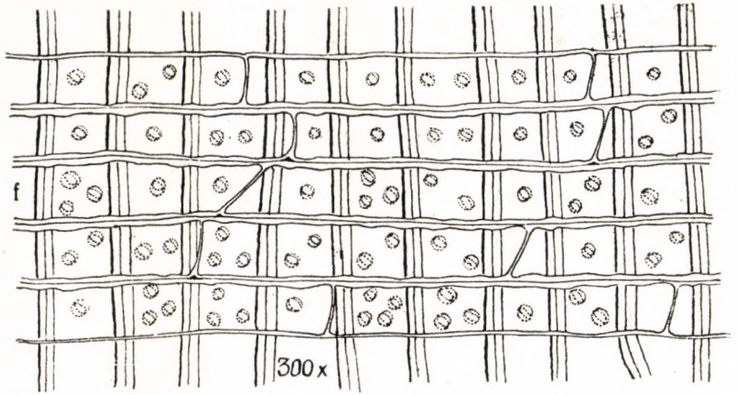


3. (300×)

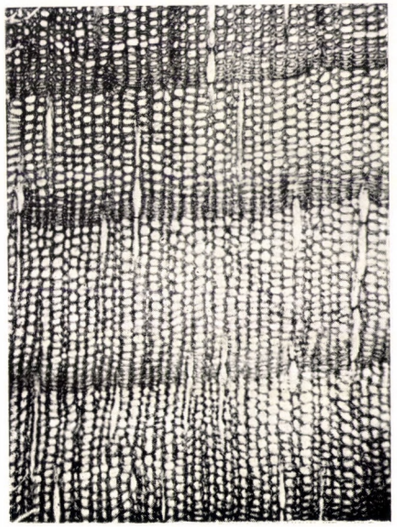


4. (300×)

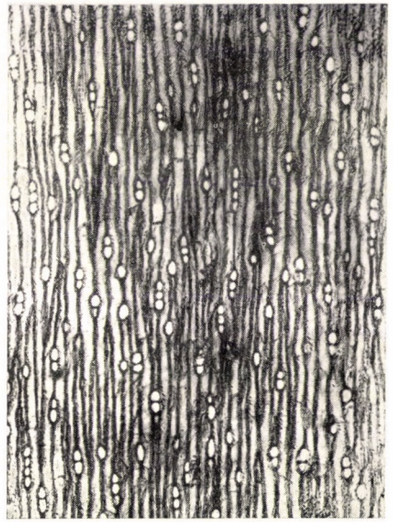




193. Taxodium mucronatum TENORE



1. (100×)



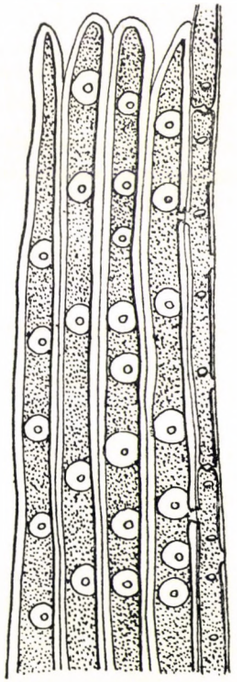
2. (100×)

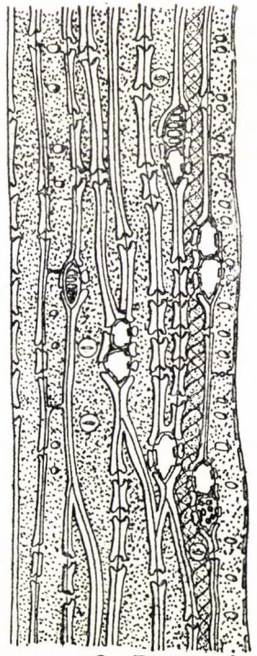


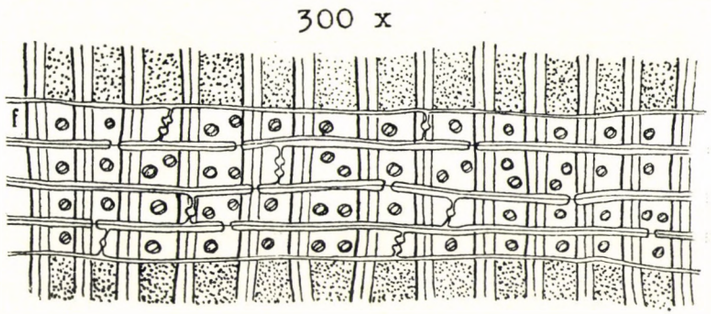
3. (300×)



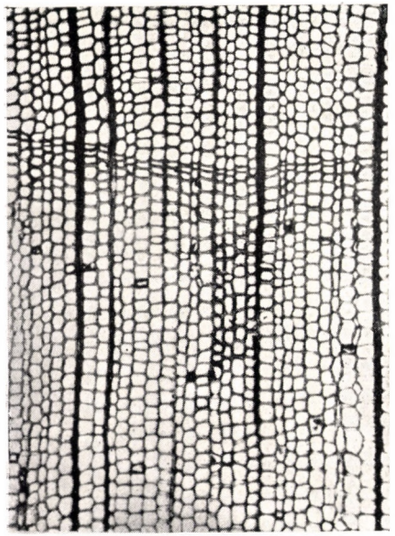
4. (300×)







194. Pherosphaera Hookeriana ARCHER



1. (100×)



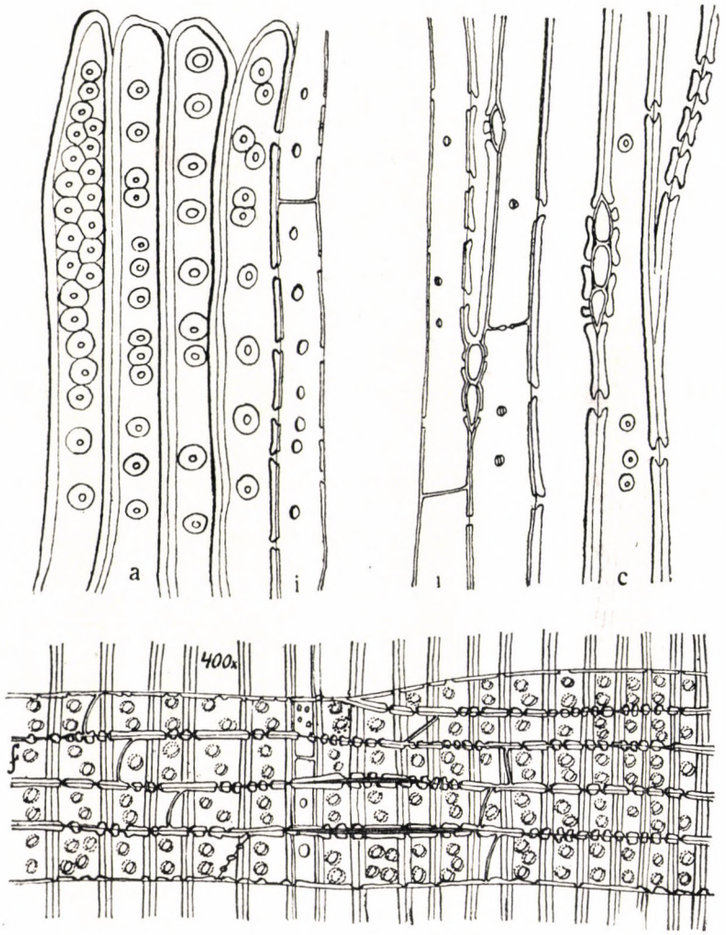
2. (100×)



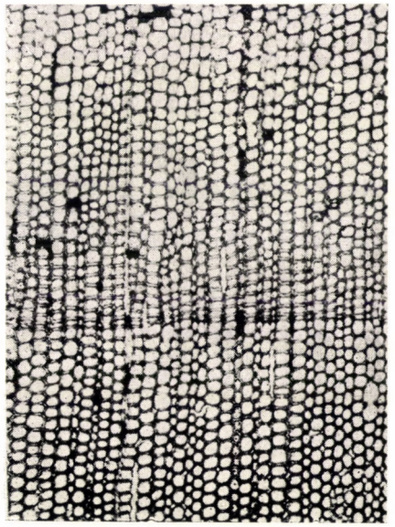
3. (300×)



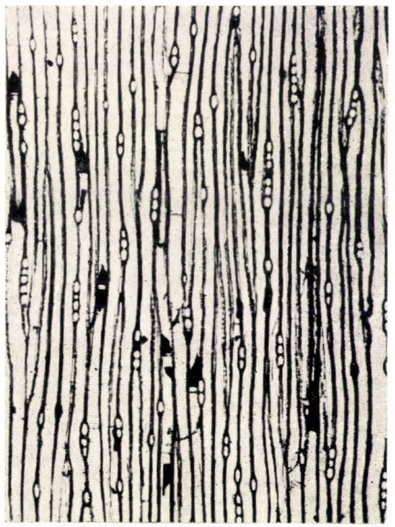
4. (300×)



195. Saxe-Gothea conspicua LINDLEY



1. (100×)



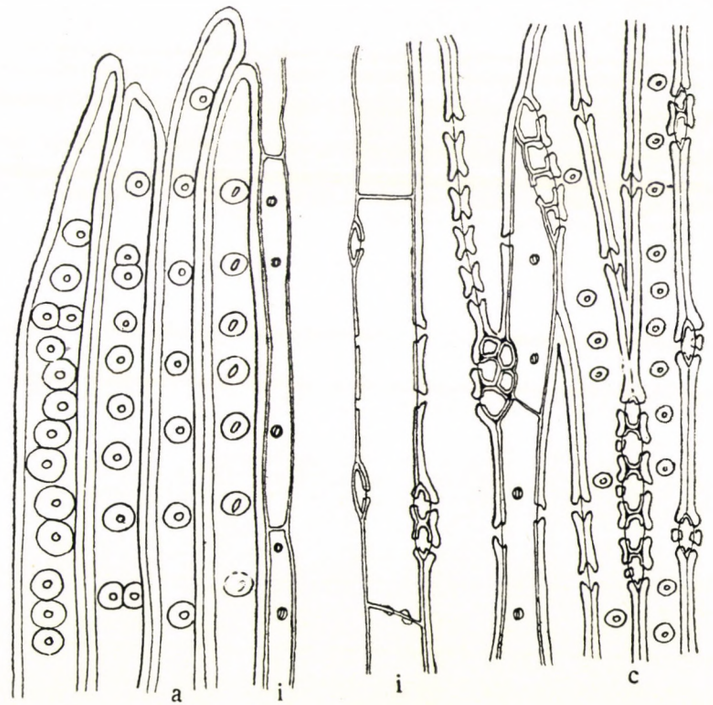
2. (100×)



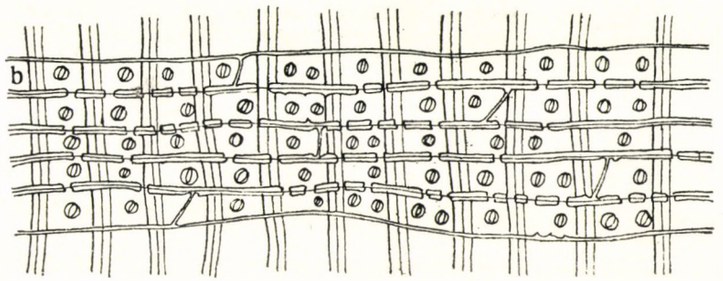
3. (300×)



4. (300×)



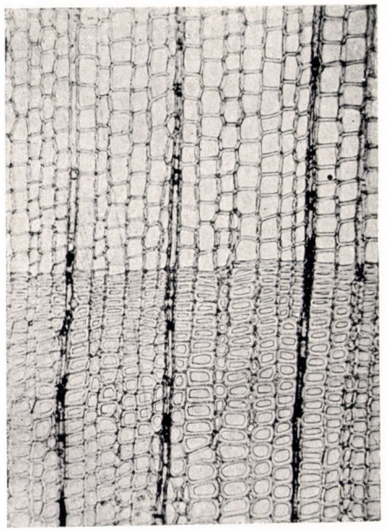
300 x



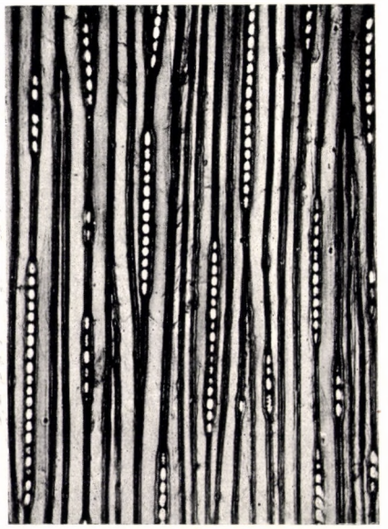
195a. Saxe-Gothea gracilis HORT.

VIII.

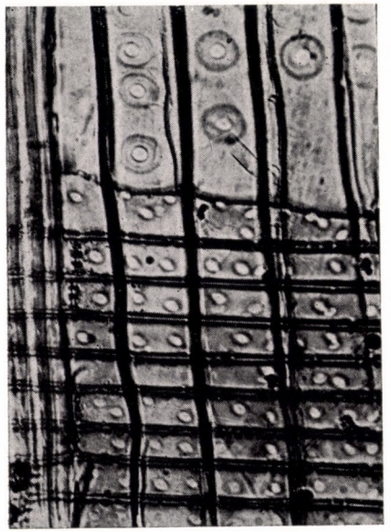
PINACEAE



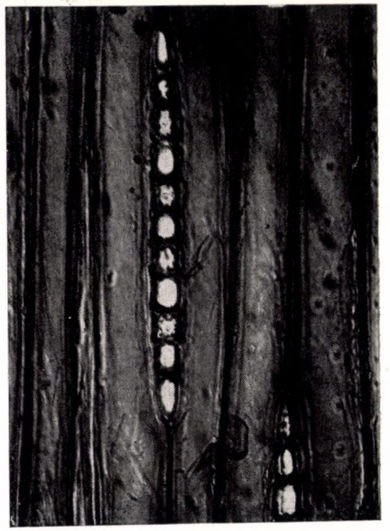
1. (100×)



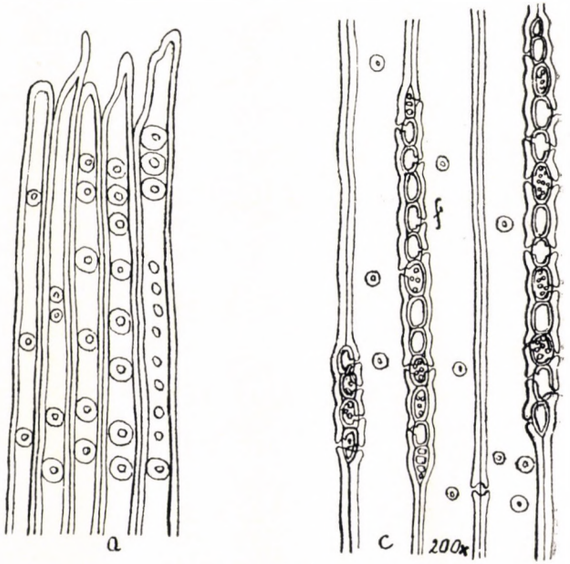
2. (100×)

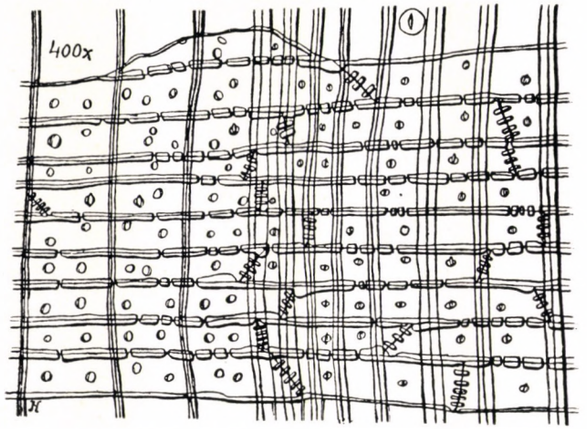


3. (300×)

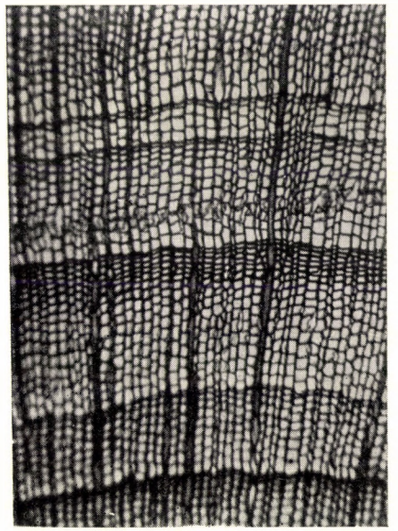


4. (300×)





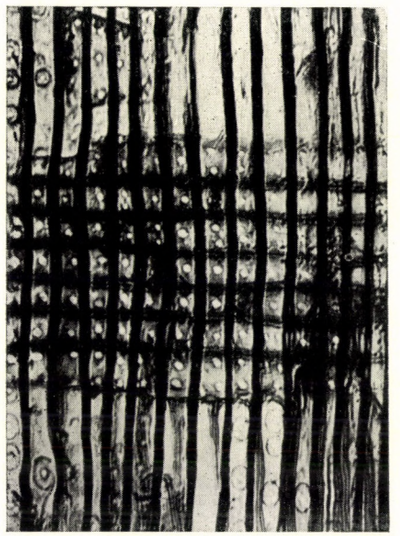
196. Abies alba MILLER



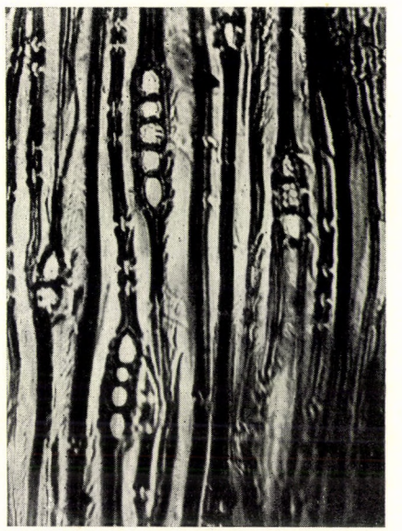
1. (100×)



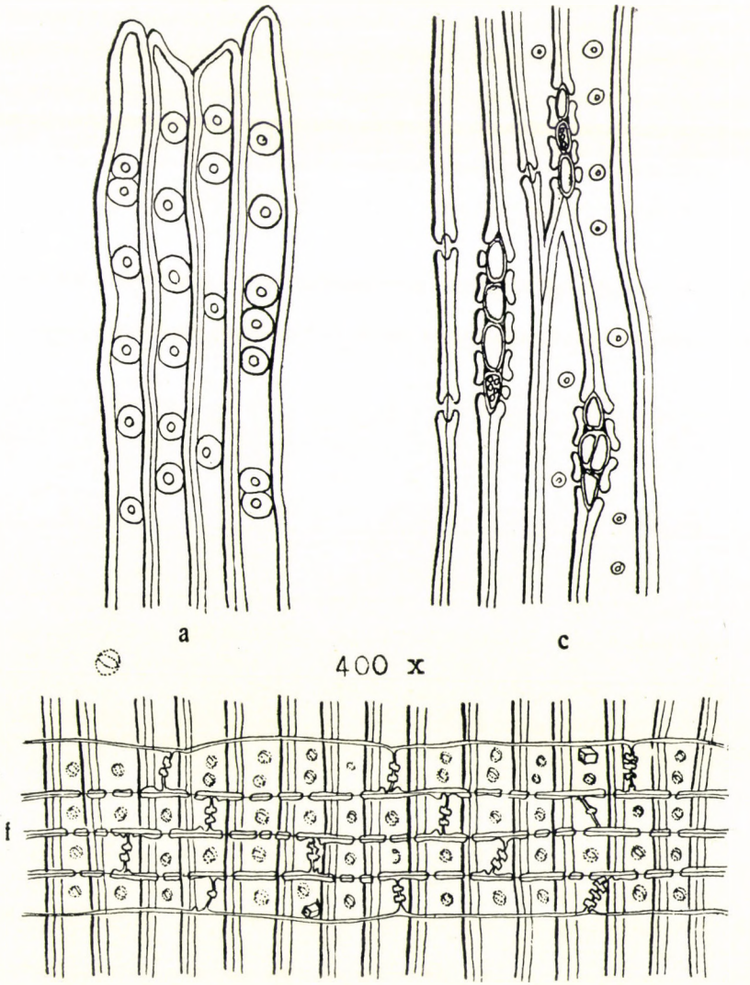
2. (100×)



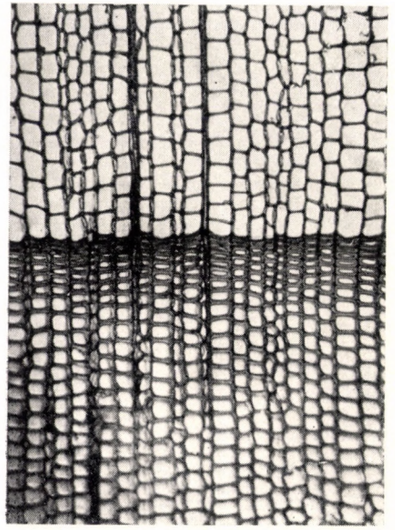
3. (300×)



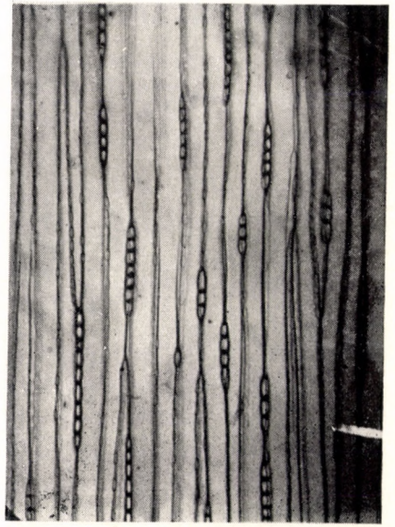
4. (300×)



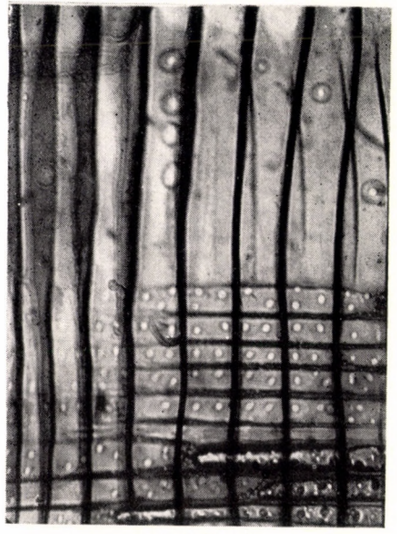
197. Abies amabilis FORBES



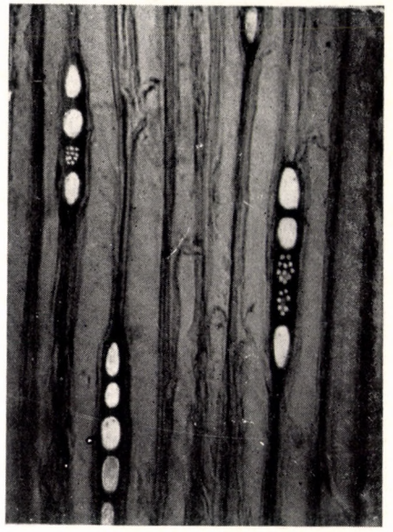
1. (100×)



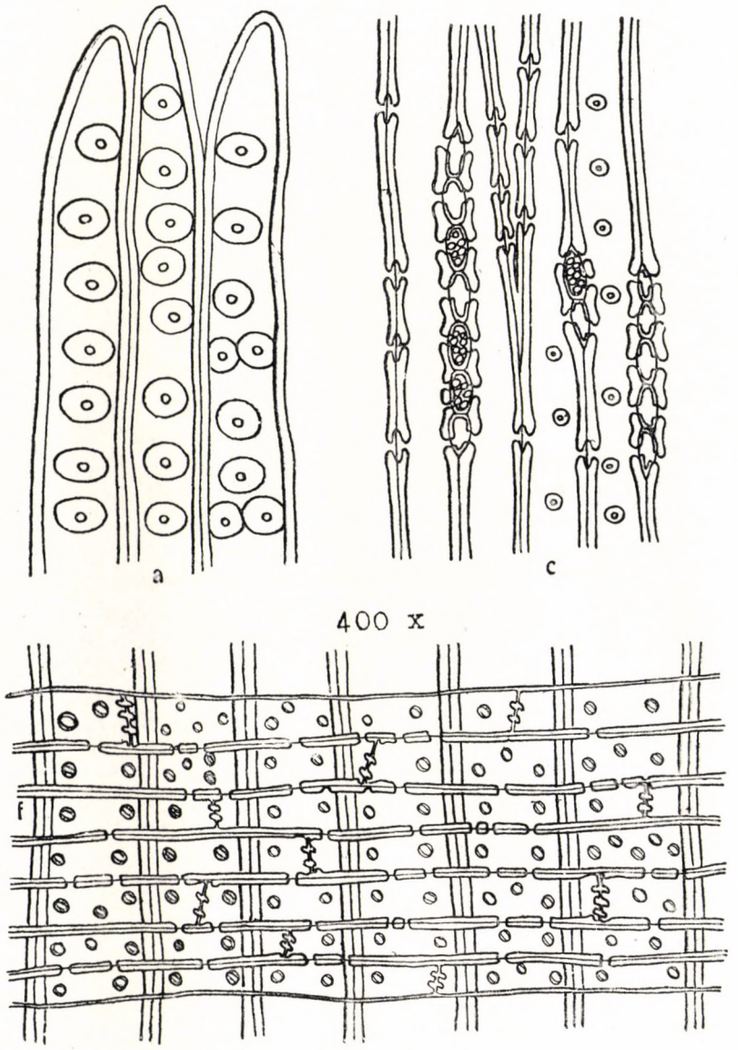
2. (100×)



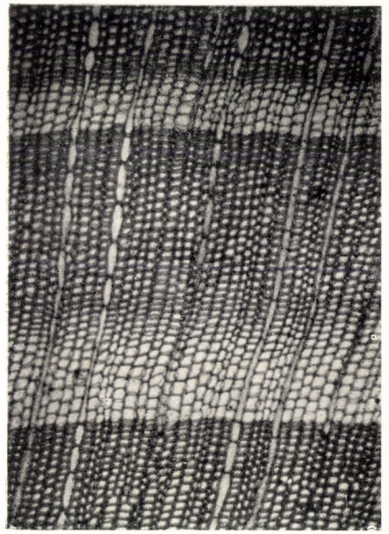
3. (300×)



4. (300×)



198. Abies balsamea MILLER



1. (100×)



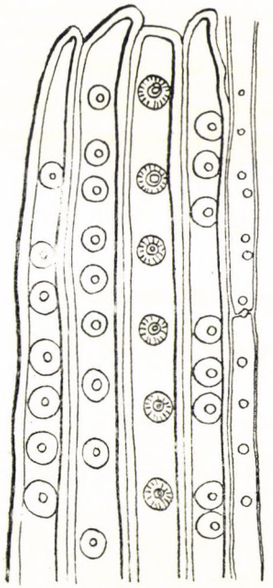
2. (100×)

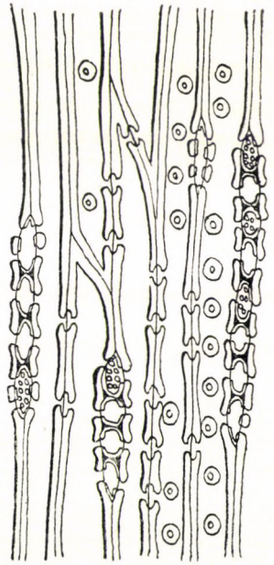


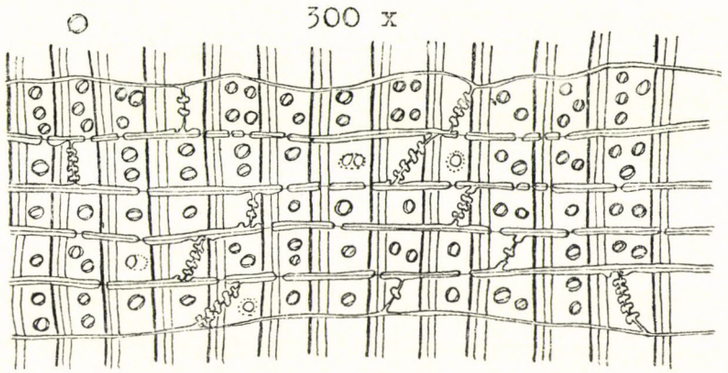
3. (300×)



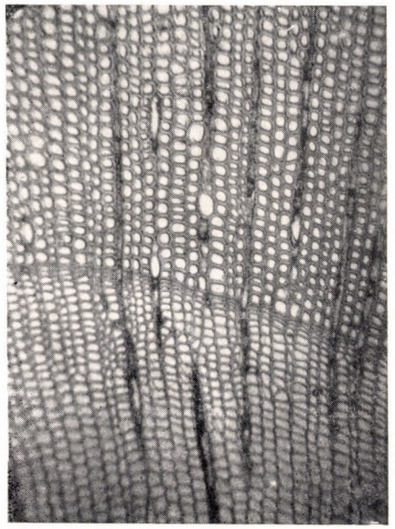
4. (300×)



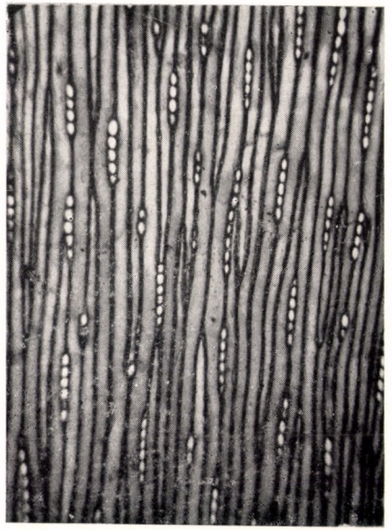




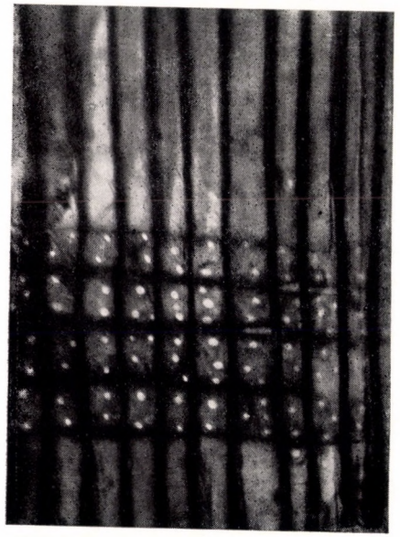
199. Abies cephalonica LOUDON



1. (100×)



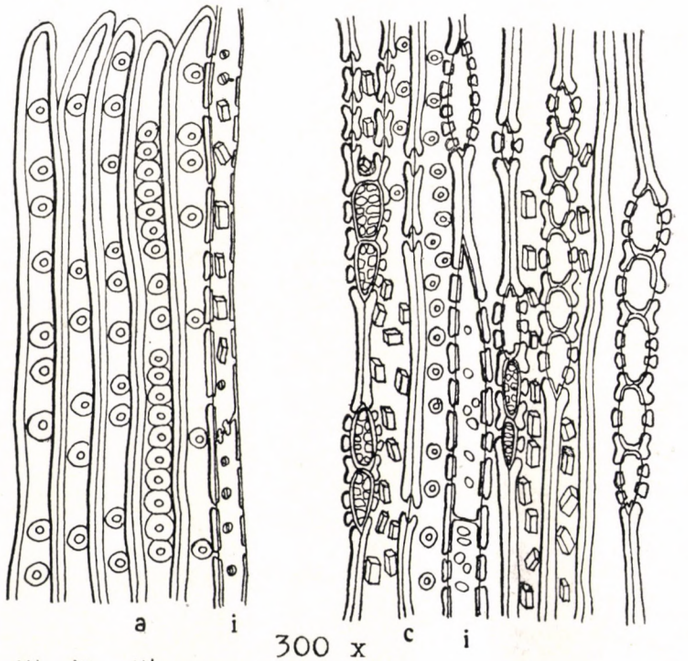
2. (100×)

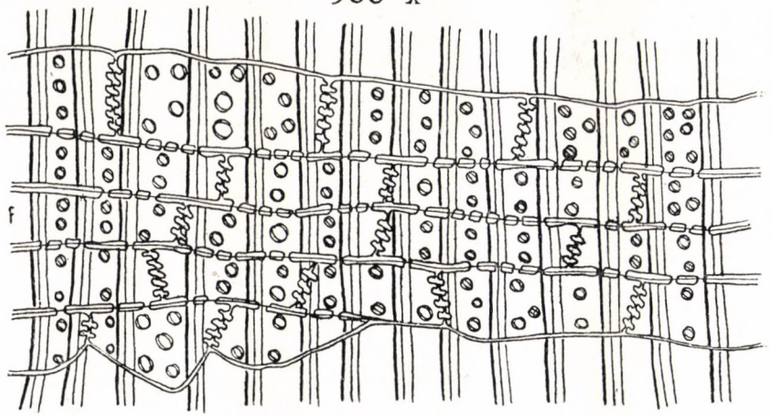


3. (300×)

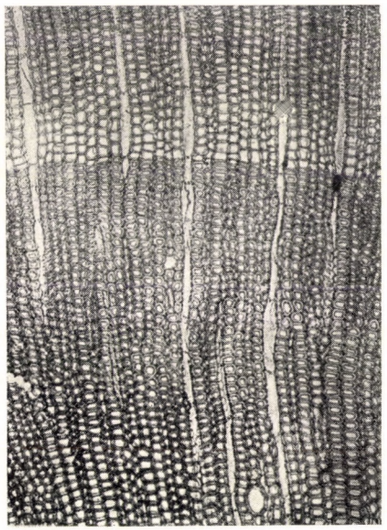


4. (300×)

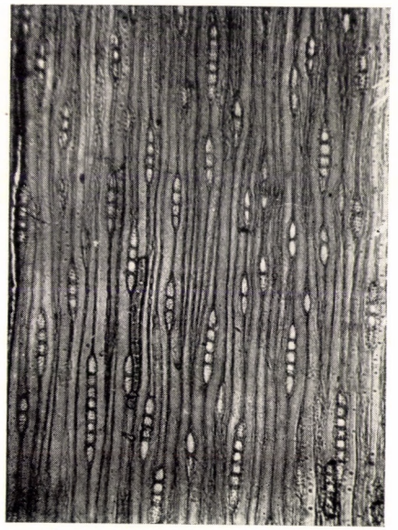




200. Abies chensiensis VAN TIEGHEM



1. (100×)



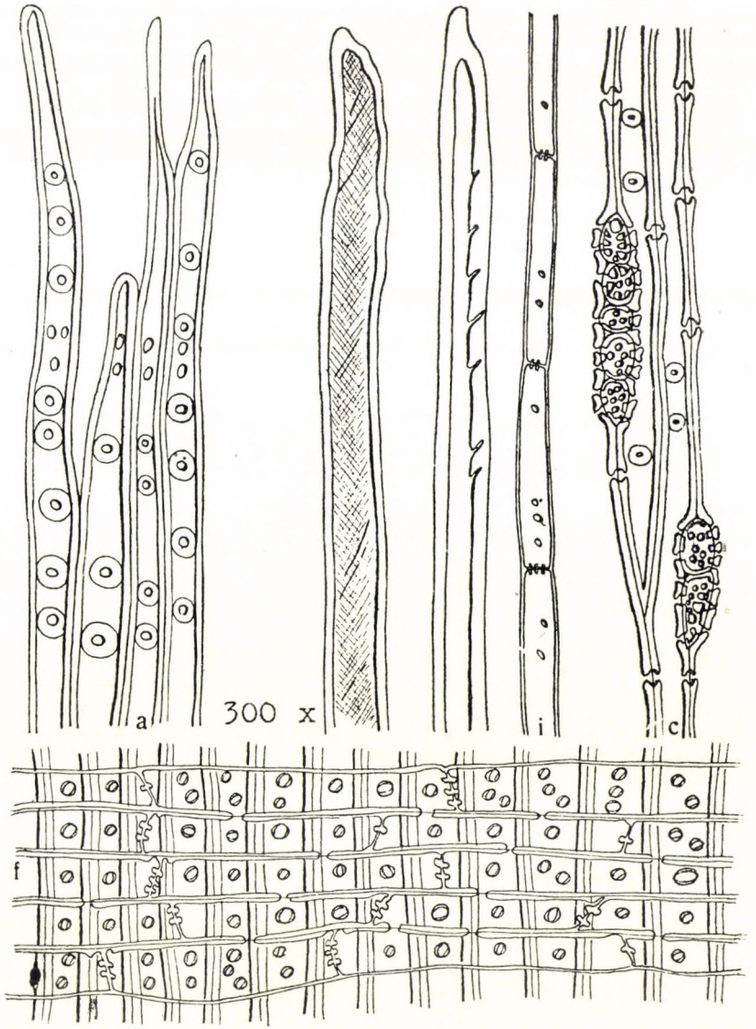
2. (100×)



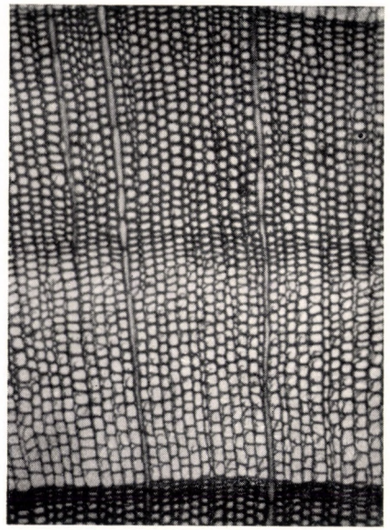
3. (300×)



4. (300×)



201. Abies cilicica CARR.



1. (100×)



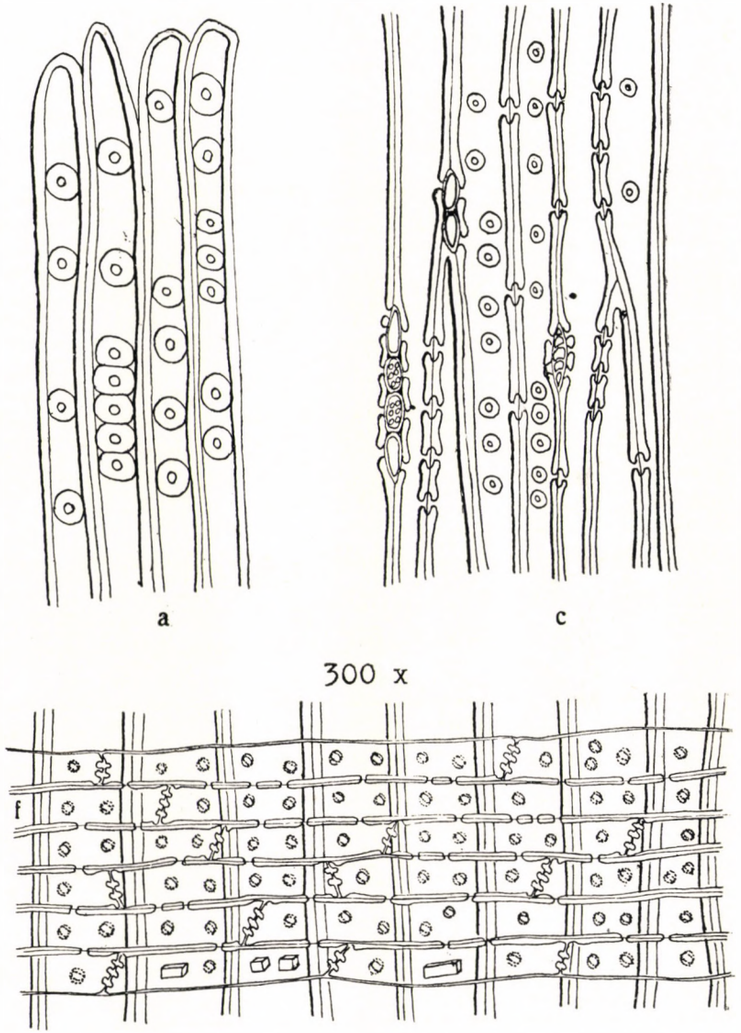
2. (100×)



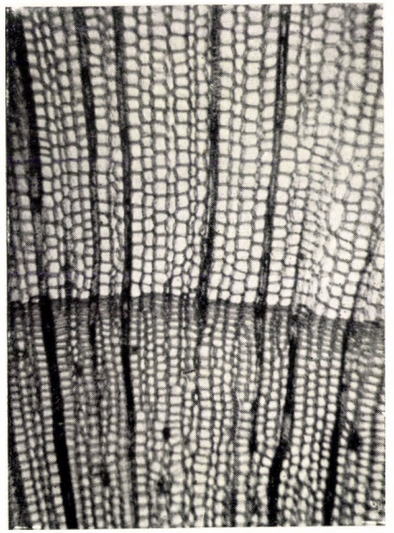
3. (300×)



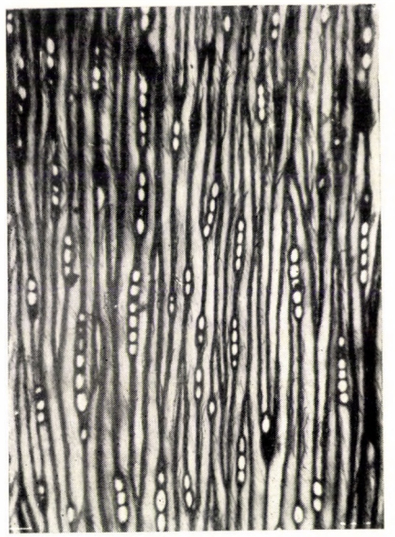
4. (300×)



202. Abies concolor Lindley et Gord.



1. (100×)



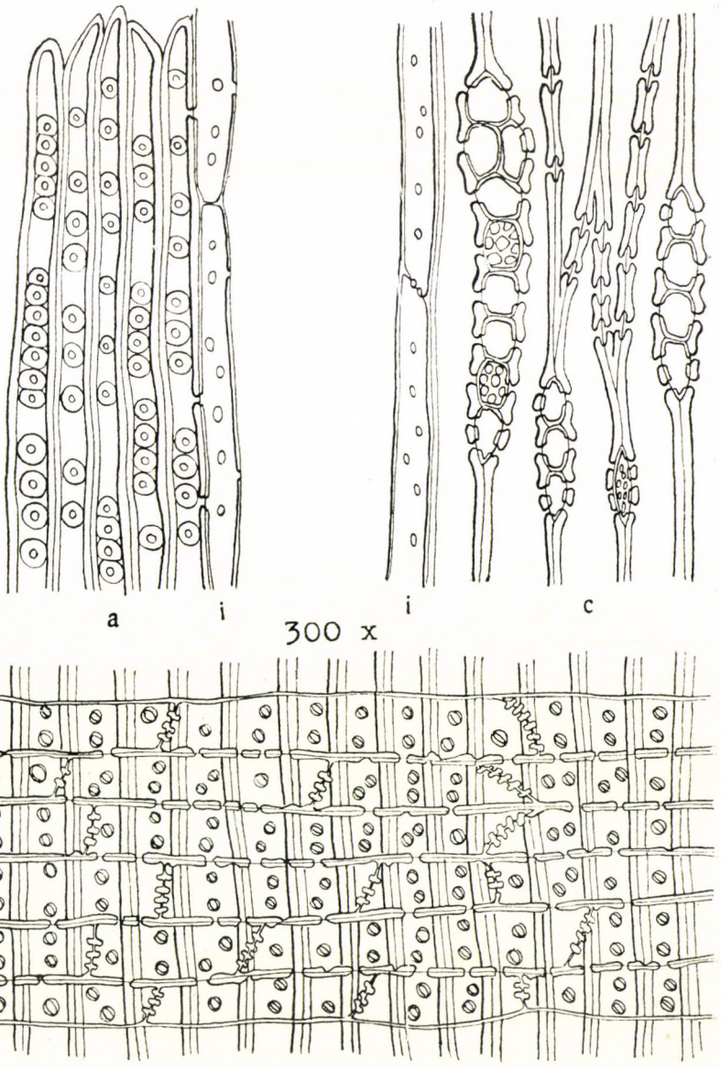
2. (100×)



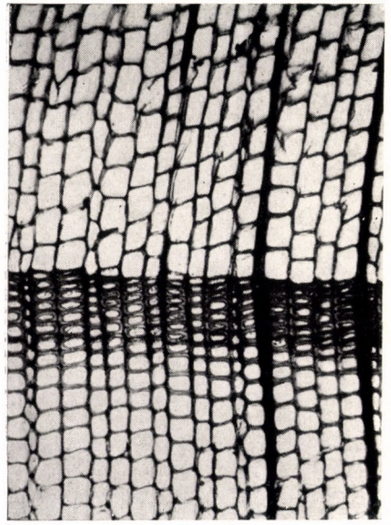
3. (300×)



4. (300×)



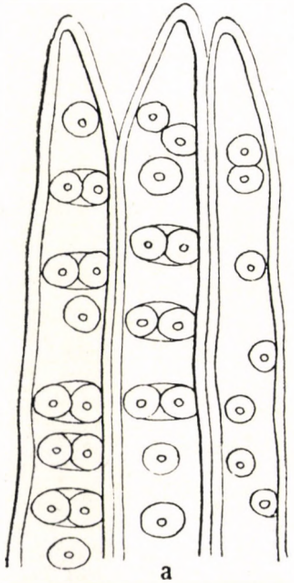
203. Abies Fabri (Mast.) Craib

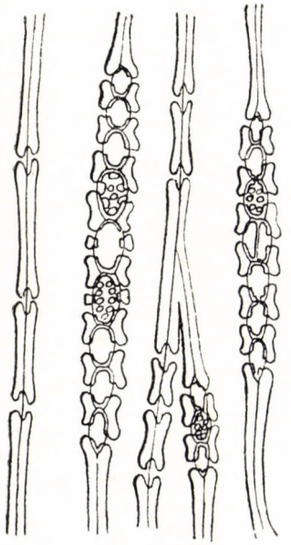


1. (100×)



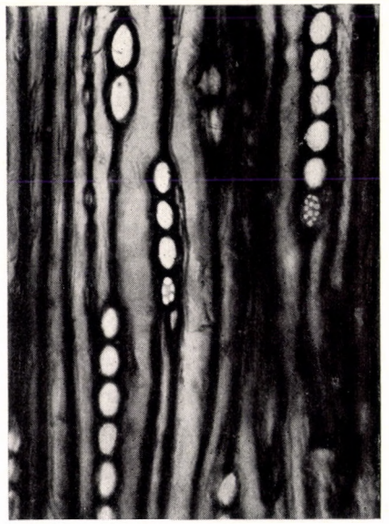
2. (100×)



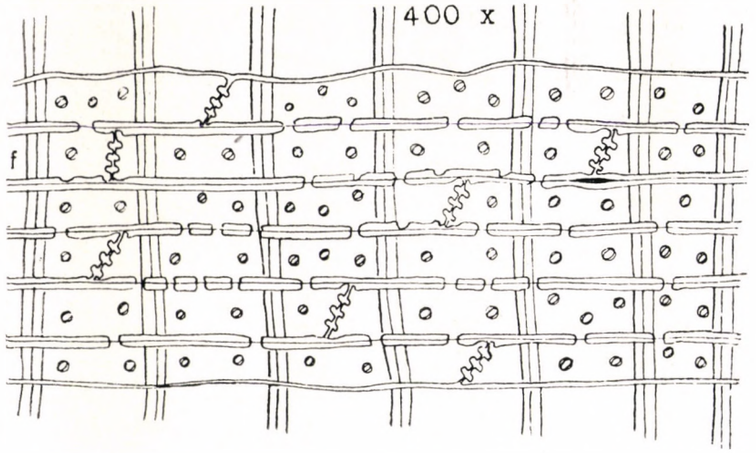




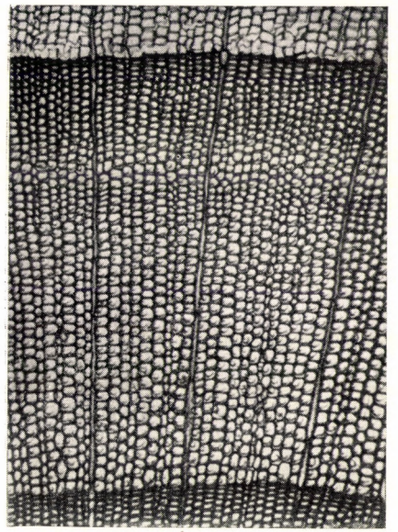
3. (300×)



4. (300×)



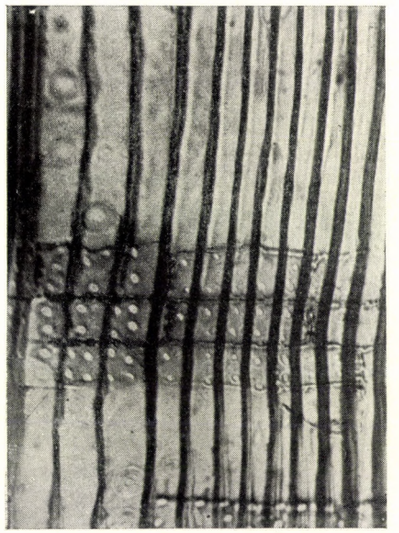
204. Abies firma SIEB. et ZUCC.



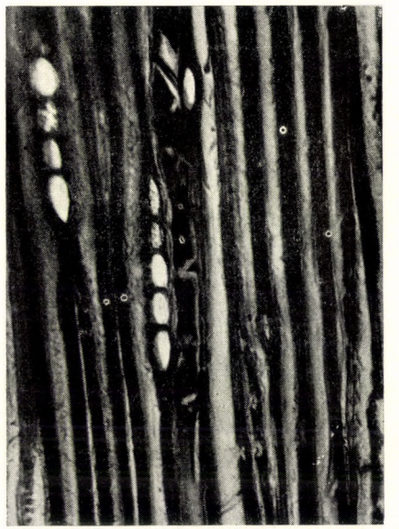
1. (100×)



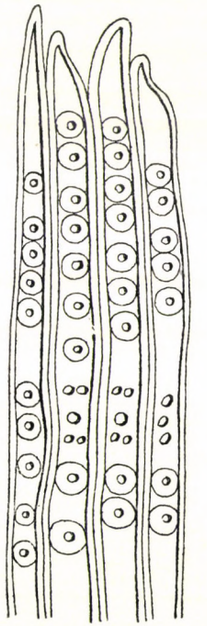
2. (100×)

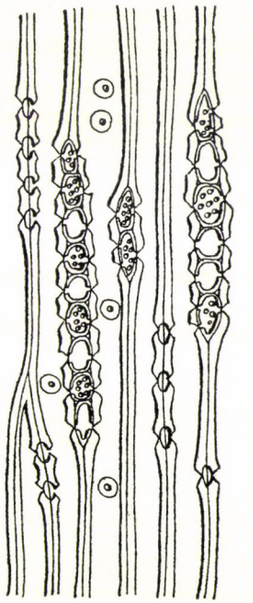


3. (300×)

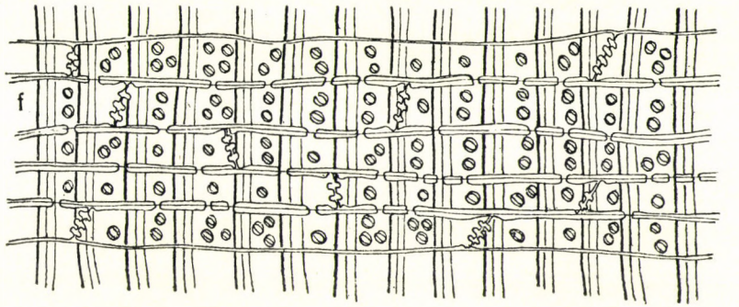


4. (300×)

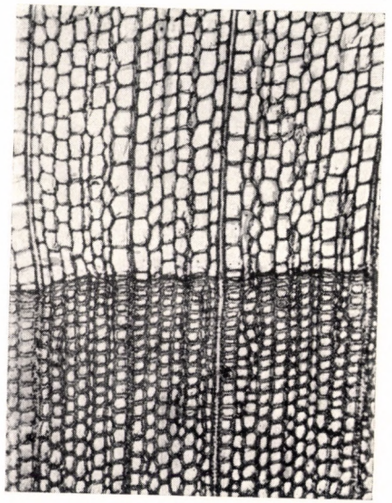




300 x



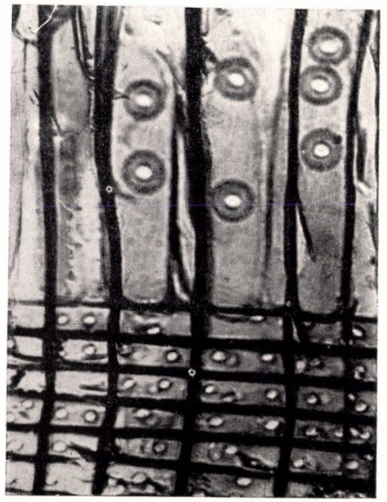
205. Abies Fraseri (Pursh) POIRET



1. (100×)



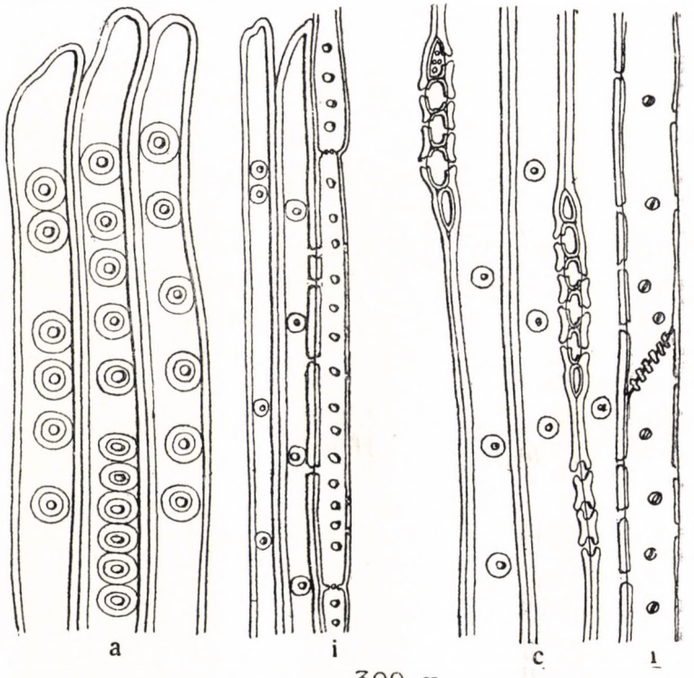
2. (100×)



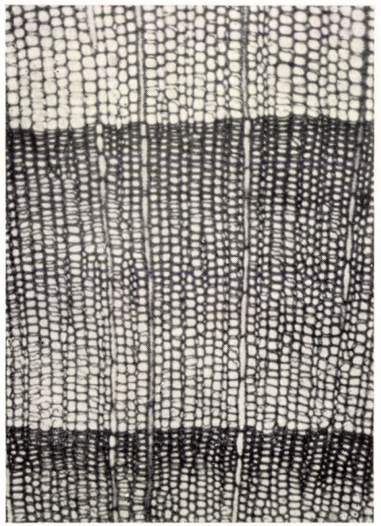
3. (300×)



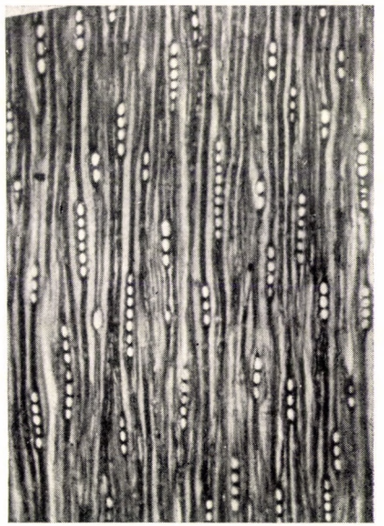
4. (300×)



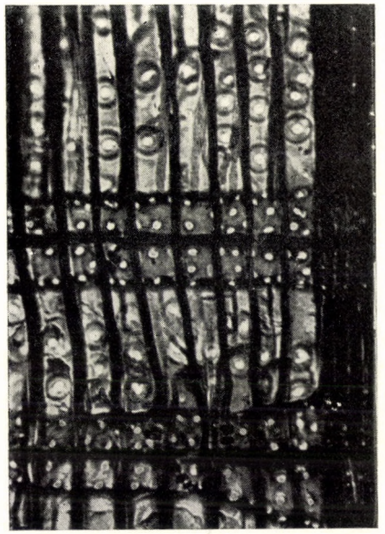
206. Abies grandis LINDLEY



1. (100×)



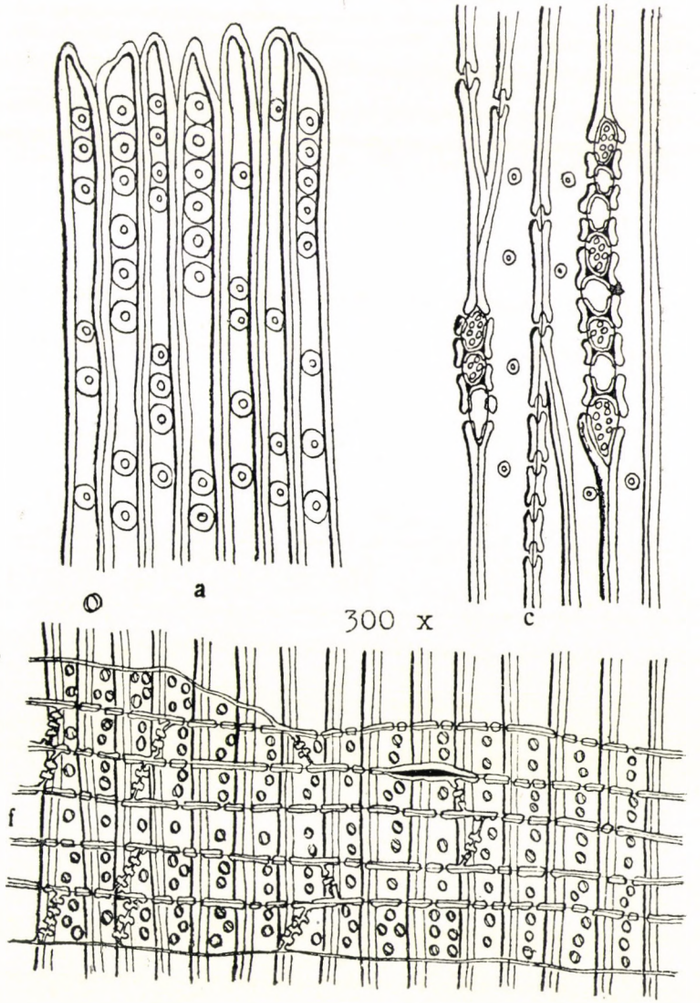
2. (100×)



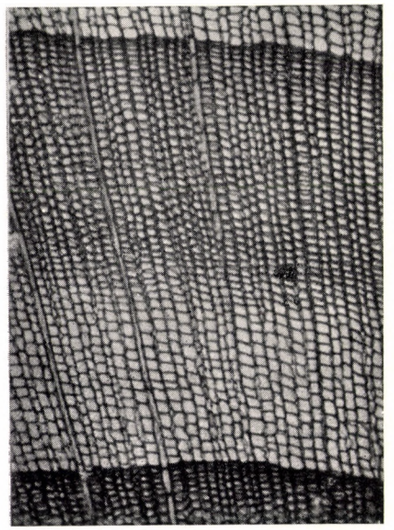
3. (300×)



4. (300×)



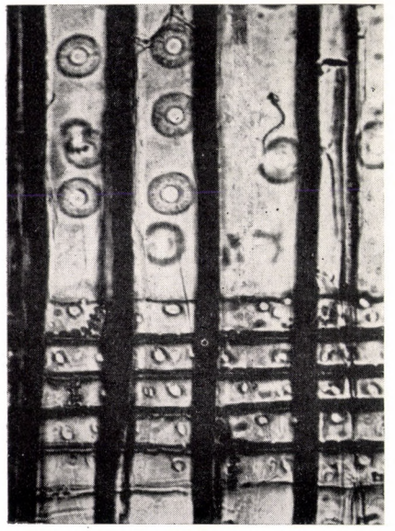
207. Abies holophylla MAXIMOWICZ



1. (100×)



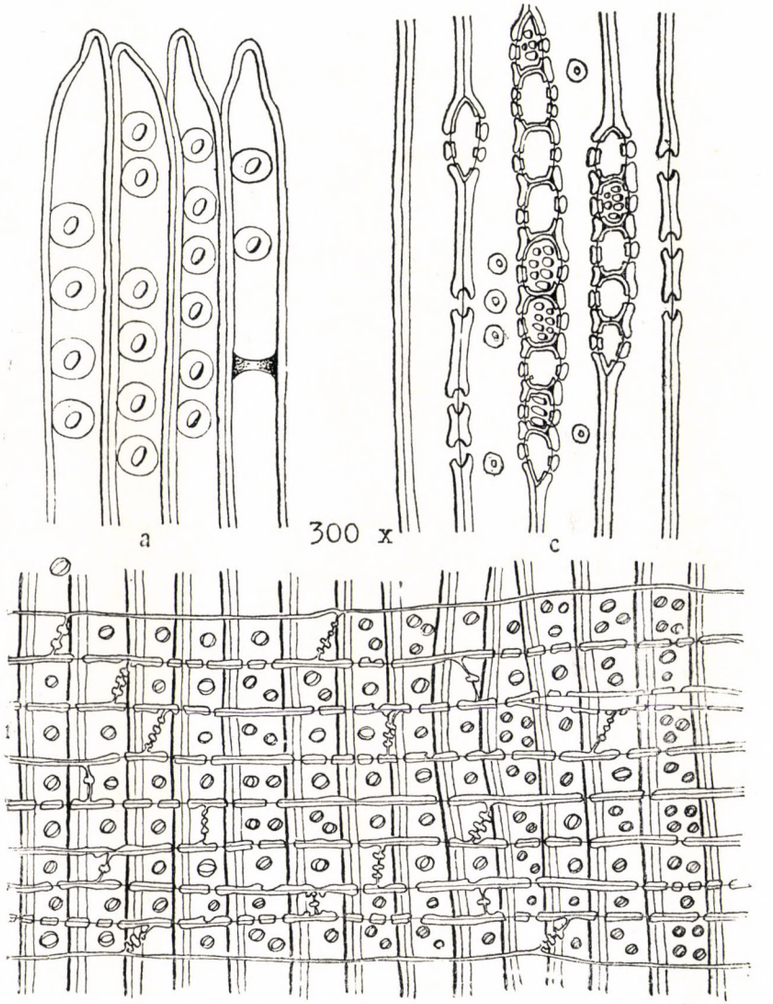
2. (100×)



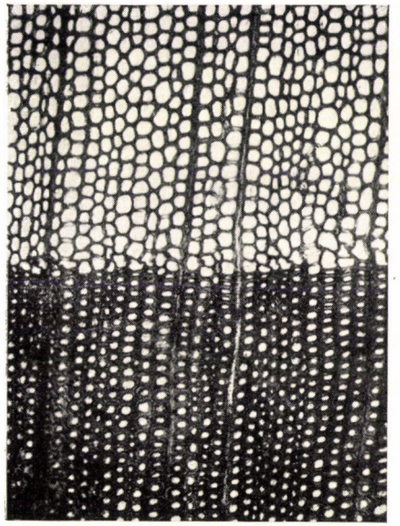
3. (300×)



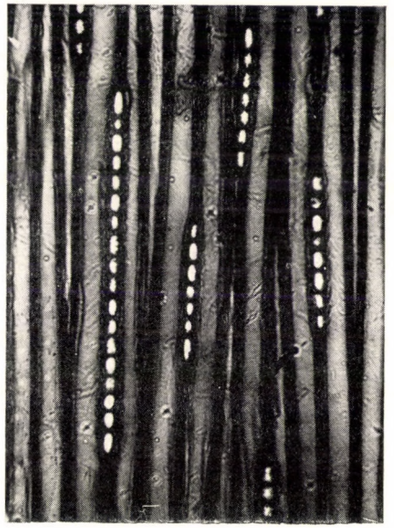
4. (300×)



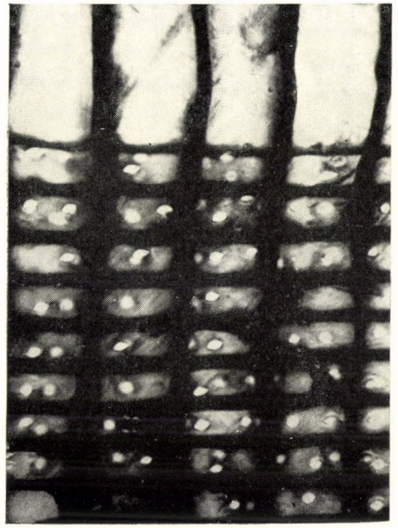
208. Abies homolepis var. umbellata (Mayr) WILSON



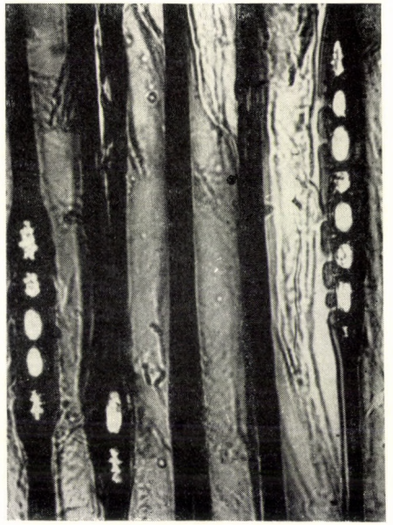
1. (100×)



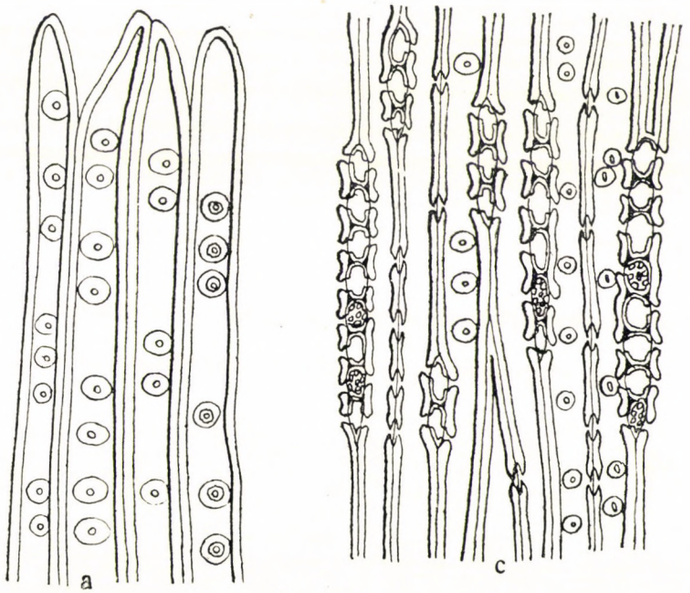
2. (100×)



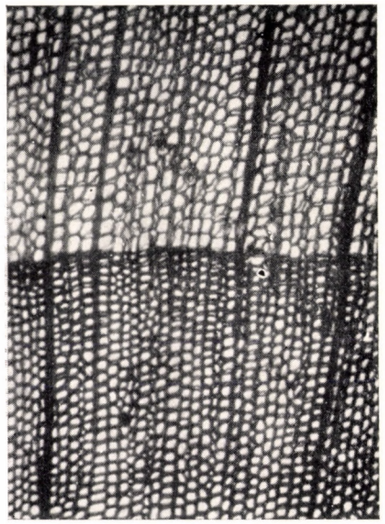
3. (300×)



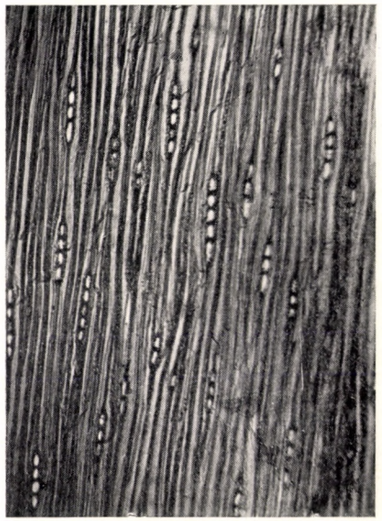
4. (300×)



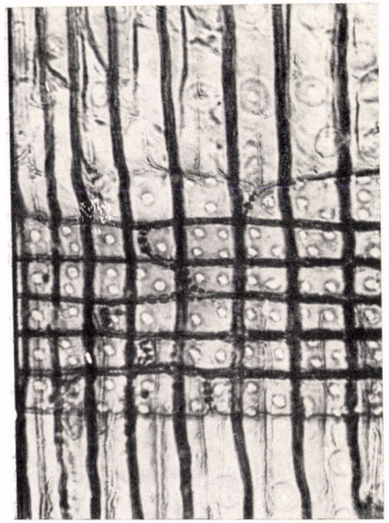
209. **Abies Kawakamii** Ito



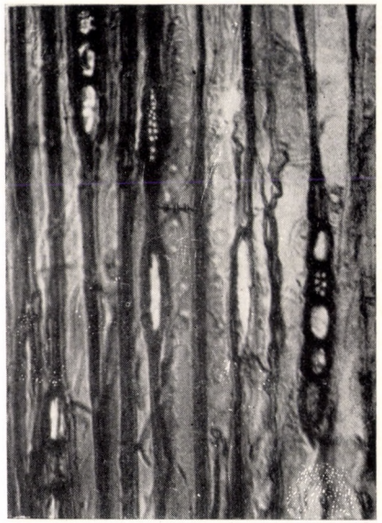
1. (100×)



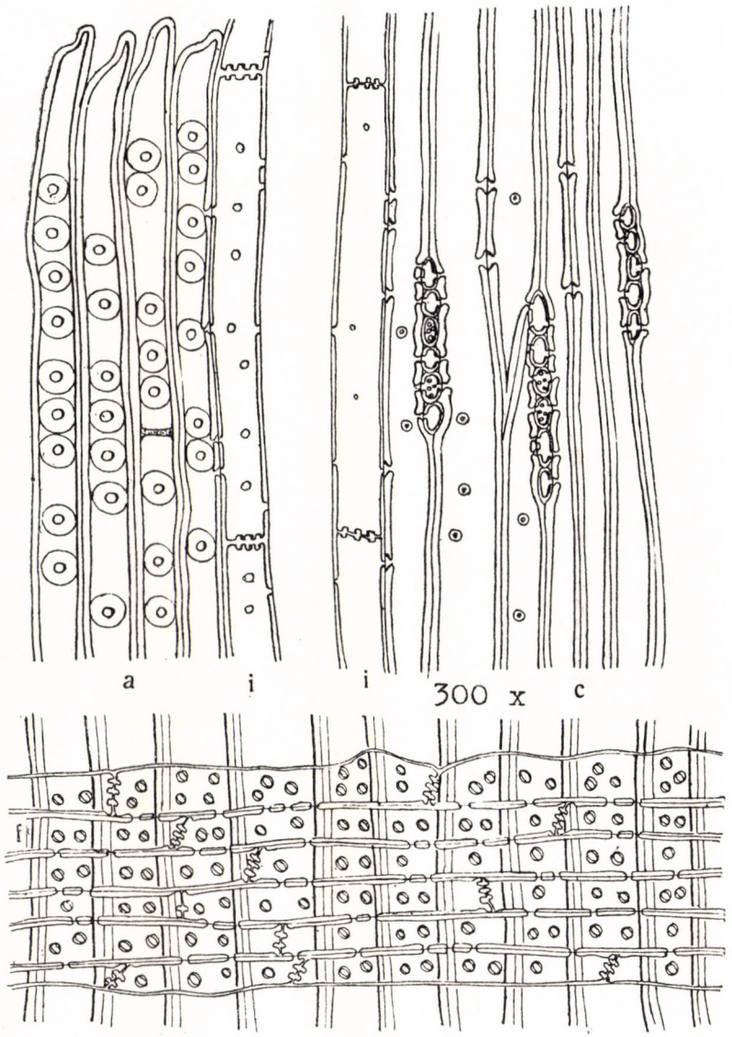
2. (100×)



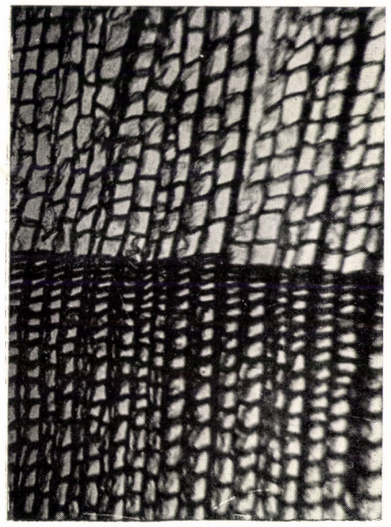
3. (300×)



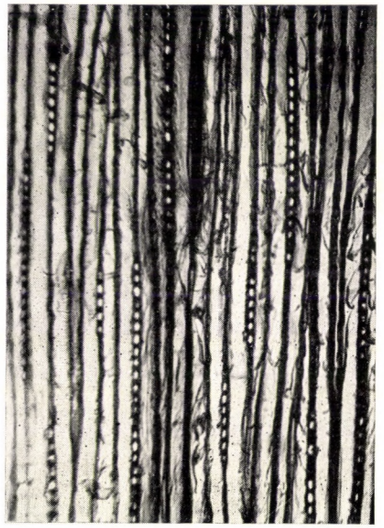
4. (300×)



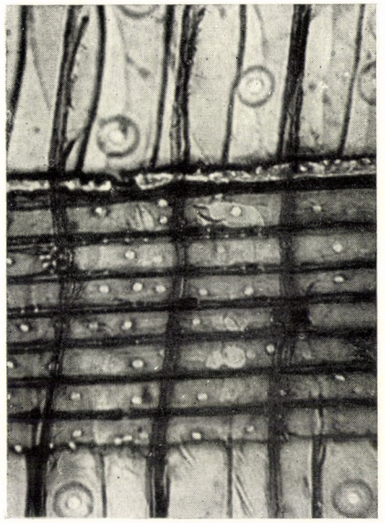
210. Abies koreana WILSON



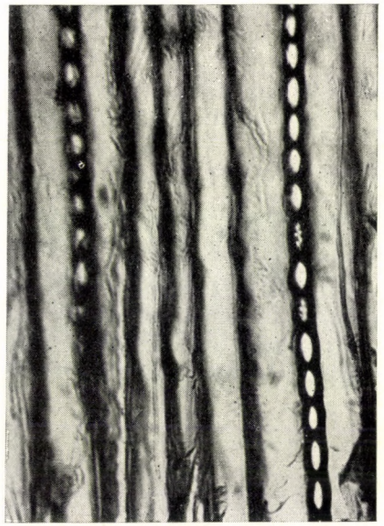
1. (100×)



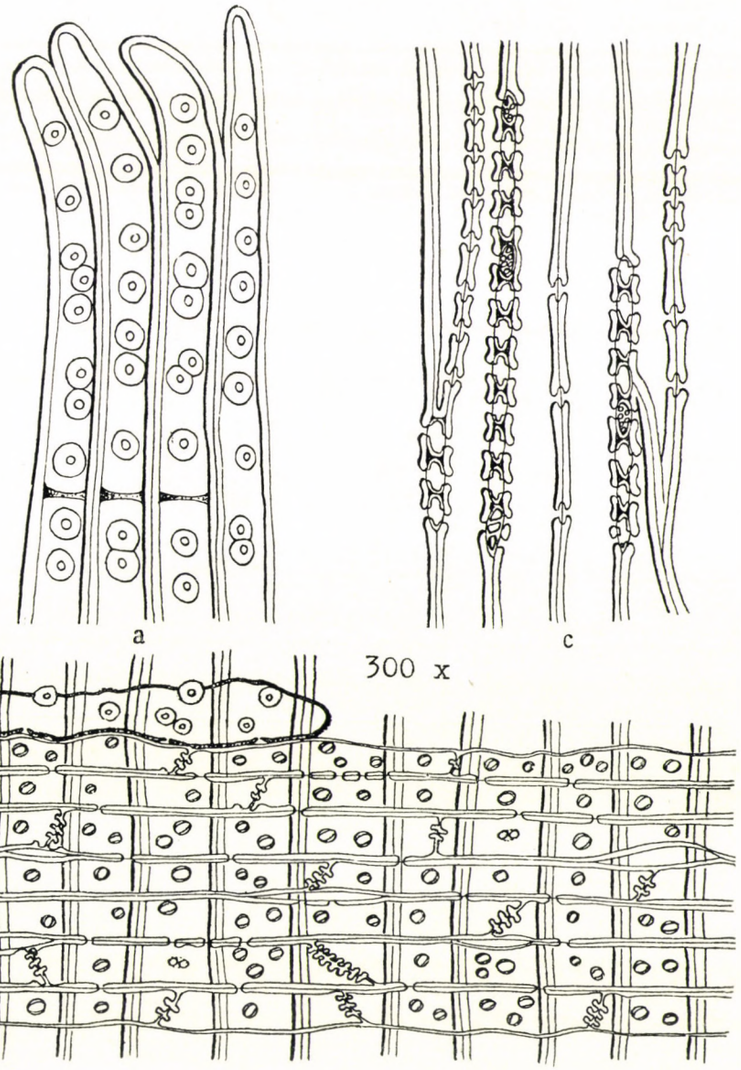
2. (100×)



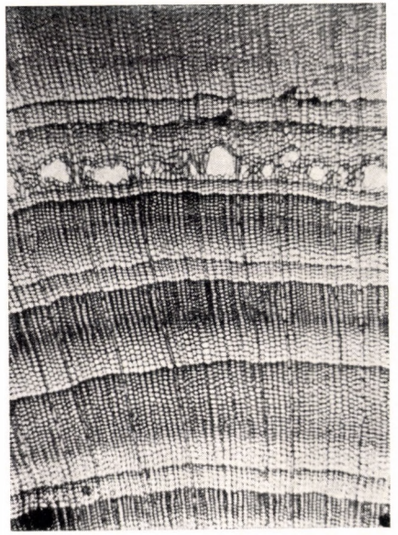
3. (300×)



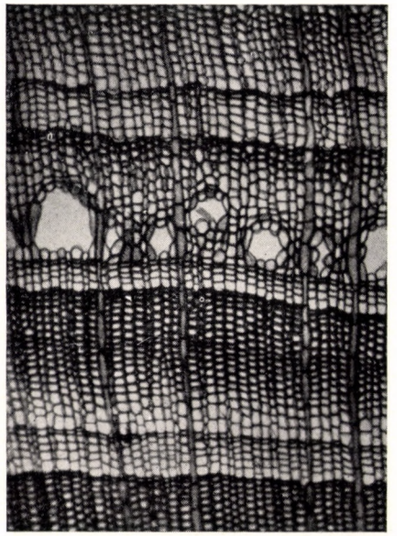
4. (300×)



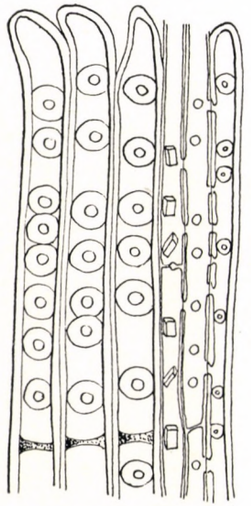
211. Abies lasiocarpa (Hook.) NUTTAL



1. (30×)



2. (100×)



a



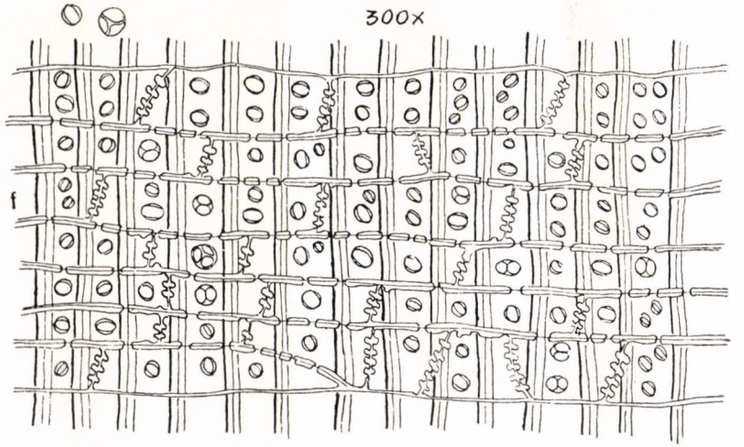
c



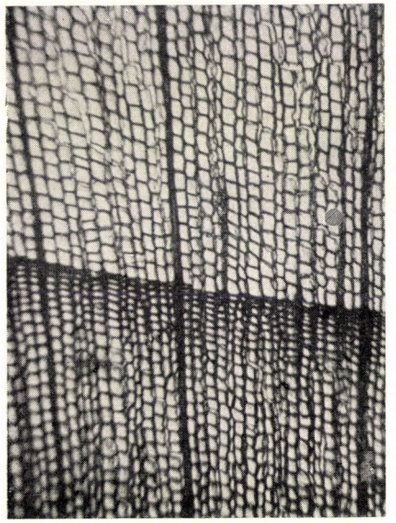
3. (300×)



4. (300×)



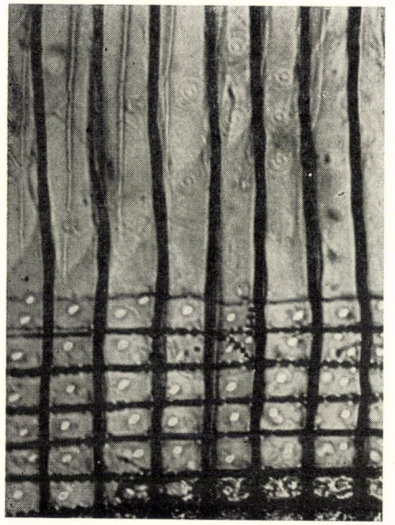
212. Abies lasiocarpa v. arizonica LEMM.



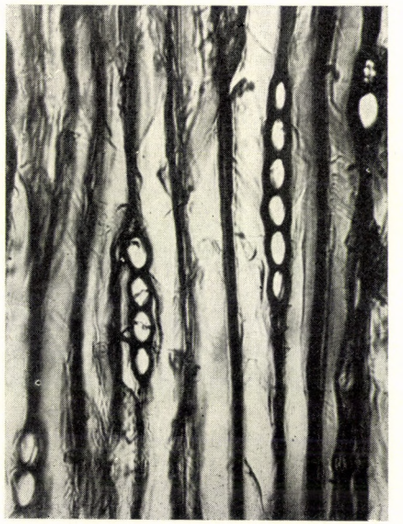
1. (100×)



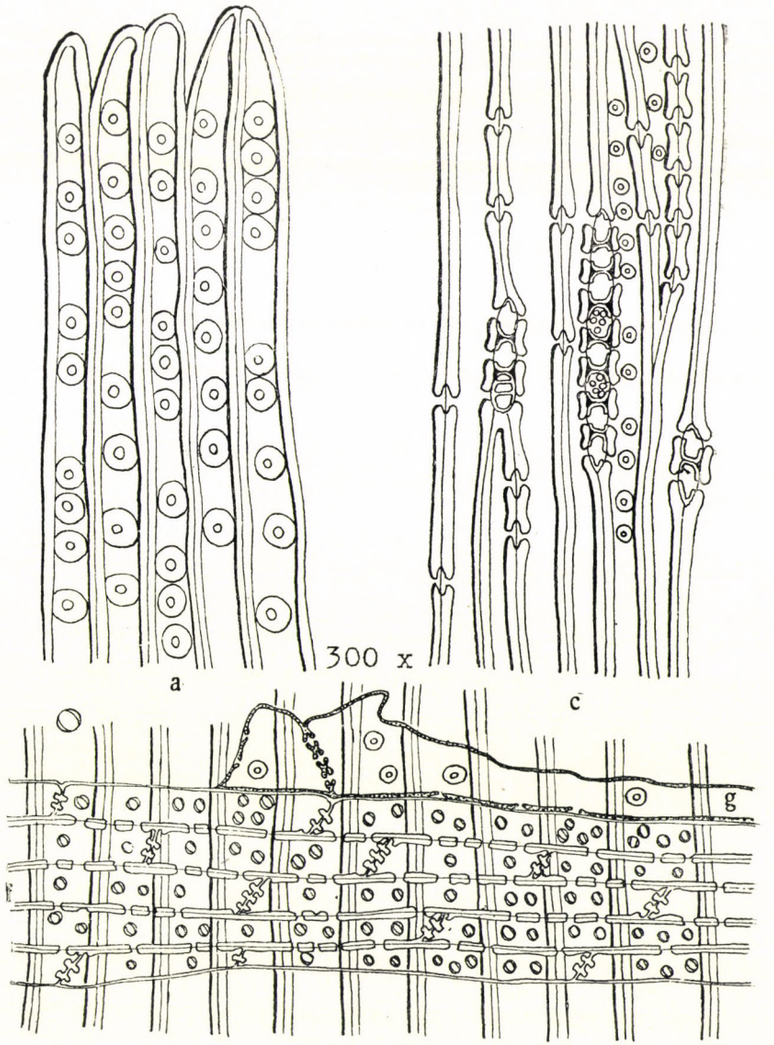
2. (100×)



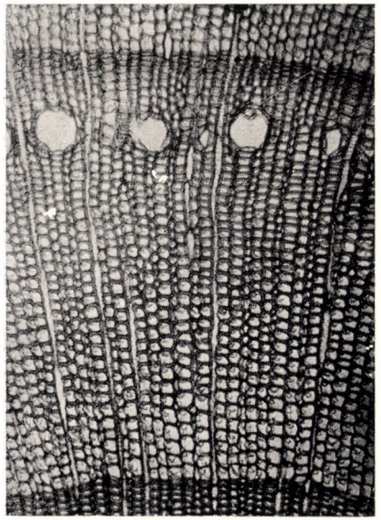
3. (300×)



4. (300×)



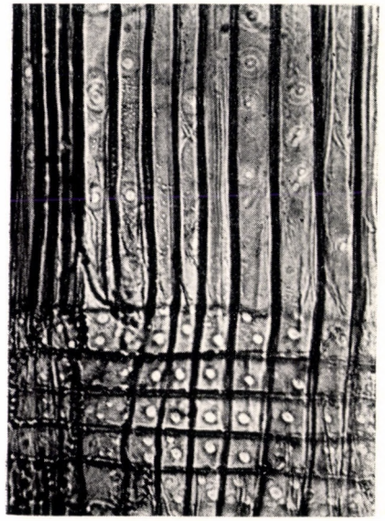
213. Abies Lowiana A. Murray



1. (100×)



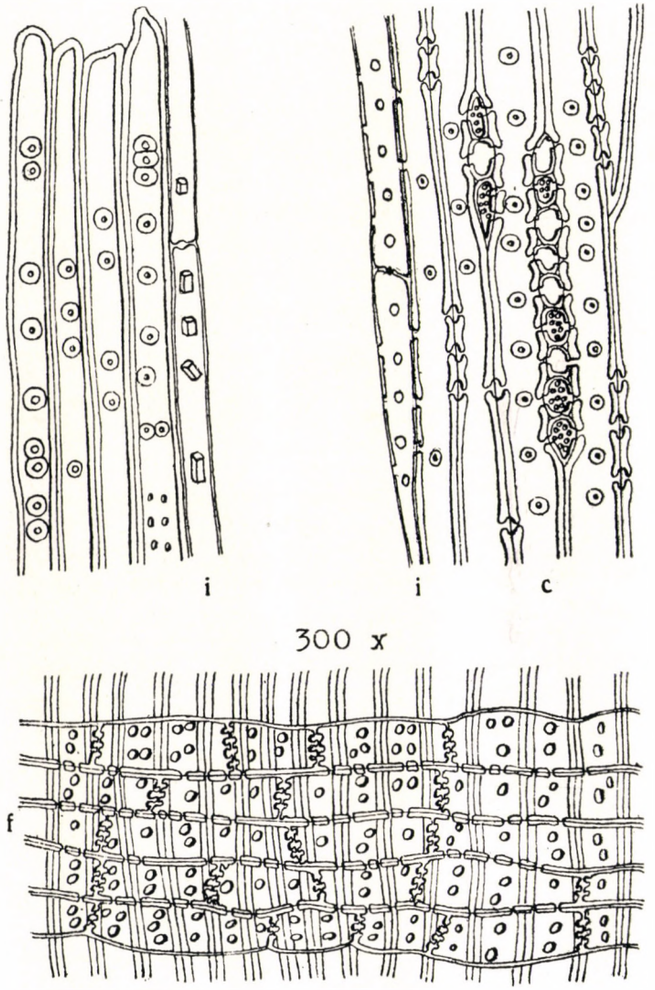
2. (100×)



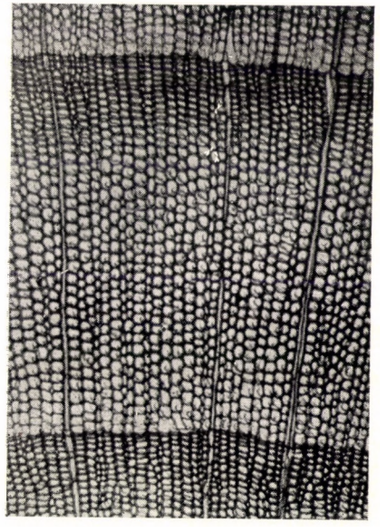
3. (300×)



4. (300×)



214. Abies magnifica A. MURRAY



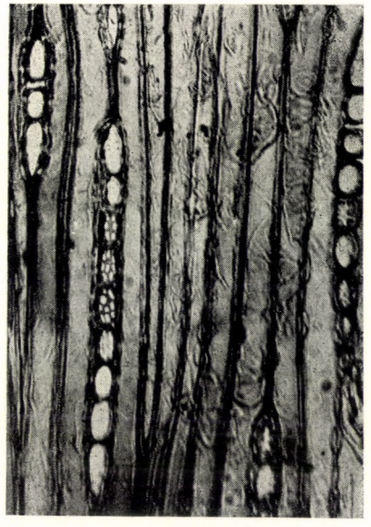
1. (100×)



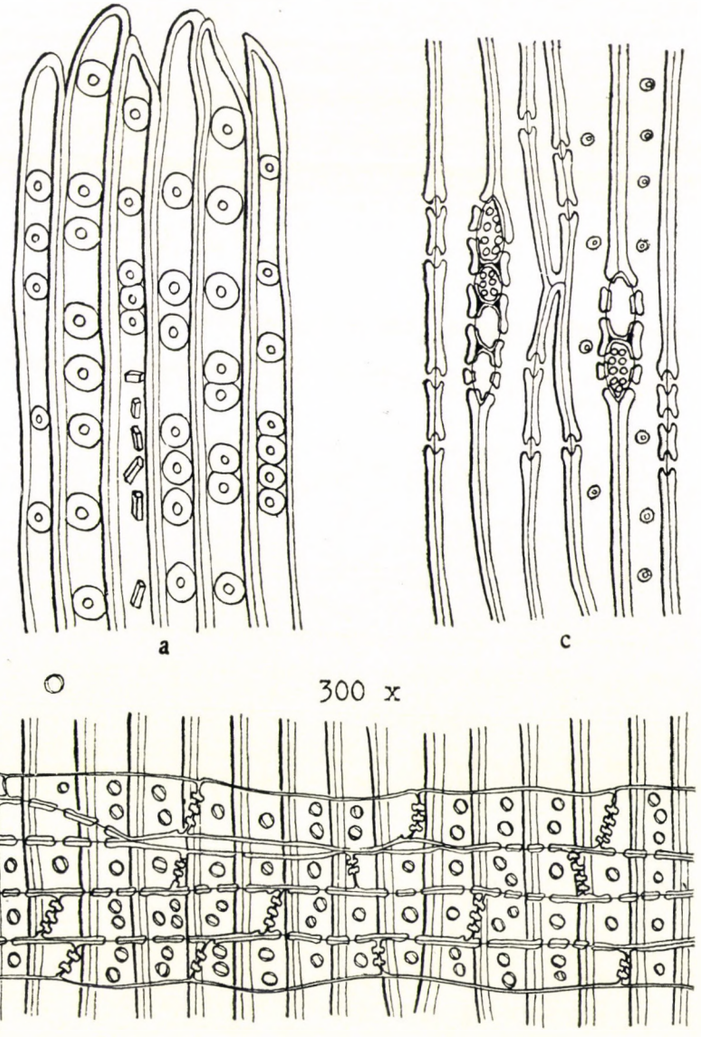
2. (100×)



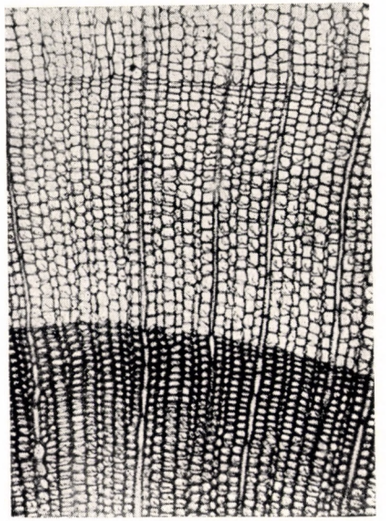
3. (300×)



4. (300×)



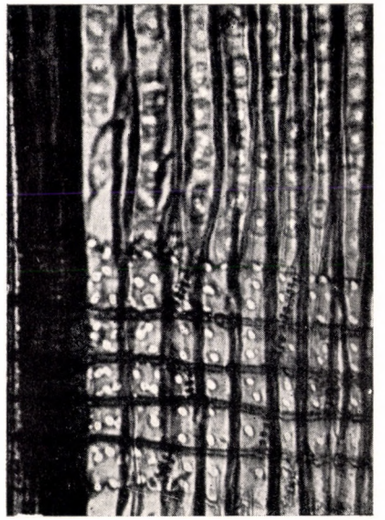
215. Abies nephrolepis MAXIMOWICZ



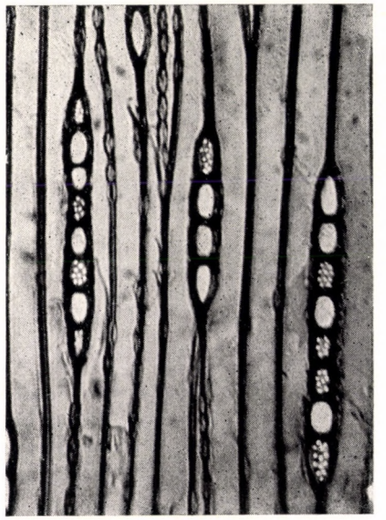
1. (100×)



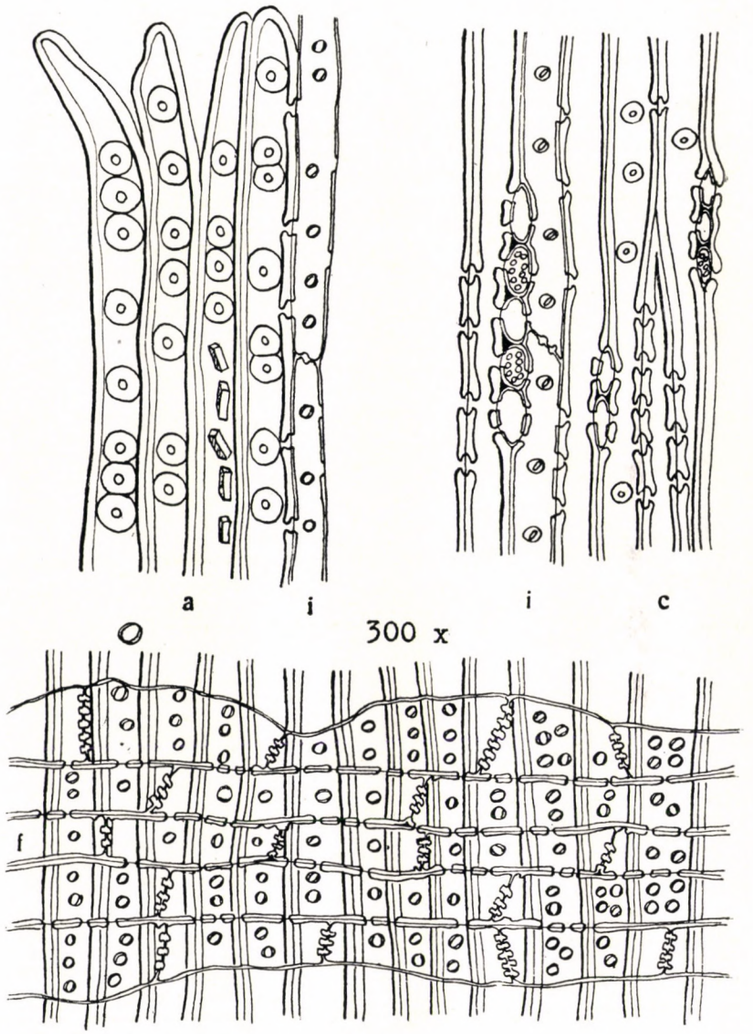
2. (100×)



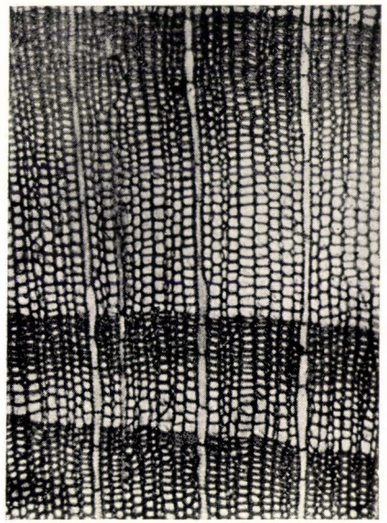
3. (300×)



4. (300×)



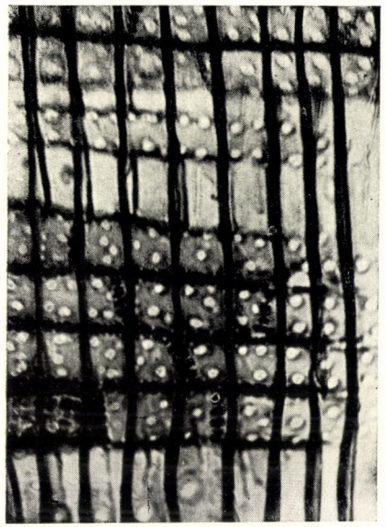
216. Abies Nordmanniana (Steven) SPACH



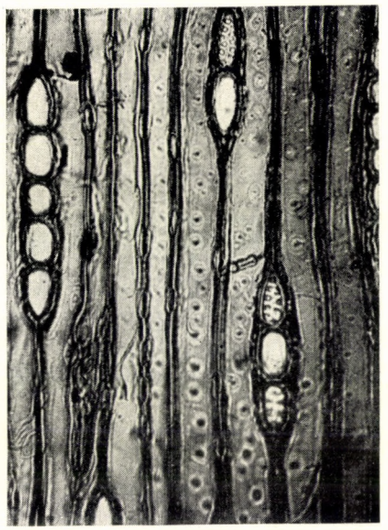
1. (100×)



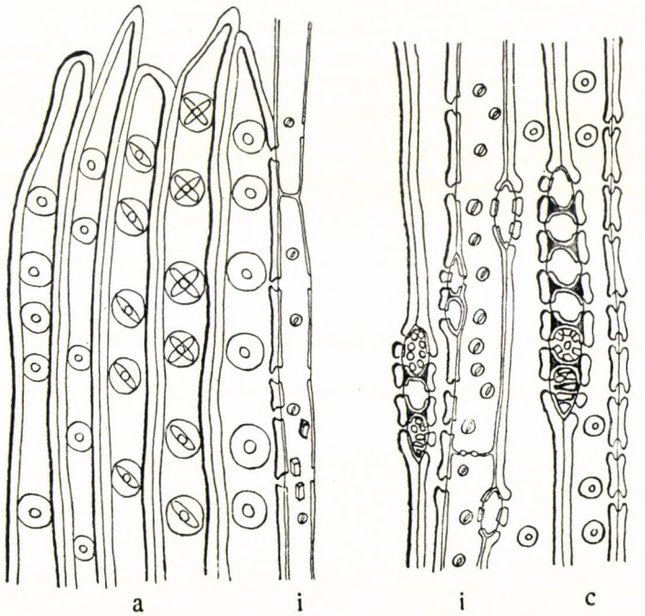
2. (100×)

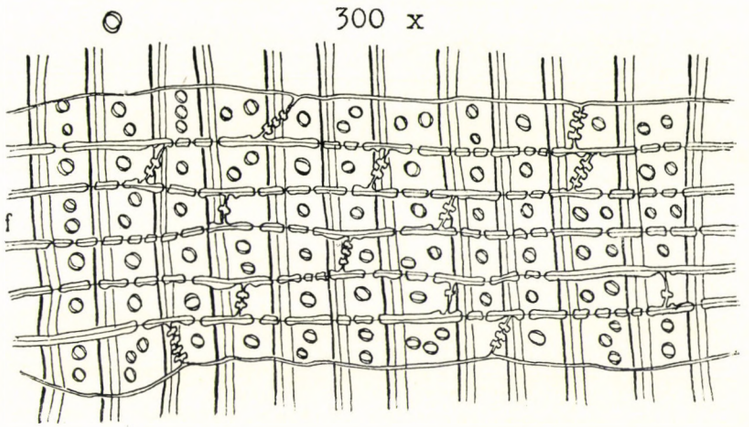


3. (300×)

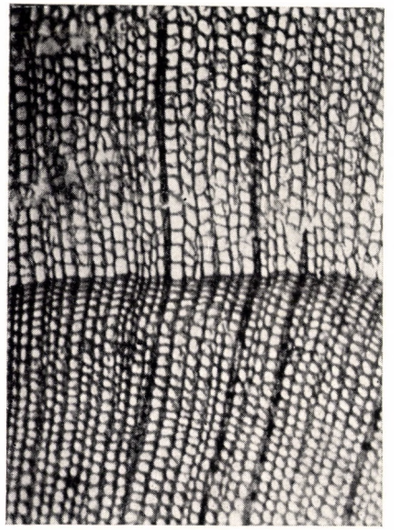


4. (300×)





217. Abies numidica De Lannoy



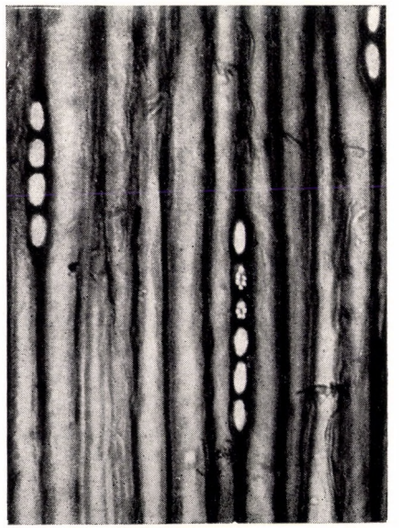
1. (100×)



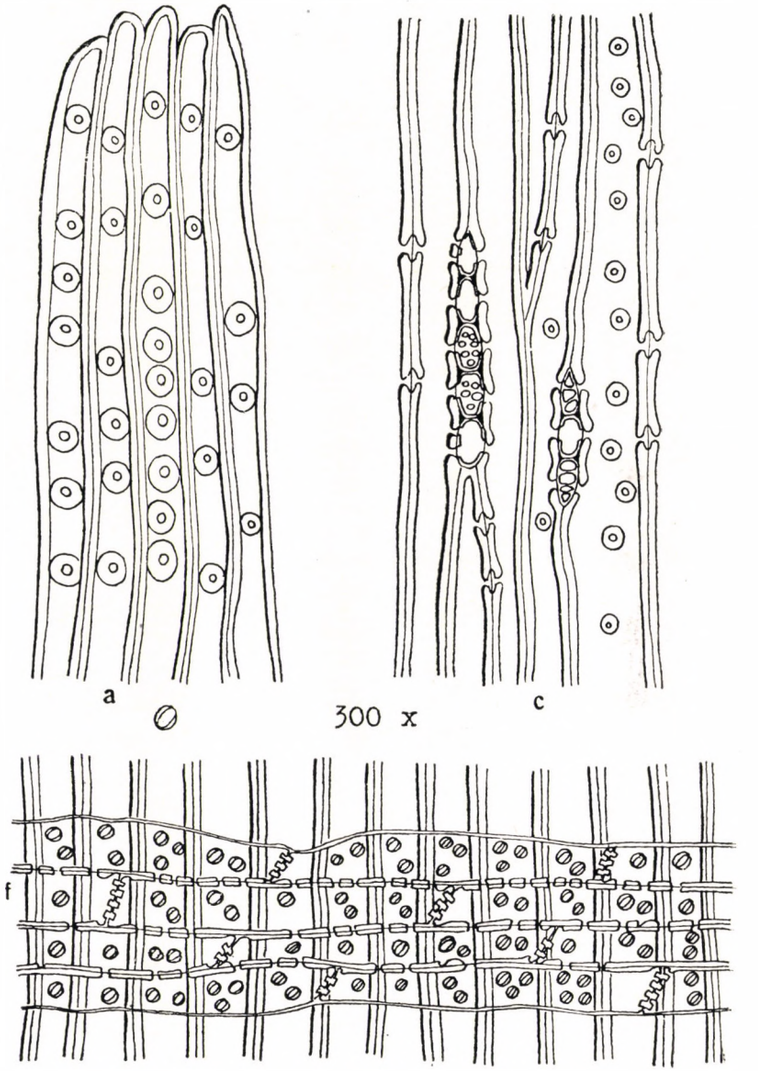
2. (100×)



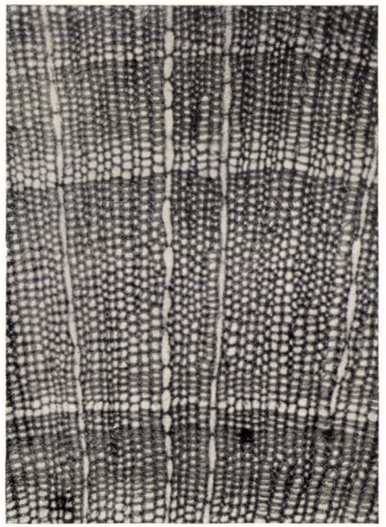
3. (300×)



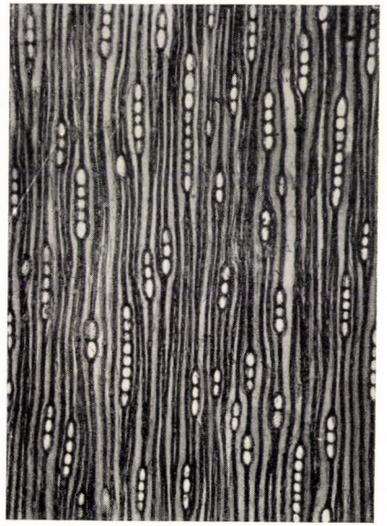
4. (300×)



218. Abies pindrow Spach



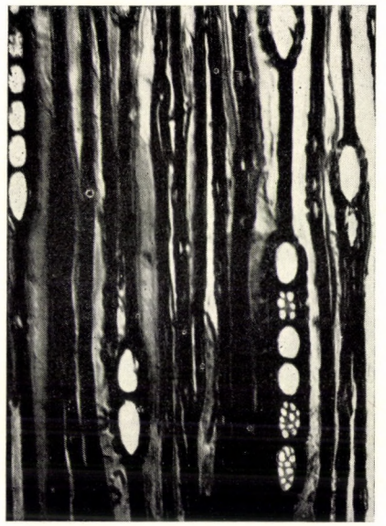
1. (100×)



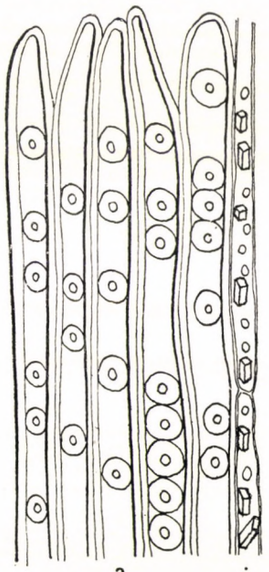
2. (100×)

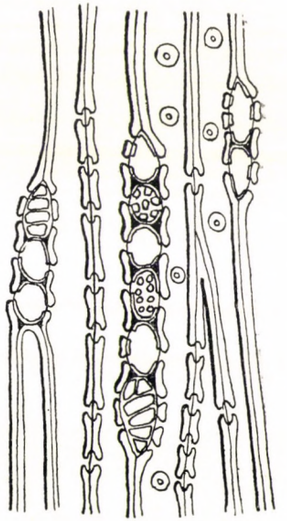


3. (300×)

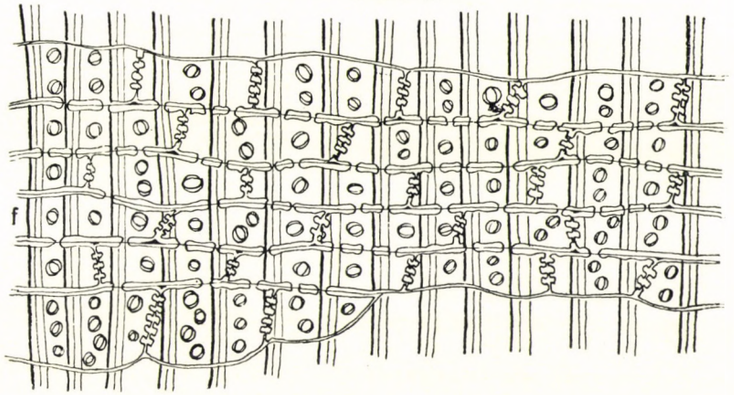


4. (300×)

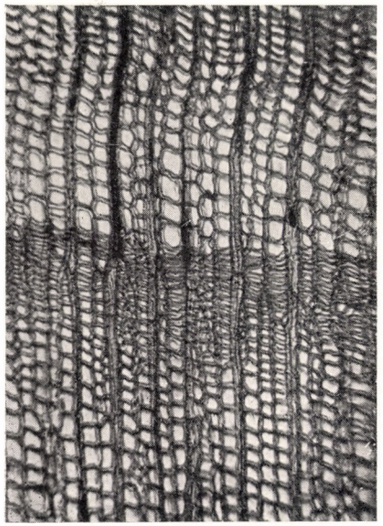




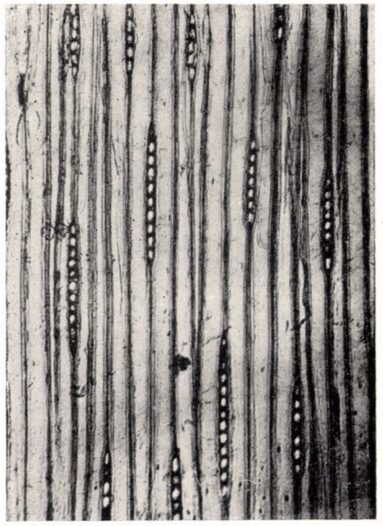
300 x



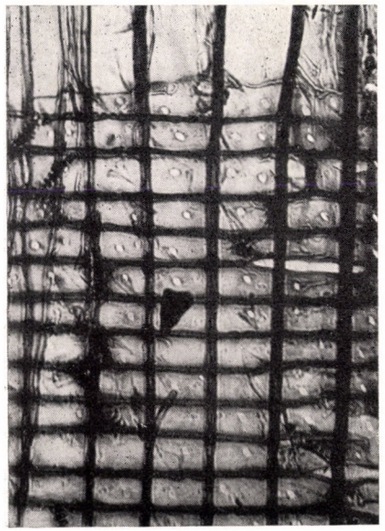
219. Abies Pinsapo Boisser



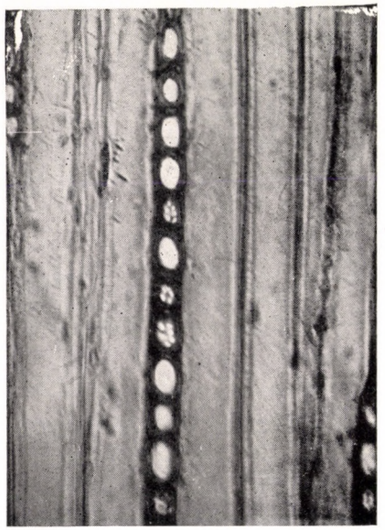
1. (100×)



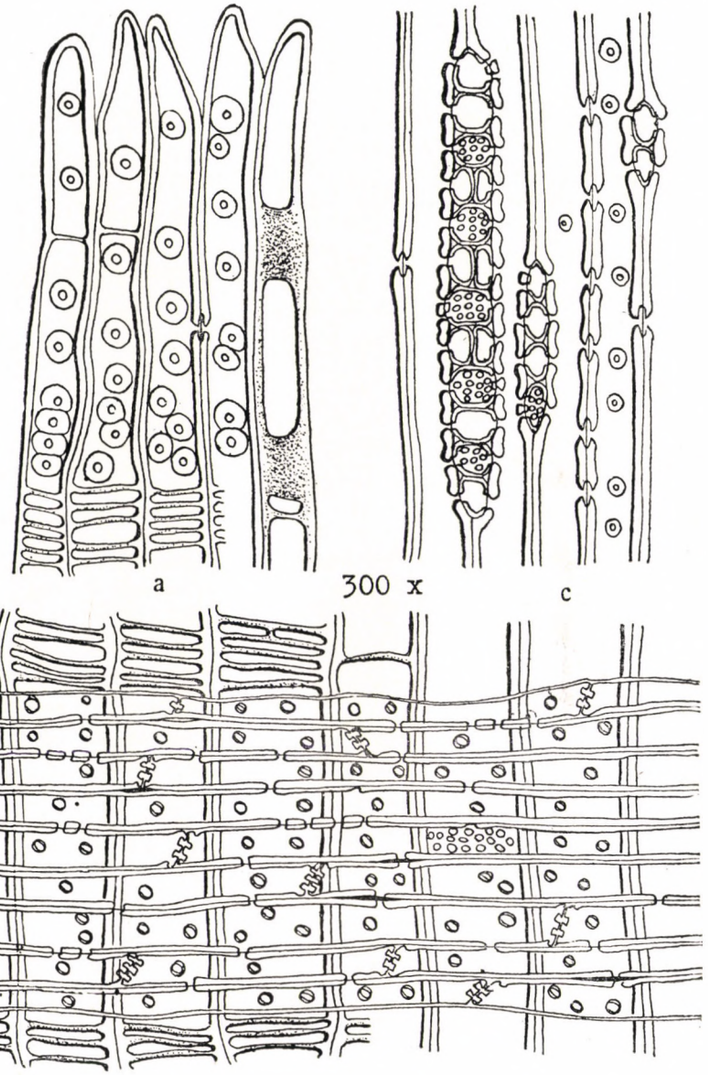
2. (100×)



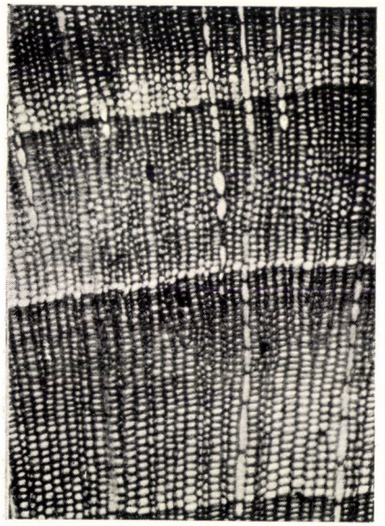
3. (300×)



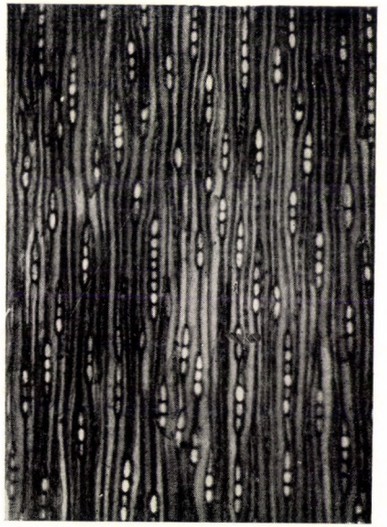
4. (300×)



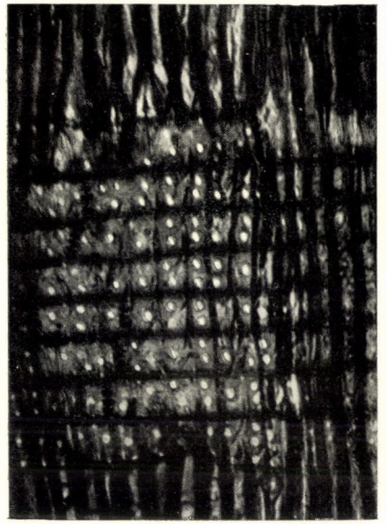
220. Abies procera REHDER



1. (100×)



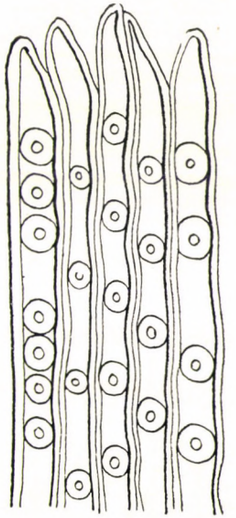
2. (100×)

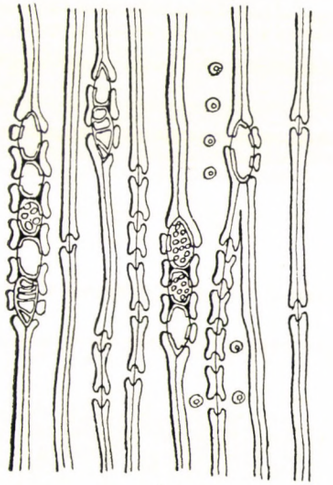


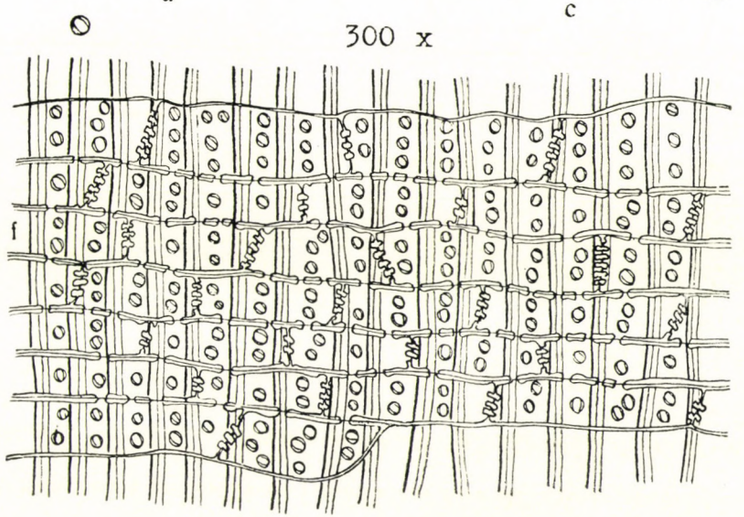
3. (300×)



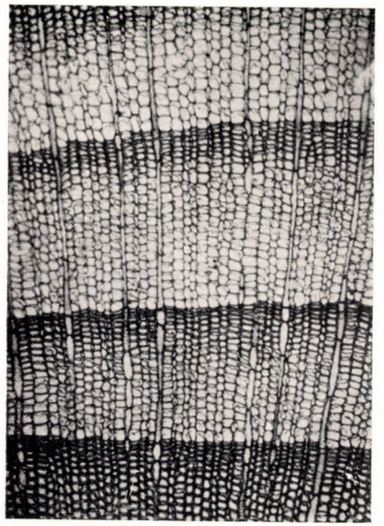
4. (300×)



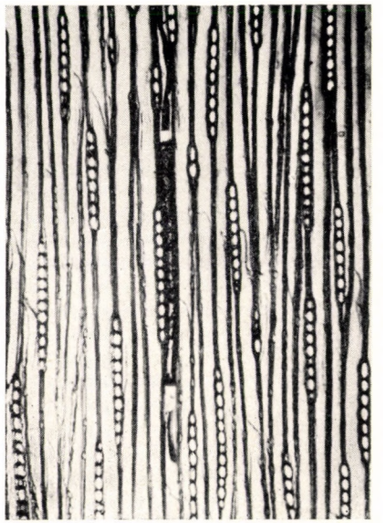




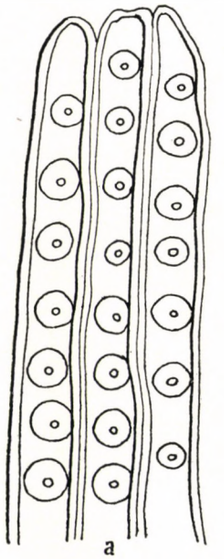
221. Abies sachalinensis MAST.

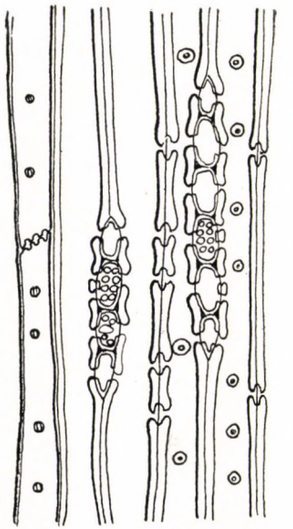


1. (100×)



2. (100×)



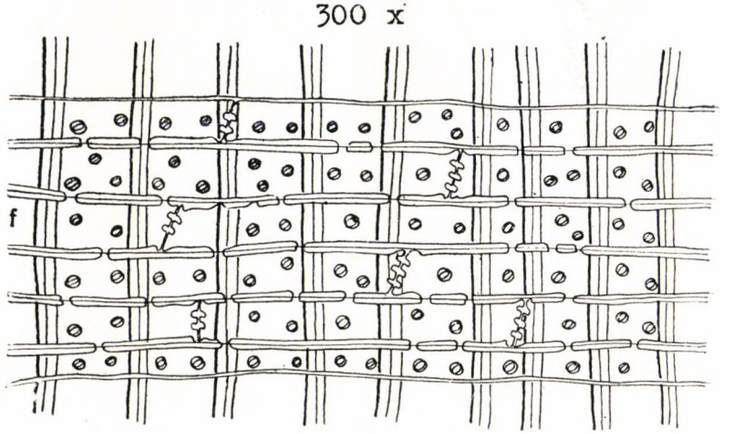




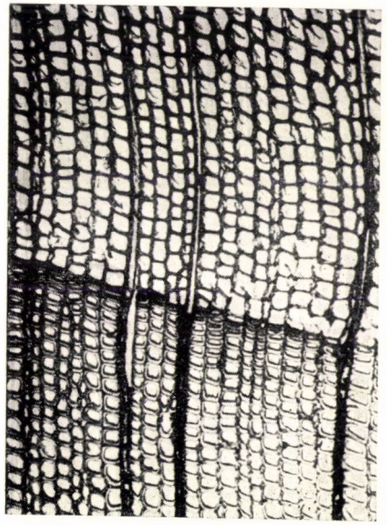
3. (300×)



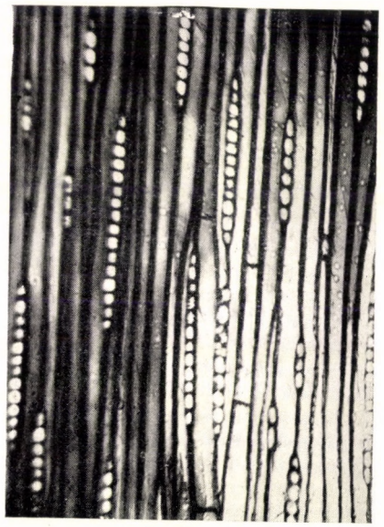
4. (300×)



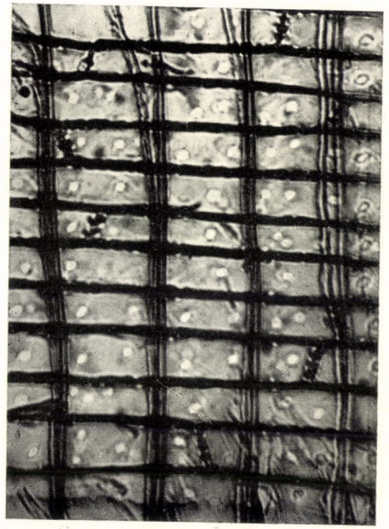
222. Abies sibirica LEDEBOUR



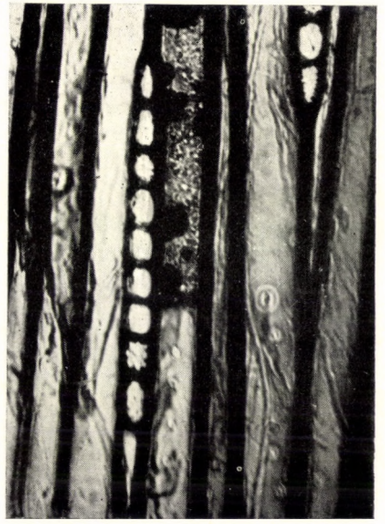
1. (100×)



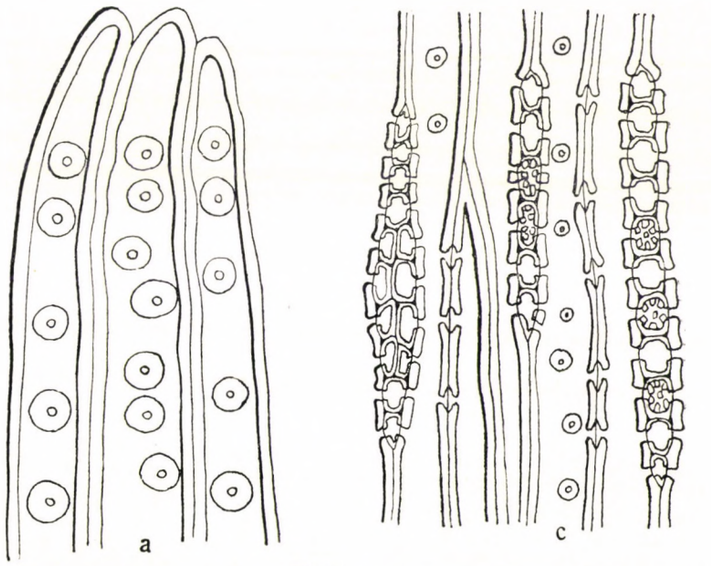
2. (100×)



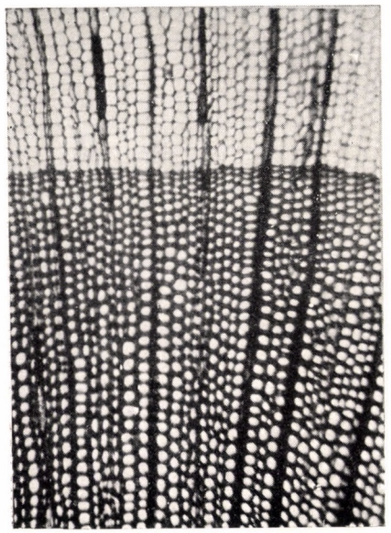
3. (300×)



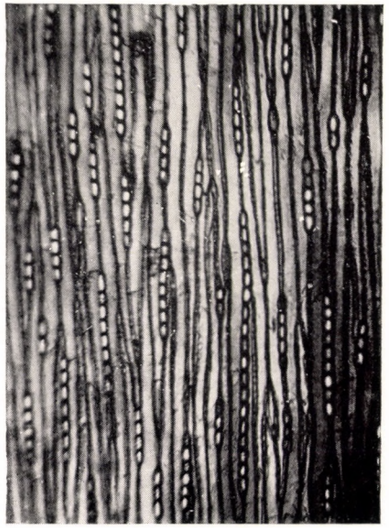
4. (300×)



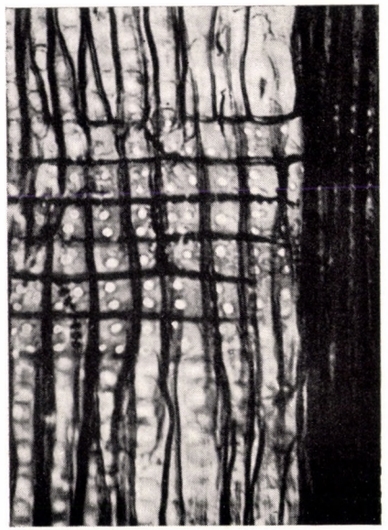
223. Abies spectabilis (D. Don) Spach



1. (100×)



2. (100×)



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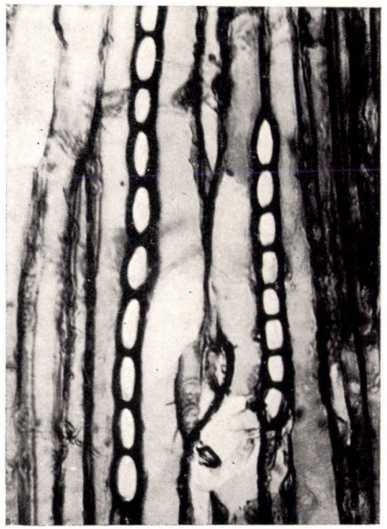

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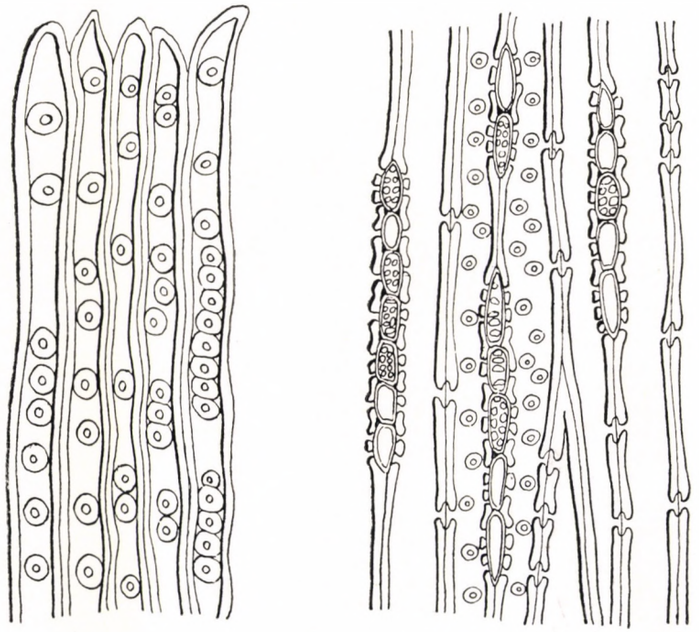
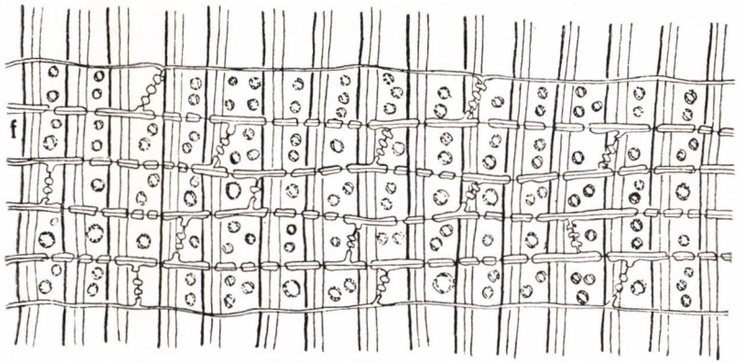
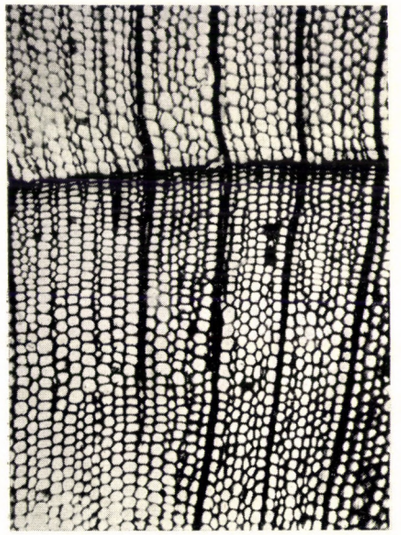


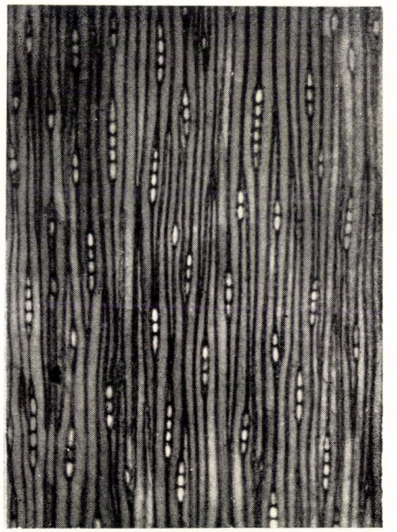
300 x



224. Abies squamata MAST.



1. (100×)



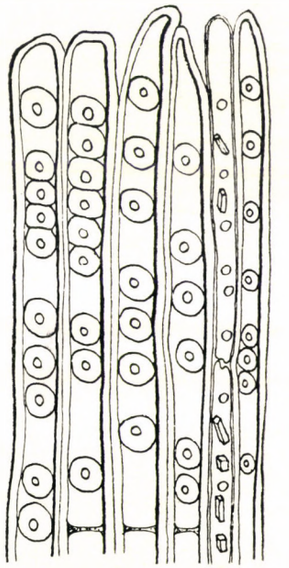
2. (100×)

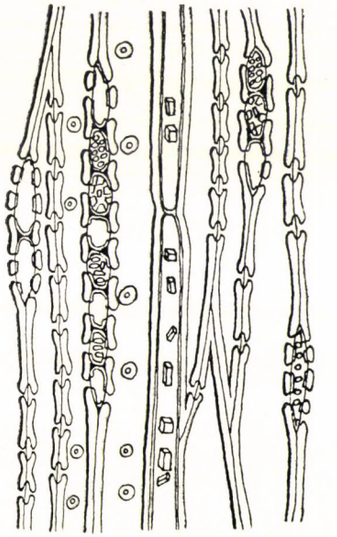


3. (300×)

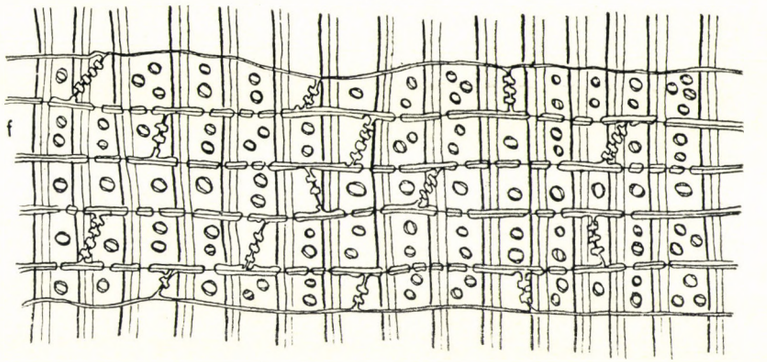


4. (300×)

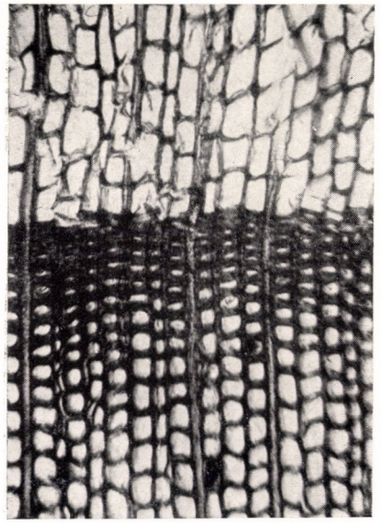




300 x



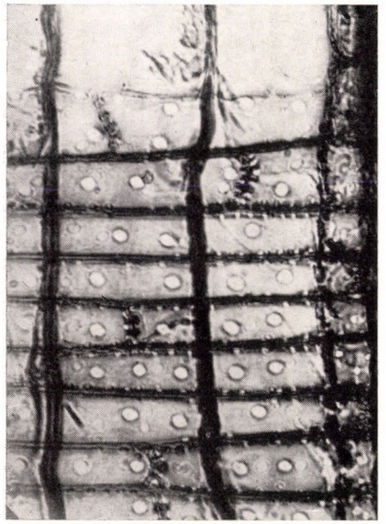
225. Abies Veitchii LINDLEY



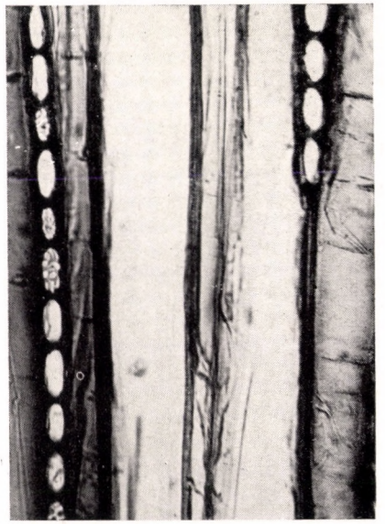
1. (100×)



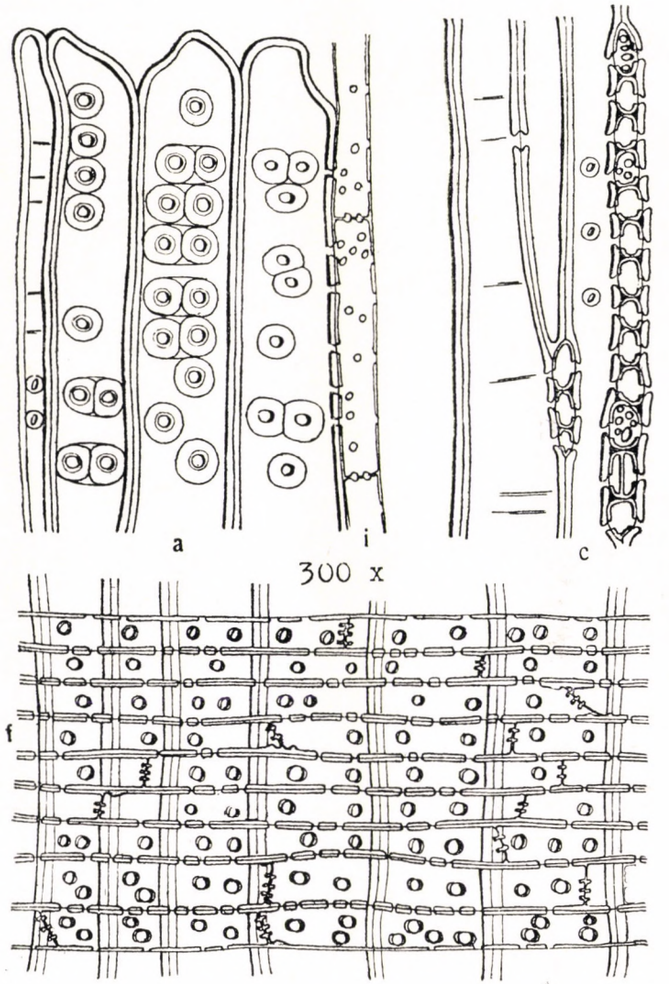
2. (100×)



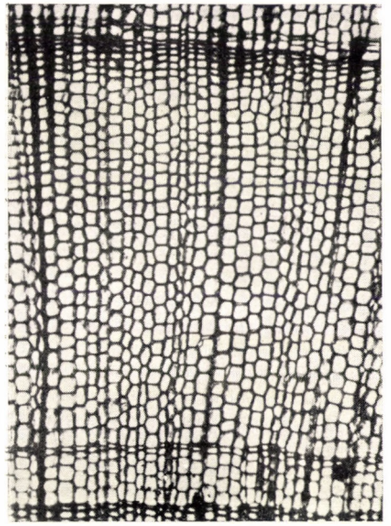
3. (300×)



4. (300×)



226. Abies venusta (Douglas) K. Koch



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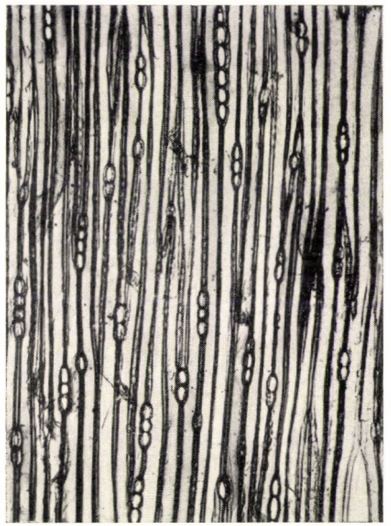

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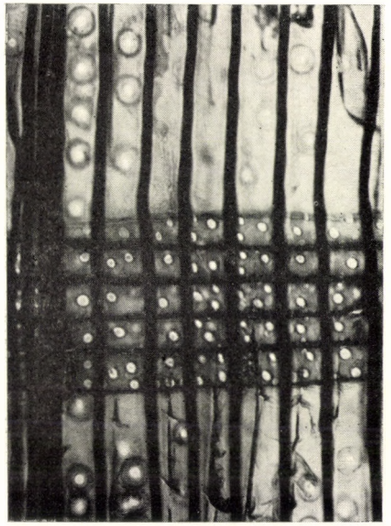

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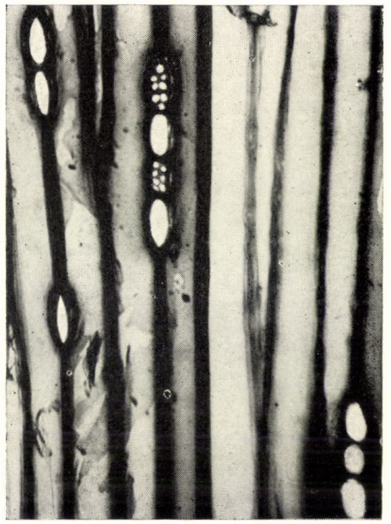
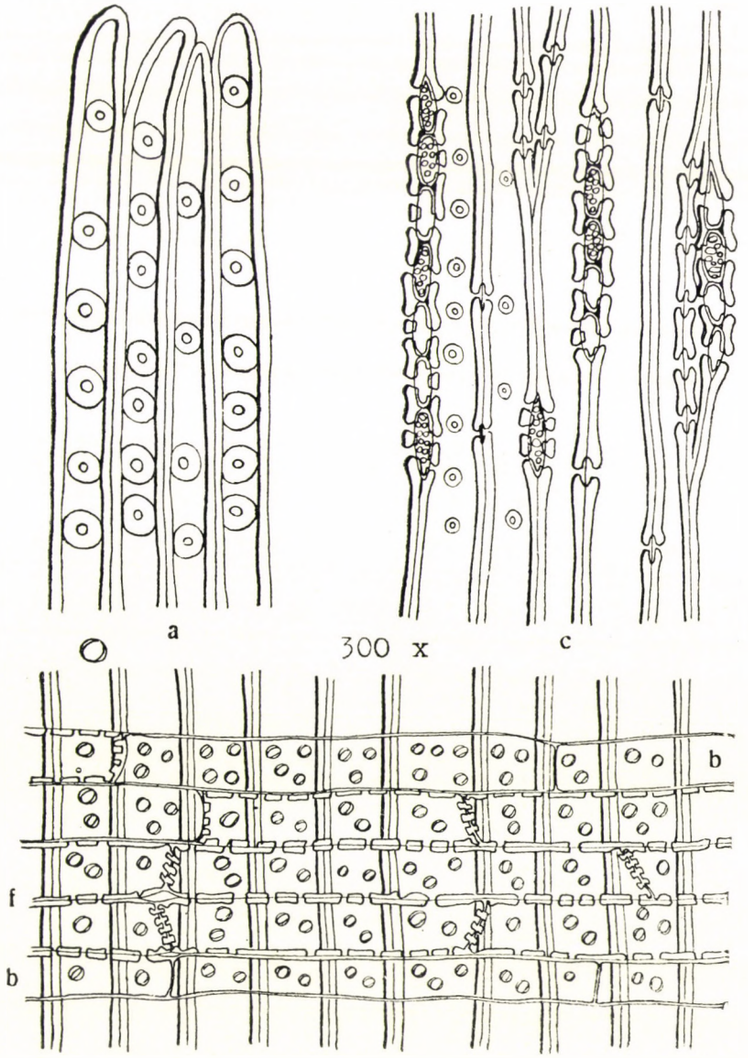
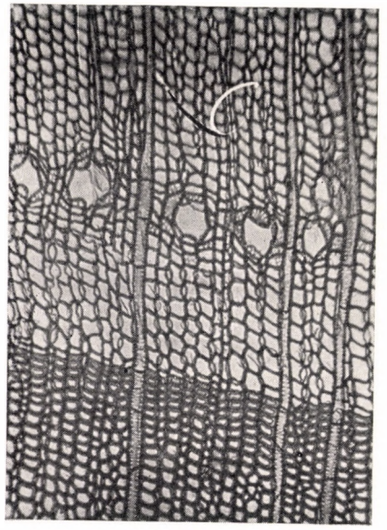


4. (300×)



227. Abies Vilmorinii MAST.



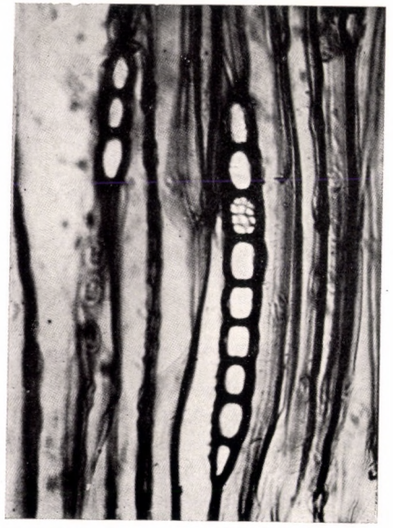
1. (100×)



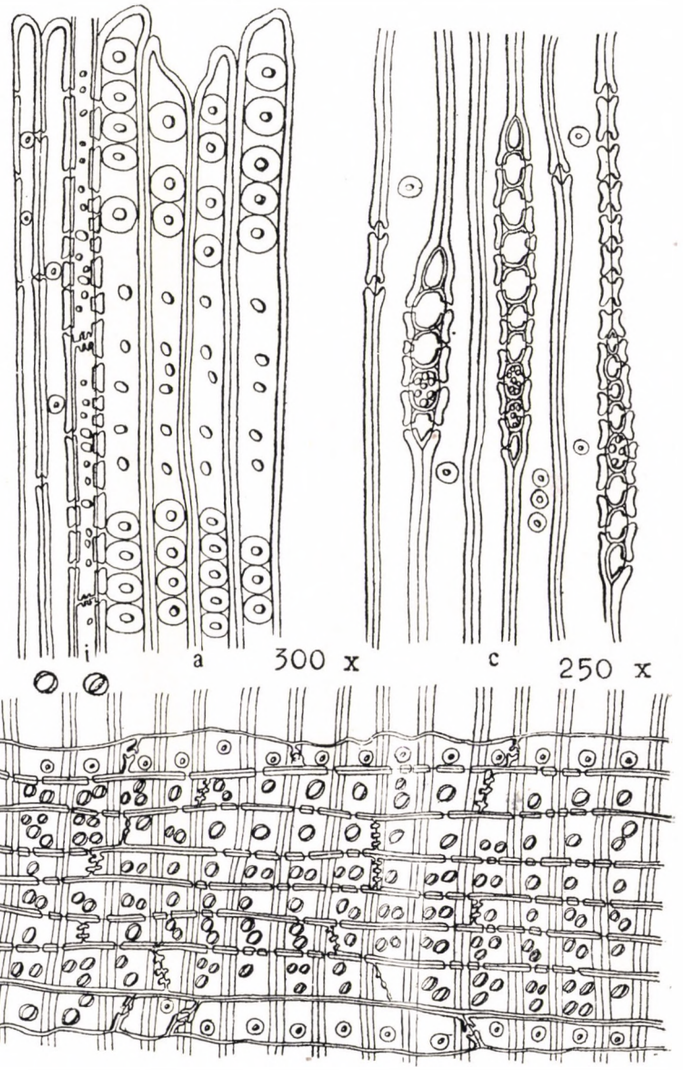
2. (100×)



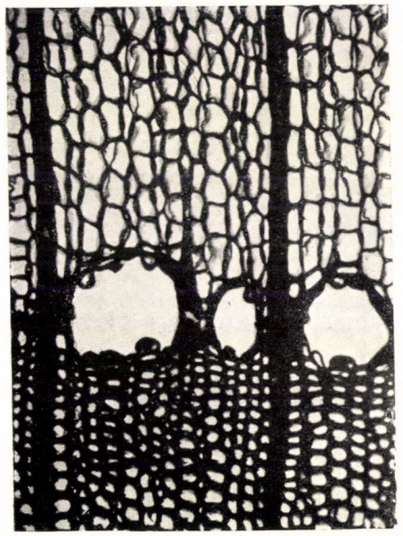
3. (300×)



4. (300×)



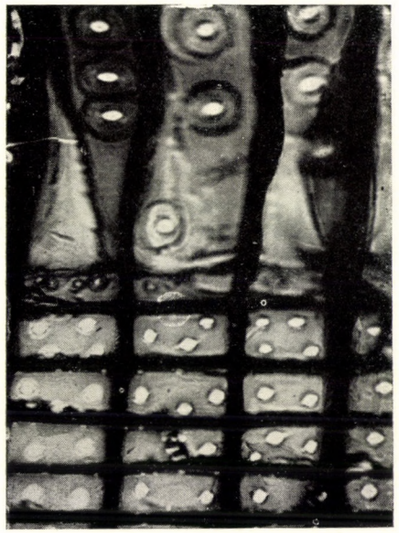
228. Cedrus atlantica MANETTI



1. (100×)



2. (100×)



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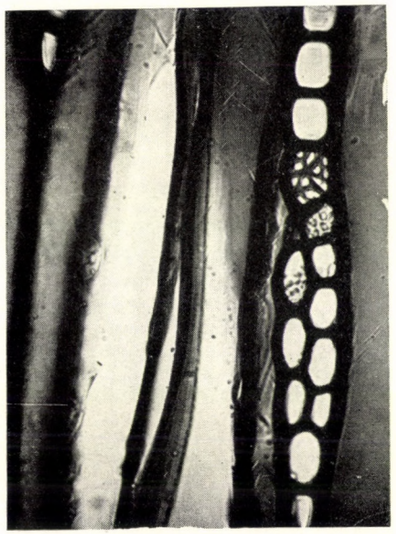
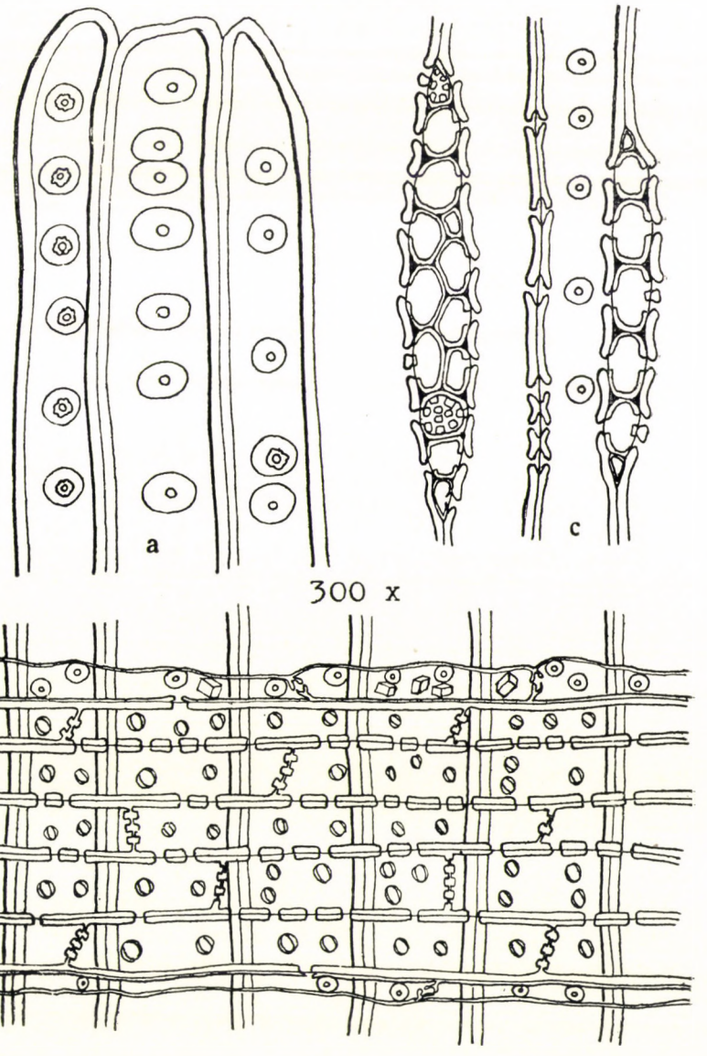


4. (300×)



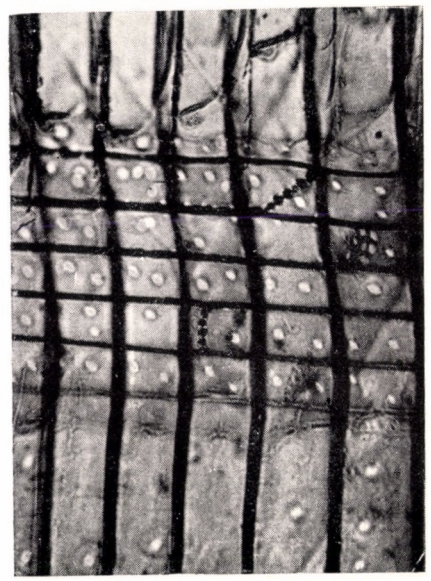
229. Cedrus brevifolia (Hooker) HENRY



1. (100×)



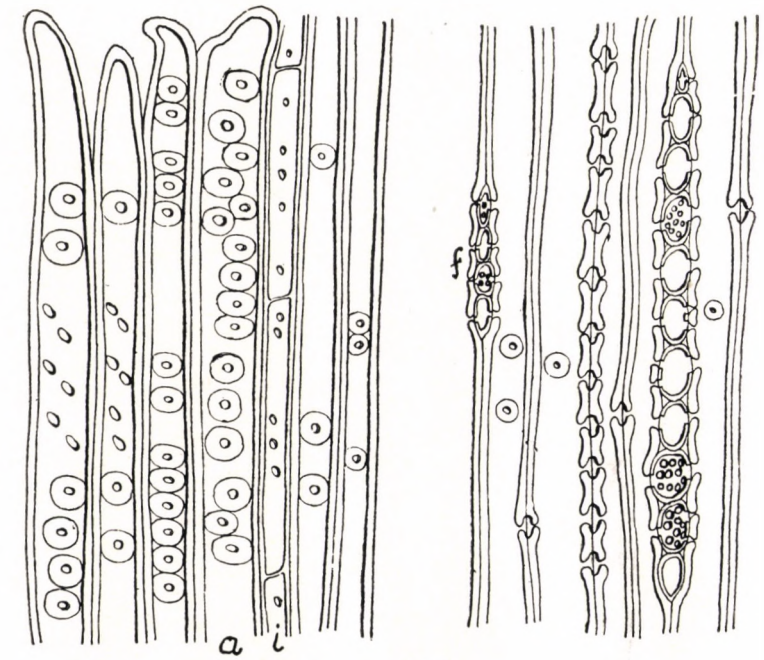
2. (100×)

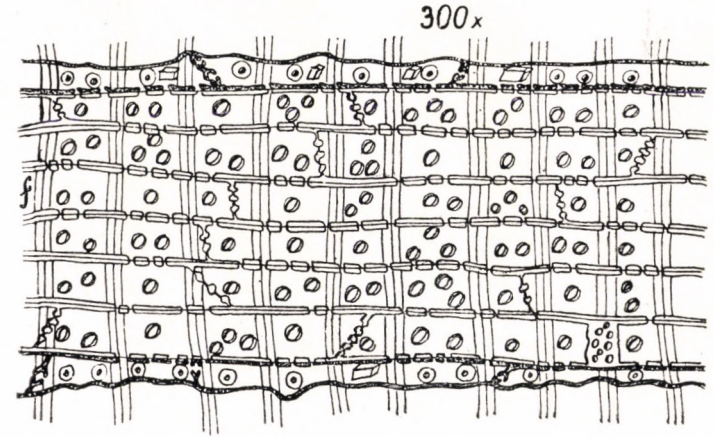


3. (300×)

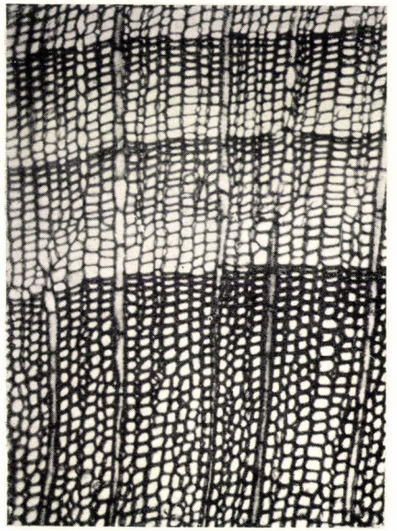


4. (300×)

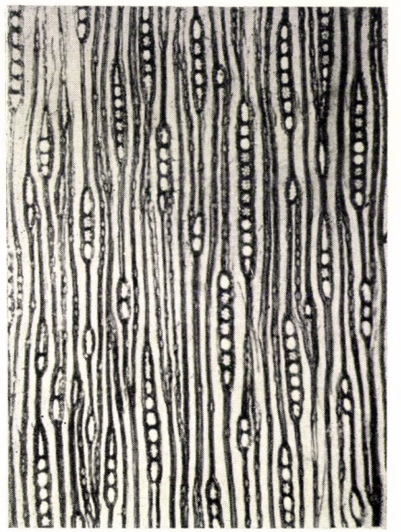




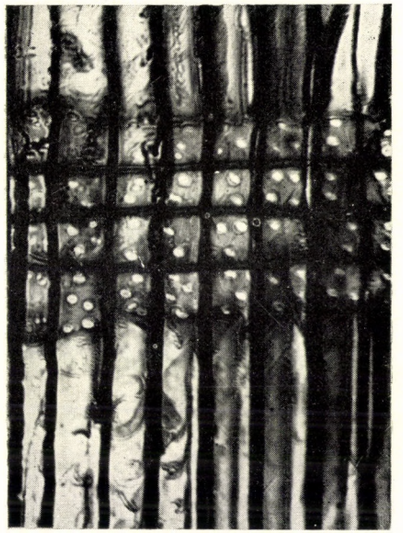
230. Cedrus Deodara (Roxburgh) Loudon



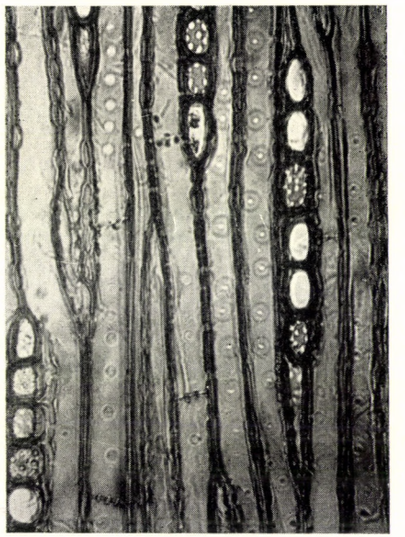
1. (100×)



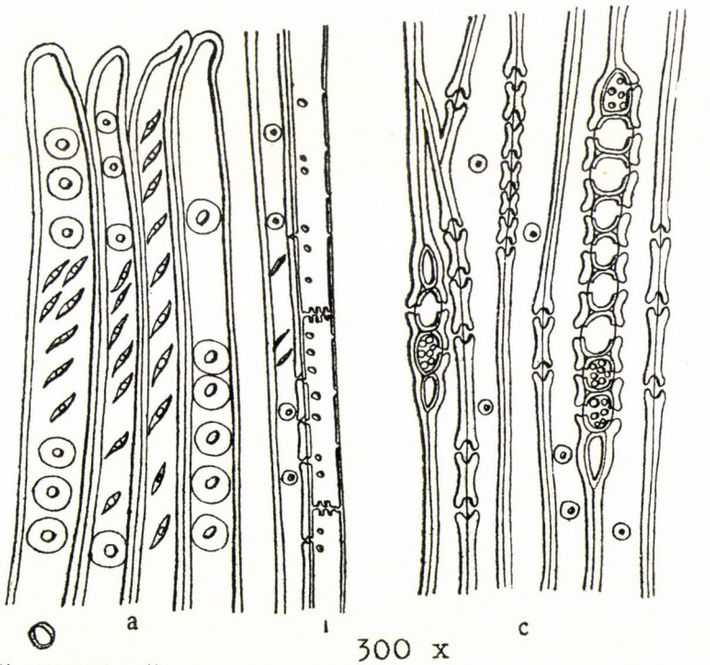
2. (100×)

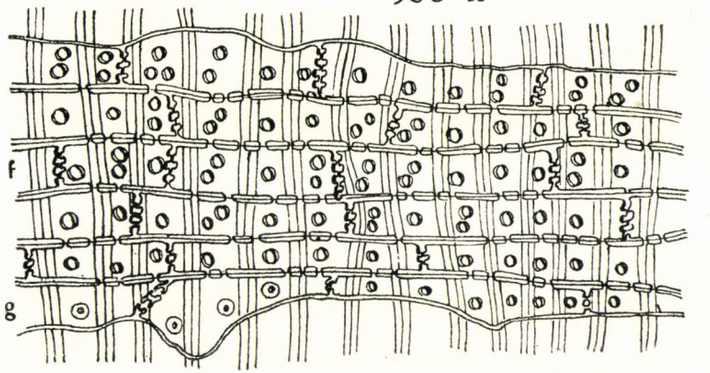


3. (300×)

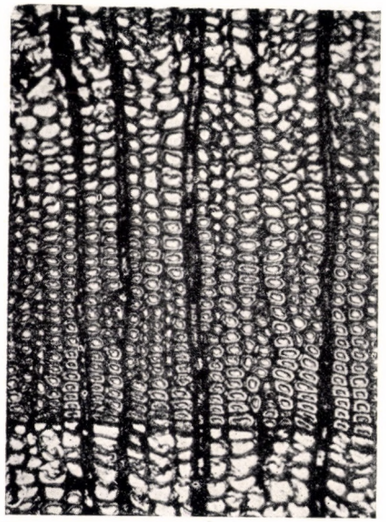


4. (300×)

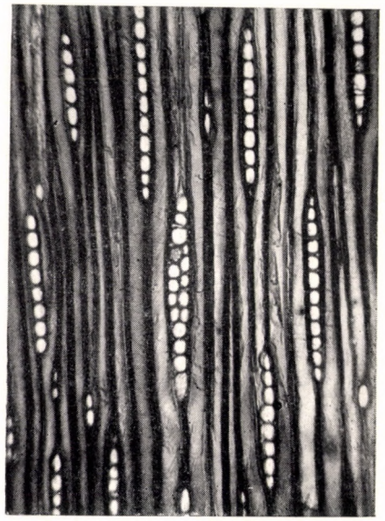




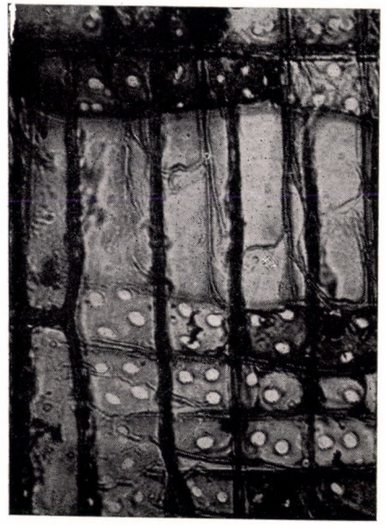
231. Cedrus libani LOUDON



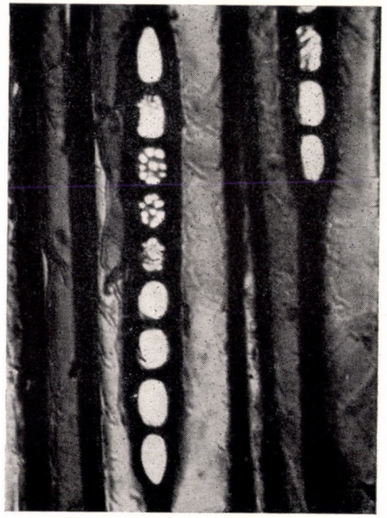
1. (100×)



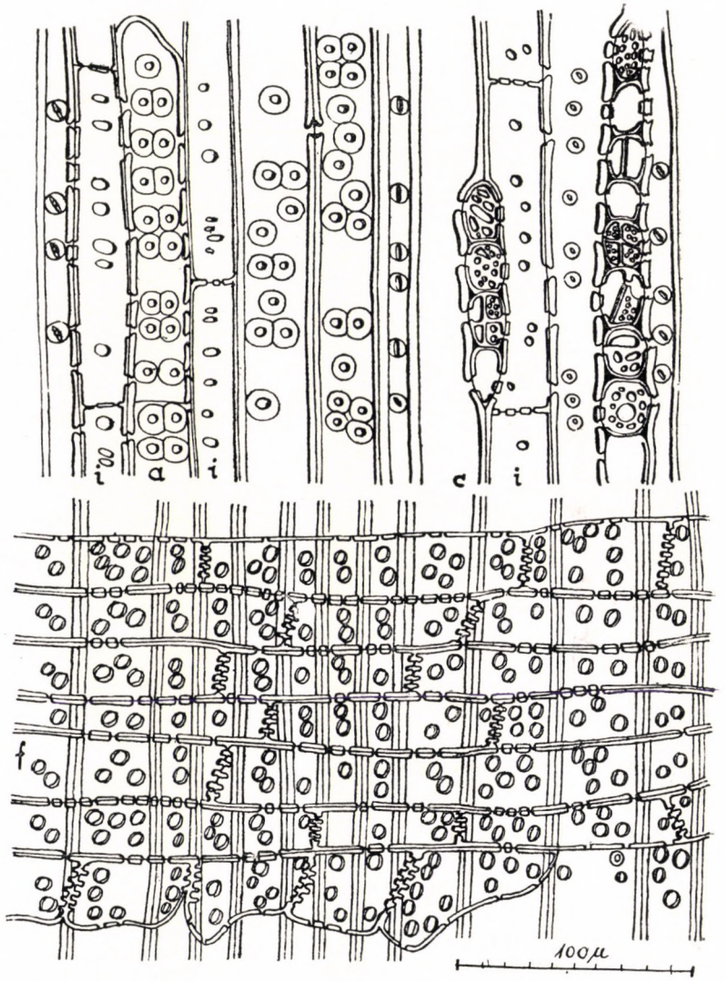
2. (100×)



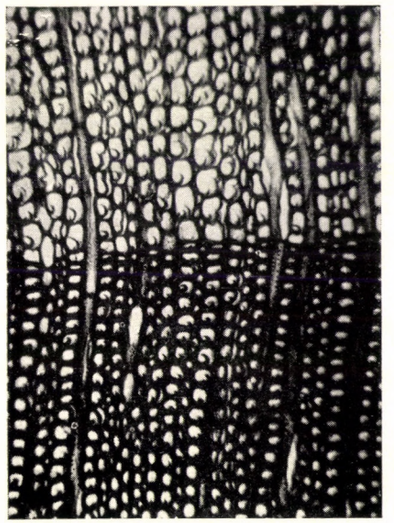
3. (300×)



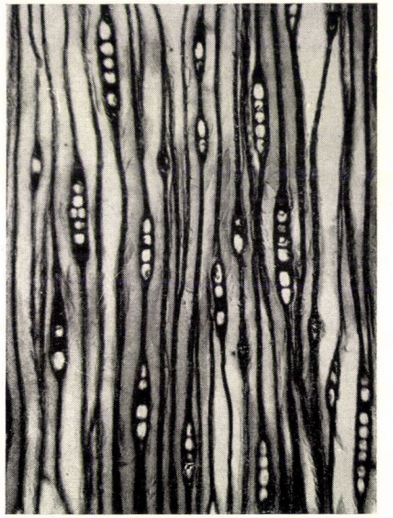
4. (300×)



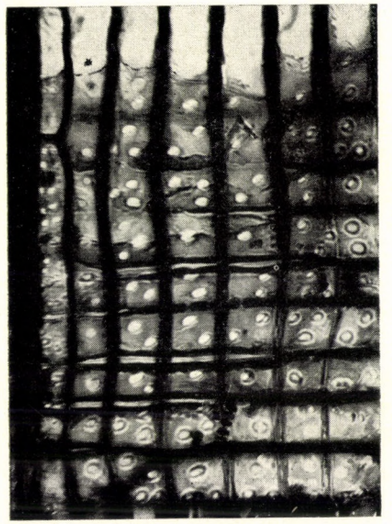
232. Keteleeria Davidiana (Franchet) Beissner



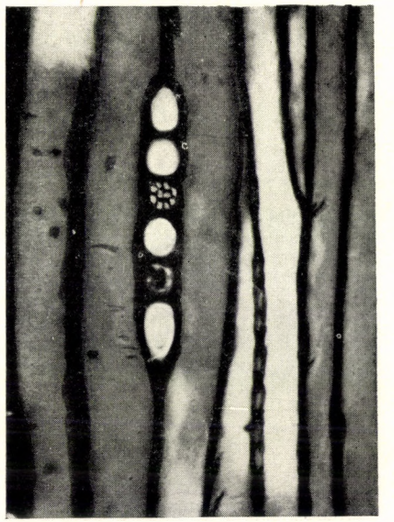
1. (100×)



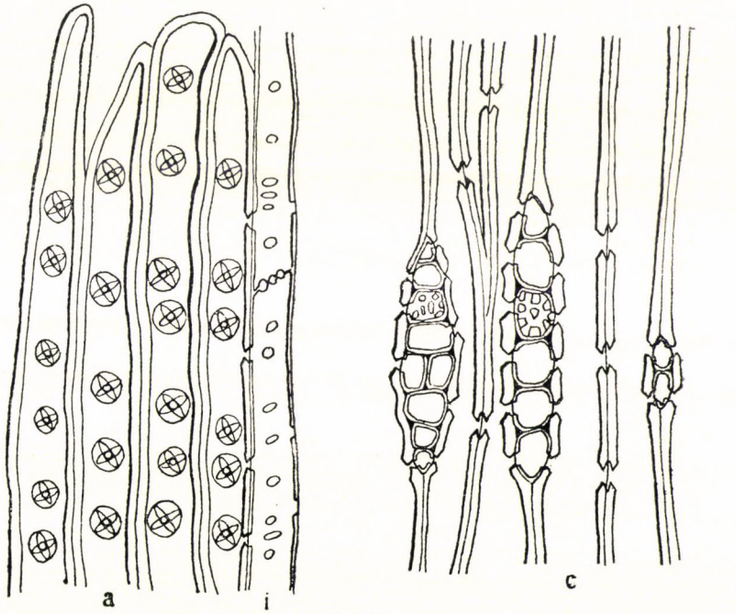
2. (100×)



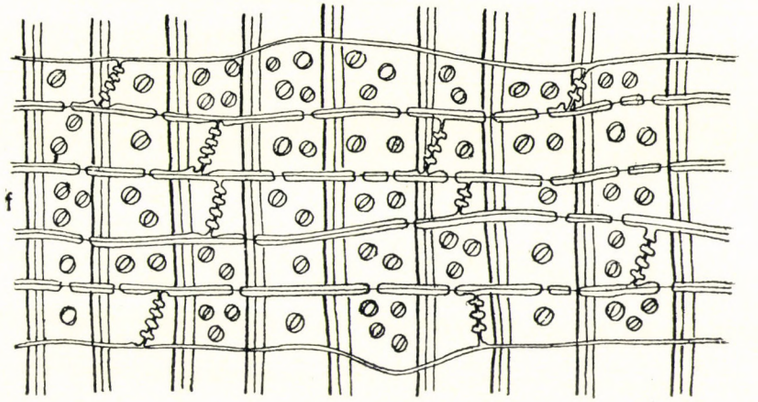
3. (300×)



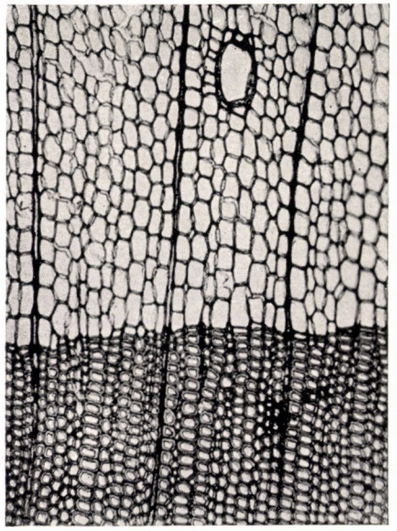
4. (300×)



300 ×



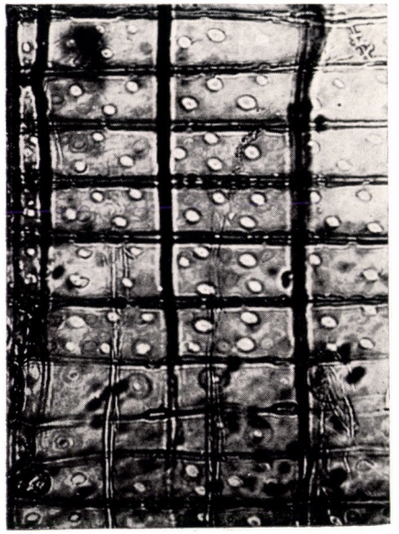
233. Keteleeria **Fortunei** (A. Murray) Carr.



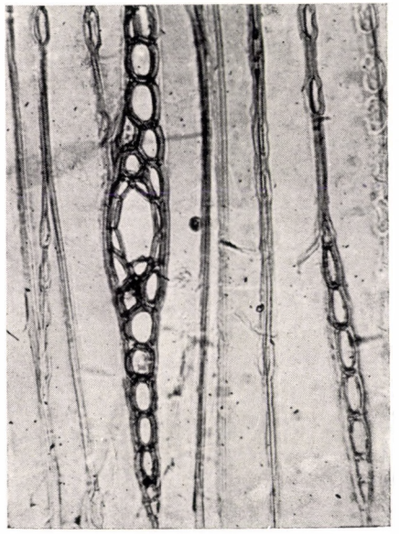
1. (100×)



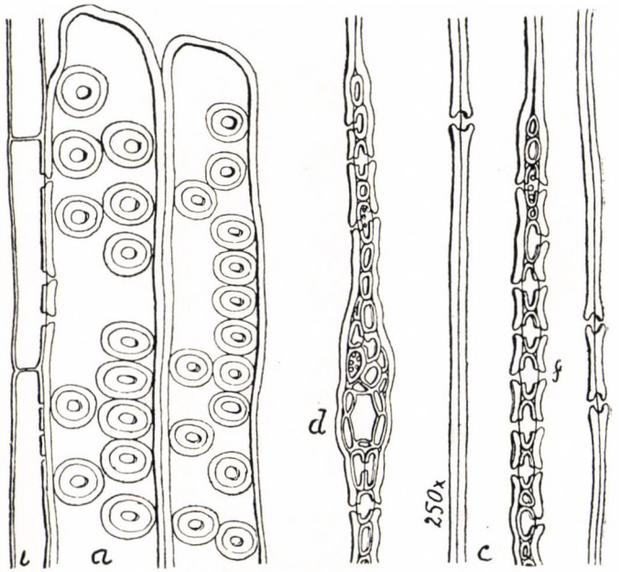
2. (100×)

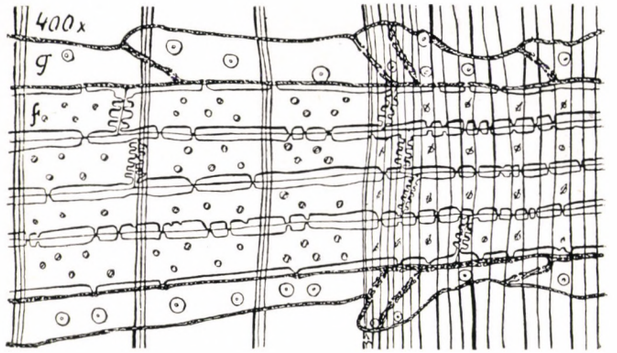


3. (300×)

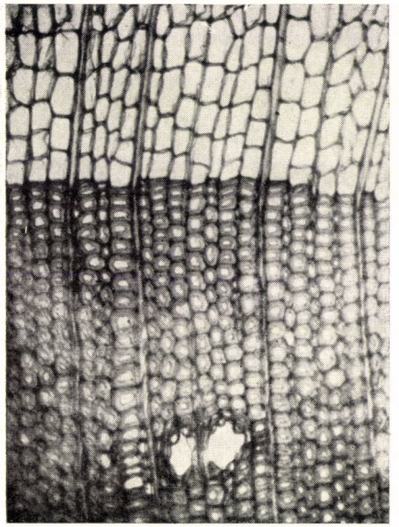


4. (300×)

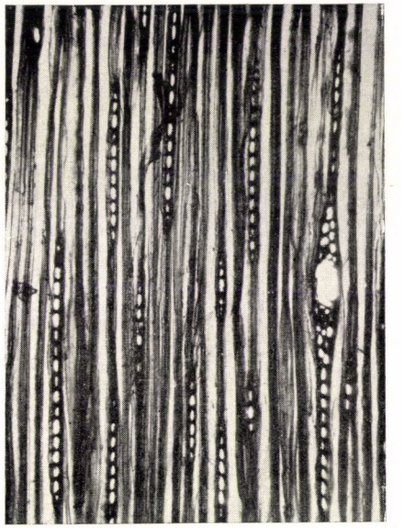




234. Larix decidua MILLER



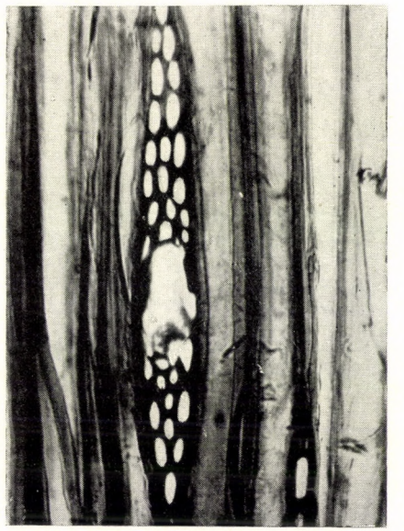
1. (100×)



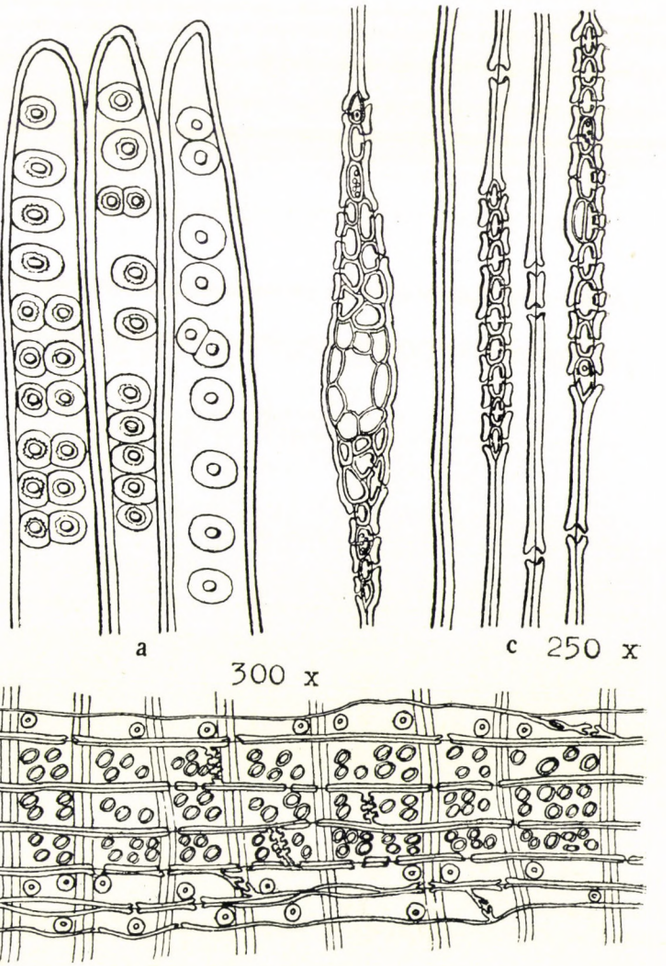
2. (100×)



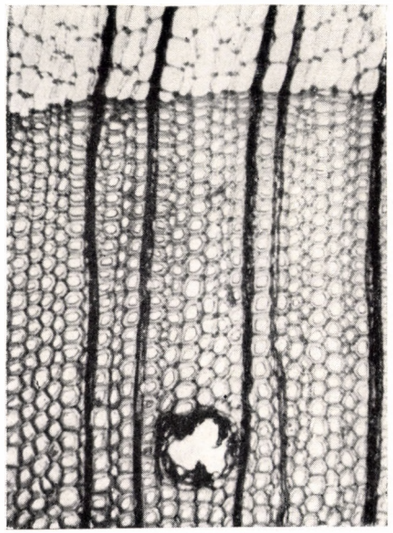
3. (300×)



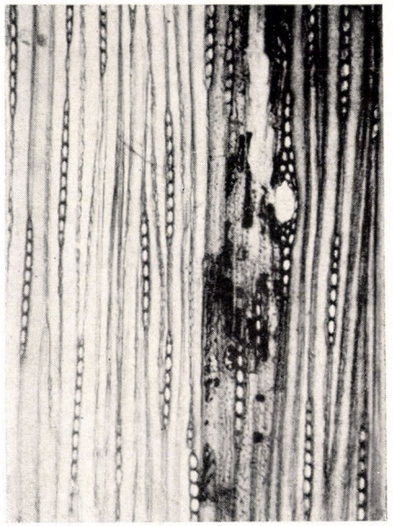
4. (300×)



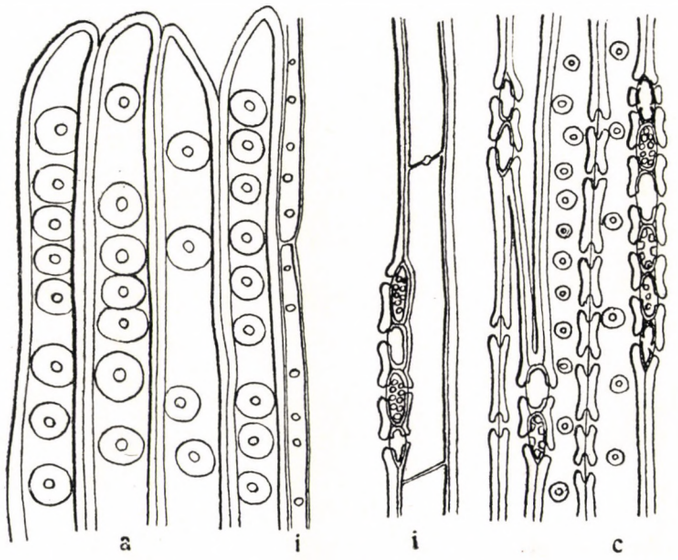
235. Larix Gmelini (Ruprecht) LITVINOV

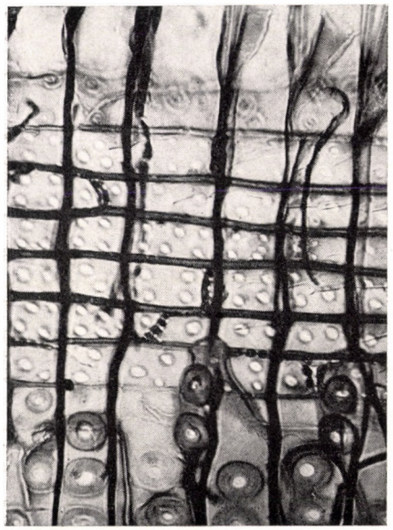


1. (100×)

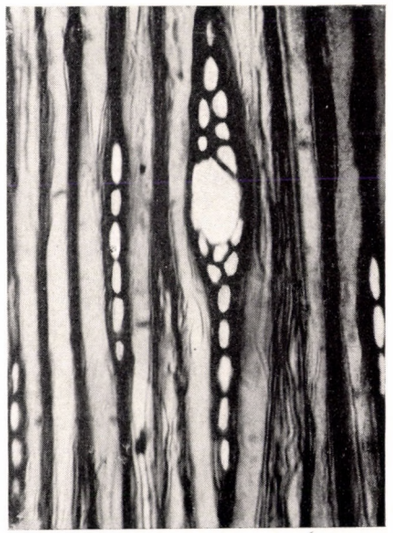


2. (100×)

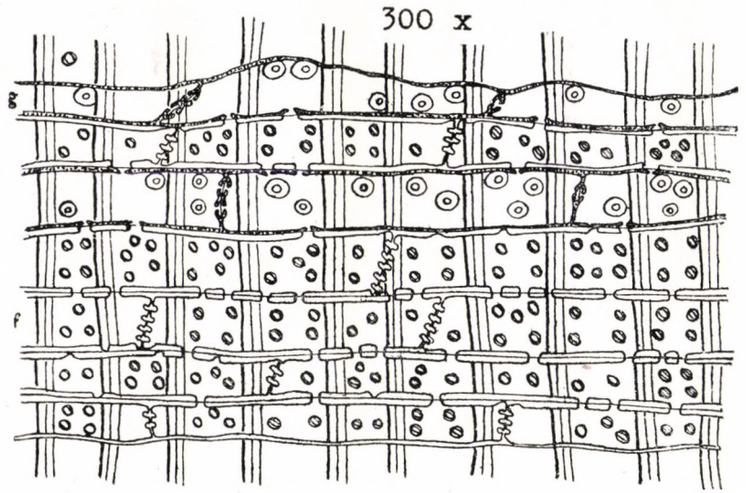




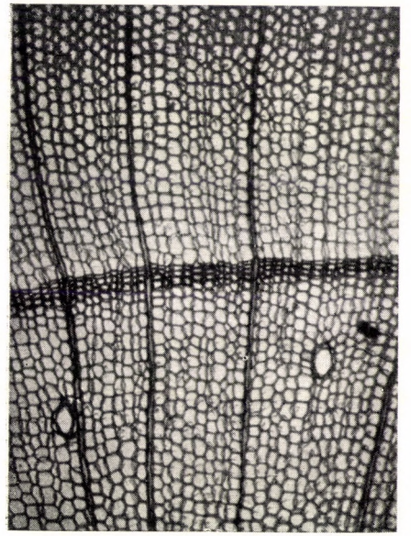
3. (300×)



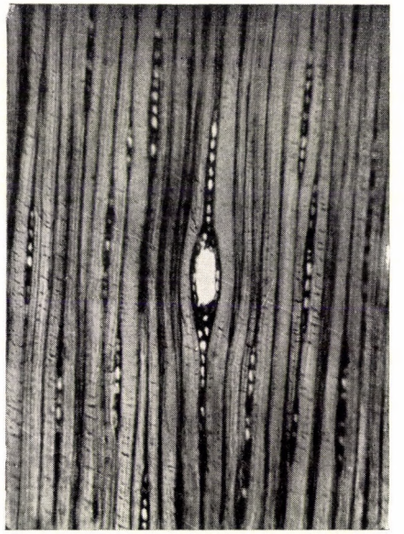
4. (300×)



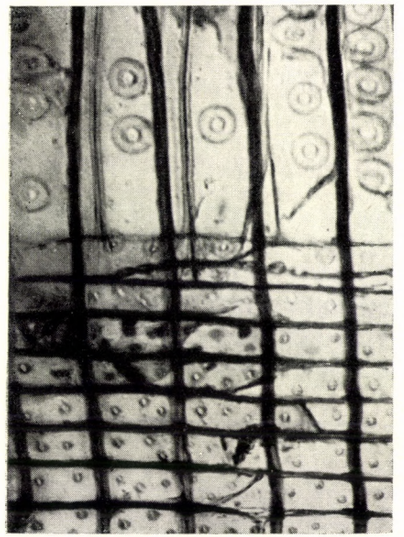
236. Larix Gmelini var. japonica (Regel) PILGER



1. (100×)



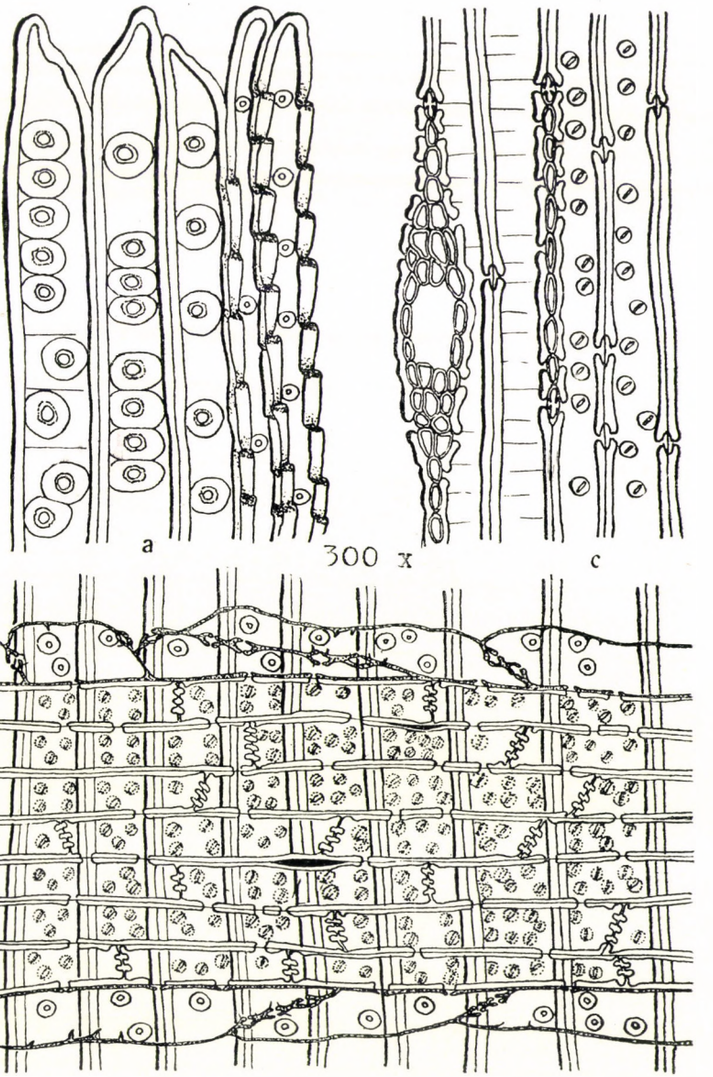
2. (100×)



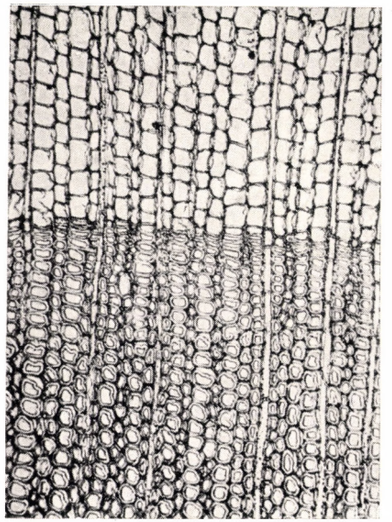
3. (300×)



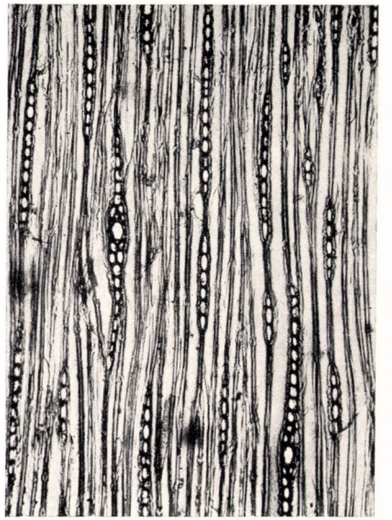
4. (300×)



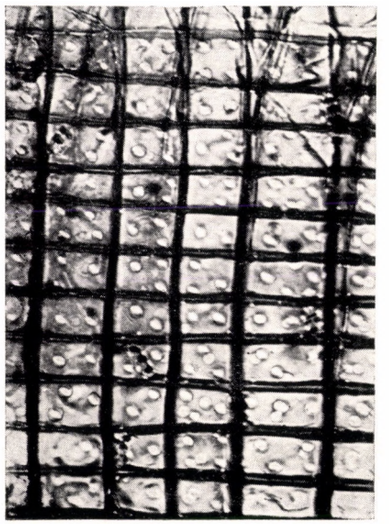
237. Larix laricina (Duroi) K. Koch



1. (100×)



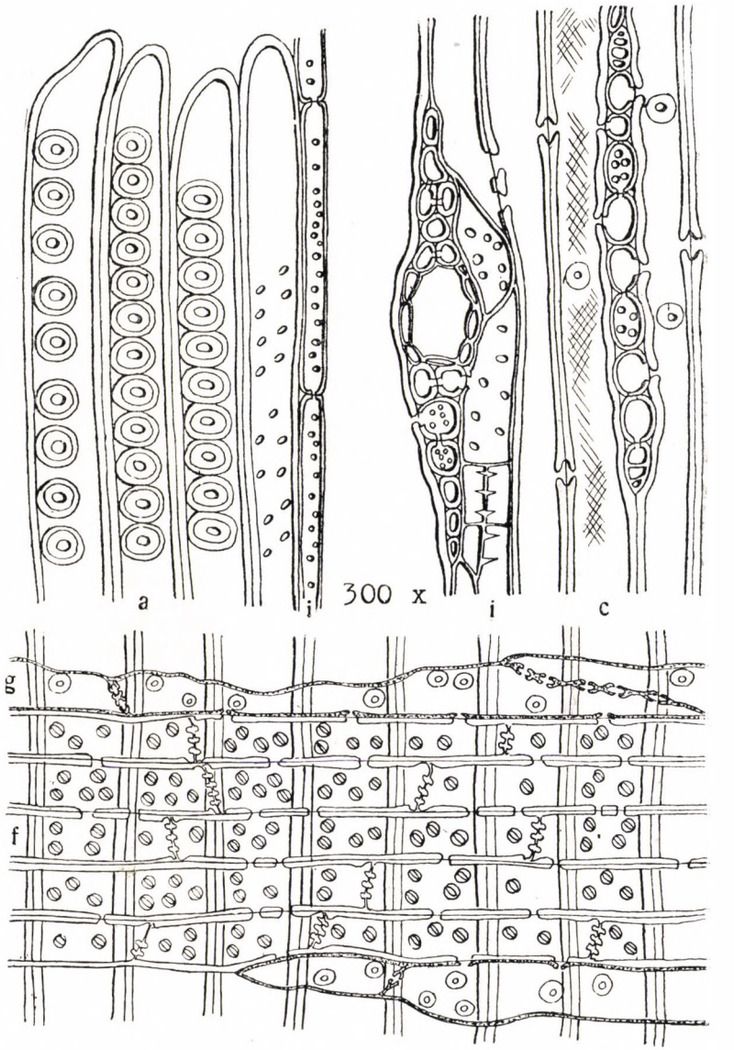
2. (100×)



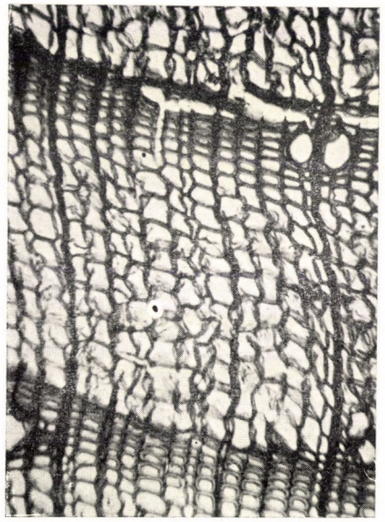
3. (300×)



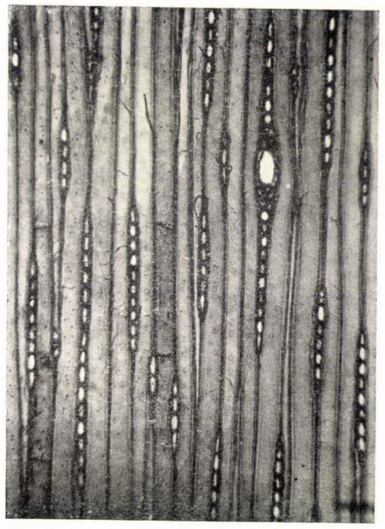
4. (300×)



238. Larix leptolepis (Sieb. et Zucc.) MURRAY



1. (100×)



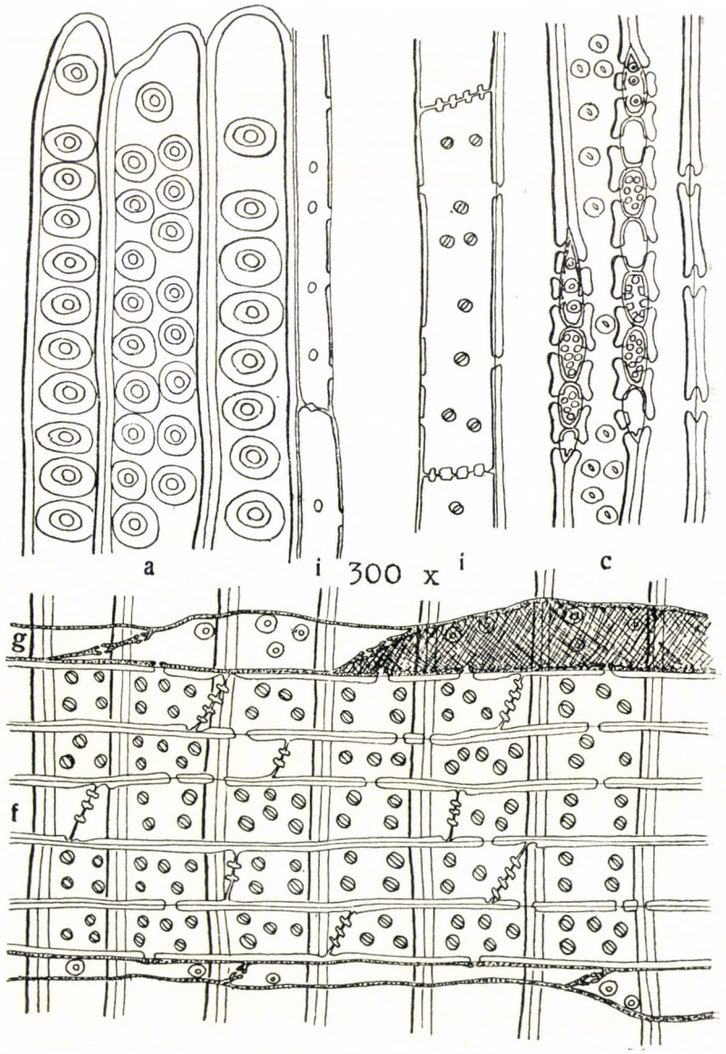
2. (100×)



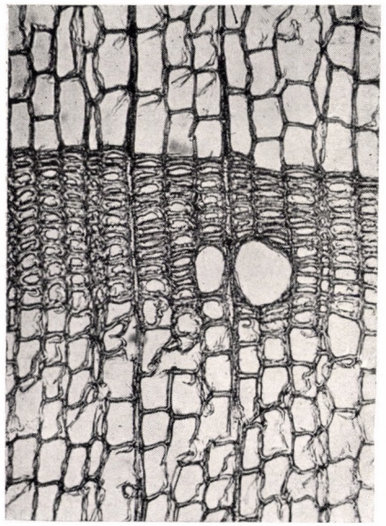
3. (300×)



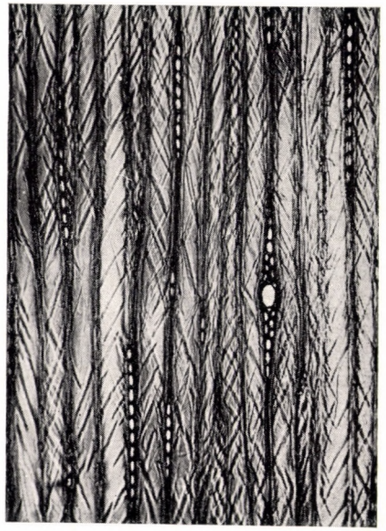
4. (300×)



239. Larix Lyallii PARL.



1. (100×)



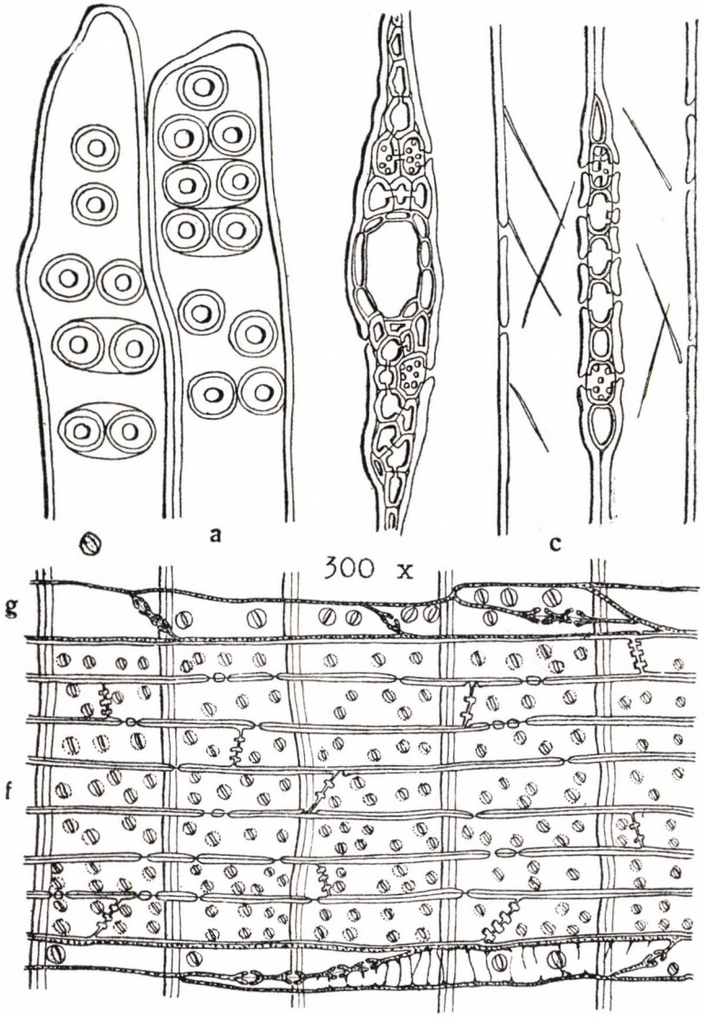
2. (100×)



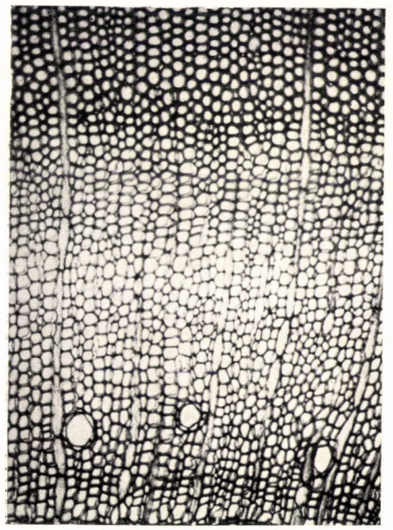
3. (300×)



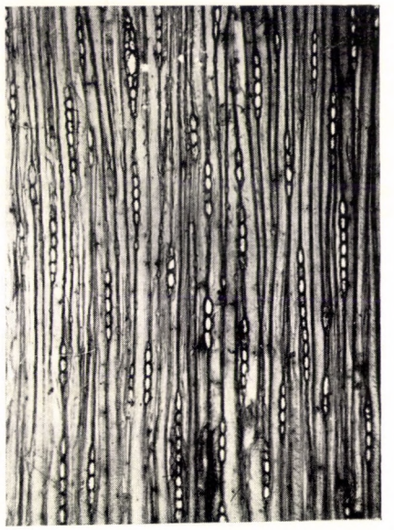
4. (300×)



240. Larix occidentalis NUTTAL



1. (100×)



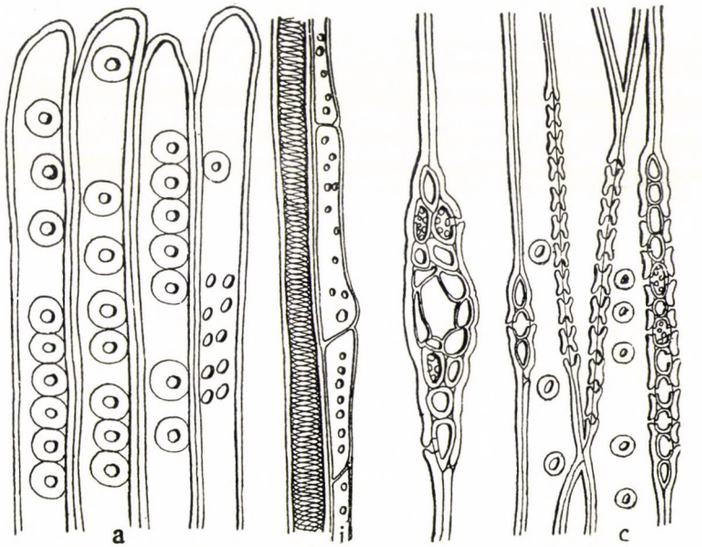
2. (100×)



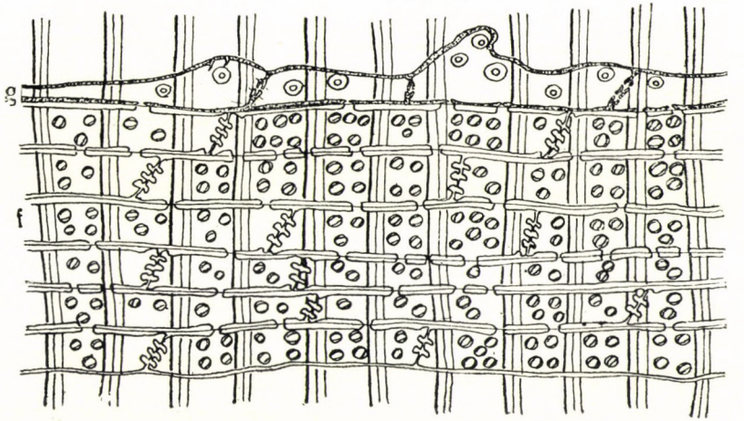
3. (300×)



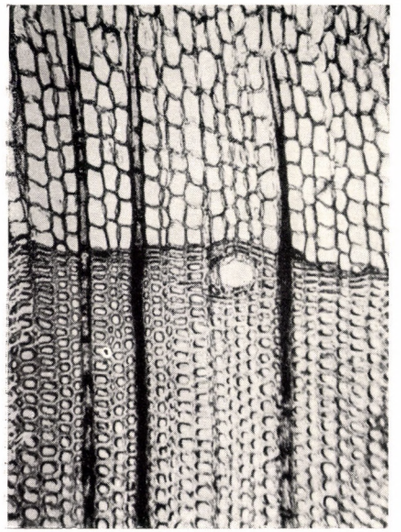
4. (300×)



300 x



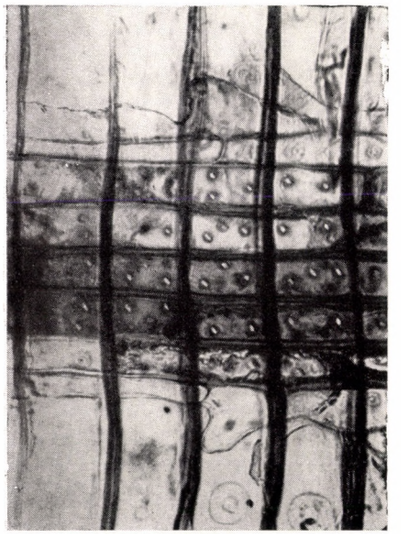
241. Larix pendula (Aiton) SALISB.



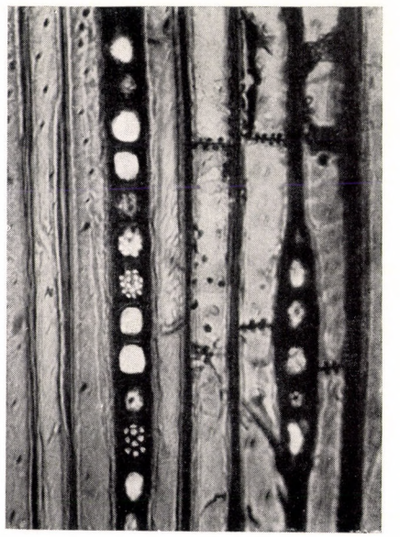
1. (100×)



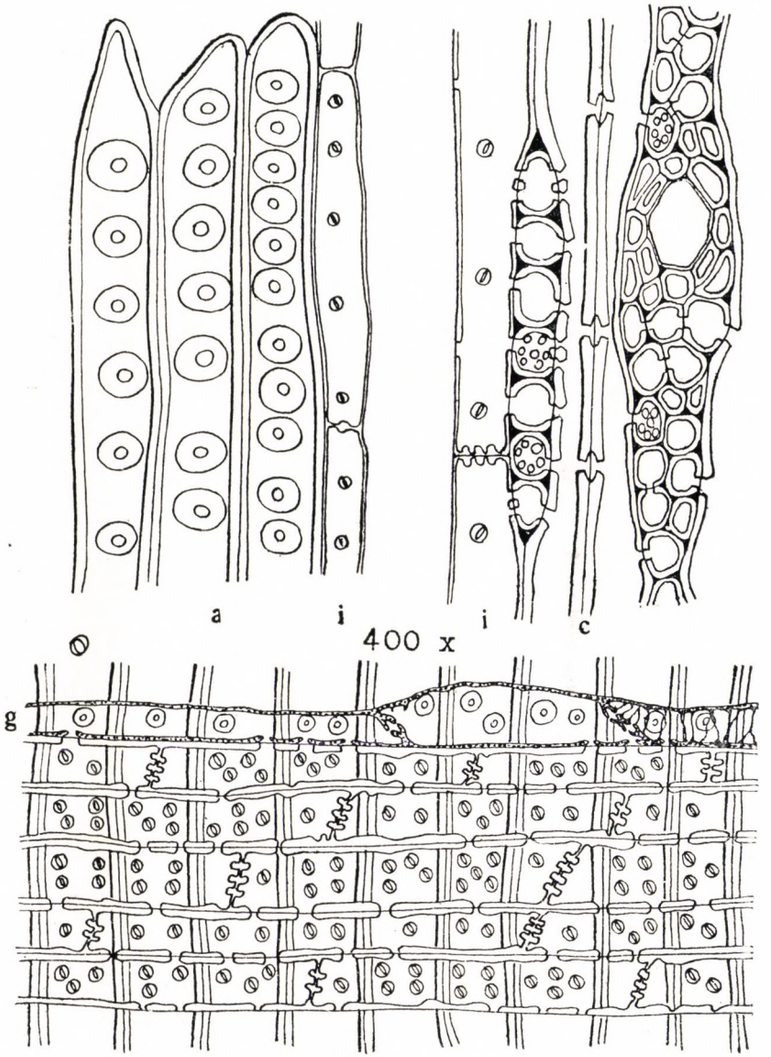
2. (100×)



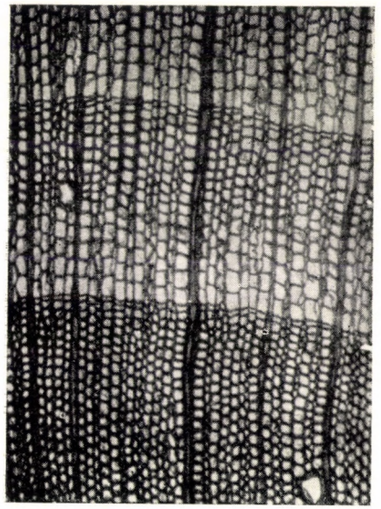
3. (300×)



4. (300×)



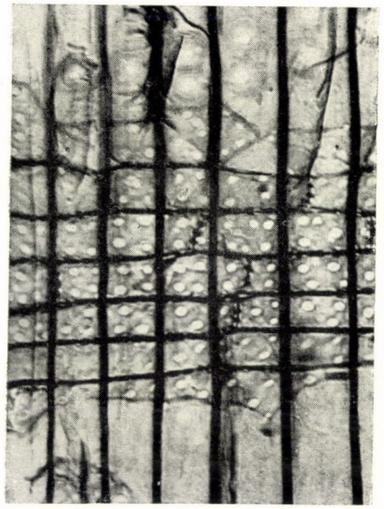
242. Larix Potanini BATALIN



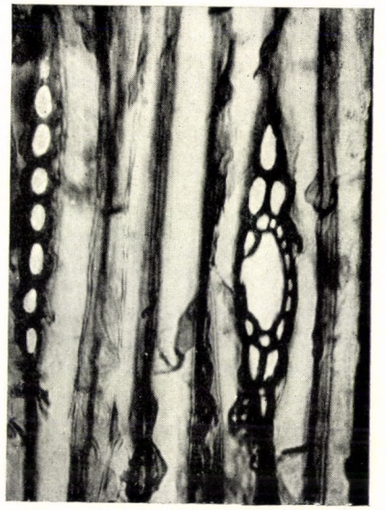
1. (100×)



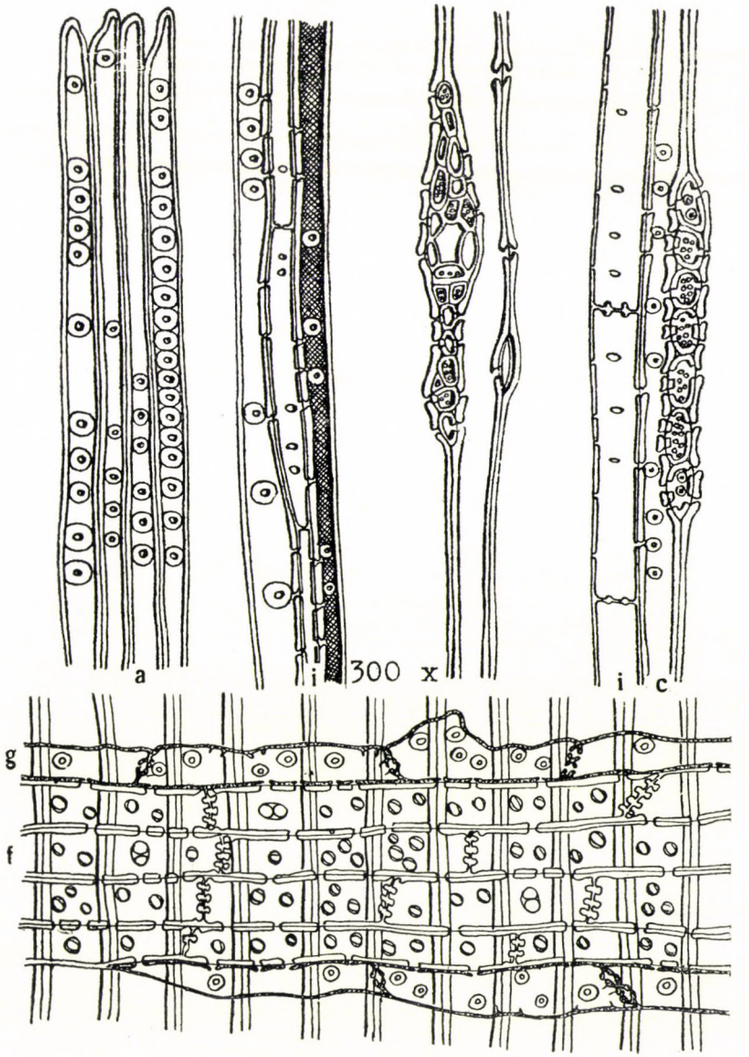
2. (100×)



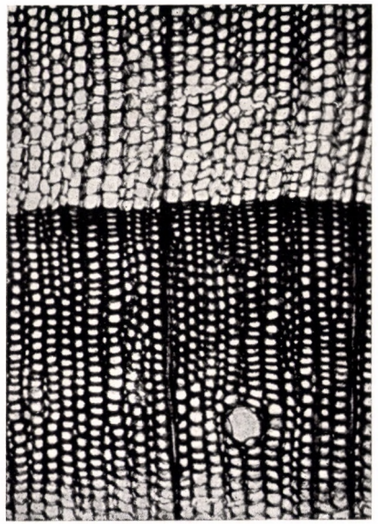
3. (300×)



4. (300×)



243. Larix sibirica LEDEBOUR



1. (100×)



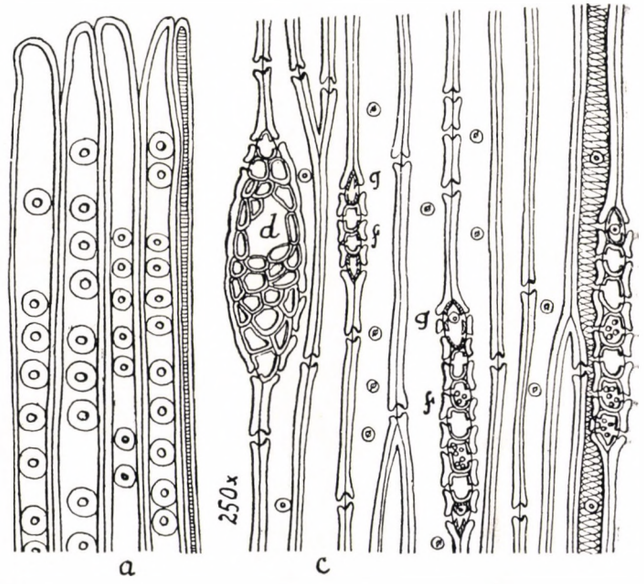
2. (100×)

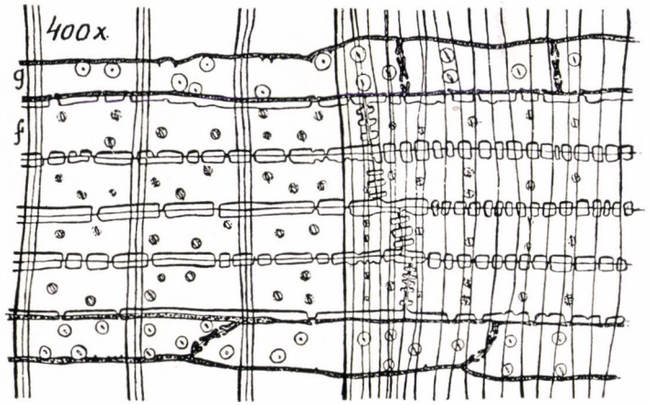


3. (300×)

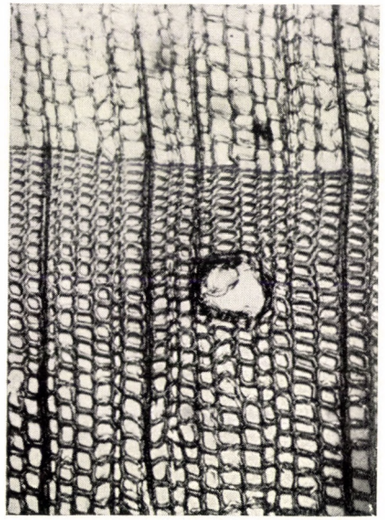


4. (300×)

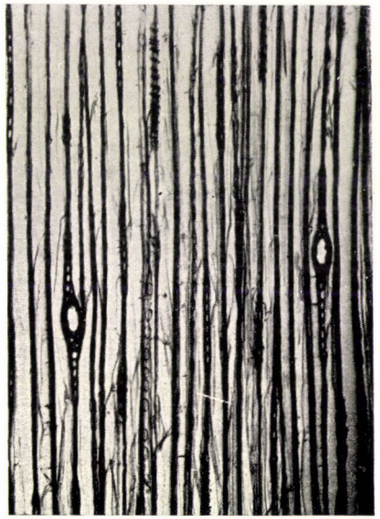




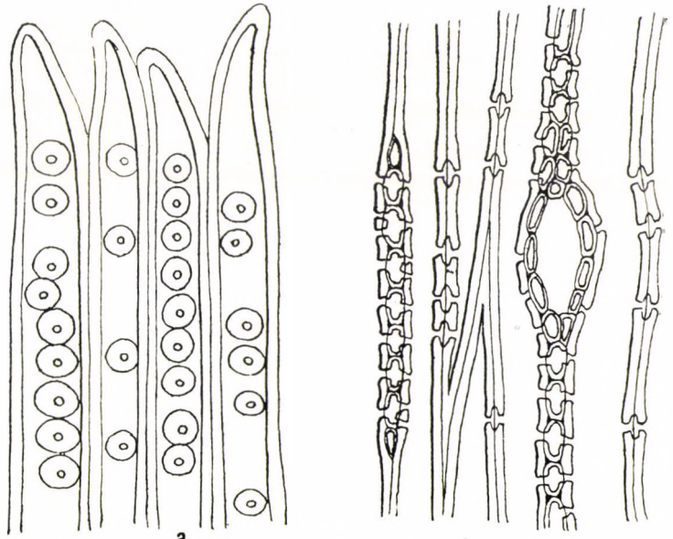
244. Picea Abies (L.) KARST



1. (100×)

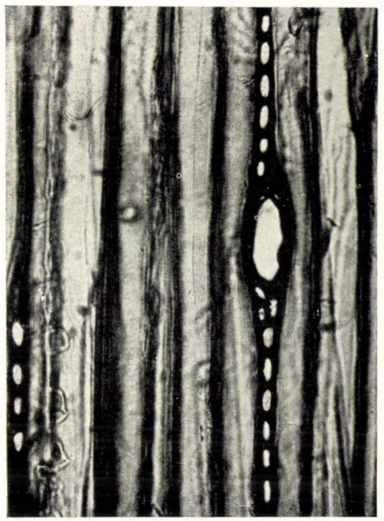


2. (100×)

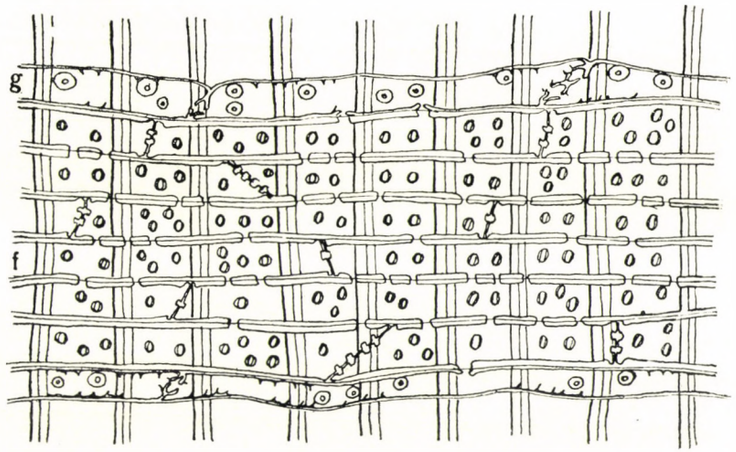




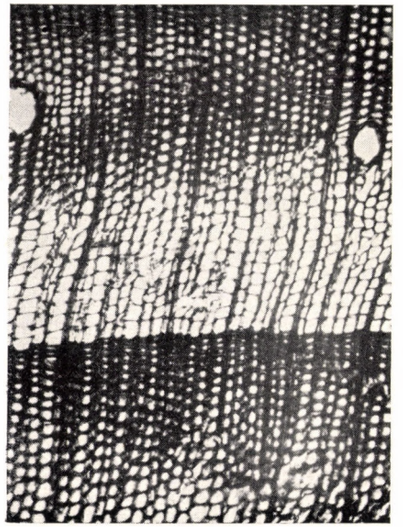
3. (300×)



4. (300×)



245. Picea albertiana STEWARDSON—BROWN



1. (100×)



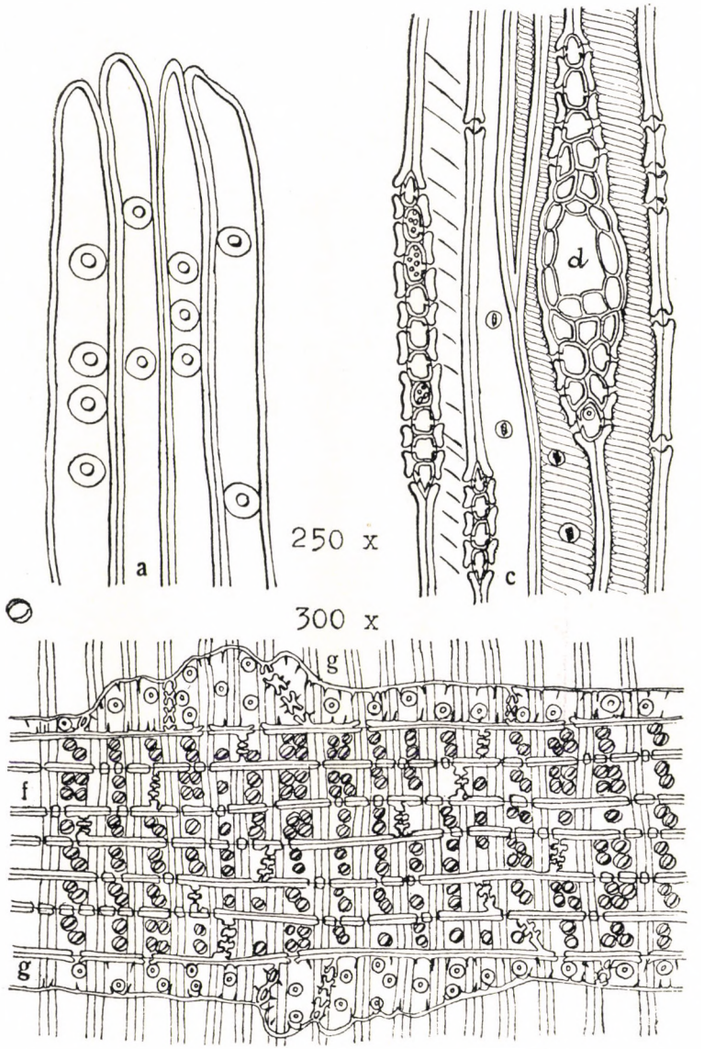
2. (100×)



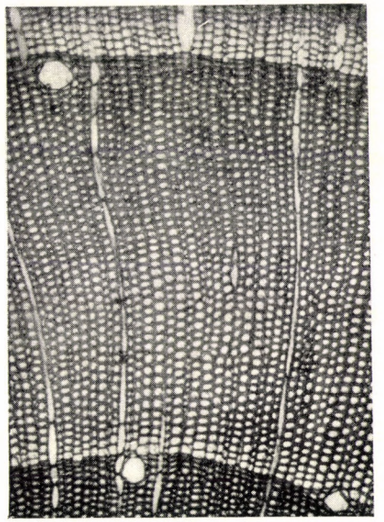
3. (300×)



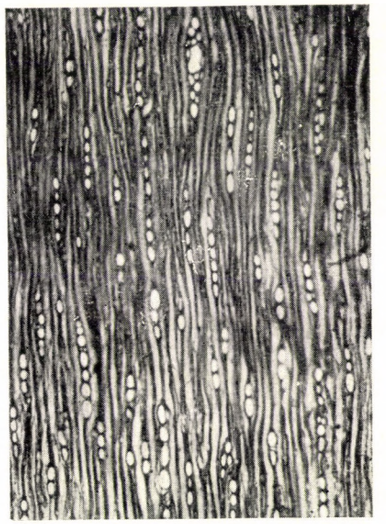
4. (300×)



246. Picea asperata MAST.



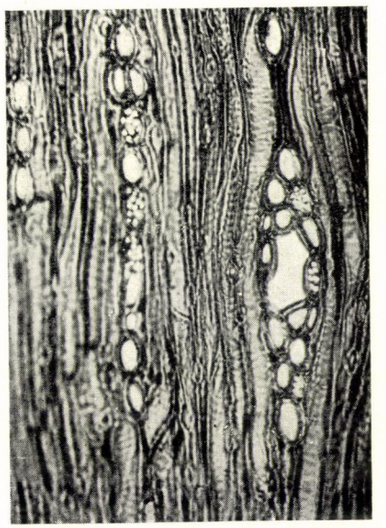
1. (100×)



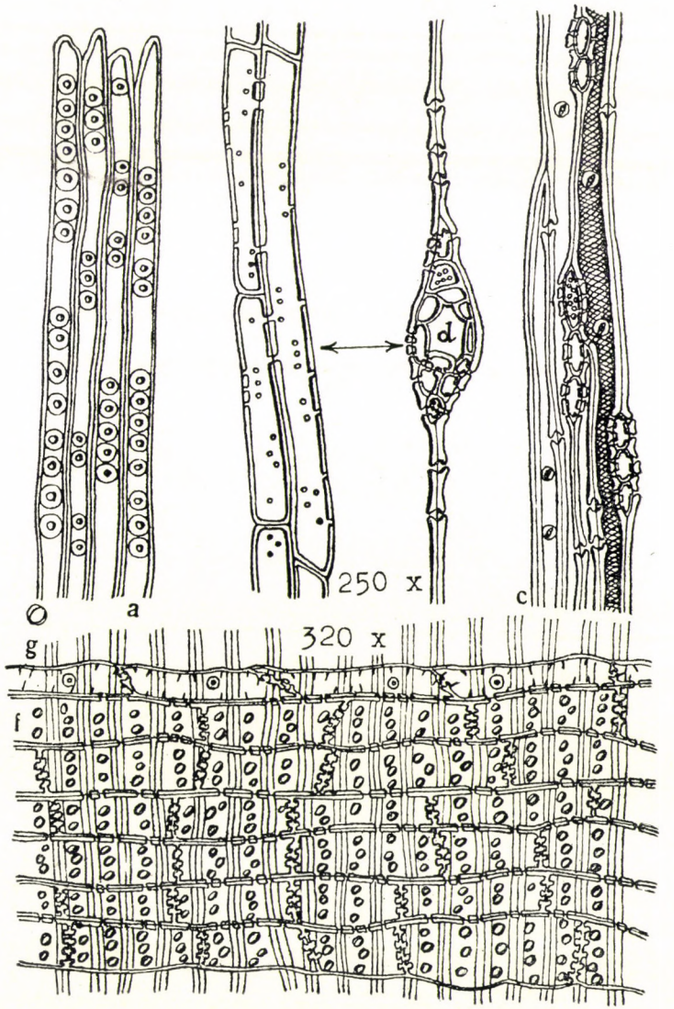
2. (100×)



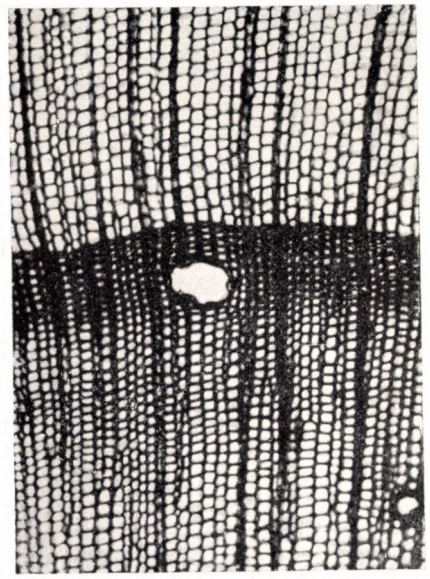
3. (300×)



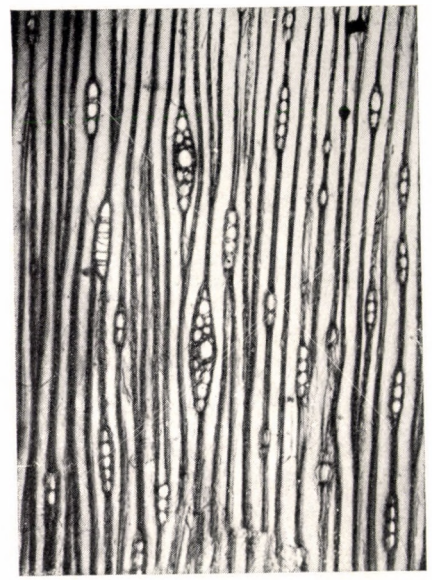
4. (300×)



247. Picea bicolor (Maximowicz) MAYR



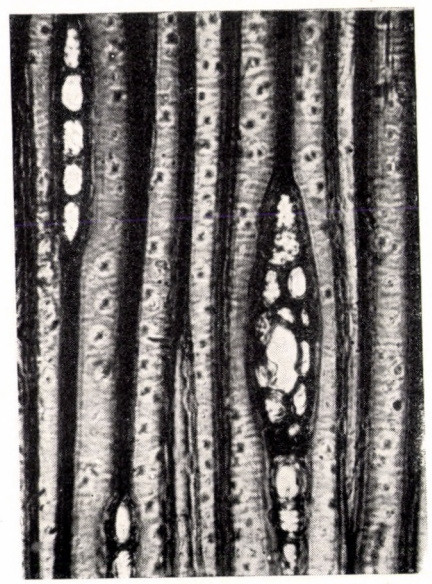
1. (100×)



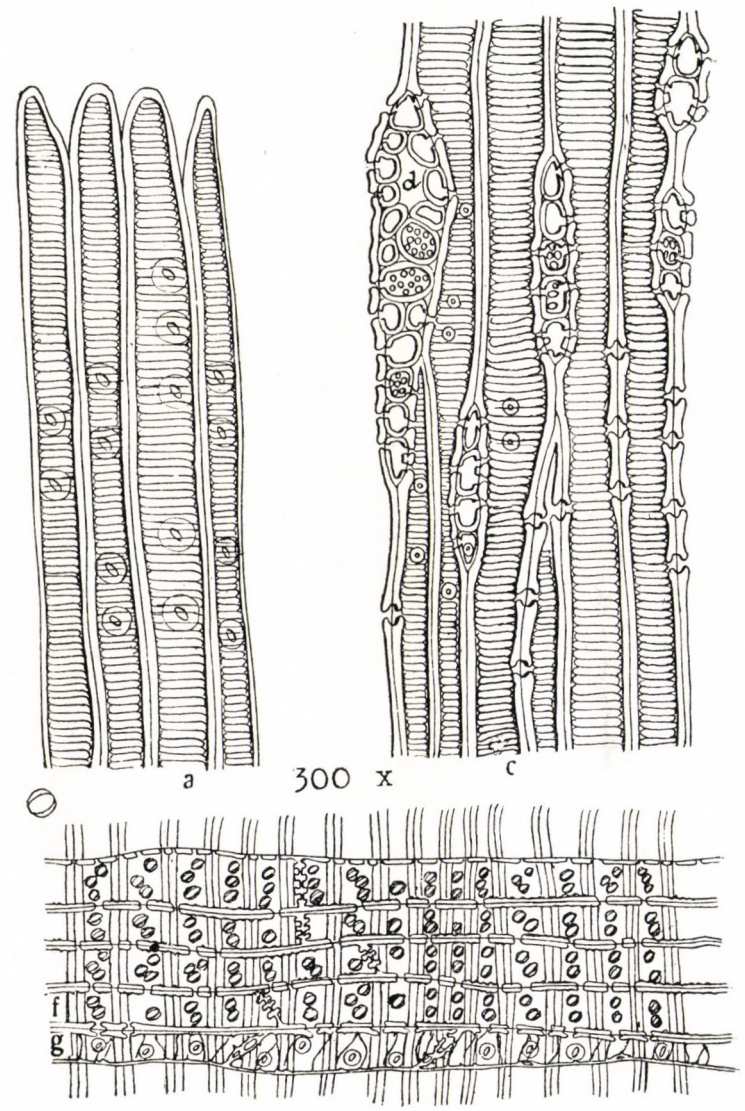
2. (100×)



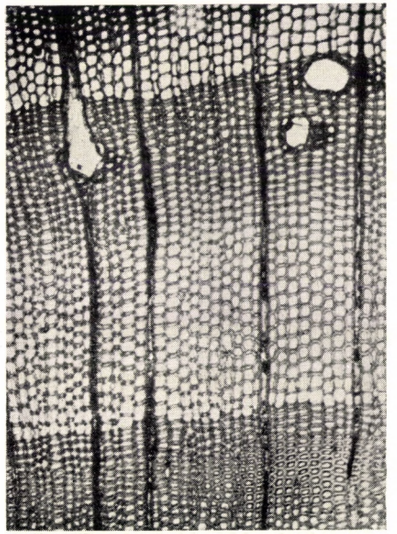
3. (300×)



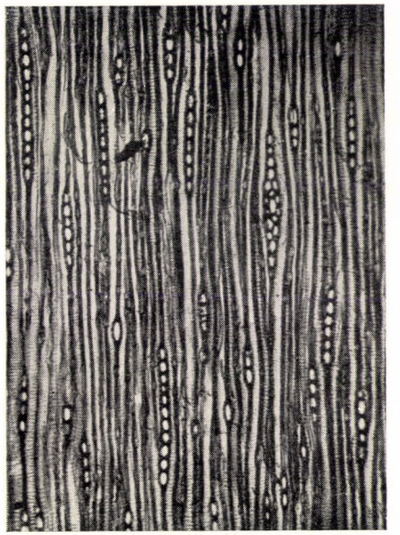
4. (300×)



248. Picea brachytyla (Franchet) Pritzel



1. (100×)



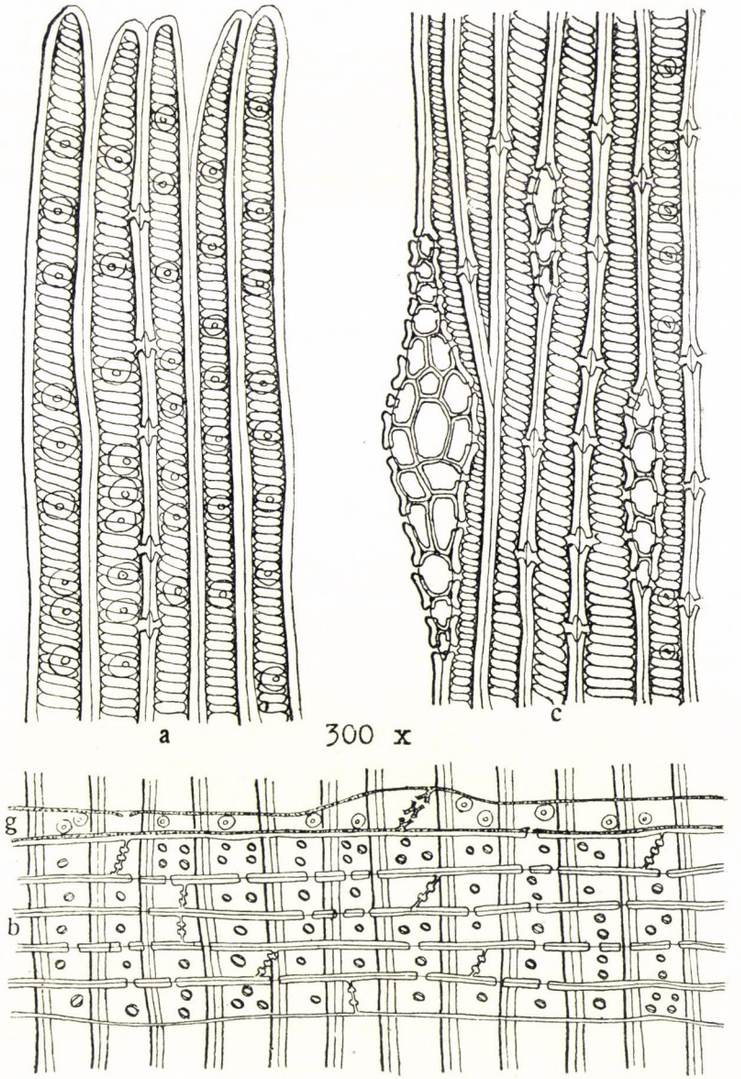
2. (100×)



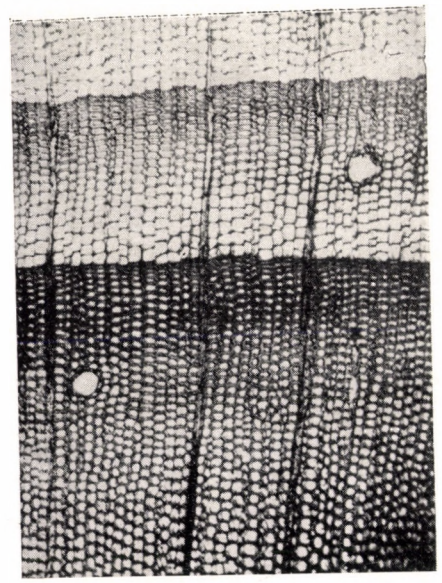
3. (300×)



4. (300×)



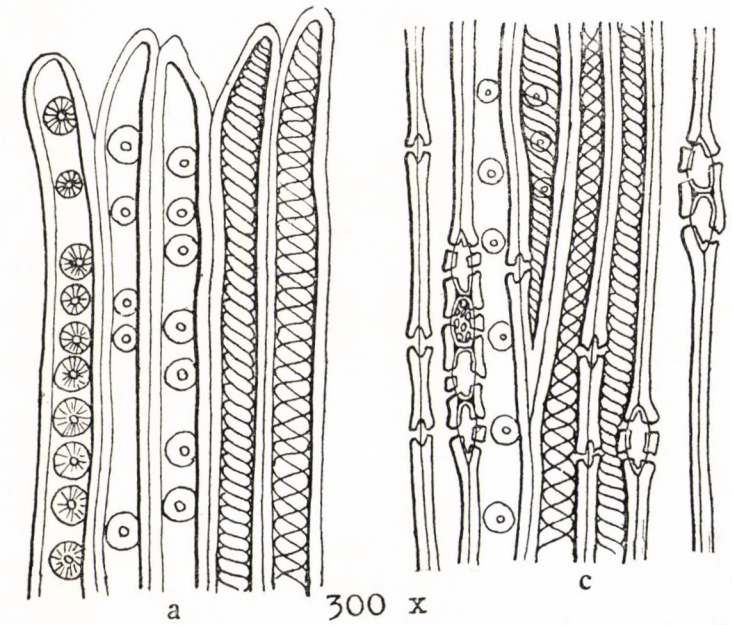
249. Picea Breweriana S. WATSON

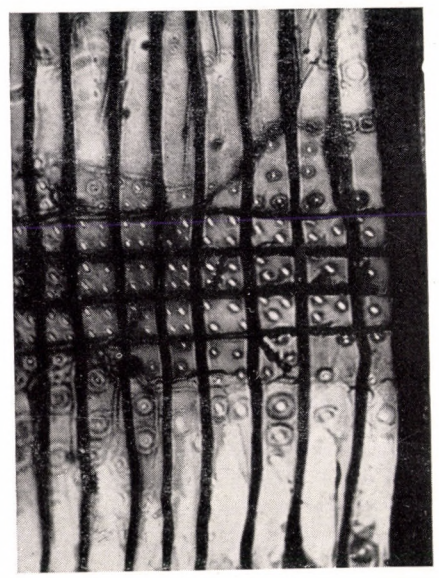


1. (100×)



2. (100×)

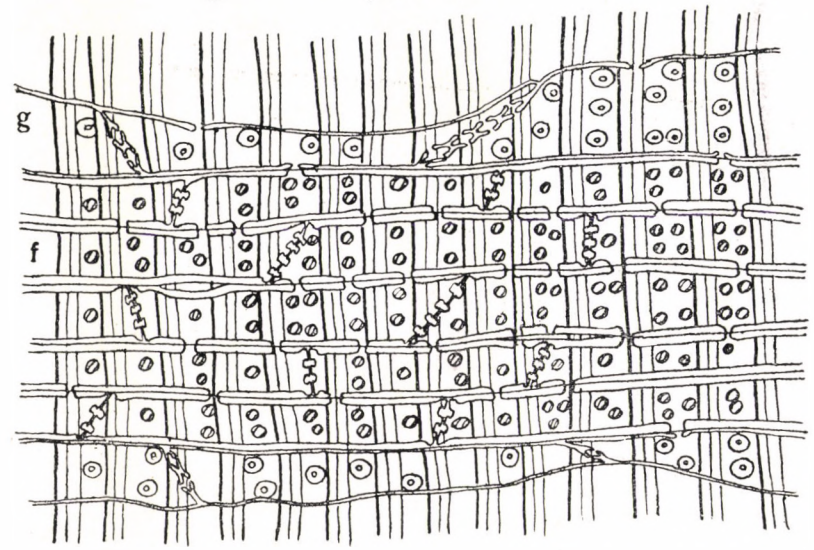




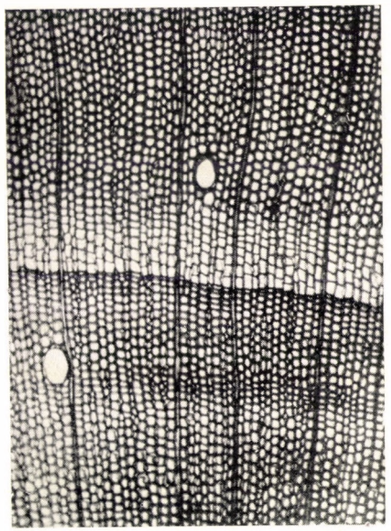
3. (300×)



4. (300×)



250. Picea Engelmanni (Parry) Engelmann



1. (100×)



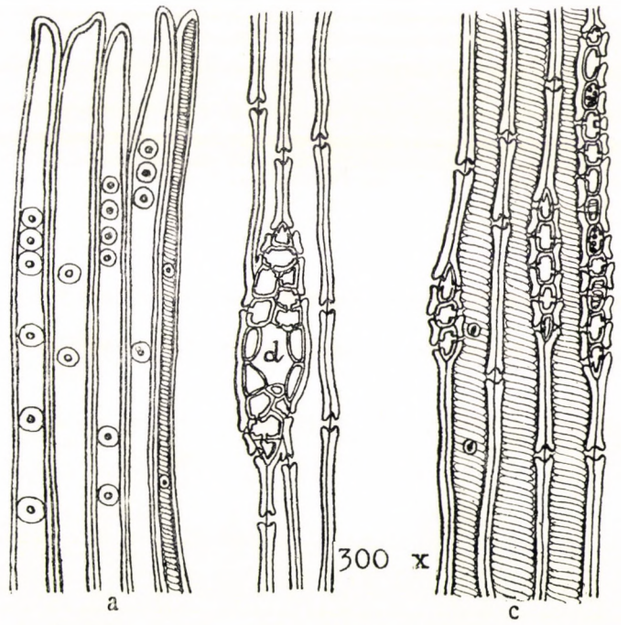
2. (100×)

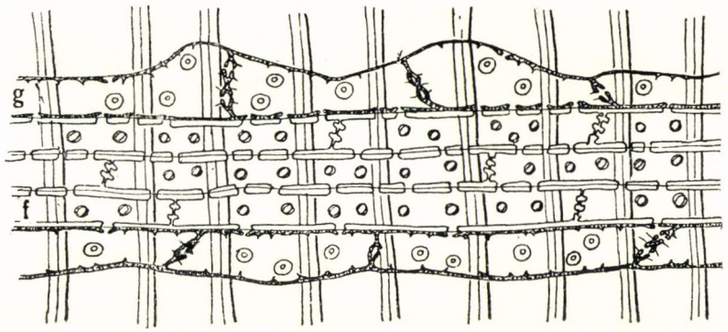


3. (300×)

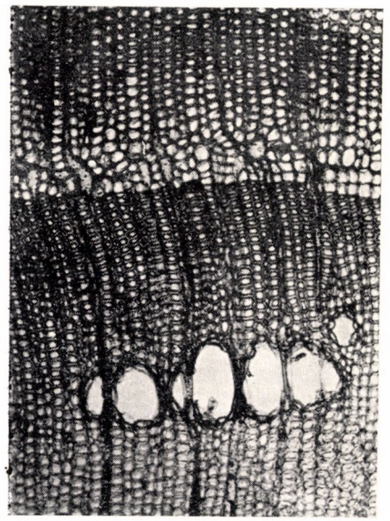


4. (300×)





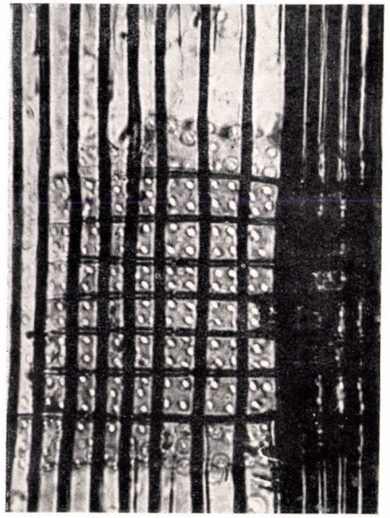
251. Picea glauca (Moench) Voss



1. (100×)



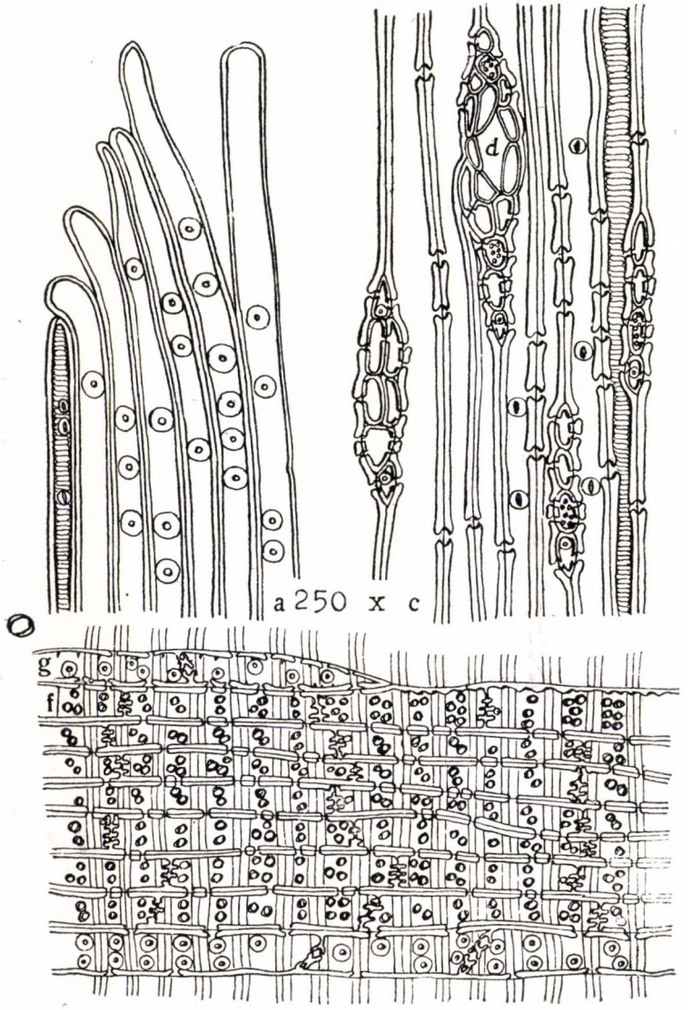
2. (100×)



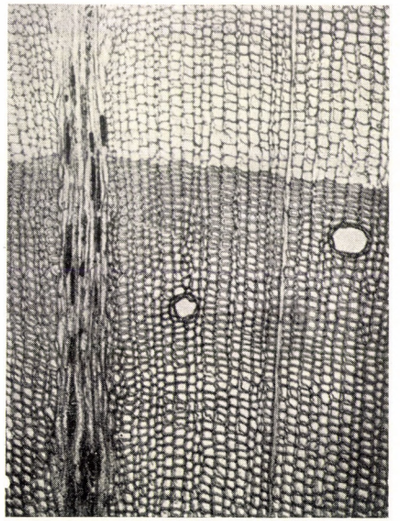
3. (300×)



4. (300×)



252. Picea Glehnii (Fr. Schmidt) MAST.



1. (100×)



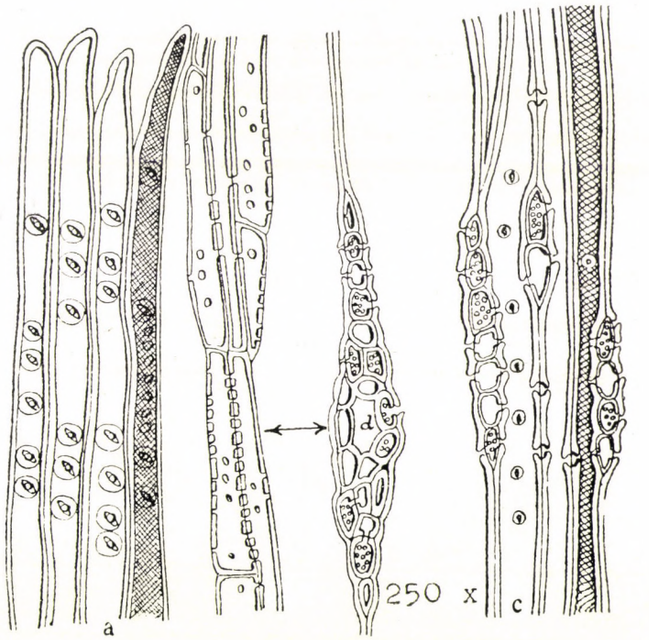
2. (100×)

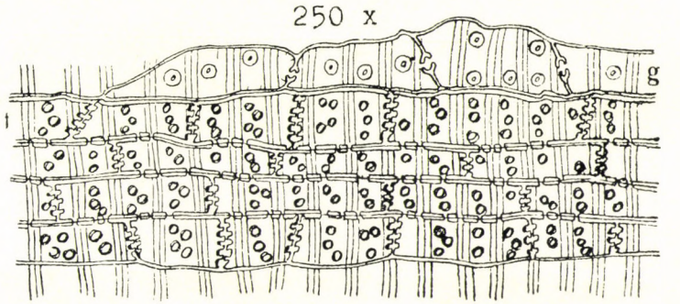


3. (300×)

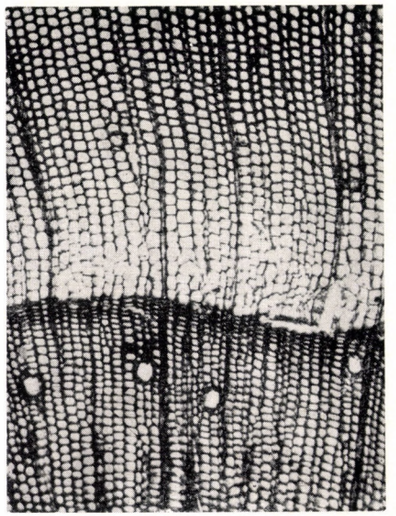


4. (300×)





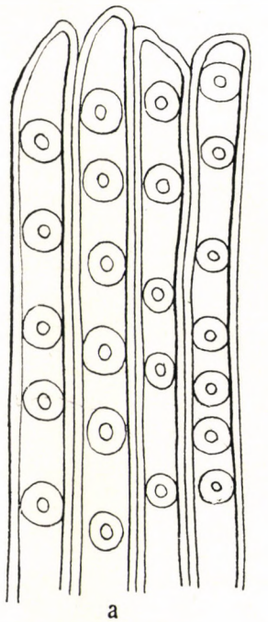
253. Picea jezoensis (Siebold et Zuccarini) CARR.

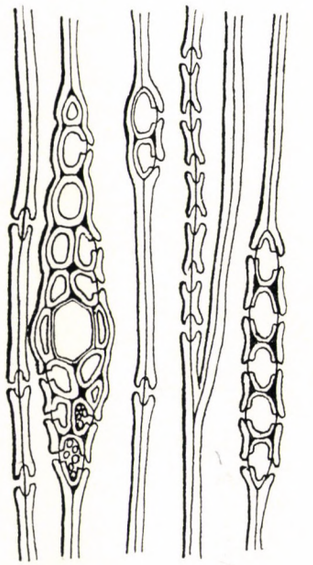


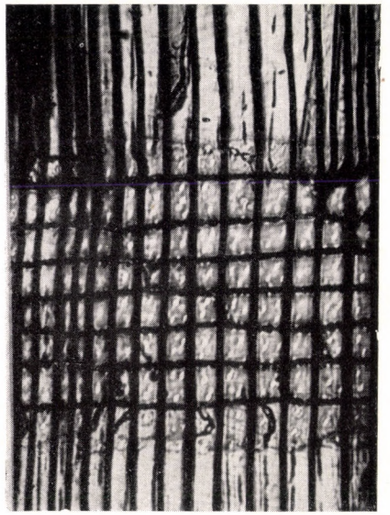
1. (100×)



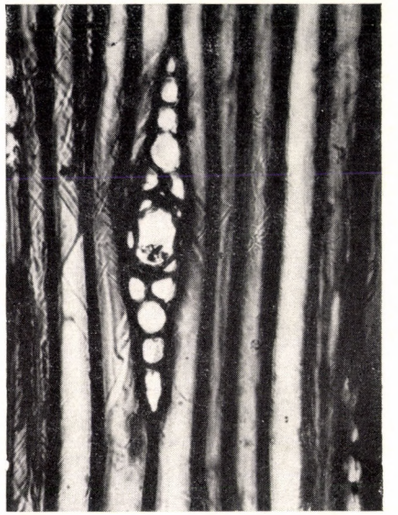
2. (100×)



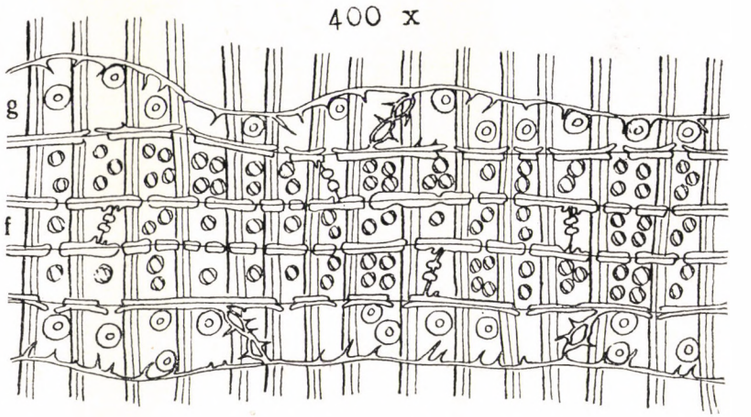




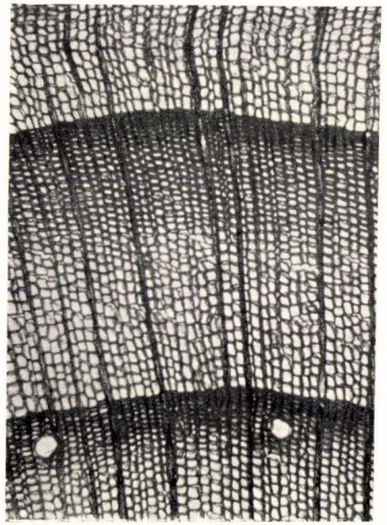
3. (300×)



4. (300×)



254. Picea junnanensis HORT.



1. (100×)



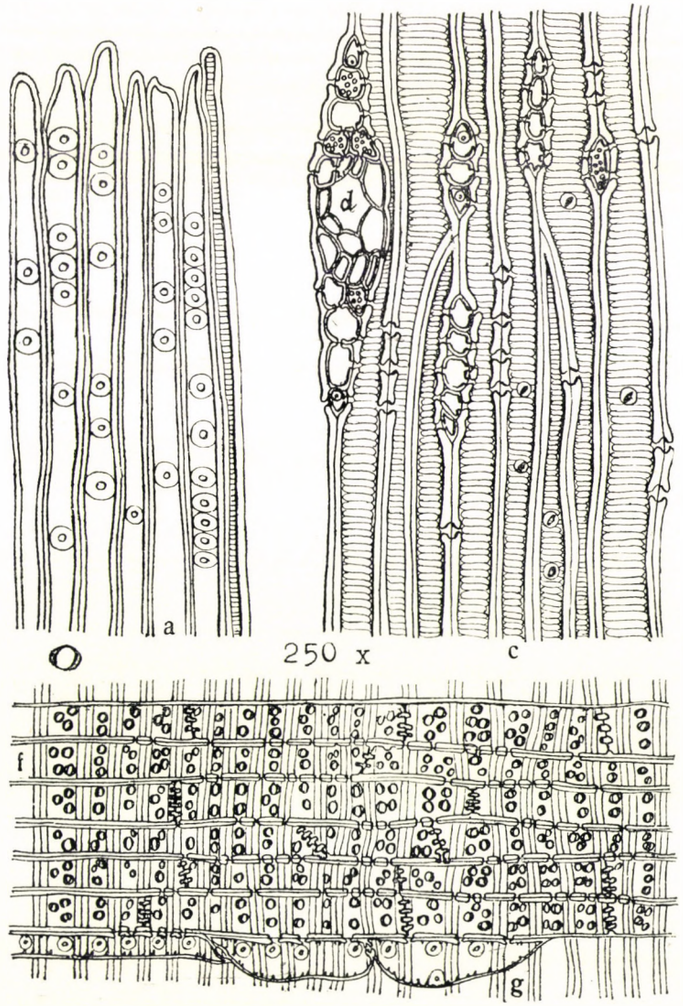
2. (100×)



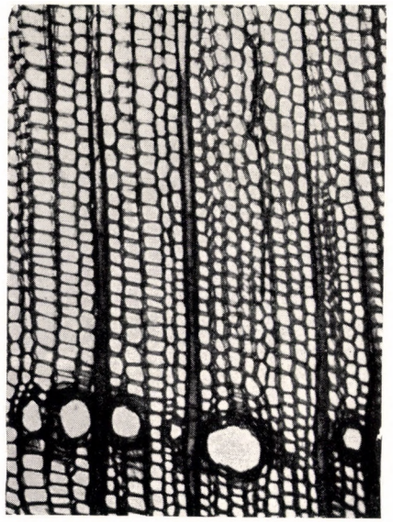
3. (300×)



4. (300×)



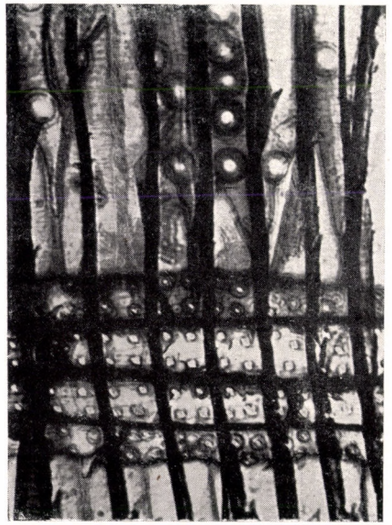
255. Picea Koyamai SHIRASAWA



1. (100×)



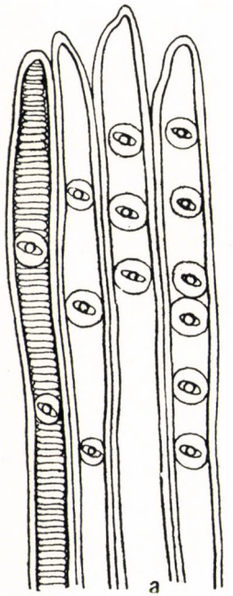
2. (100×)

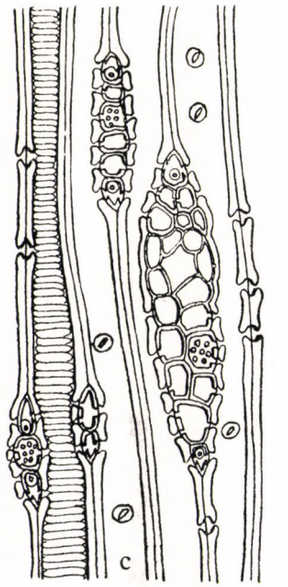


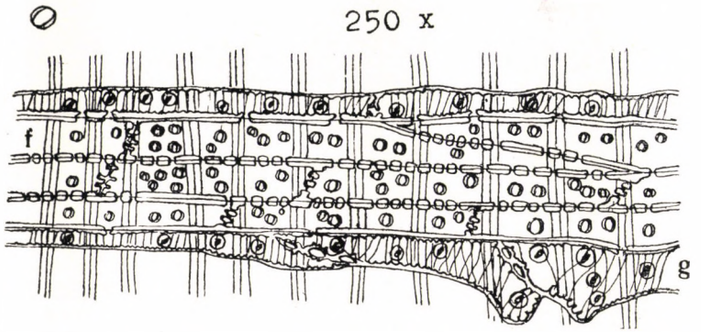
3. (300×)



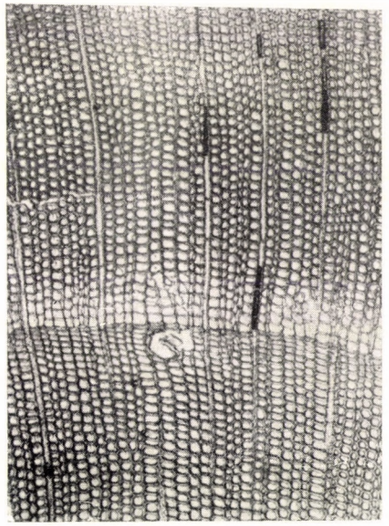
4. (300×)







256. Picea likiangensis (Franchet) Pritzel



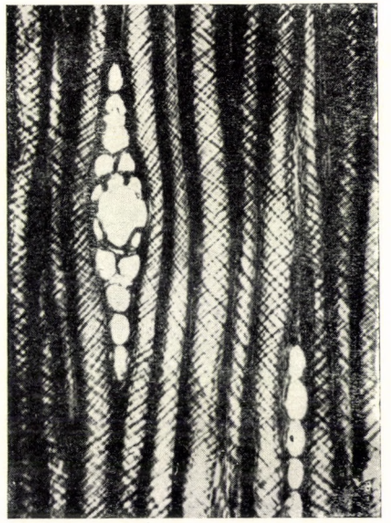
1. (100×)



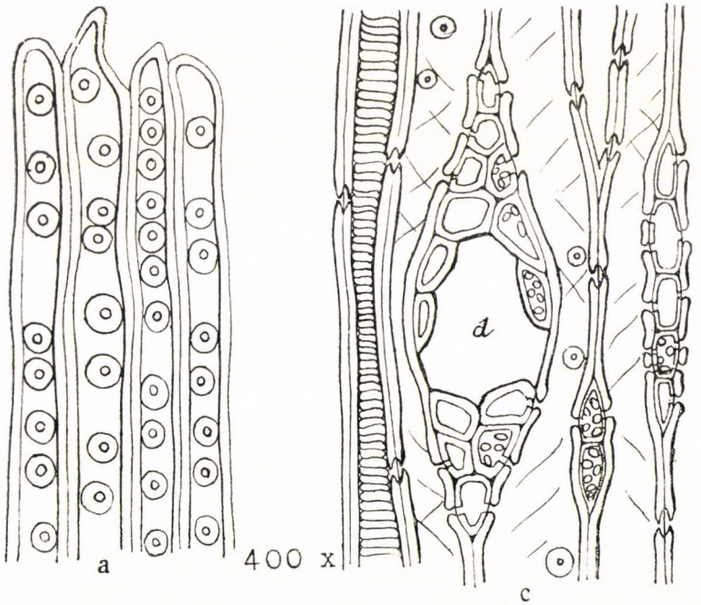
2. (100×)

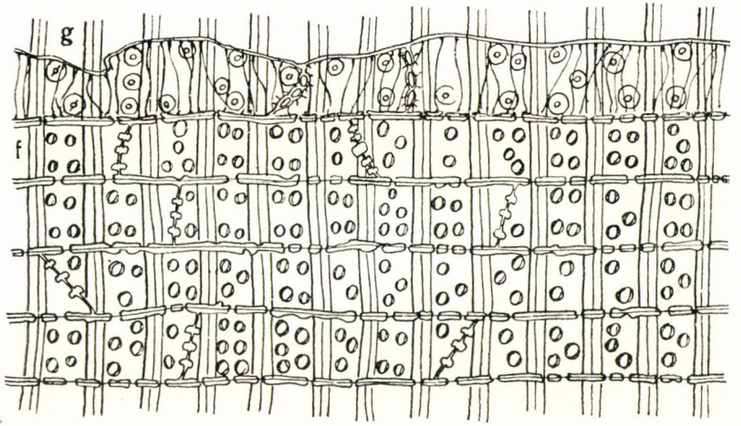


3. (300×)

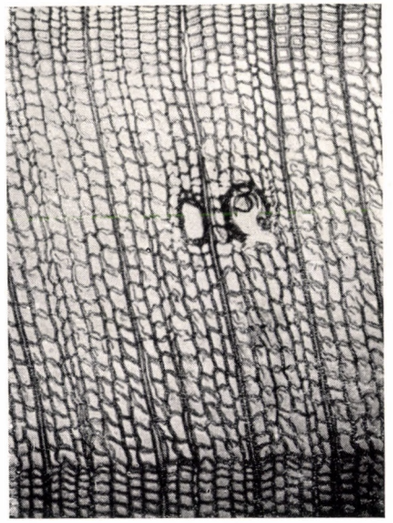


4. (300×)

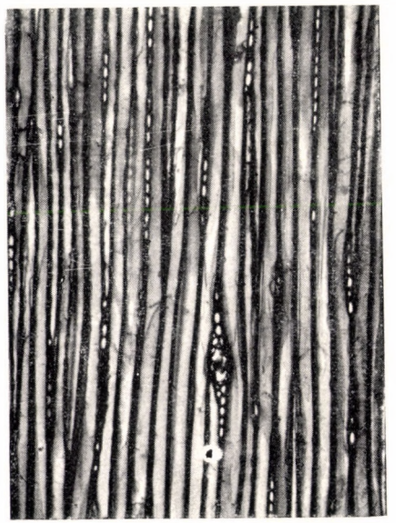




257. Picea likiangensis var. purpurea DALLIMORE et JACKSON



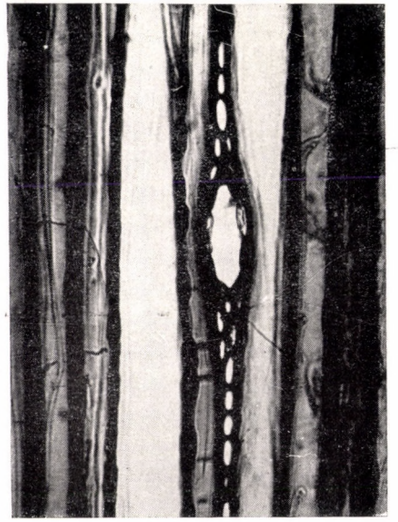
1. (100×)



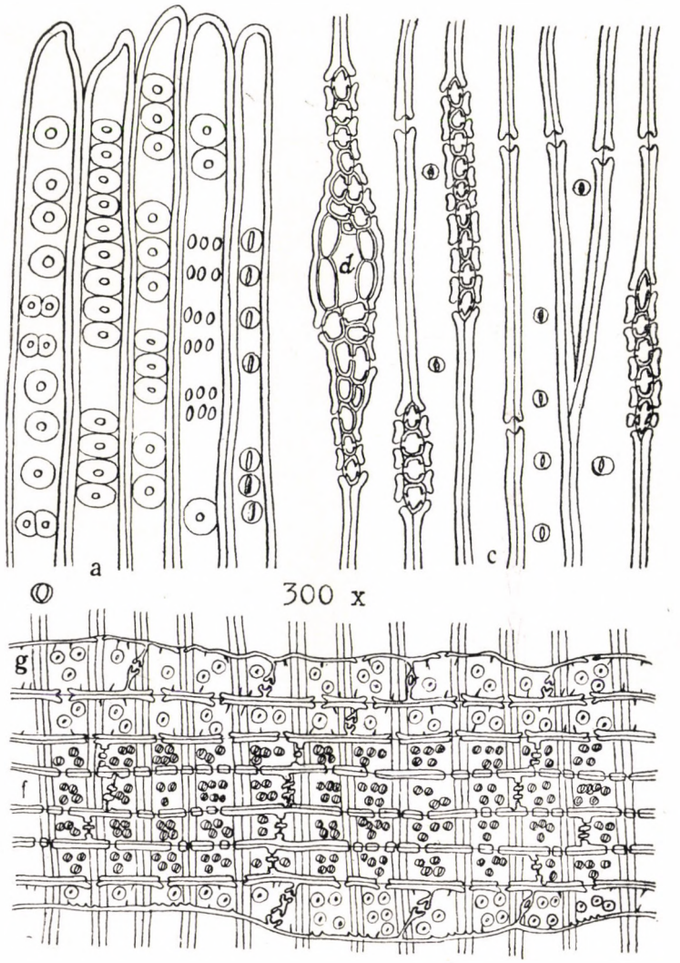
2. (100×)



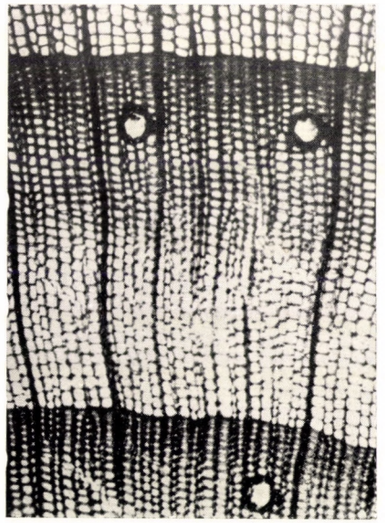
3. (300×)



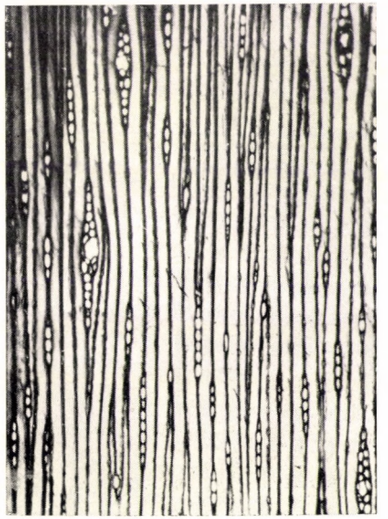
4. (300×)



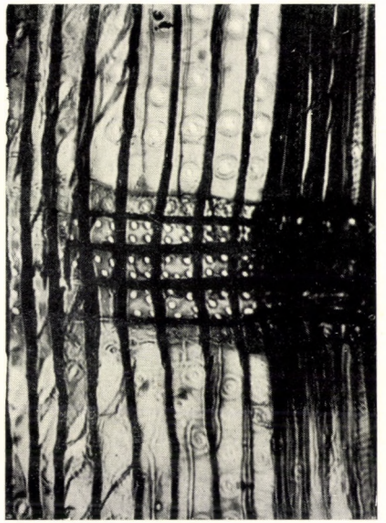
258. Picea mariana (Miller) Britton, Sterns et Poggenberg



1. (100×)



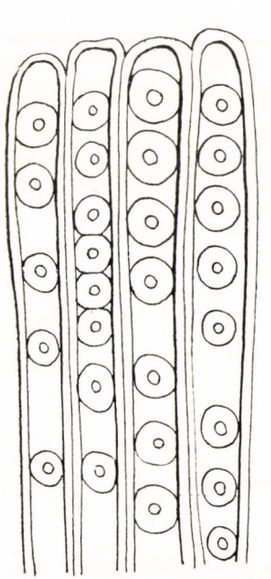
2. (100×)

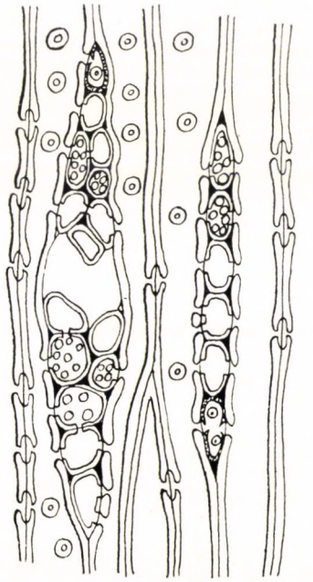


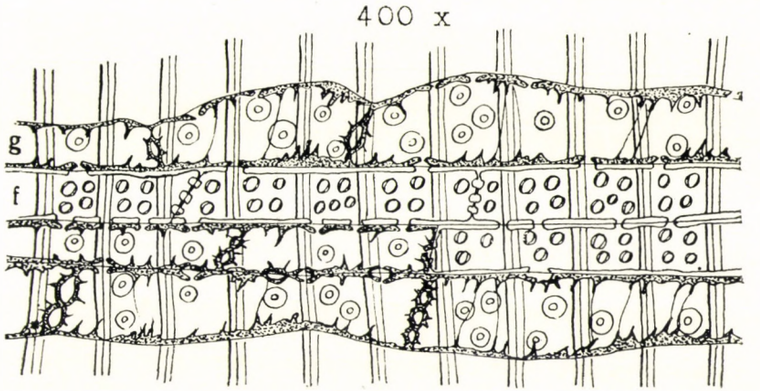
3. (300×)



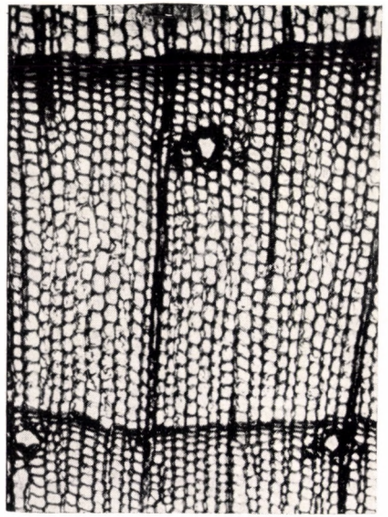
4. (300×)







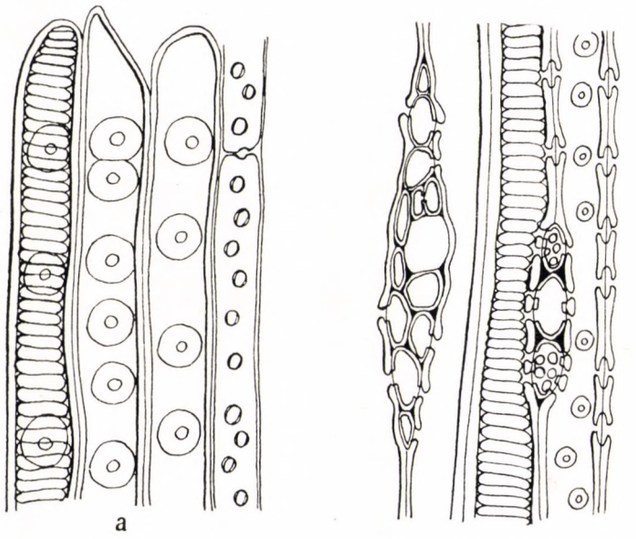
259. Picea Maximowiczii REGEL



1. (100×)

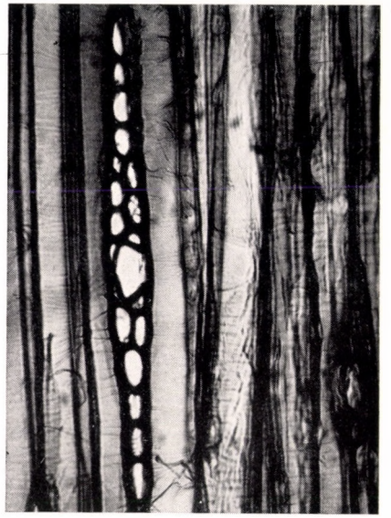


2. (100×)

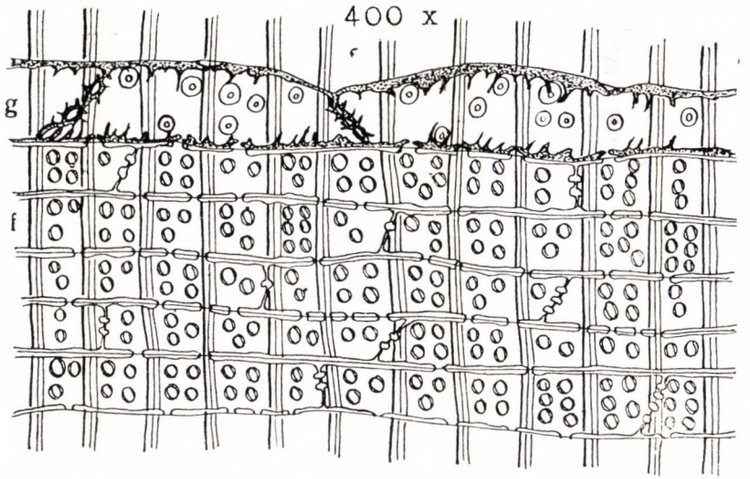




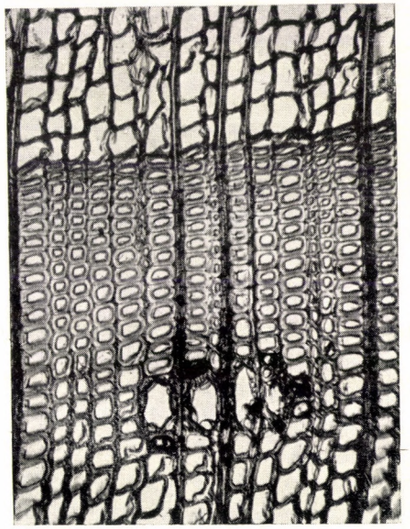
3. (300×)



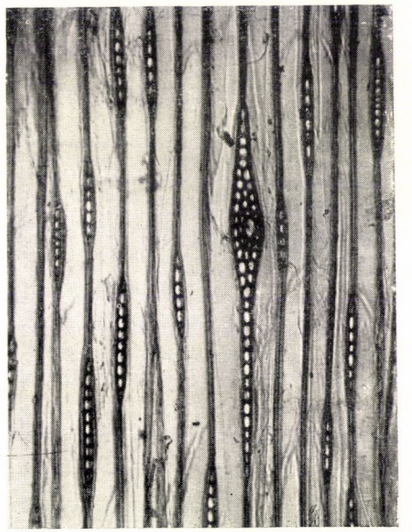
4. (300×)



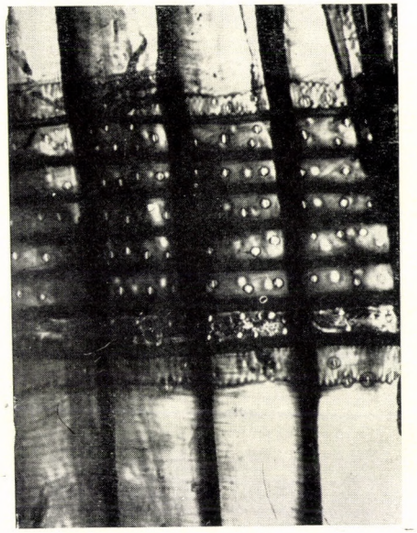
260. Picea morrisonicola HAYATA



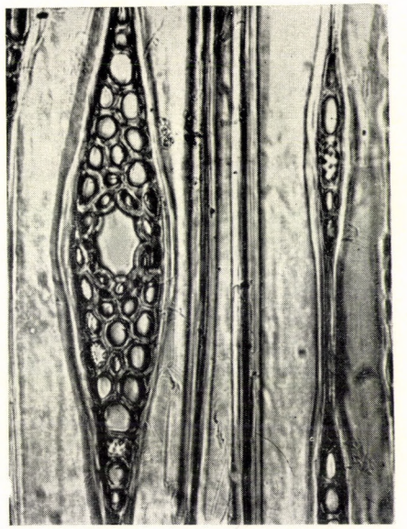
1. (100×)



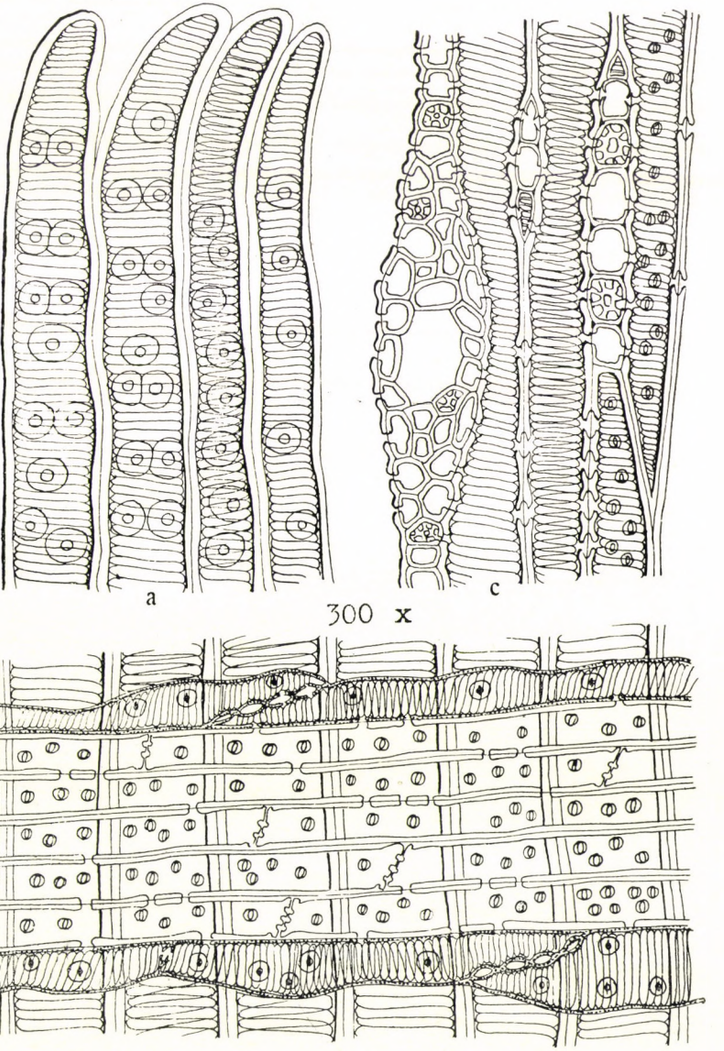
2. (100×)



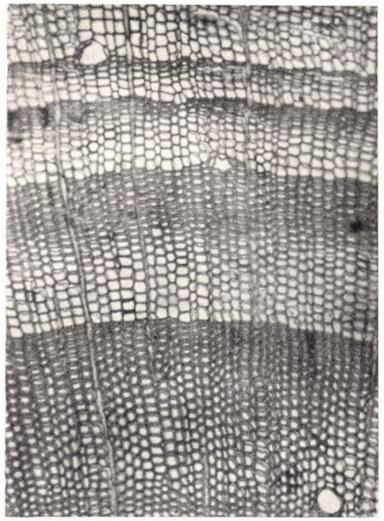
3. (300×)



4. (300×)



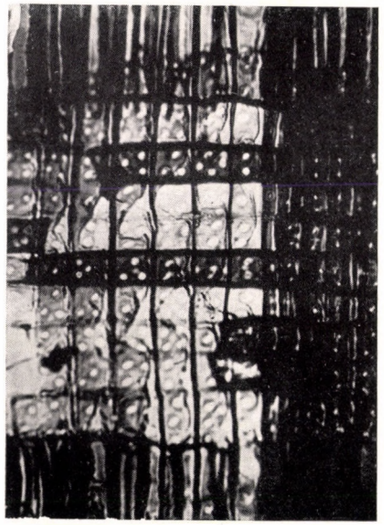
260a Picea Neoveithü



1. (100×)



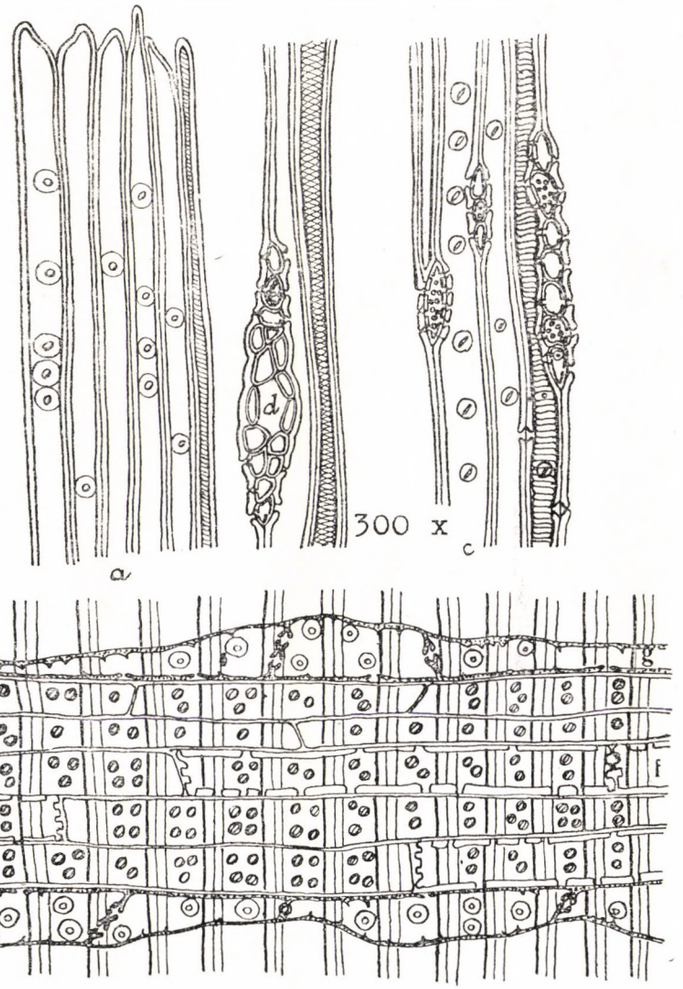
2. (100×)



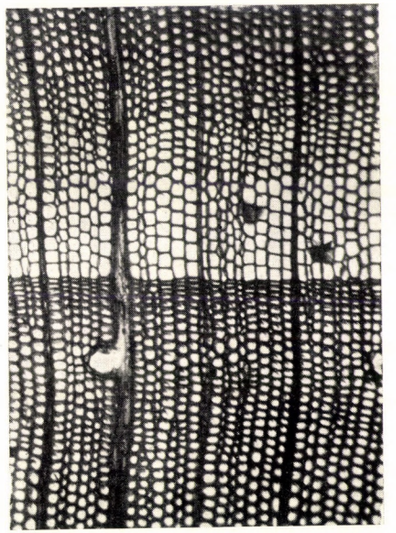
3. (300×)



4. (300×)



261. Picea obovata LEDEB.



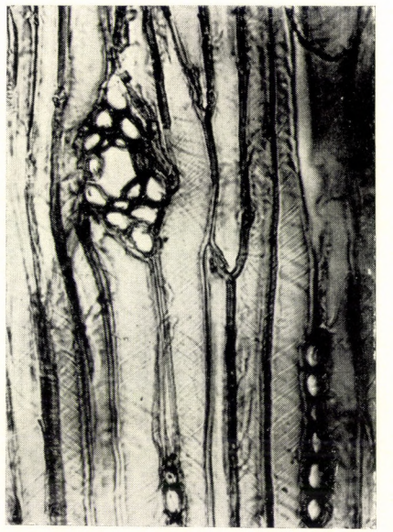
1. (100×)



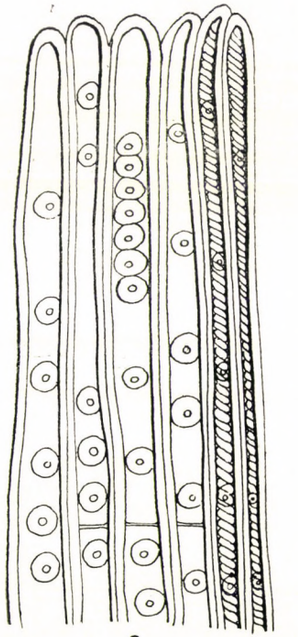
2. (100×)

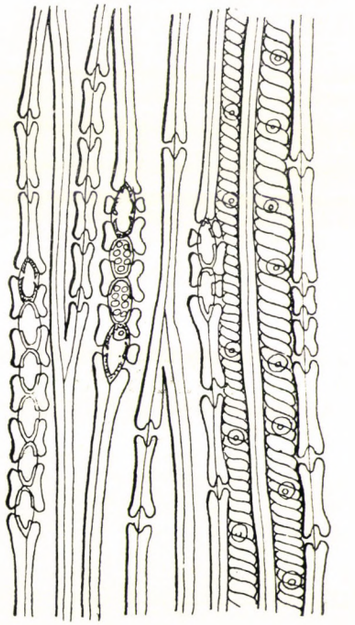


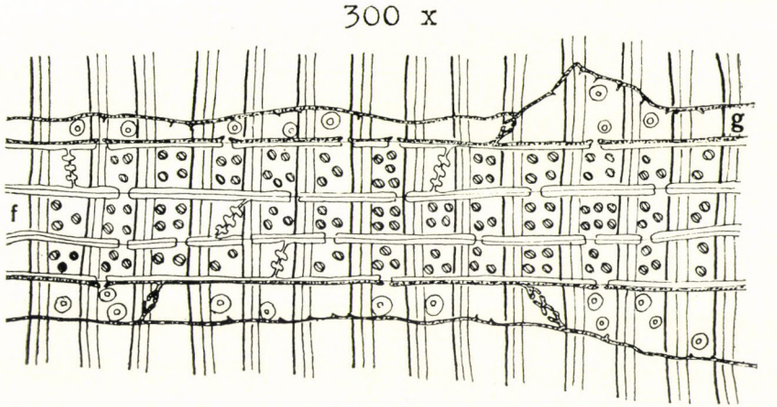
3. (300×)



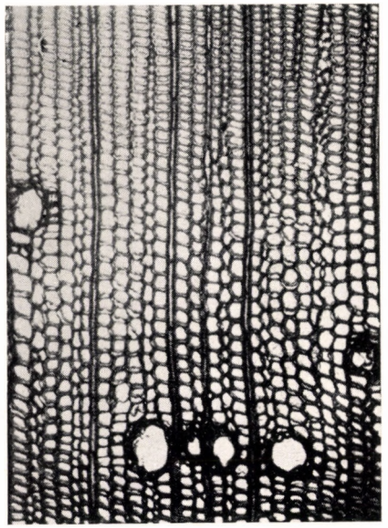
4. (300×)



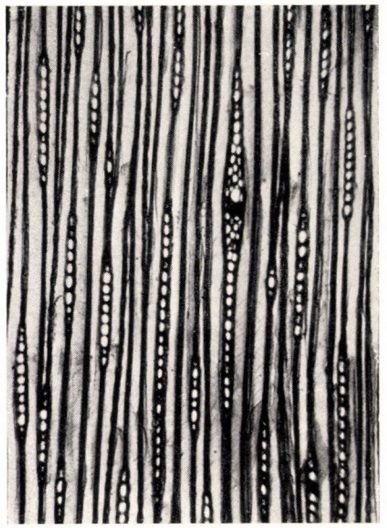




262. Picea Omorica (Pančič) Bolle



1. (100×)



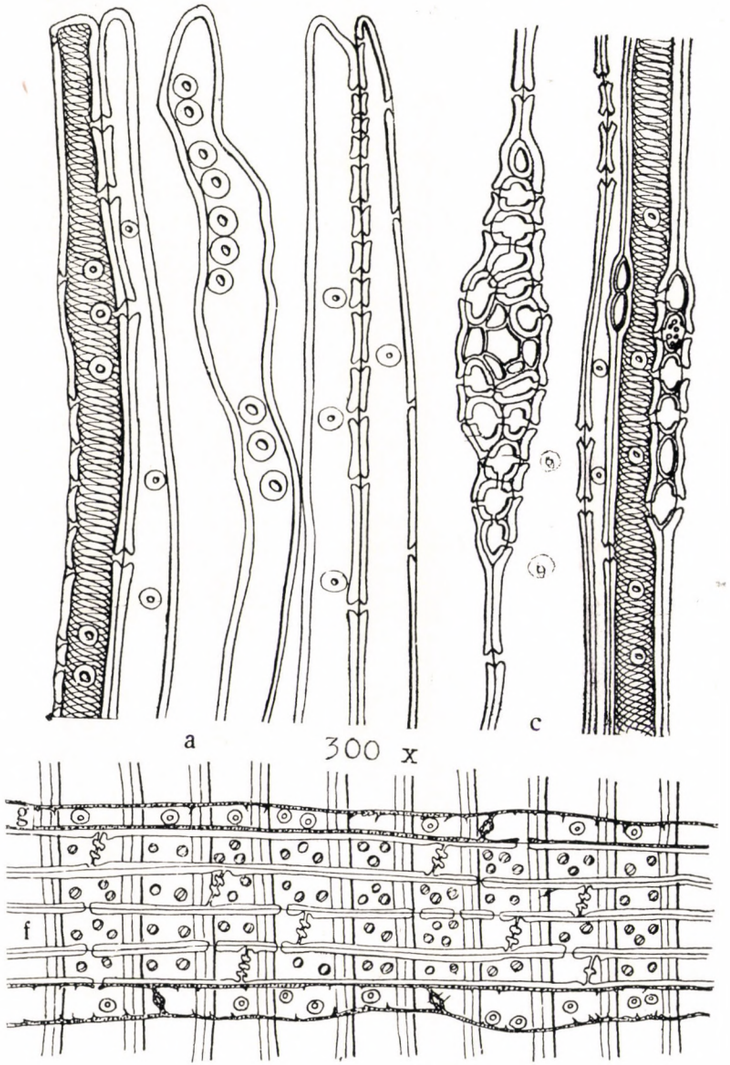
2. (100×)



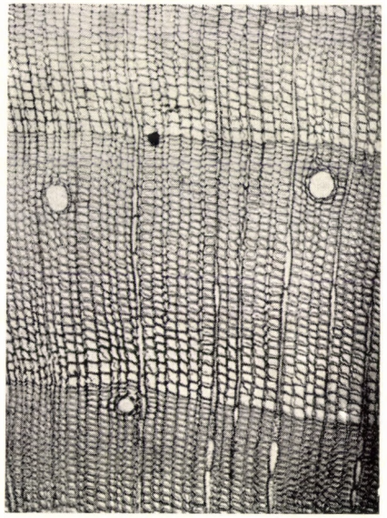
3. (300×)



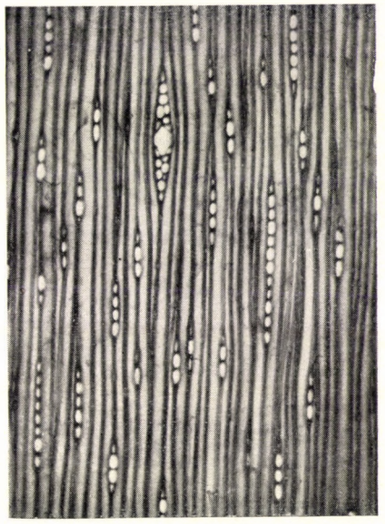
4. (300×)



263. Picea orientalis (L.) Carr.



1. (100×)



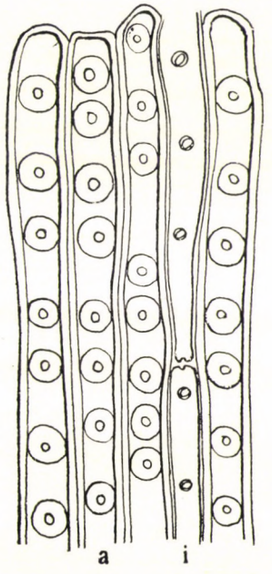
2. (100×)

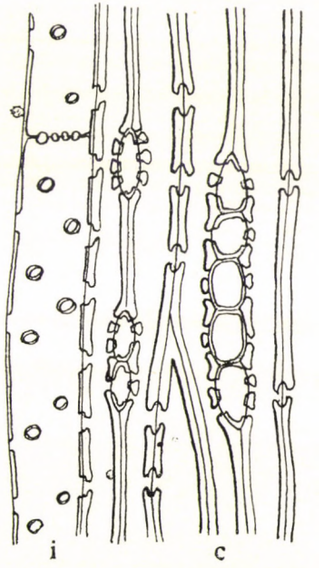


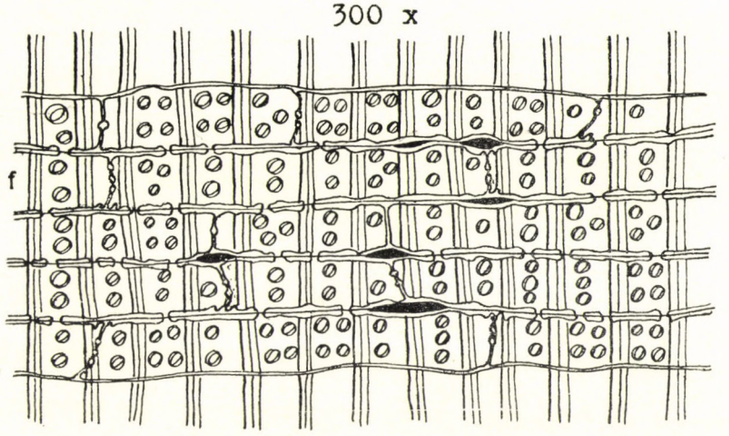
3. (300×)



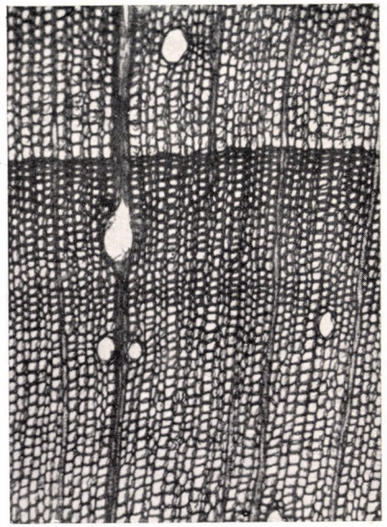
4. (300×)







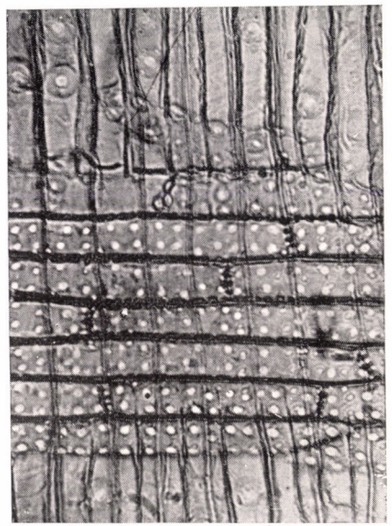
264. Picea polita (Sieb. et Zucc.) Carr.



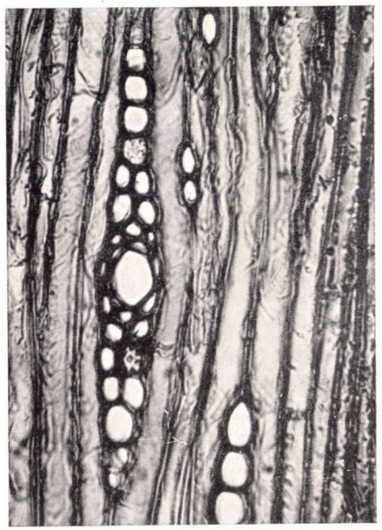
1. (100×)



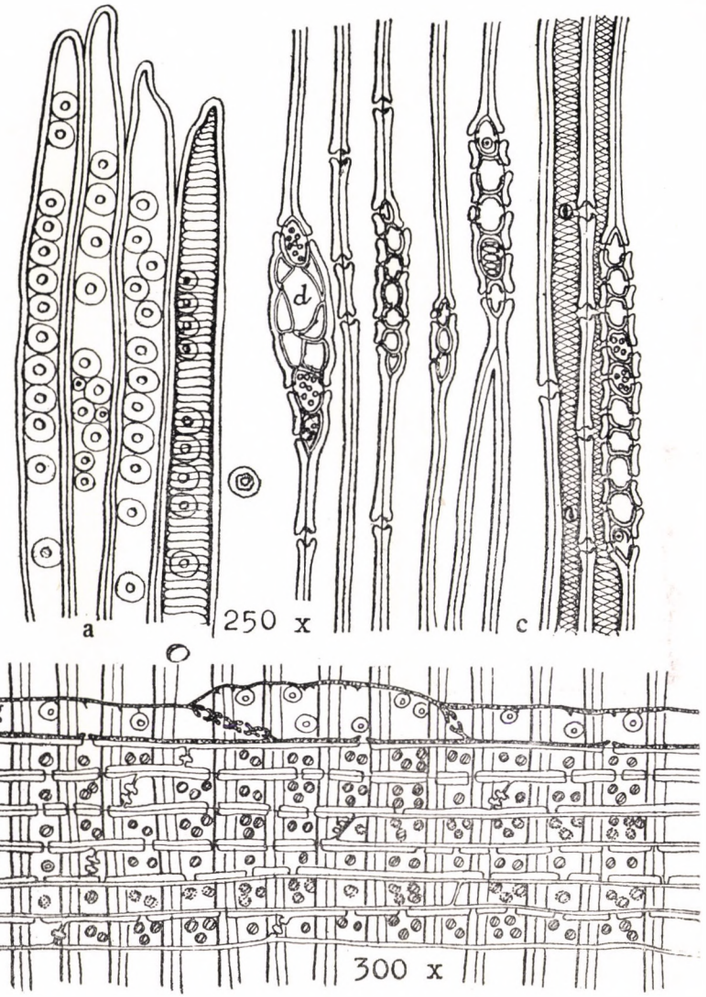
2. (100×)



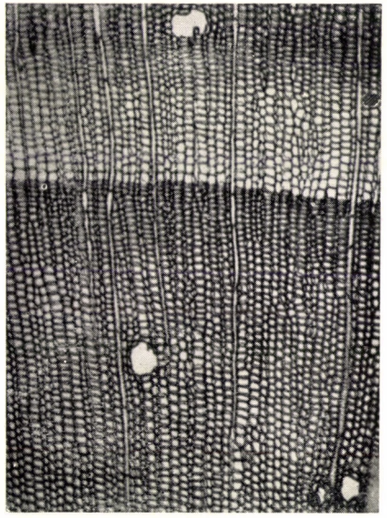
3. (300×)



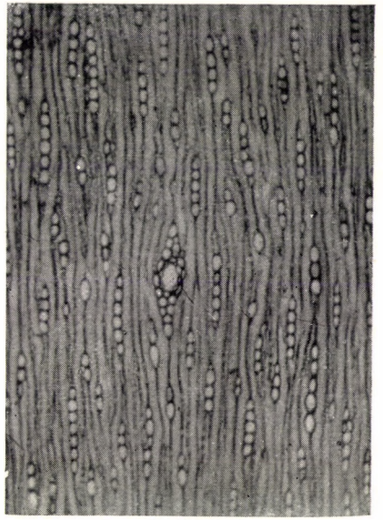
4. (300×)



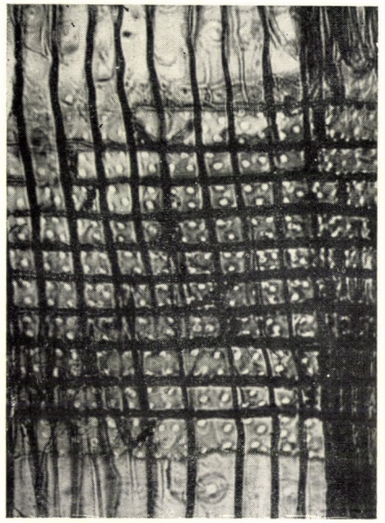
265. Picea pungens ENGELMANN



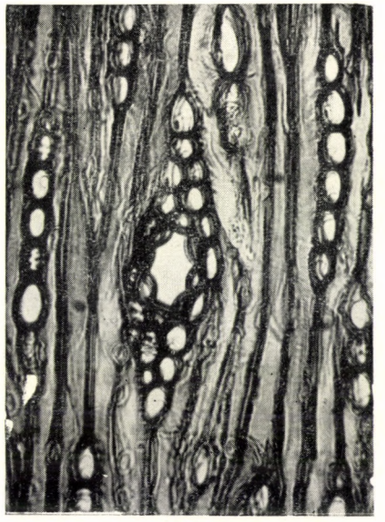
1. (100×)



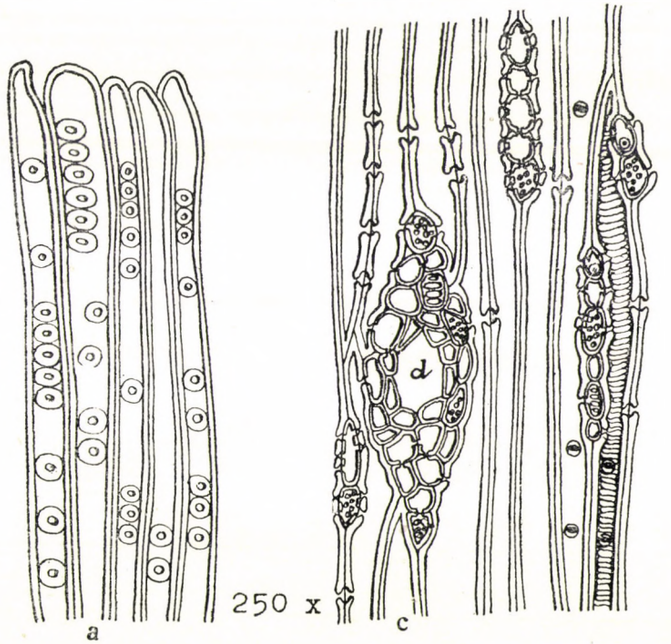
2. (100×)

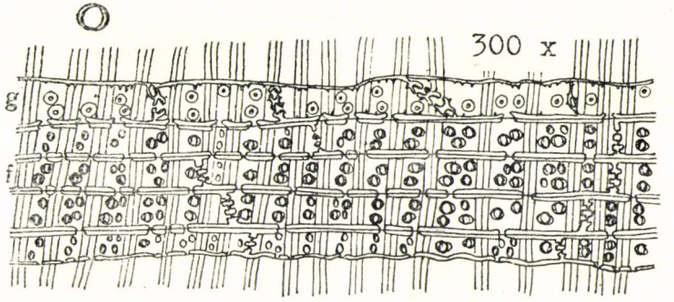


3. (300×)

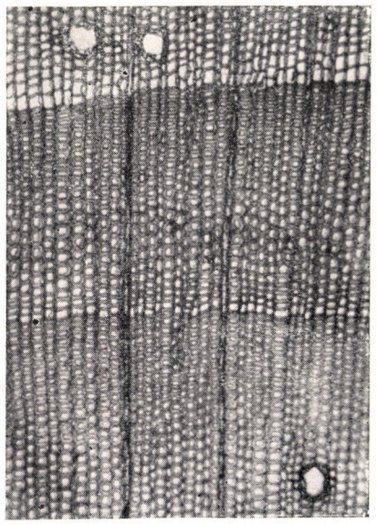


4. (300×)





266. Picea Schrenkiana FISCHER et MEYER



1. (100×)



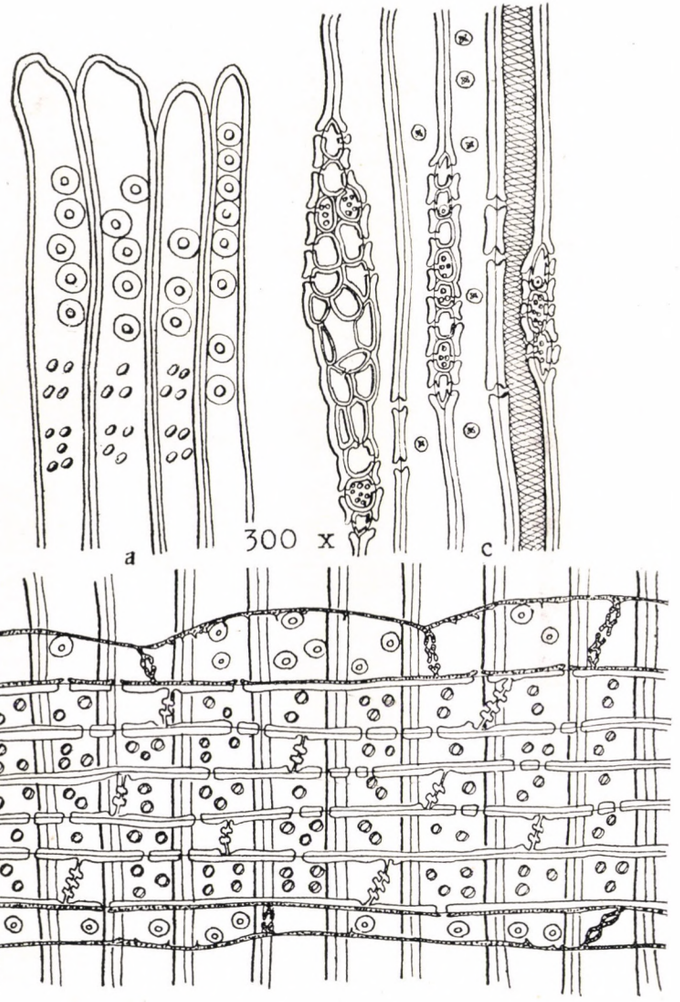
2. (100×)



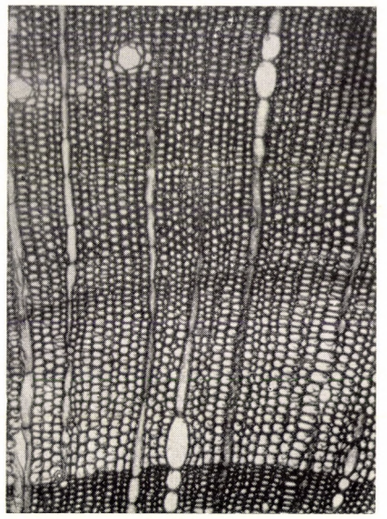
3. (300×)



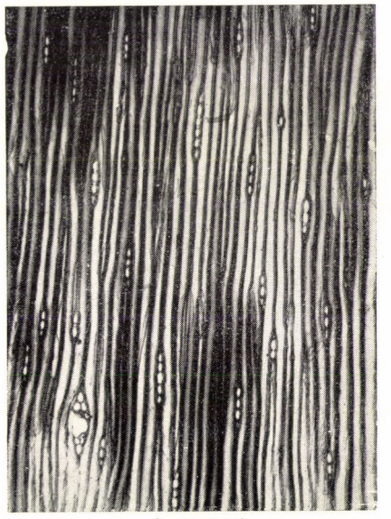
4. (300×)



267. Picea sitchensis (Bongard) Carr.



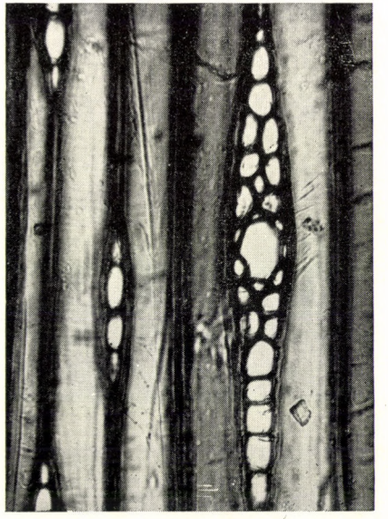
1. (100×)



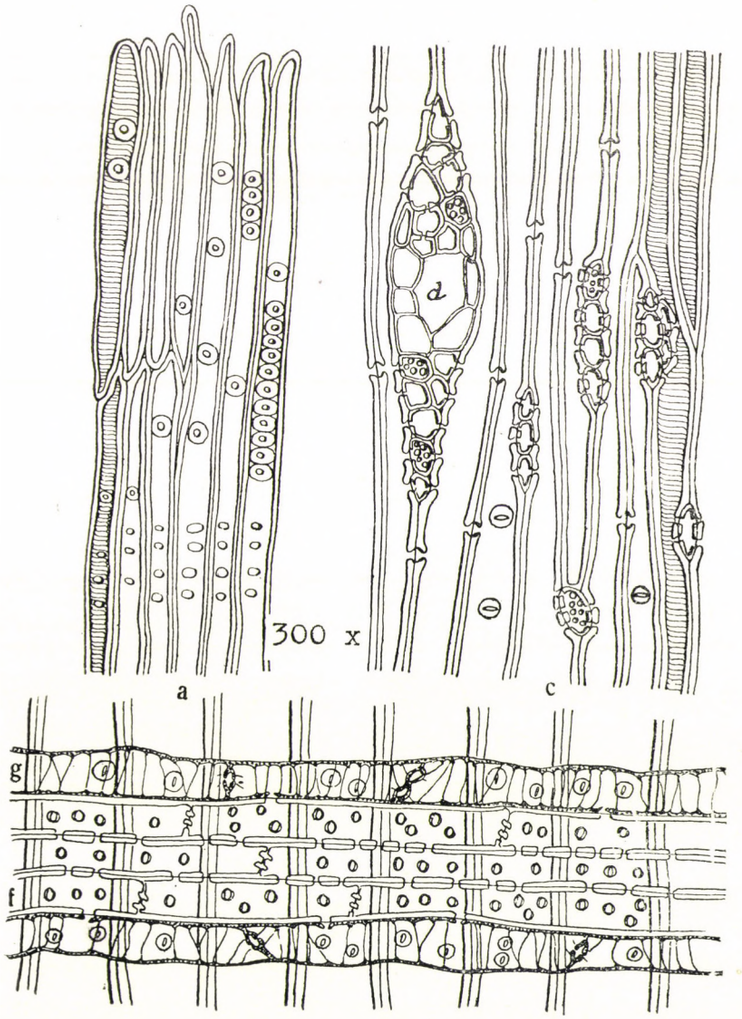
2. (100×)



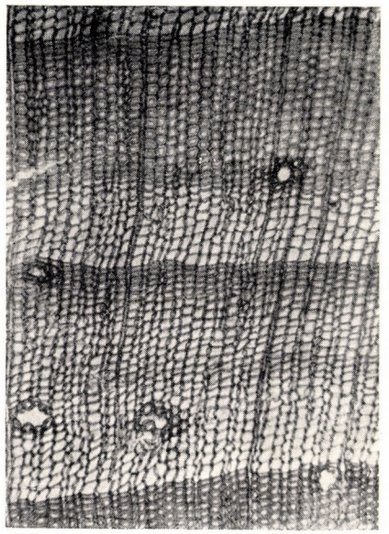
3. (300×)



4. (300×)



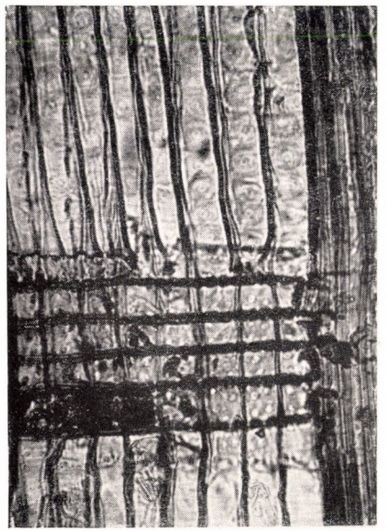
268. Picea Smithiana (Wallich) Boisser



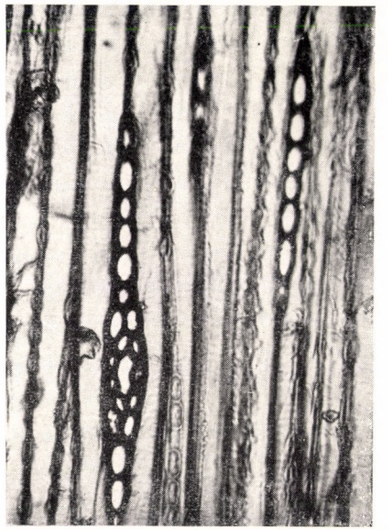
1. (100×)



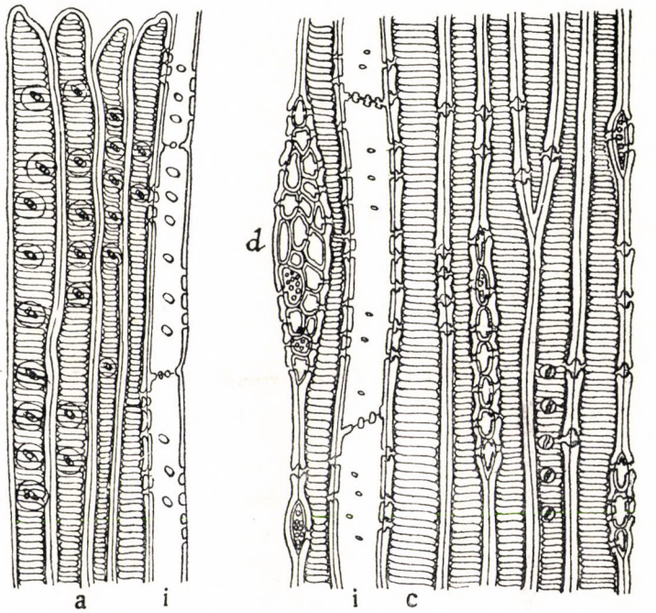
2. (100×)



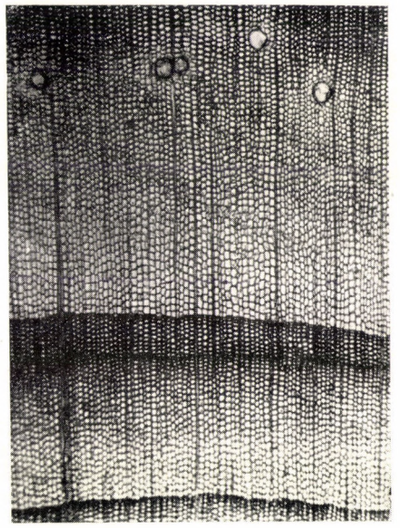
3. (300×)



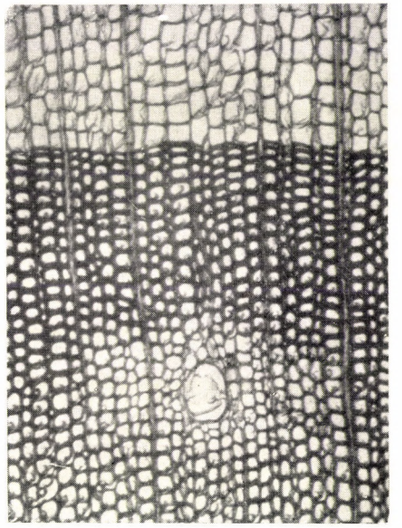
4. (300×)



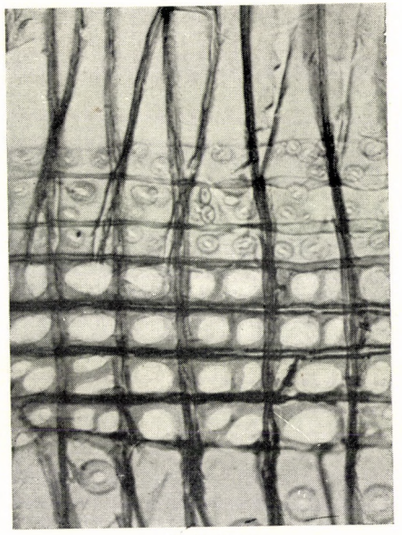
269. Picea Wilsonii MAST.



1. (30×)



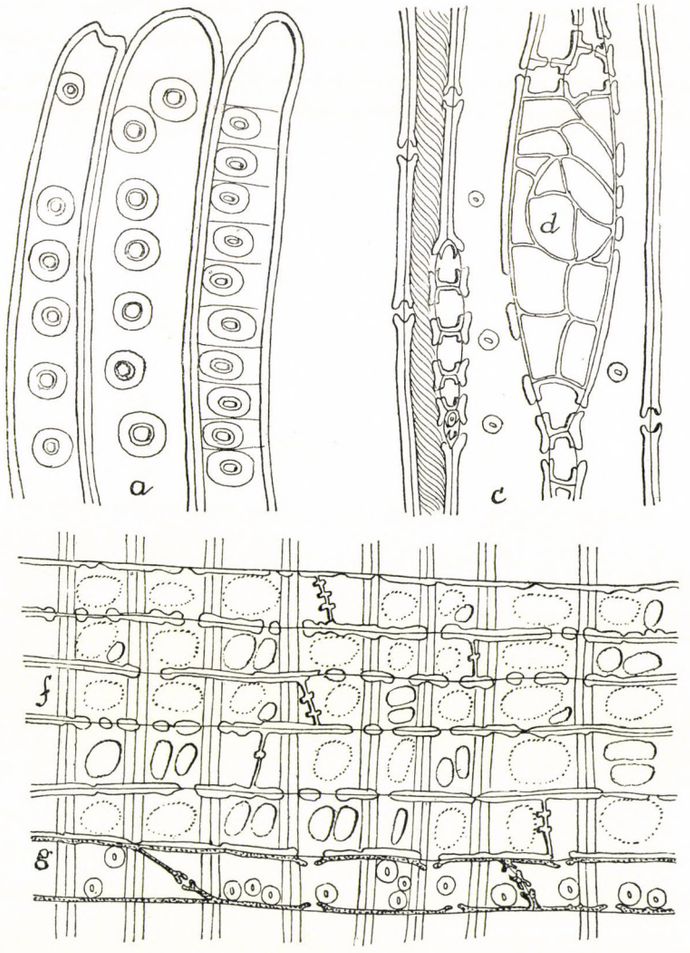
2. (100×)



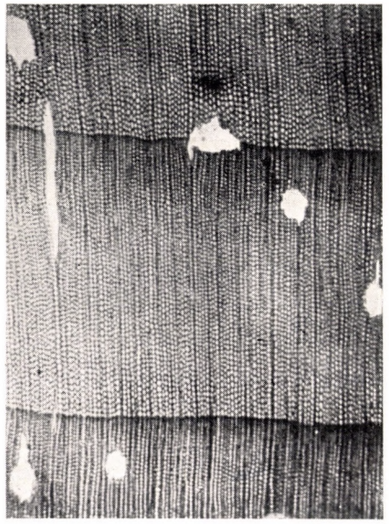
3. (300×)



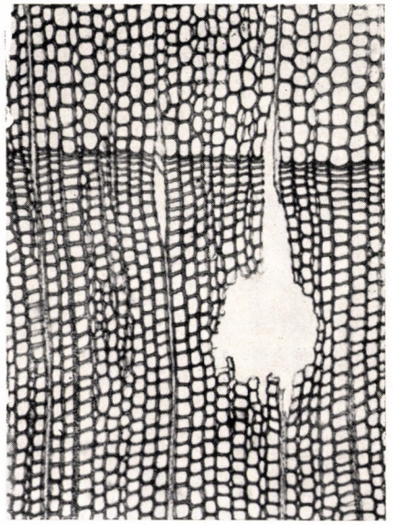
4. (100×)



270. Pinus albicaulis ENGELMANN



1. (30×)



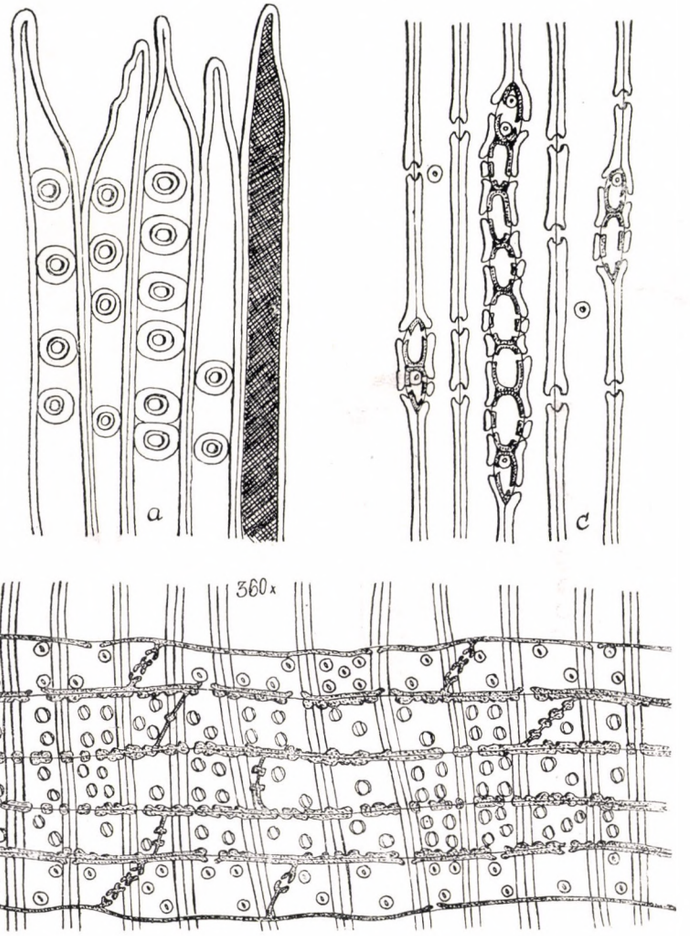
2. (100×)



3. (300×)



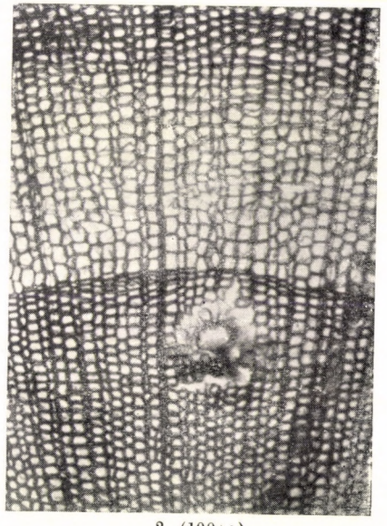
4. (100×)



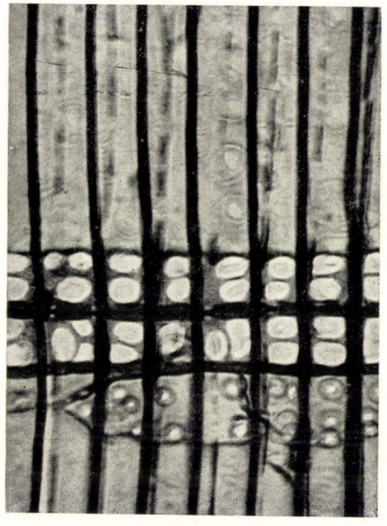
271. Pinus aristata ENGELMANN



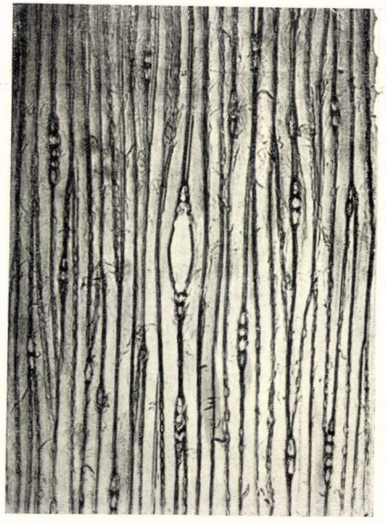
1. (30×)



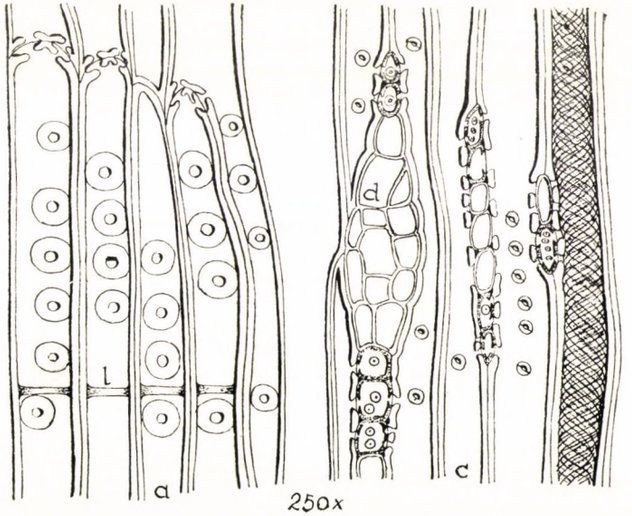
2. (100×)

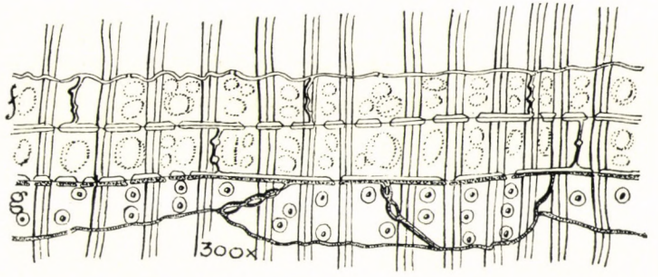


3. (300×)

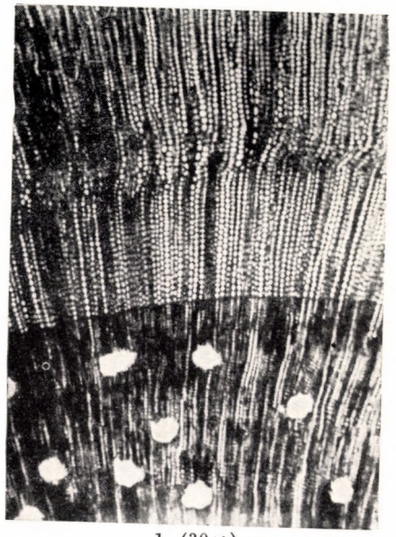


4. (100×)

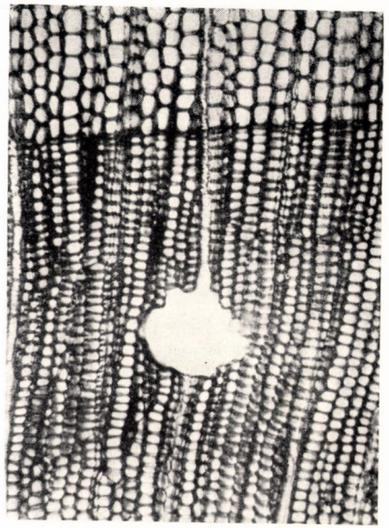




272. Pinus Armandi FRANCHET



1. (30×)



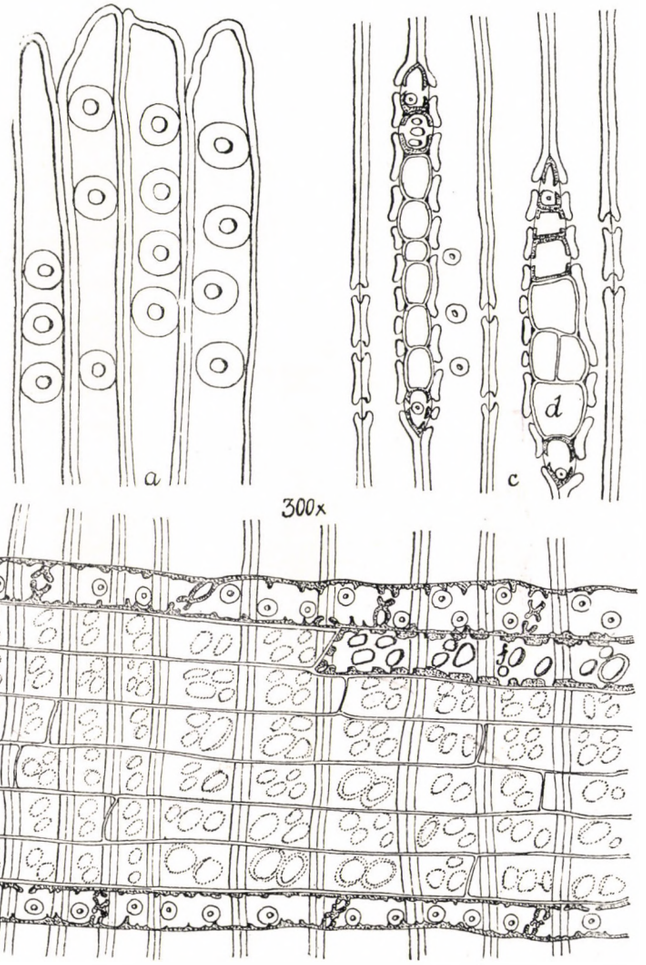
2. (100×)



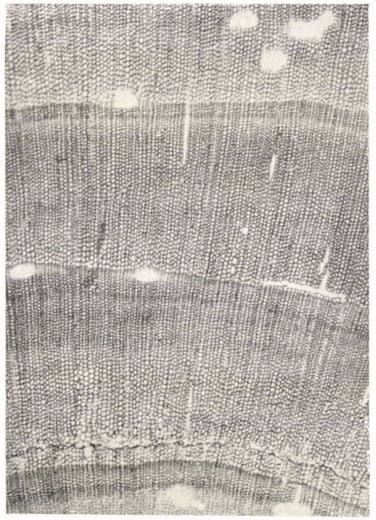
3. (300×)



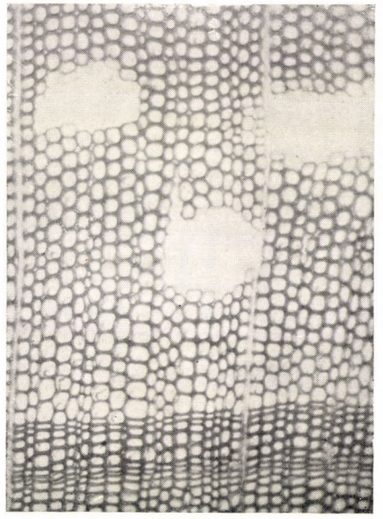
4. (100×)



273. Pinus attenuata LEMON



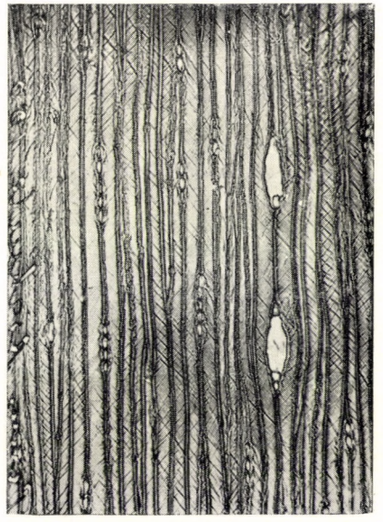
1. (30×)



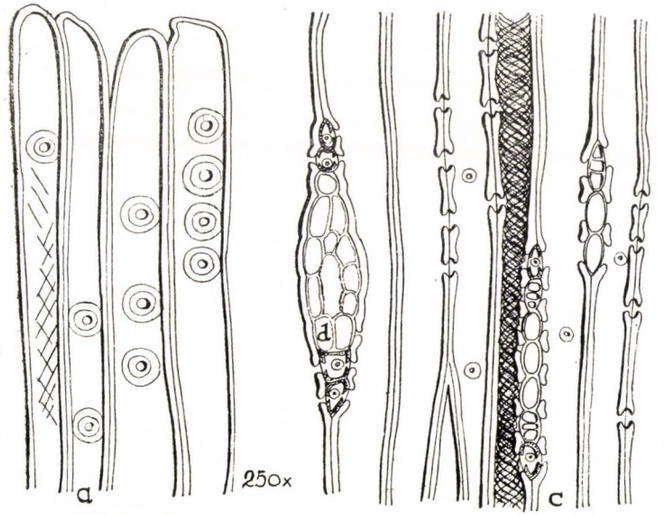
2. (100×)

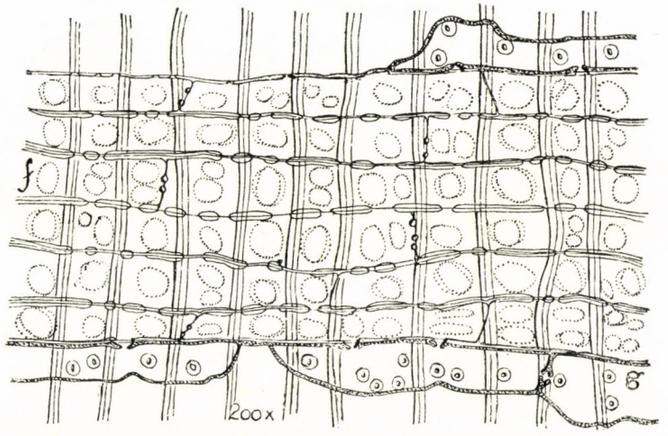


3. (300×)

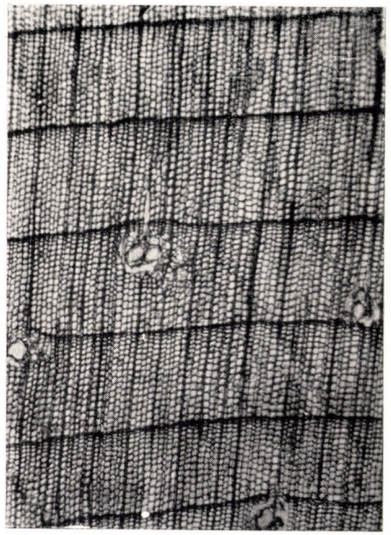


4. (100×)

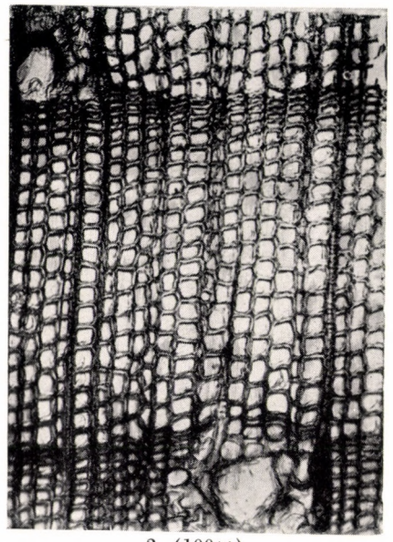




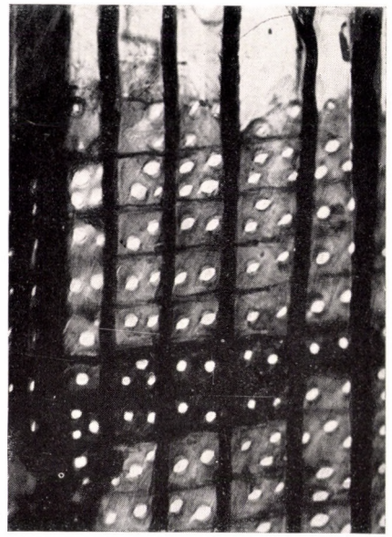
274. Pinus Ayacahuite EHRENBERG



1. (30×)



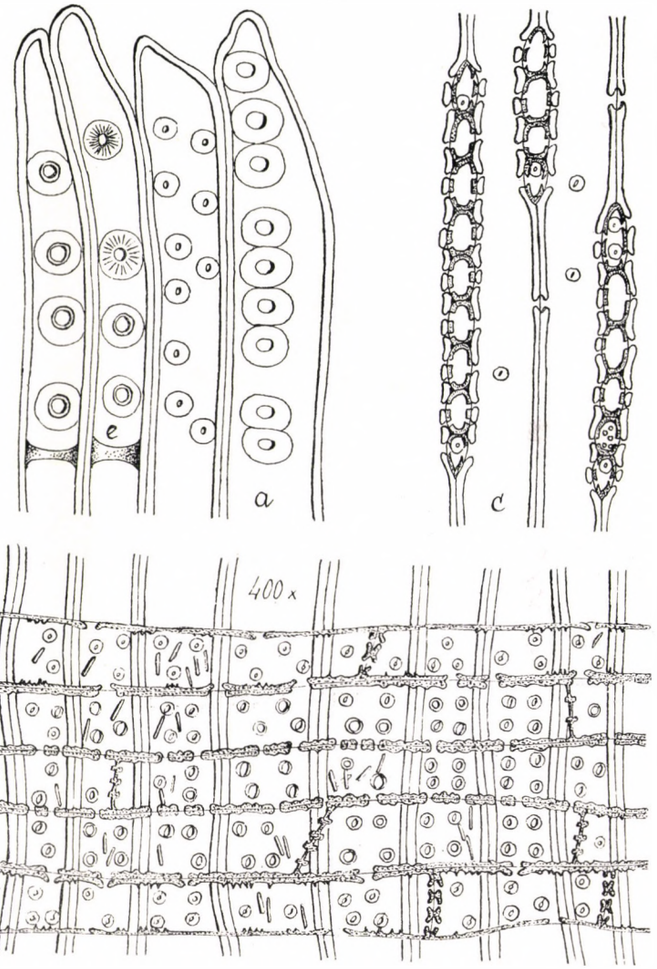
2. (100×)



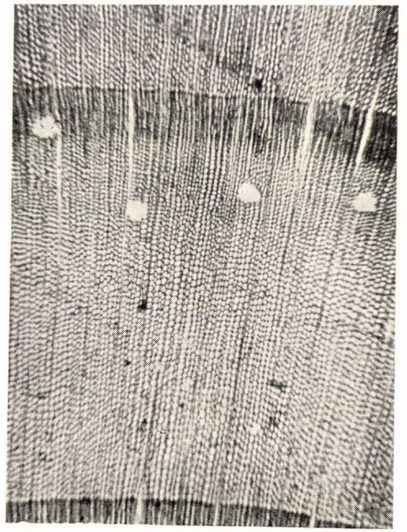
3. (300×)



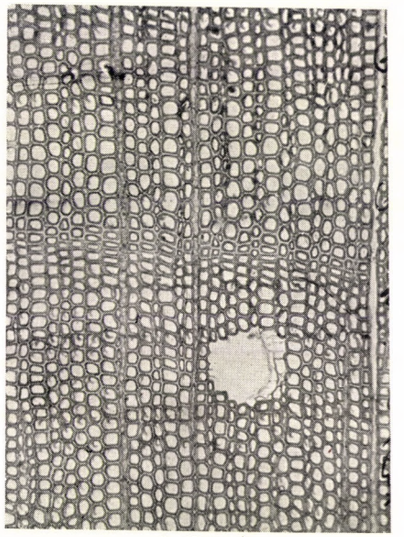
4. (100×)



275. Pinus Balfouriana JEFFREY et A. MURRAY



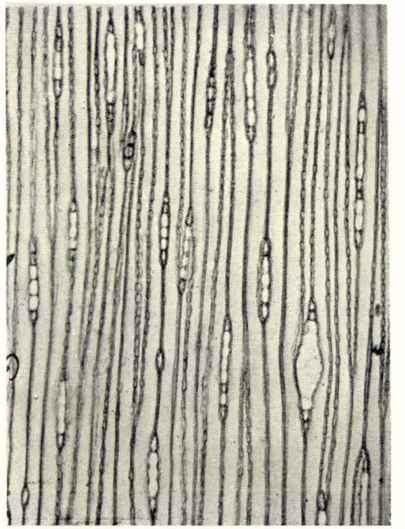
1. (30×)



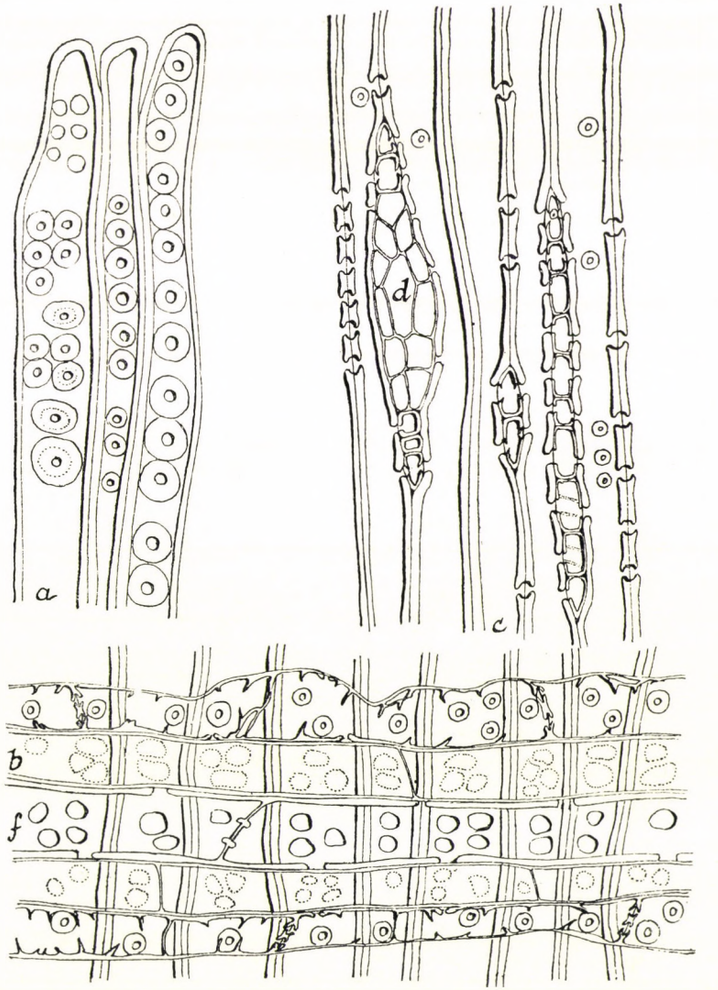
2. (100×)



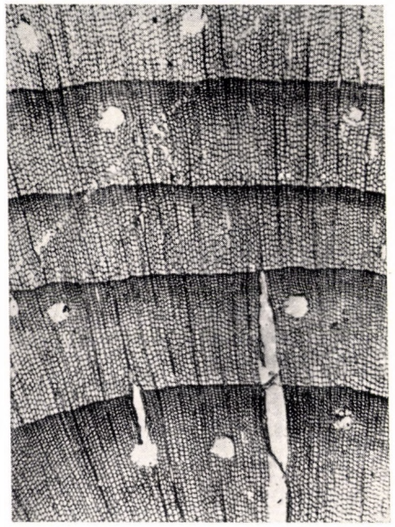
3. (300×)



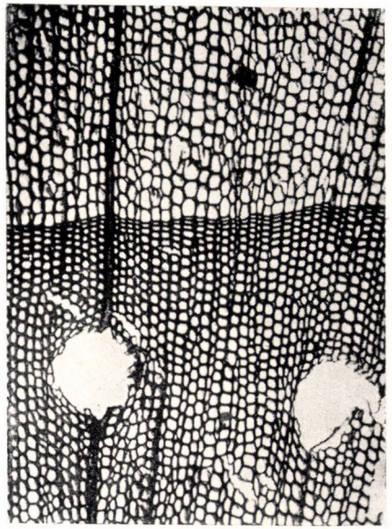
4. (100×)



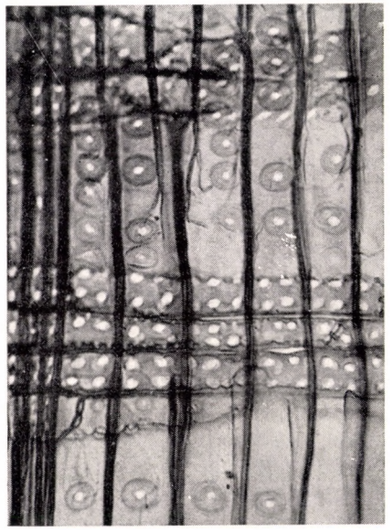
276. Pinus Banksiana LAMBERT



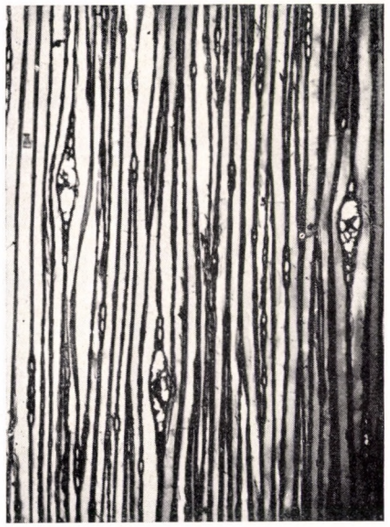
1. (30×)



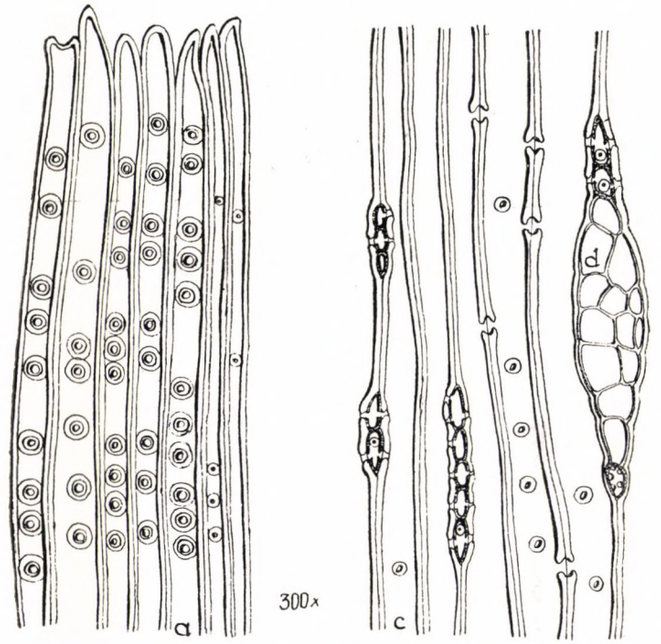
2, (100×)

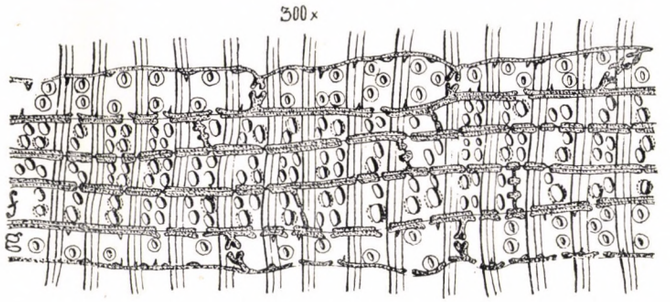


3. (300×)

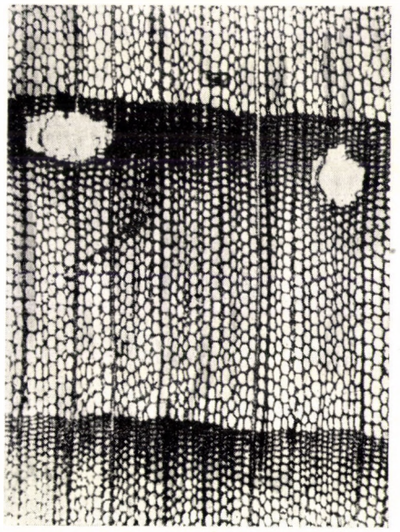


4. (100×)

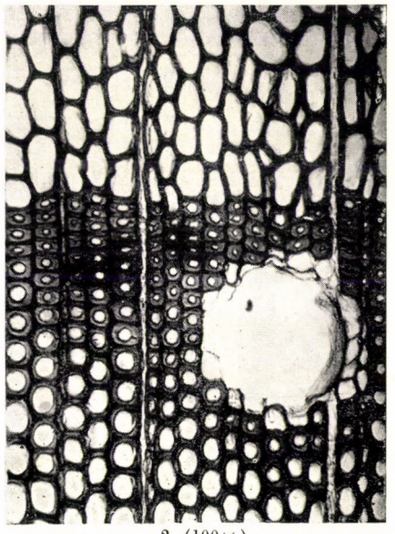




277. Pinus Bungeana Zucc.



1. (30×)



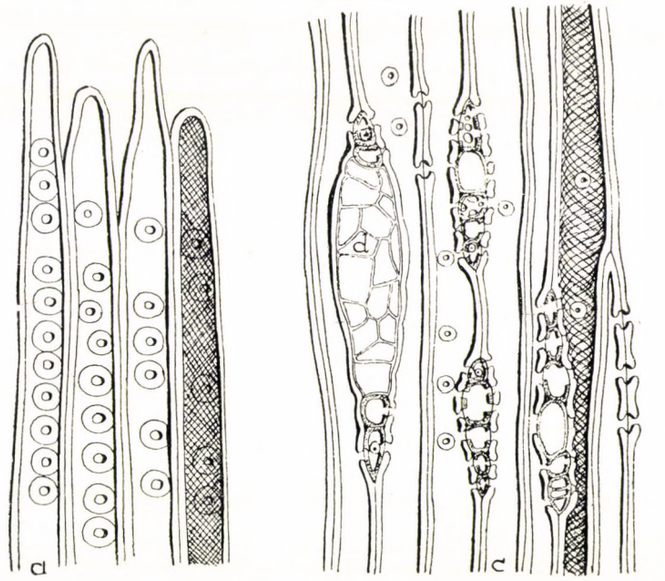
2. (100×)

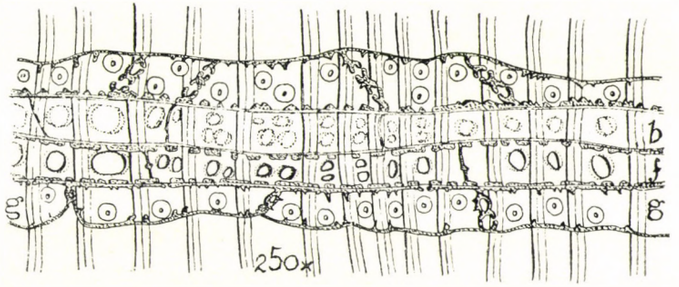


3. (300×)

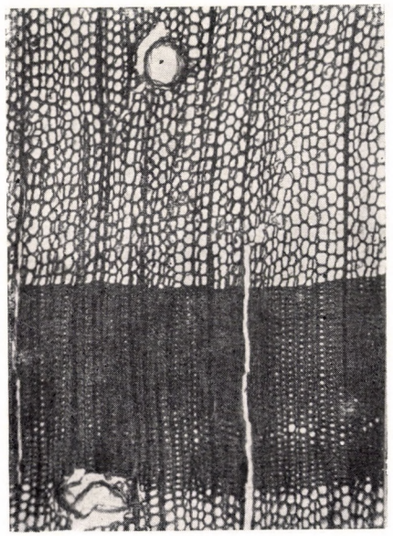


4. (100×)

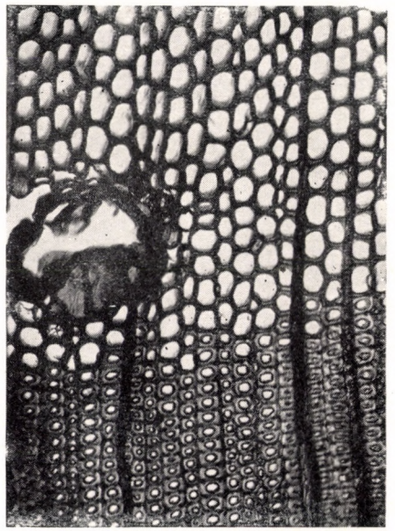




278. **Pinus canariensis** C. SMITH



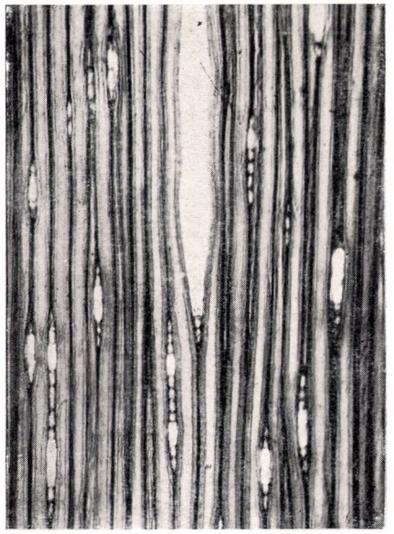
1. (30×)



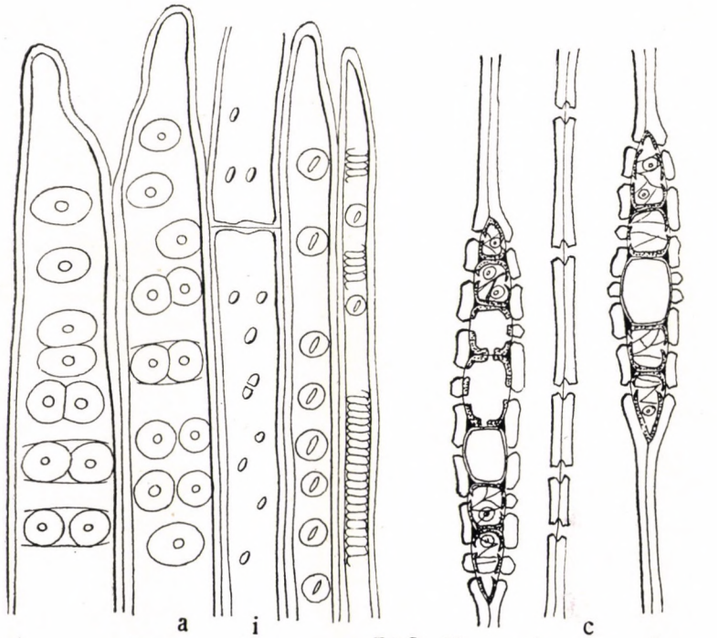
2. (100×)

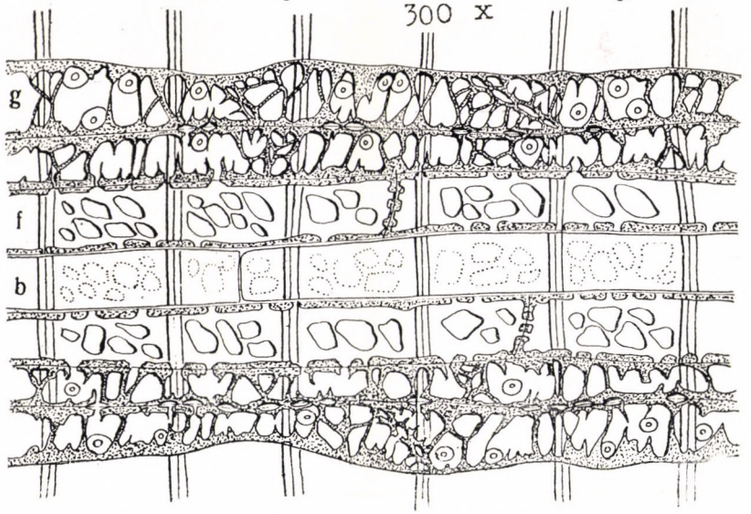


3. (300×)*

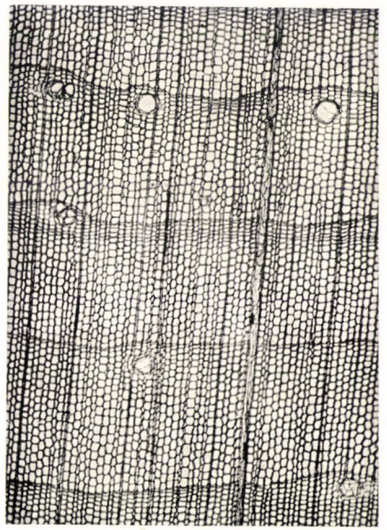


4. (100×)

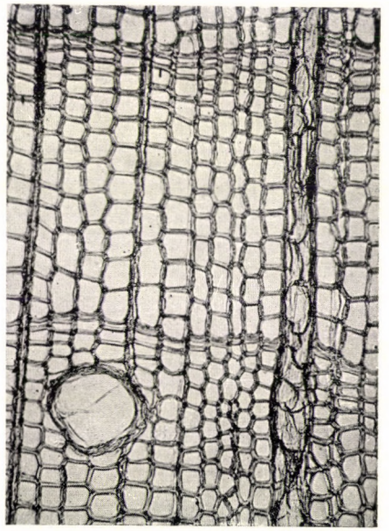




278a Pinus caribaea MOORE



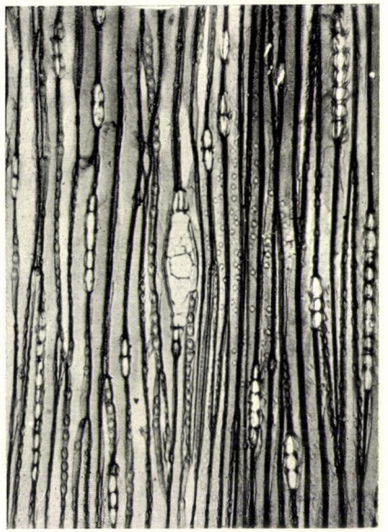
1. (30×)



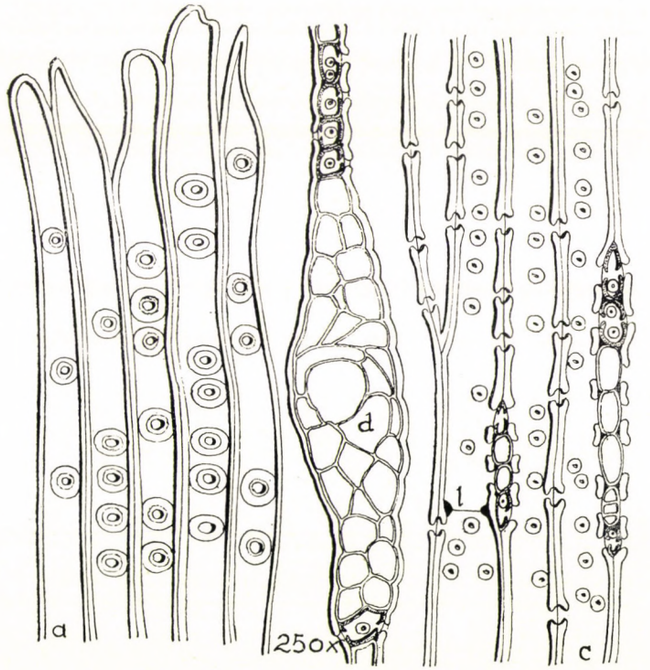
2. (100×)

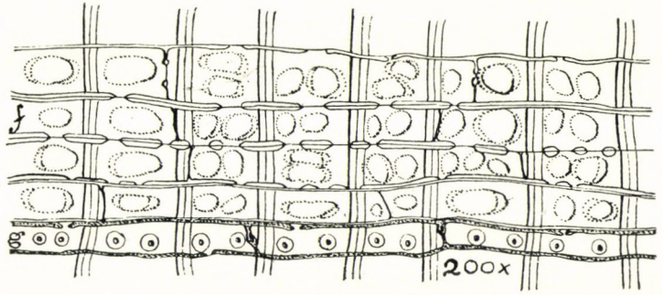


3. (300×)

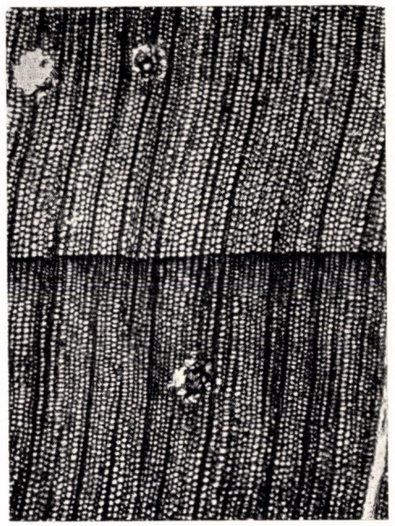


4. (100×)

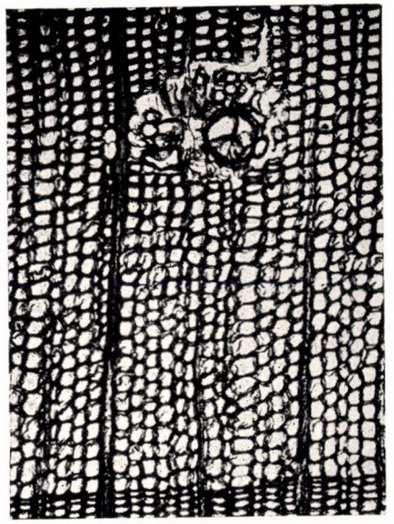




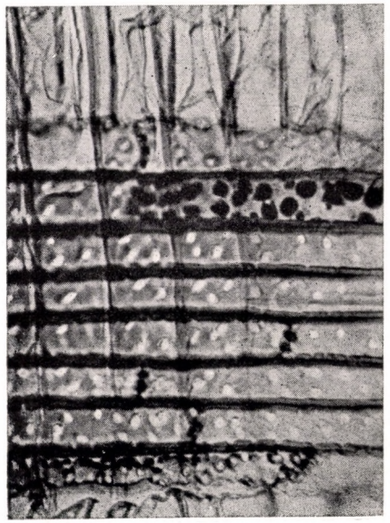
279. Pinus Cembra L.



1. (30×)



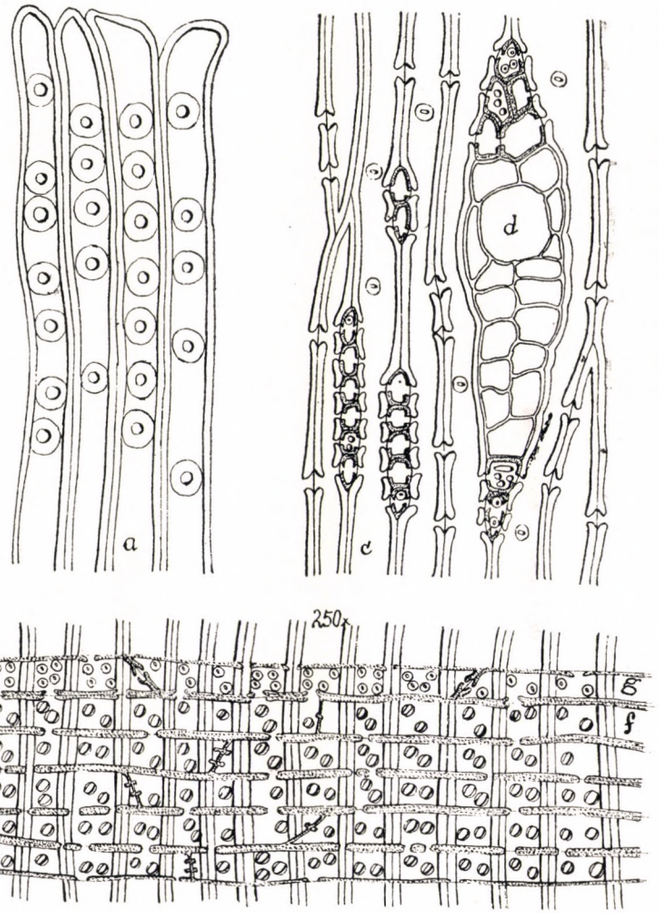
2. (100×)



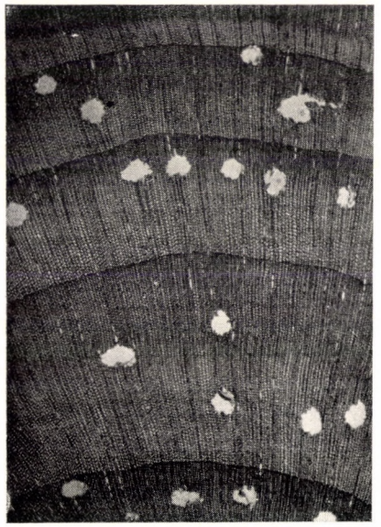
3. (300×)



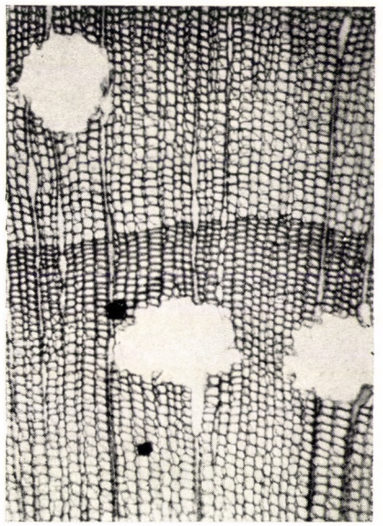
4. (100×)



280. Pinus cembroides Zucc.



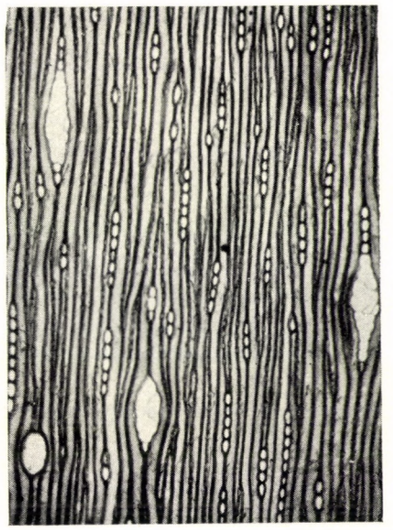
1. (30×)



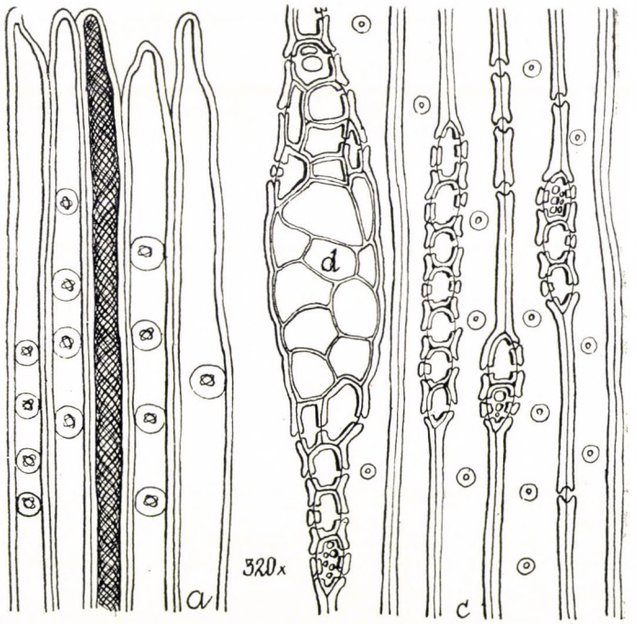
2. (100×)

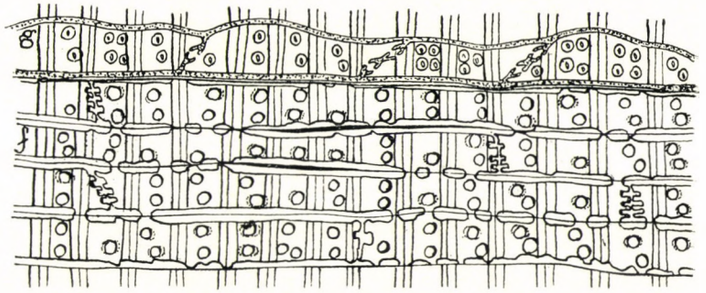


3. (300×)

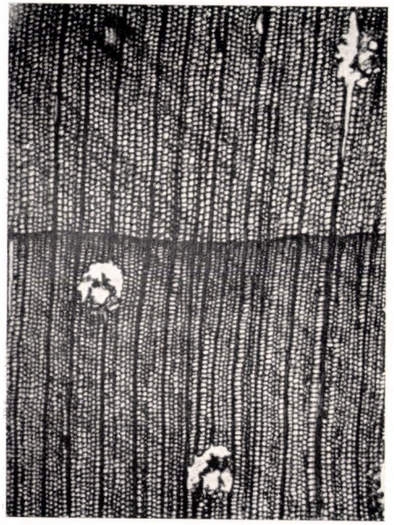


4. (100×)

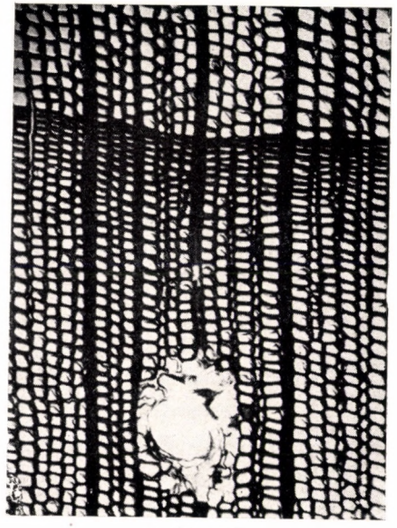




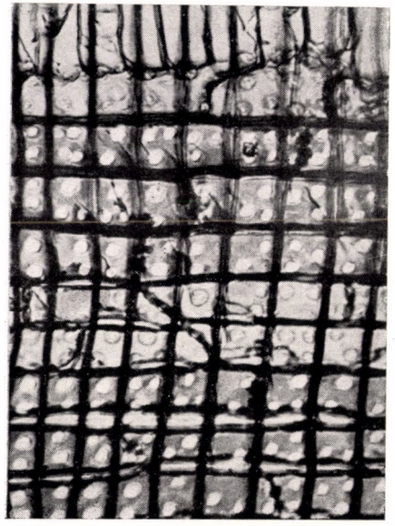
281. Pinus cembroides var. edulis (Engelmann) Voss



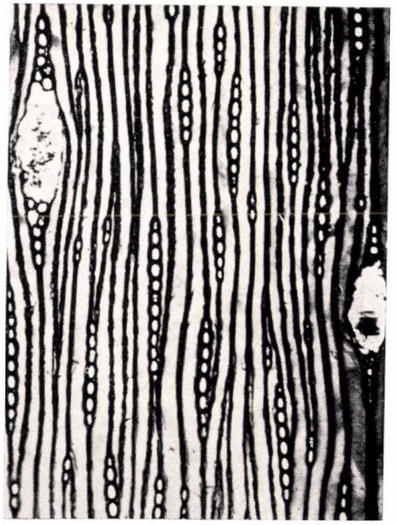
1. (30×)



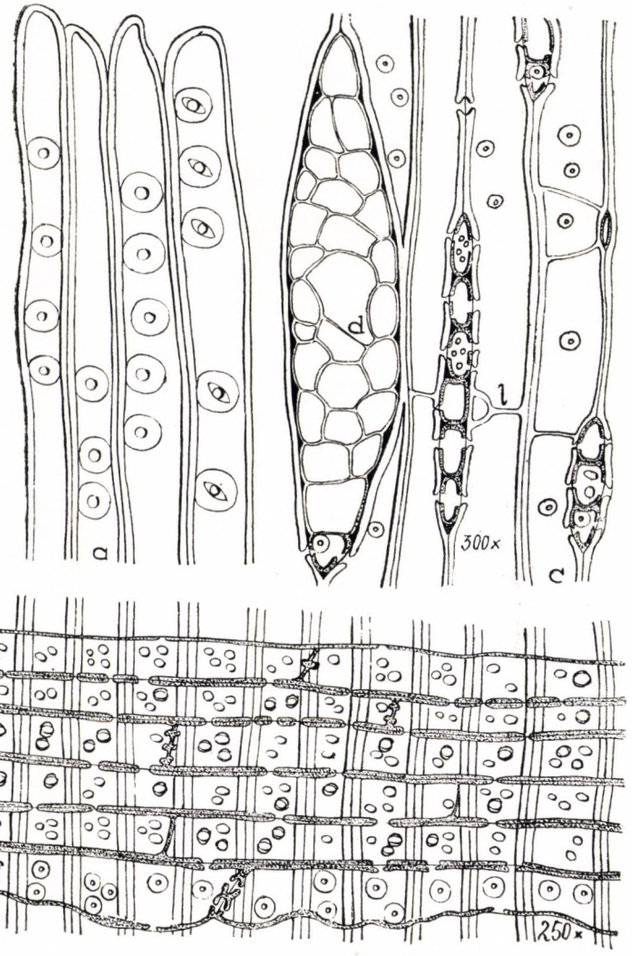
2. (100×)



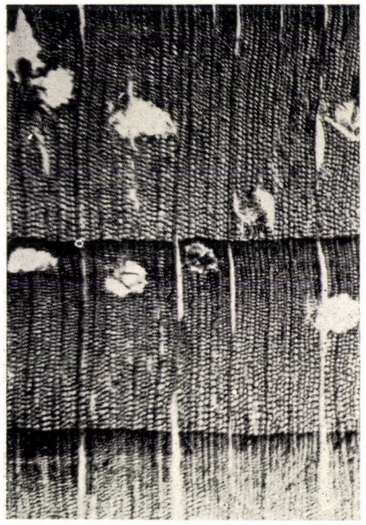
3. (300×)



4. (100×)



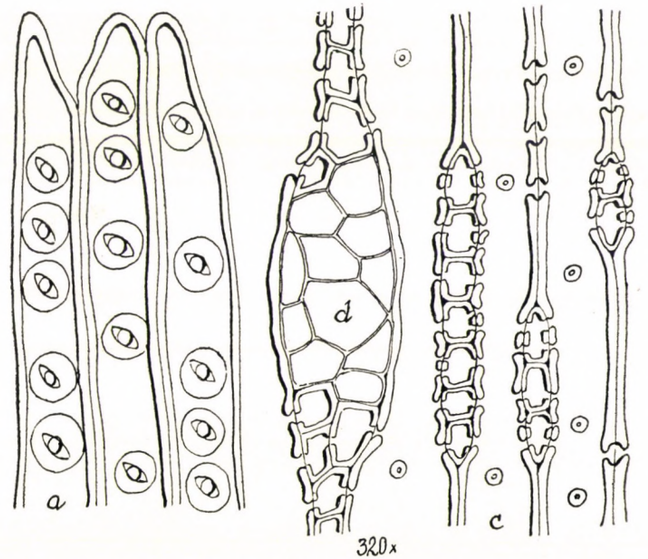
282. Pinus cembroides var. monophylla (Torrey et Fremont) Voss



1. (30×)



2. (100×)

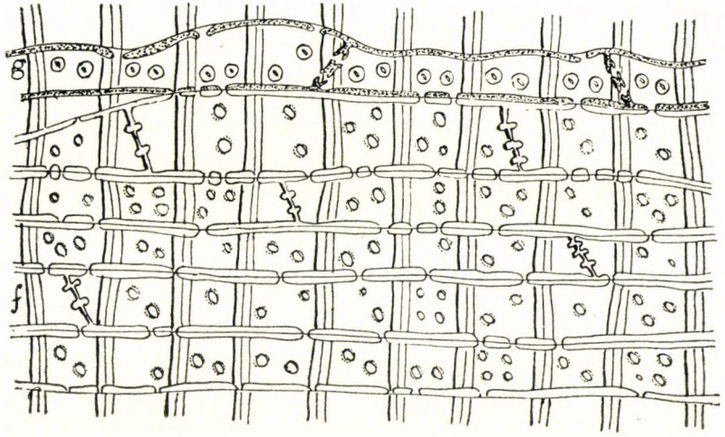




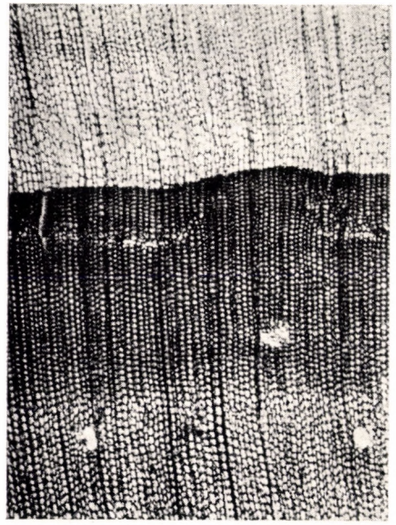
3. (300×)



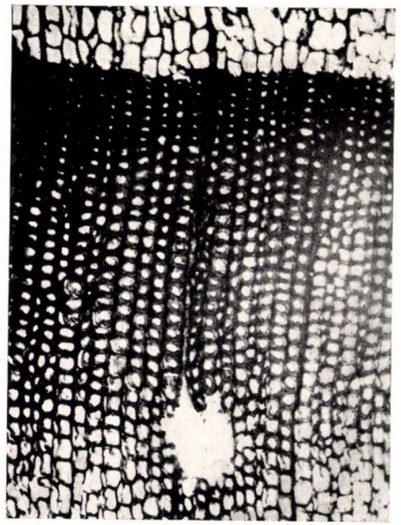
4. (100×)



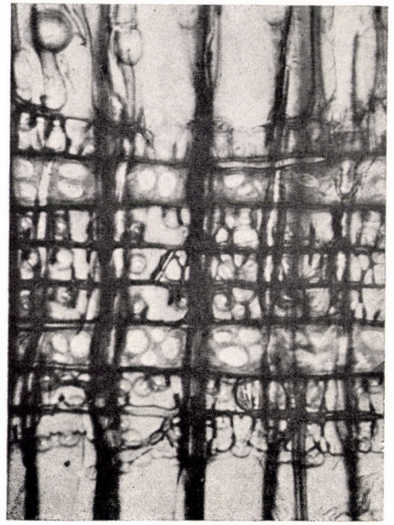
283. Pinus cembroides var. **Parryana** (Engelmann) Voss



1. (30×)



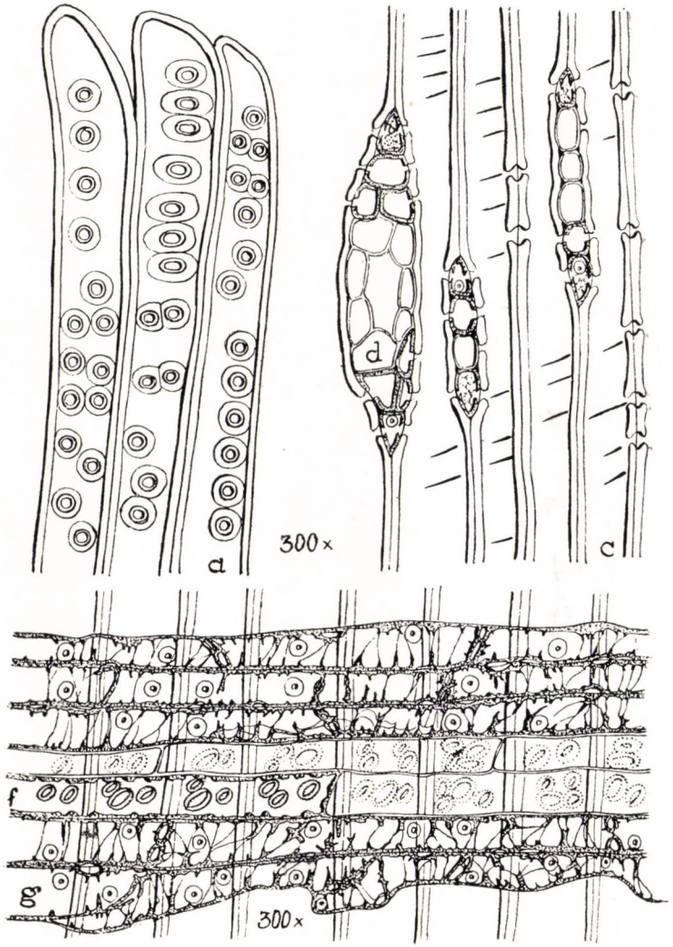
2. (100×)



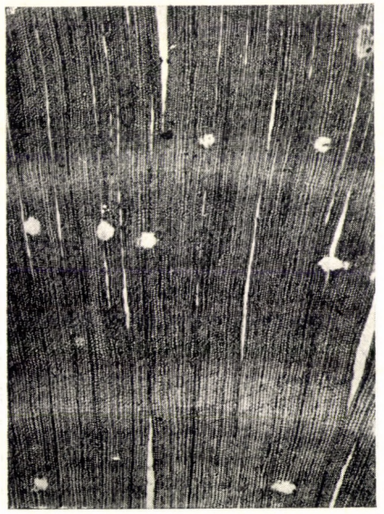
3. (300×)



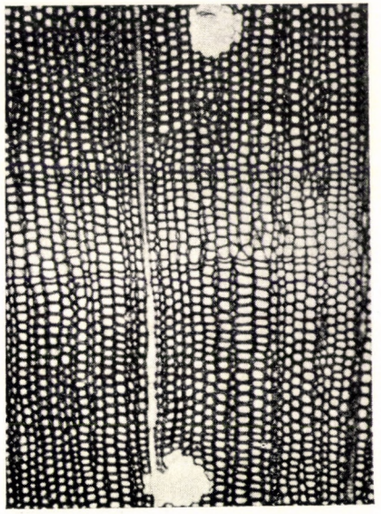
4. (100×)



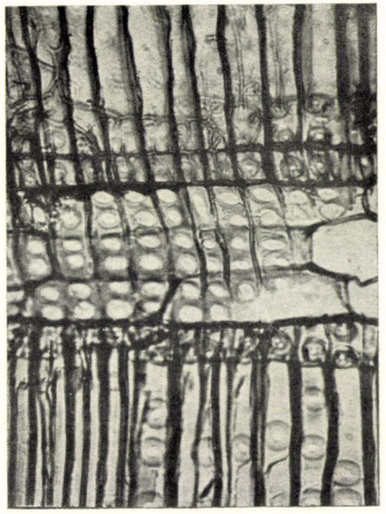
284. Pinus clausa VASEY



1. (30×)



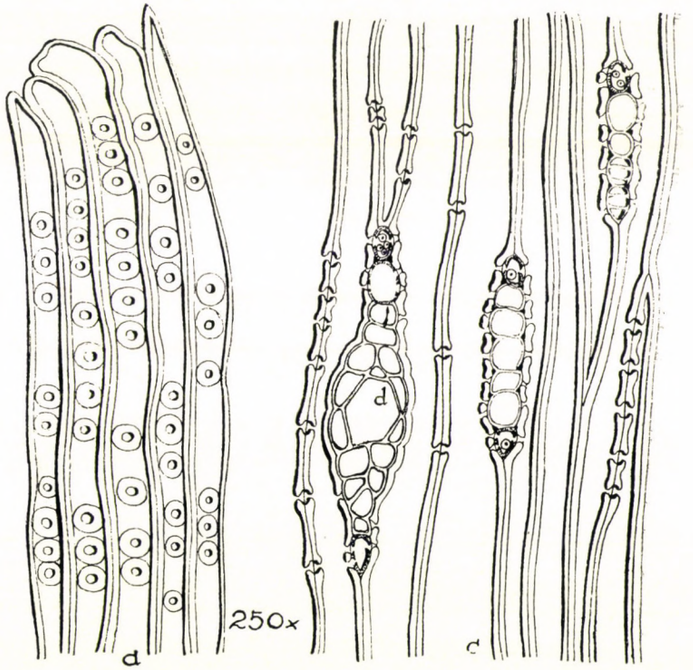
2. (100×)

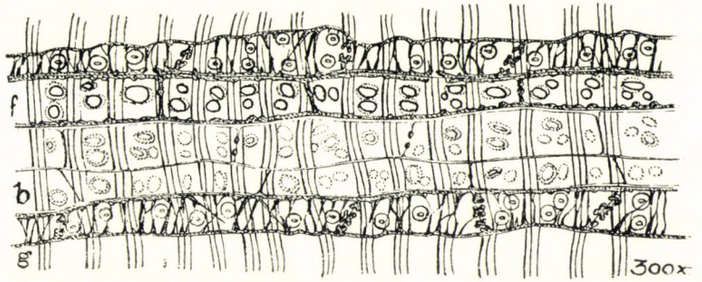


3. (300×)

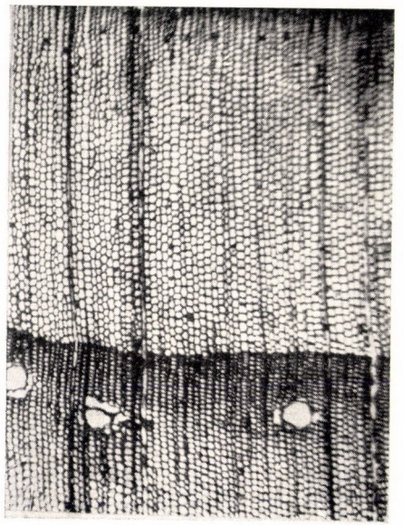


4. (100×)

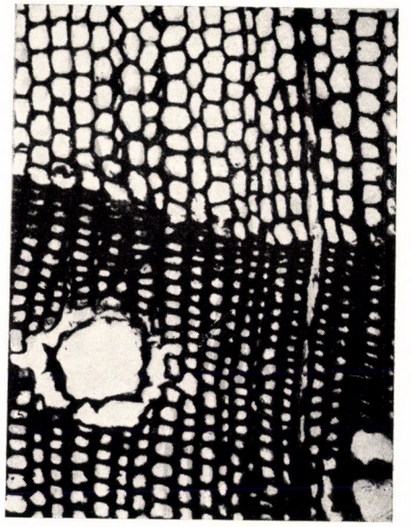




285. Pinus contorta DOUGLAS



1. (30×)



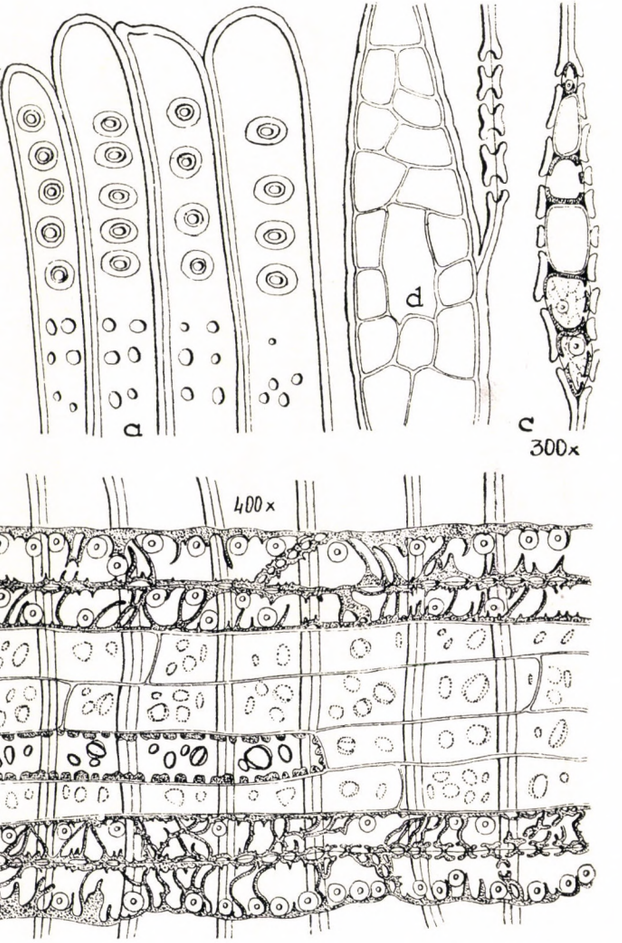
2. (100×)



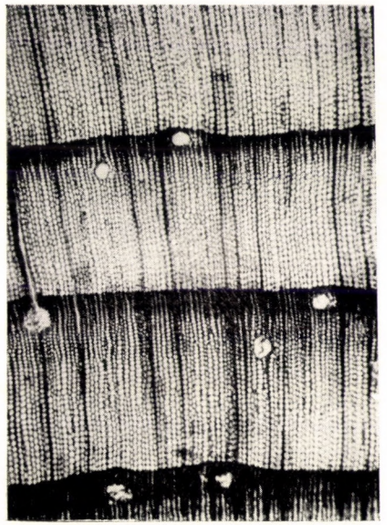
3. (300×)



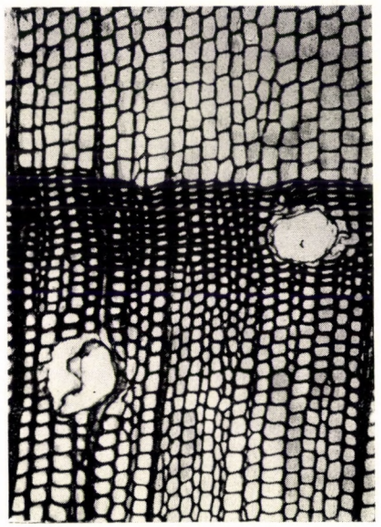
4. (100×)



286. Pinus Coulteri D. Don



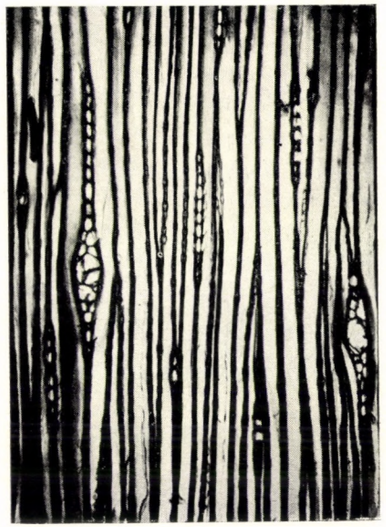
1. (30×)



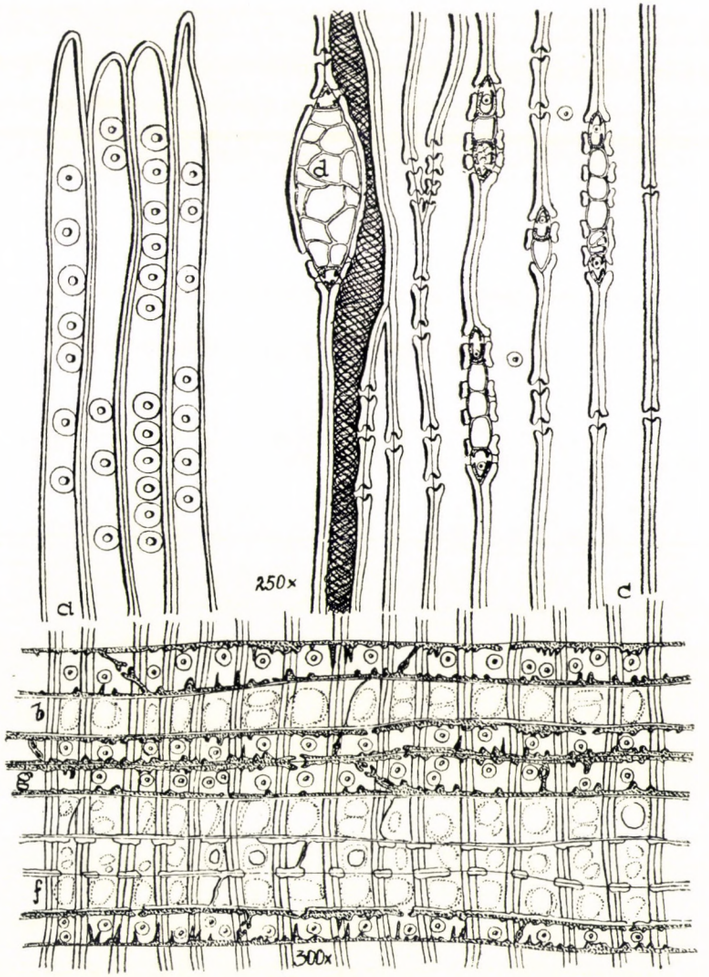
2. (100×)



3. (300×)



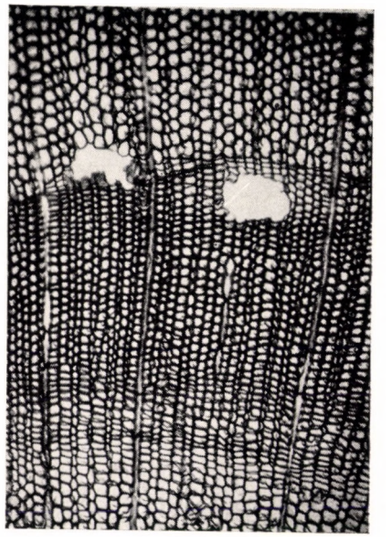
4. (100×)



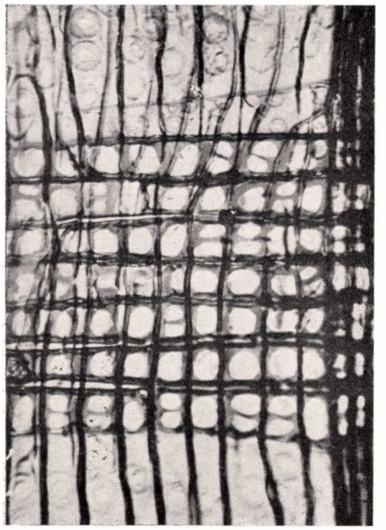
287. **Pinus densiflora** SIEB. et ZUCC.



1. (30×)



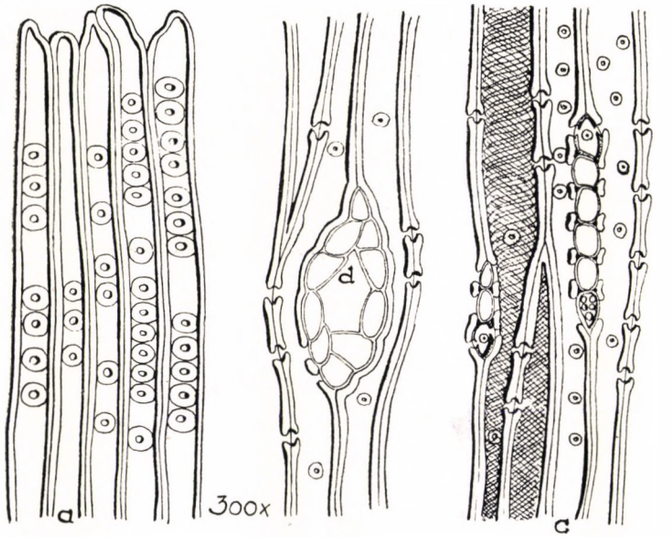
2. (100×)

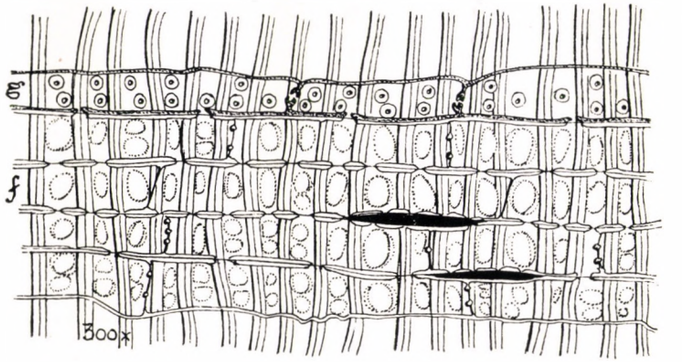


3. (300×)



4. (100×)

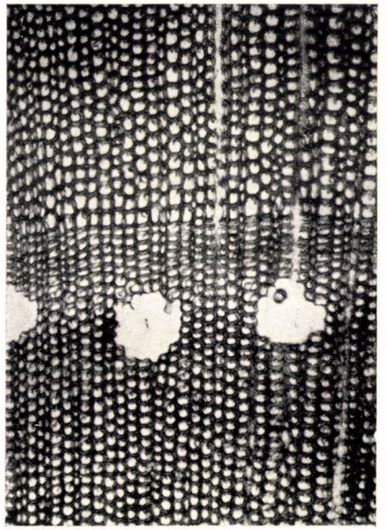




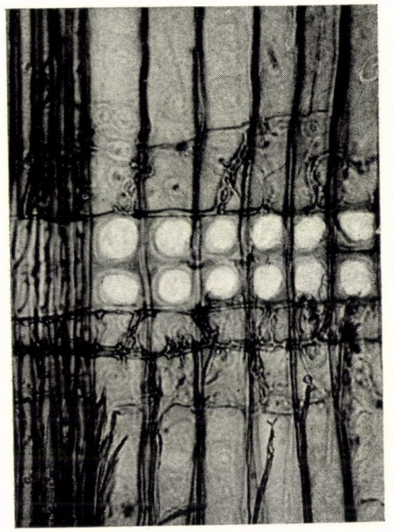
288. Pinus flexilis JAMES



1. (30×)



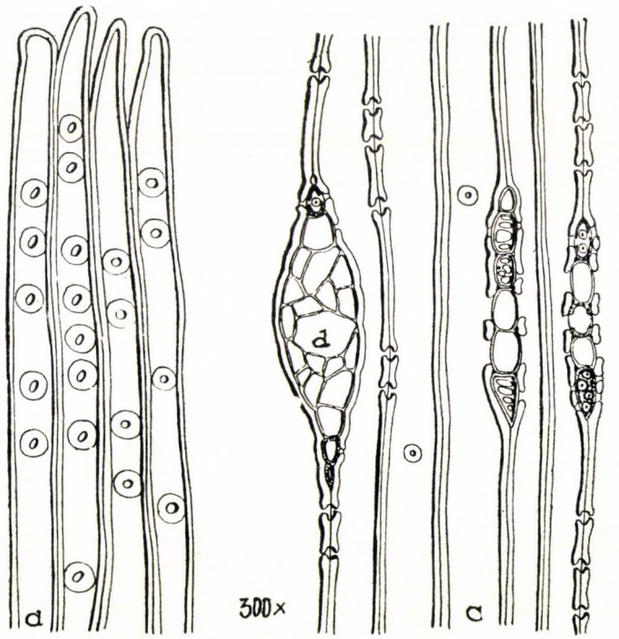
2. (100×)

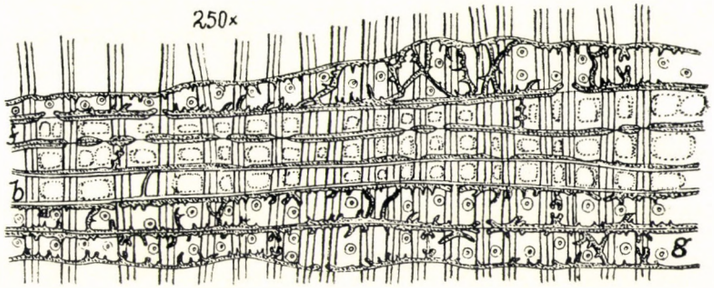


3. (300×)



4. (100×)





289. Pinus funebris KOMATSU



1. (30×)



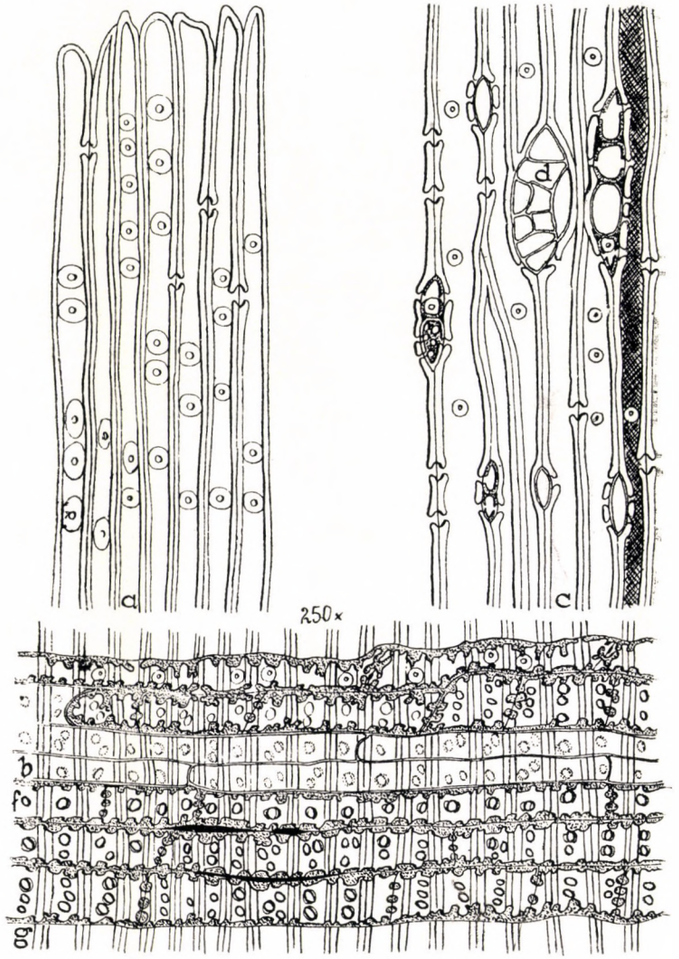
2. (100×)



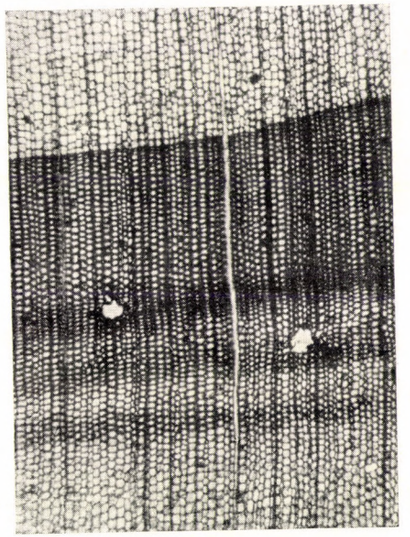
3. (300×)



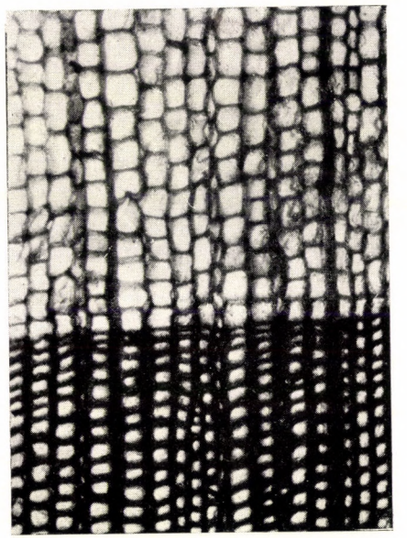
4. (100×)



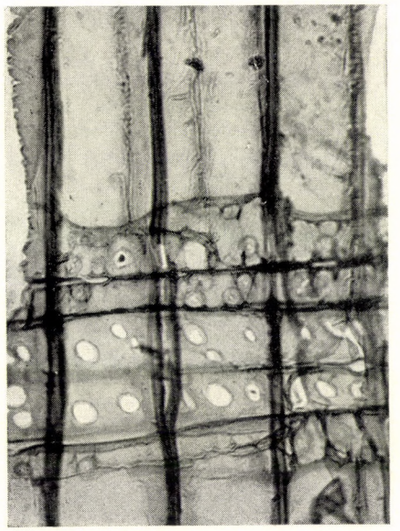
290. Pinus Gerardiana WALLICH



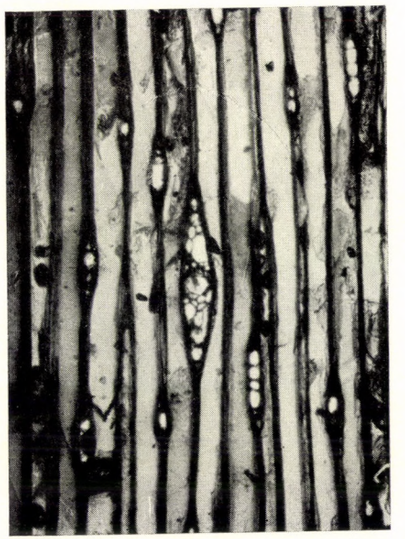
1. (30×)



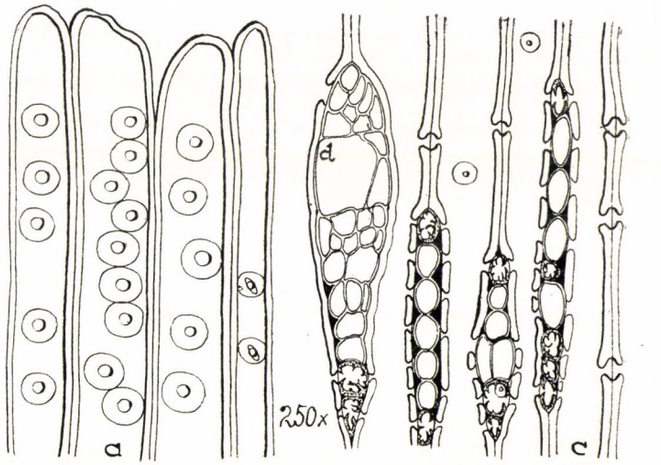
2. (100×)

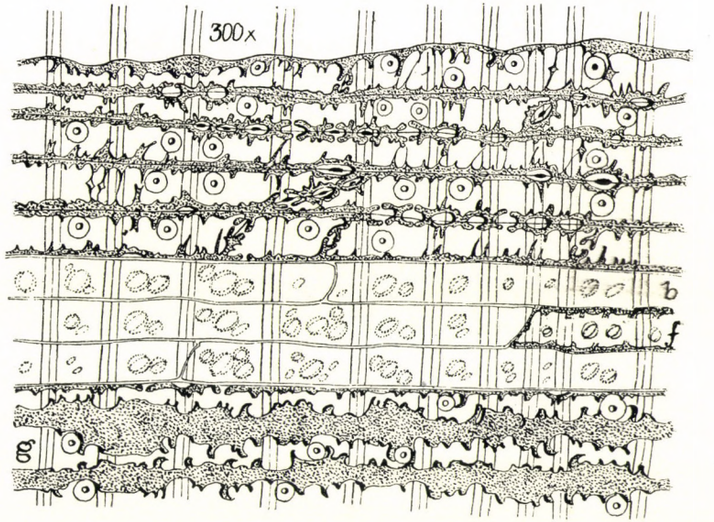


3. (300×)



4. (100×)

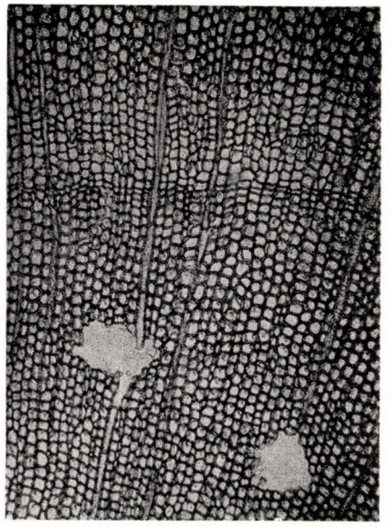




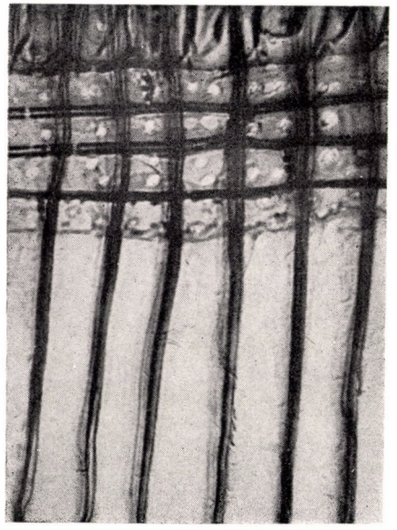
291. Pinus glabra WALTER



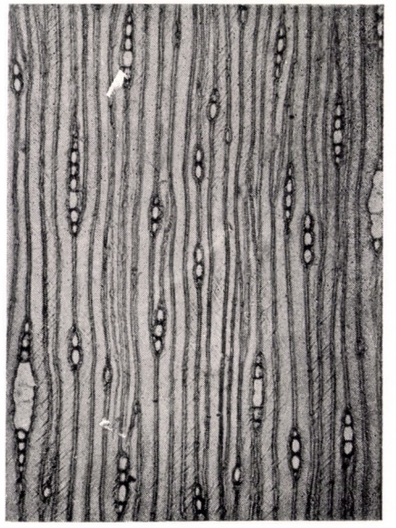
1. (30×)



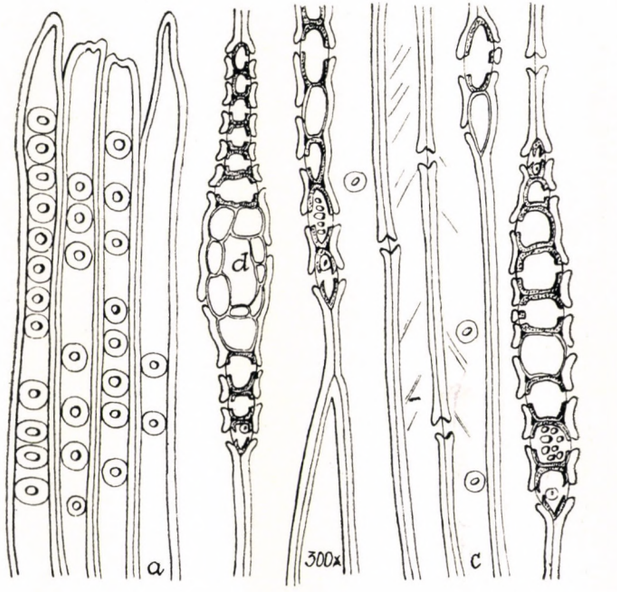
2. (100×)

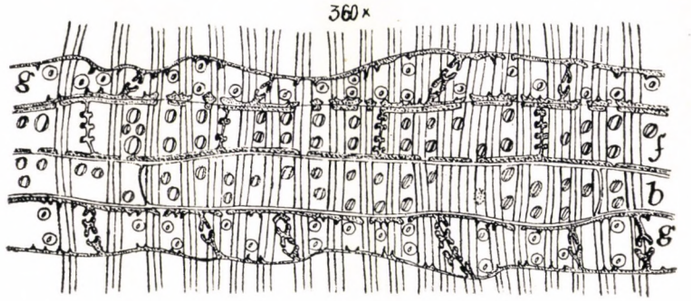


3. (300×)

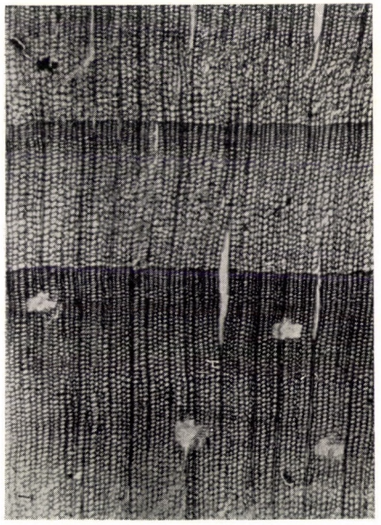


4. (100×)

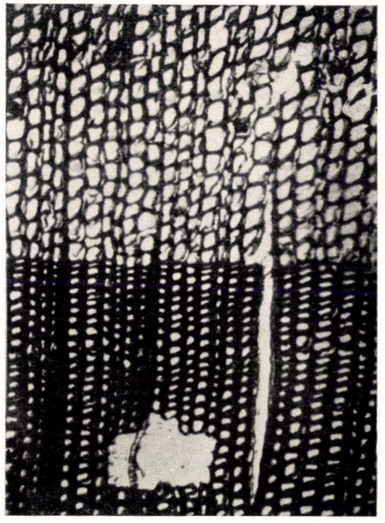




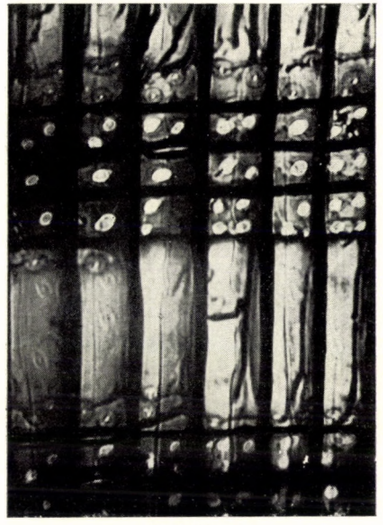
292. Pinus halepensis MILLER



1. (30×)



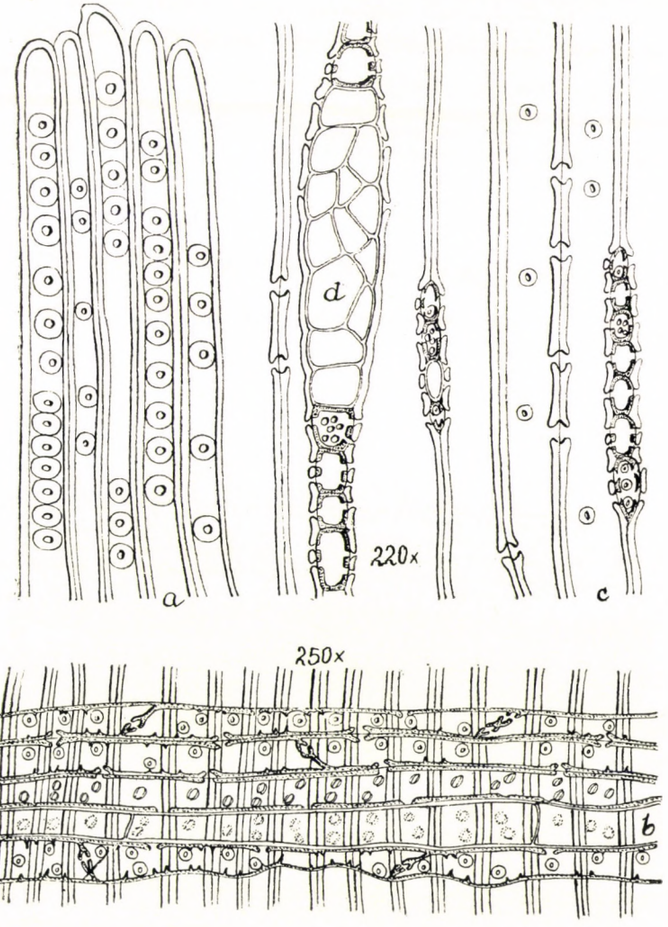
2. (100×)



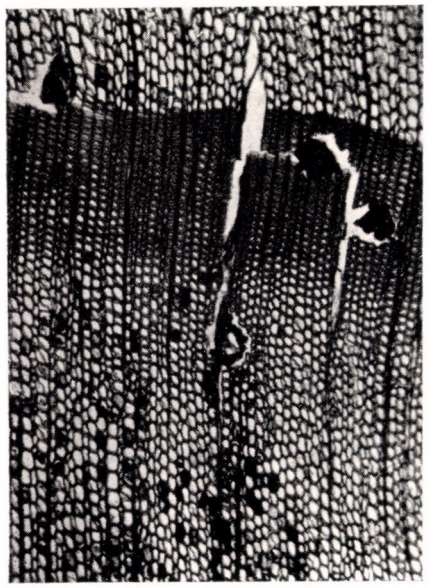
3. (300×)



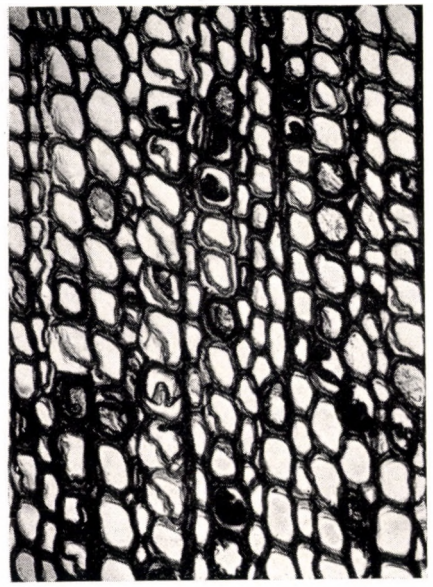
4. (100×)



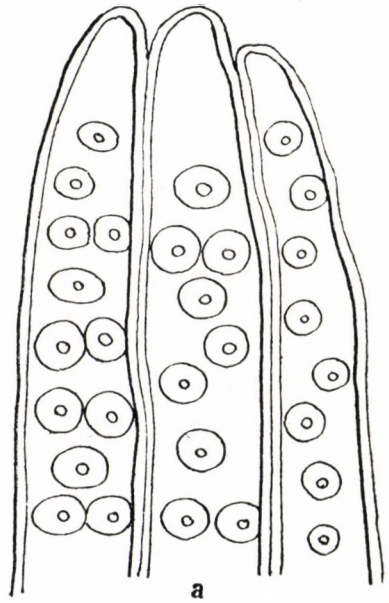
293. Pinus halepensis var. brutia (Tenore) ELWES et HENRY

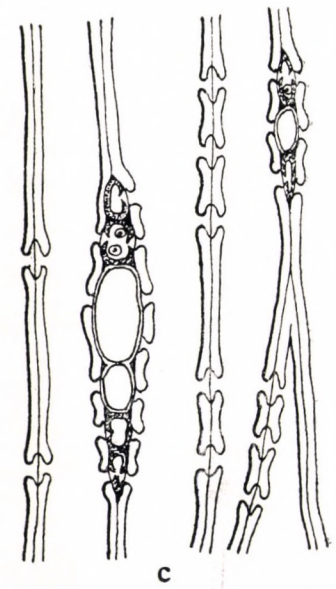


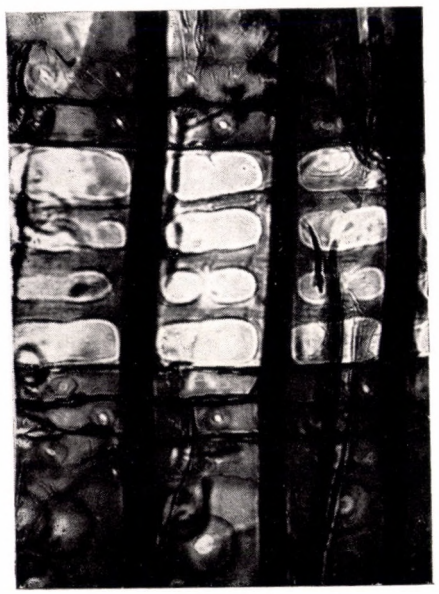
1. (30×)



2. (100×)



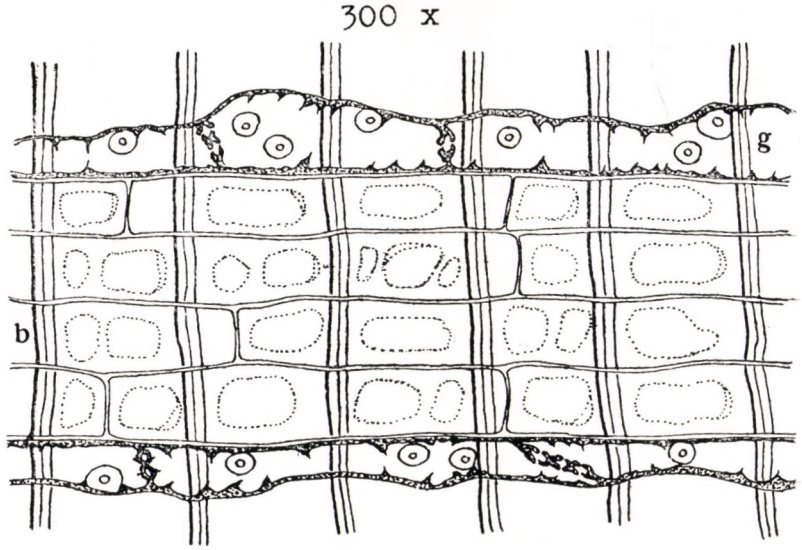




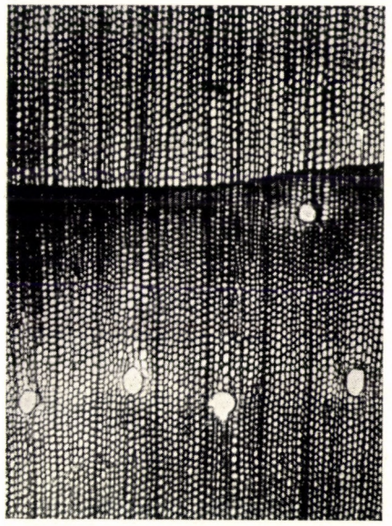
3. (300×)



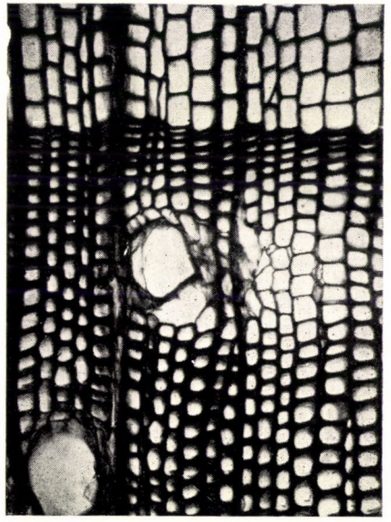
4. (100×)



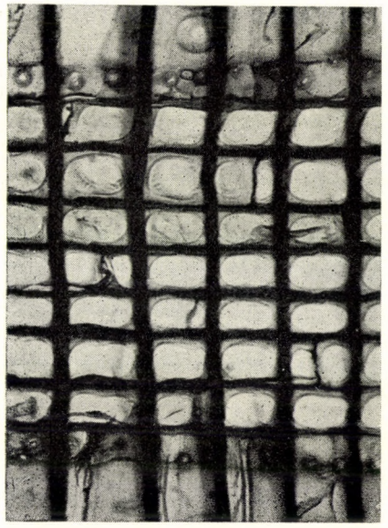
294. Pinus khasya ROYLE



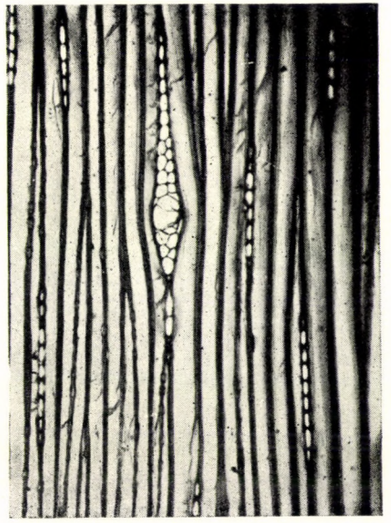
1. (30×)



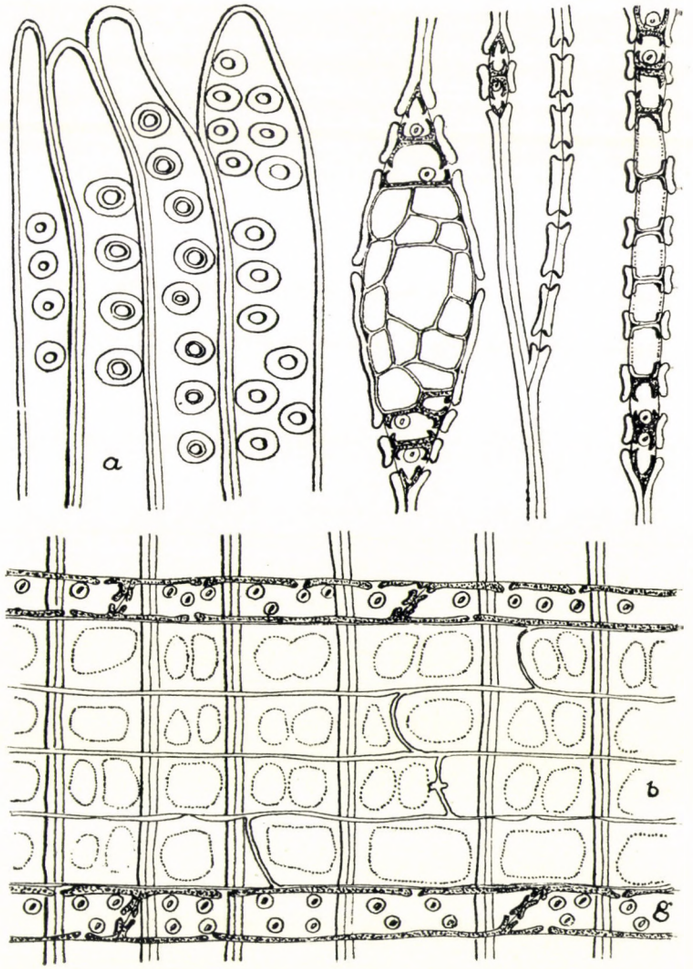
2. (100×)



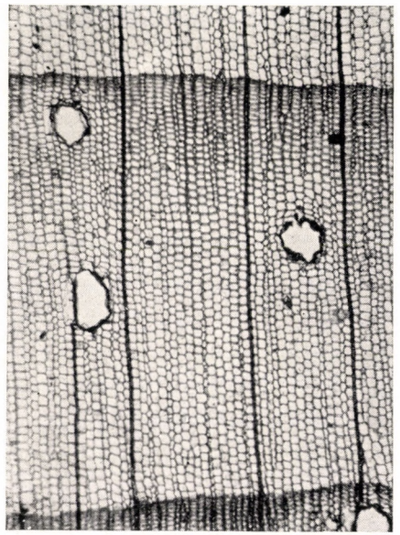
3. (300×)



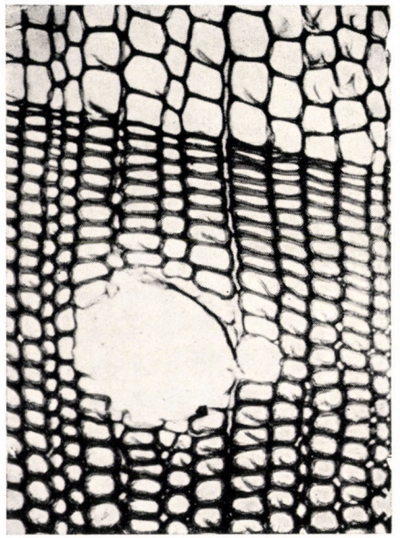
4. (100×)



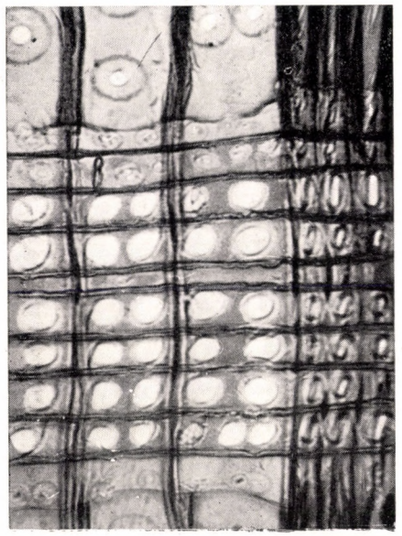
295. Pinus koraiensis SIEB. et ZUCC.



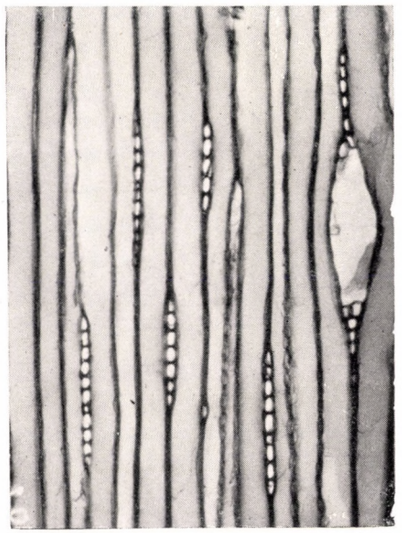
1. (30×)



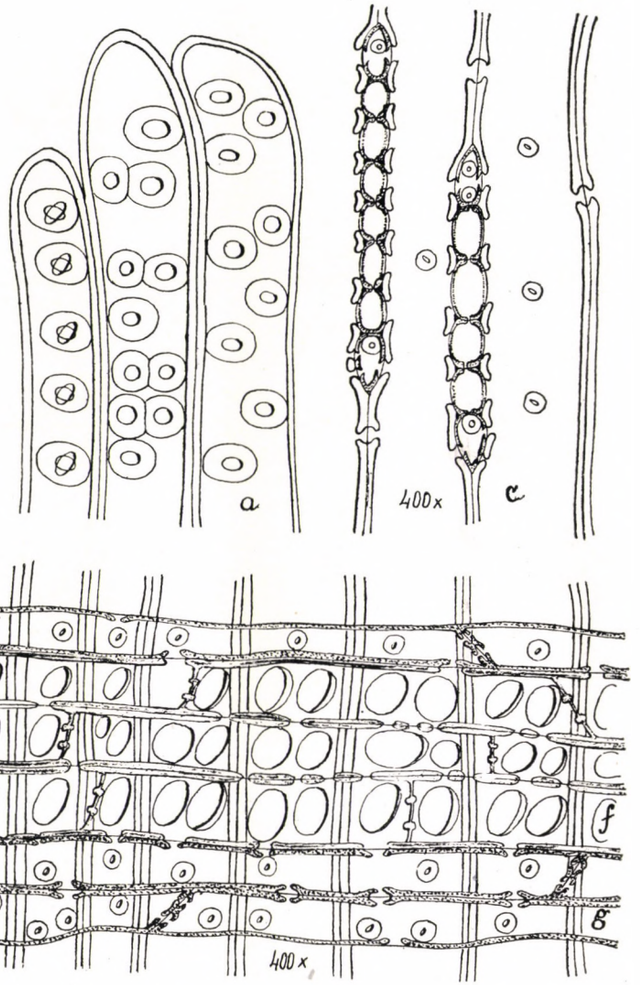
2. (100×)



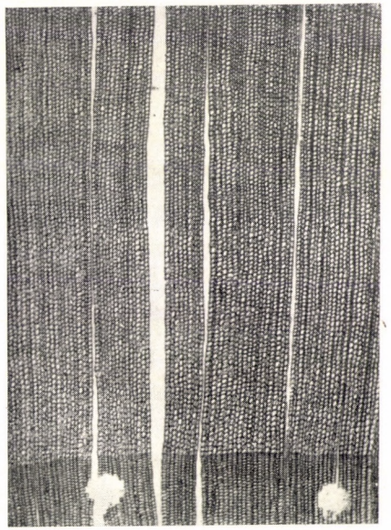
3. (300×)



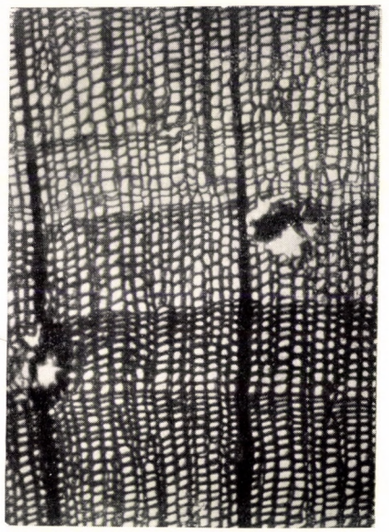
4. (100×)



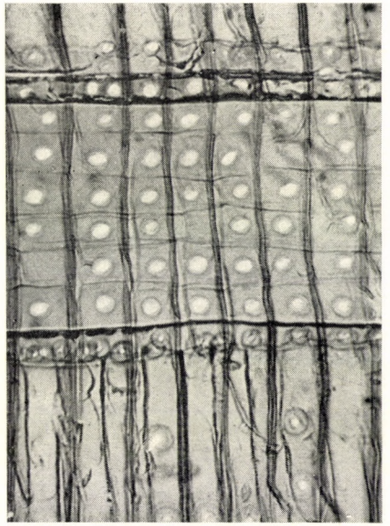
296. Pinus Lambertiana DOUGLAS



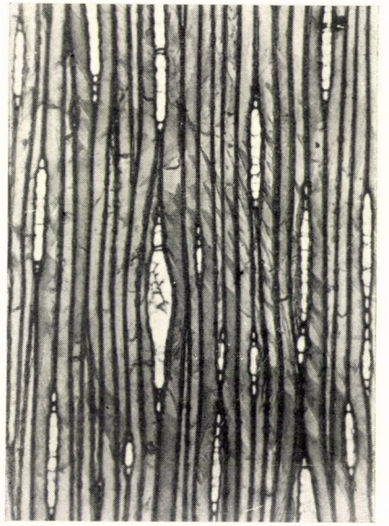
1. (30×)



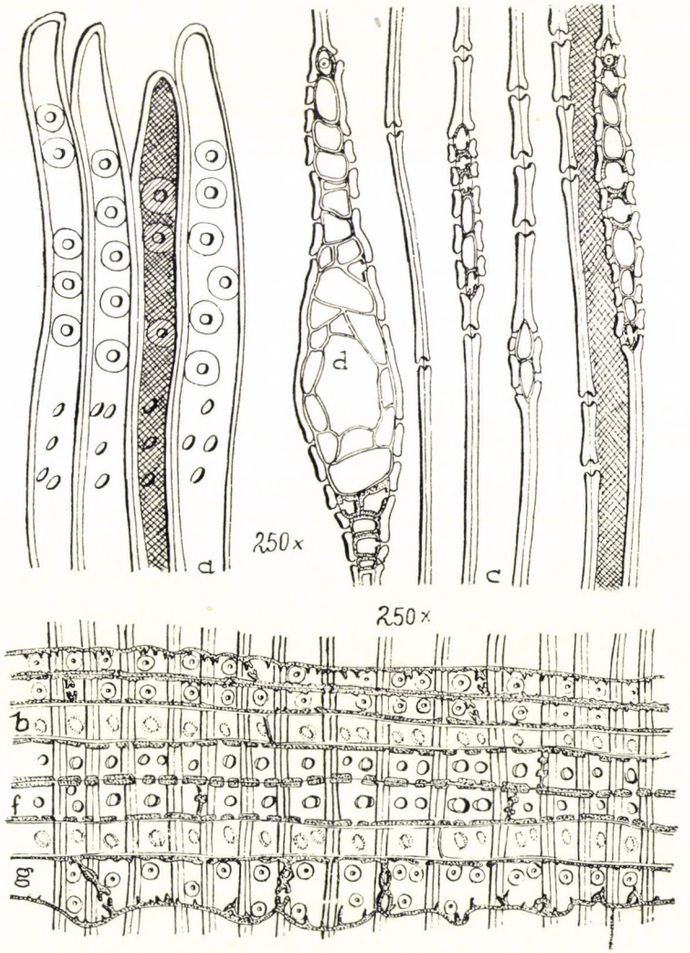
2. (100×)



3. (300×)



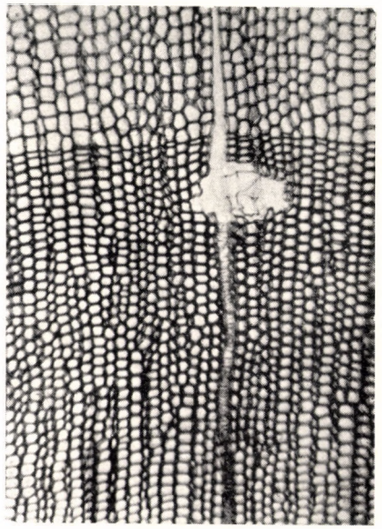
4. (100×)



297. Pinus Laricio POIRET



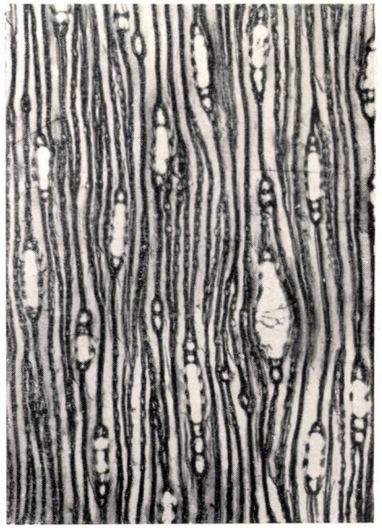
1. (30×)



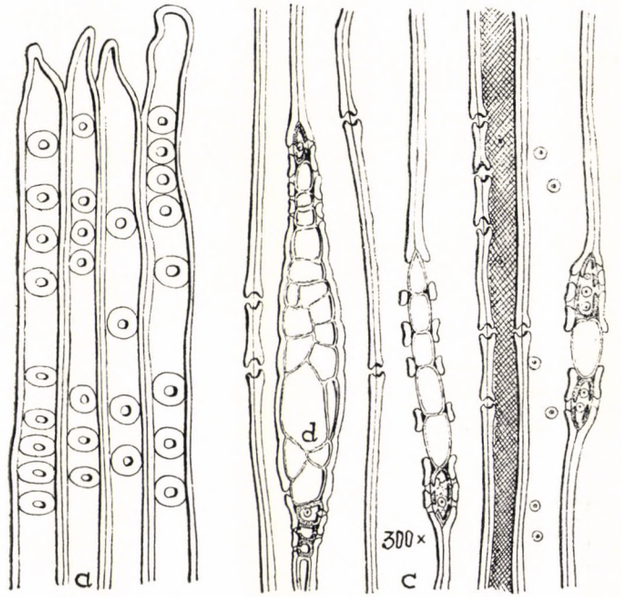
2. (100×)

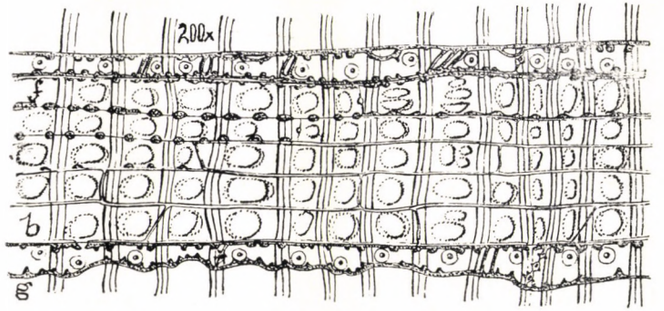


3. (300×)

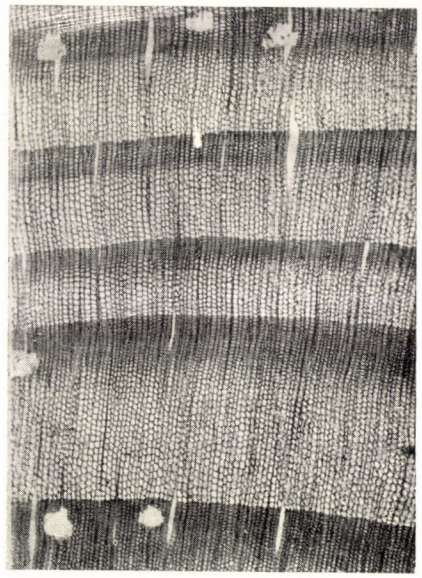


4. (100×)

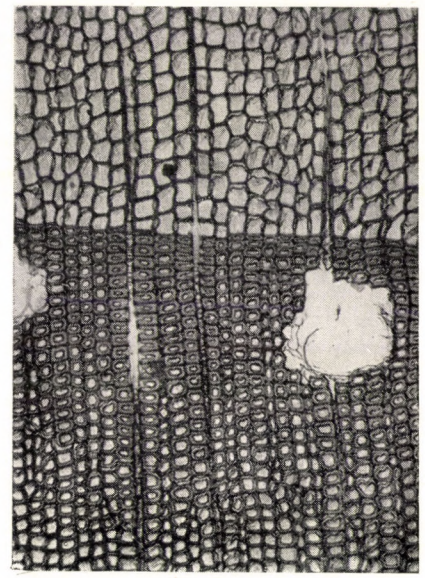




298. Pinus Laricio v. nigricans PARL.



1. (30×)



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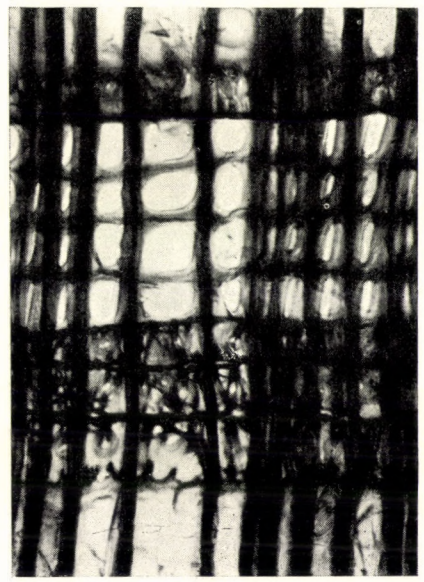

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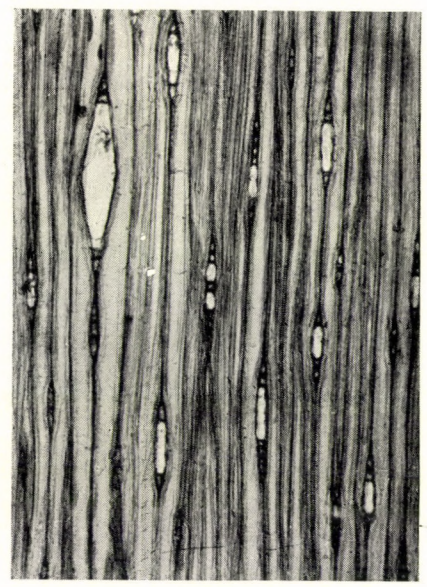

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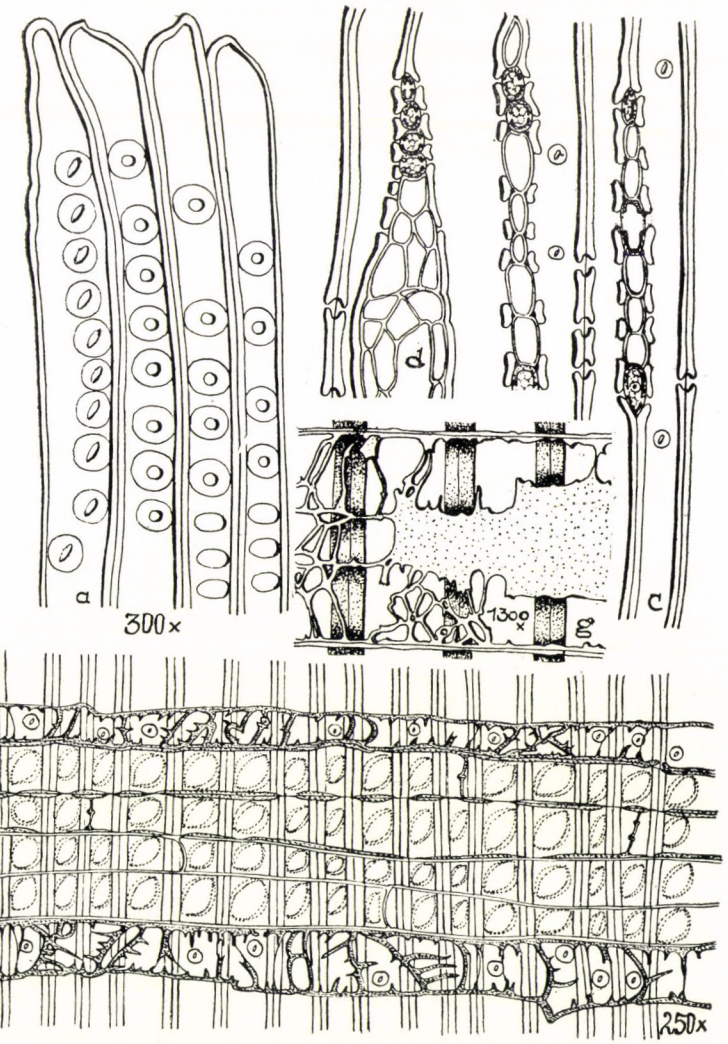
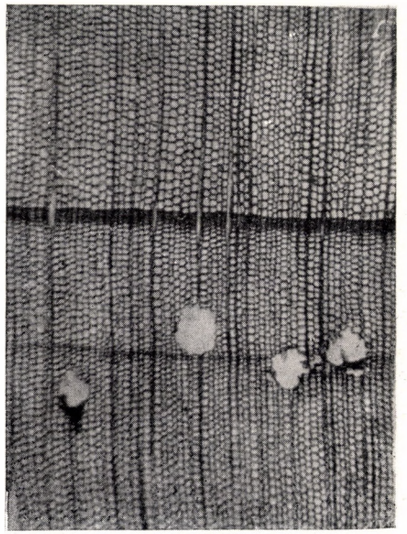
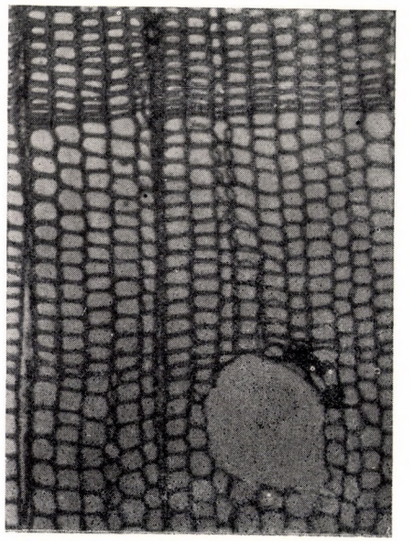


299. Pinus Laricio v. Pallasiana ENDL.



1. (30×)



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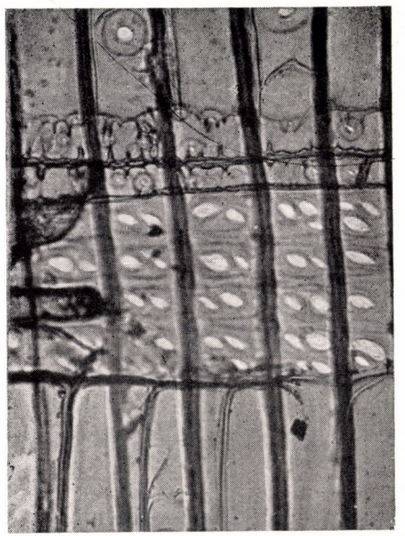

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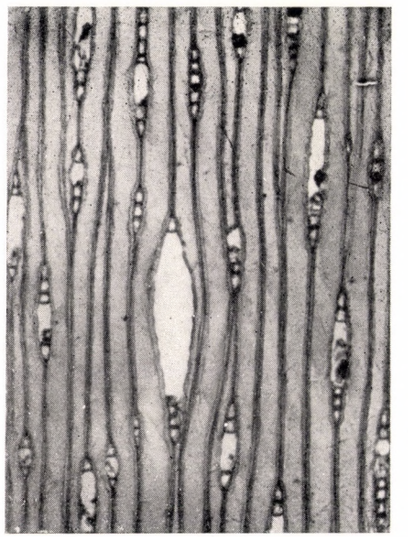

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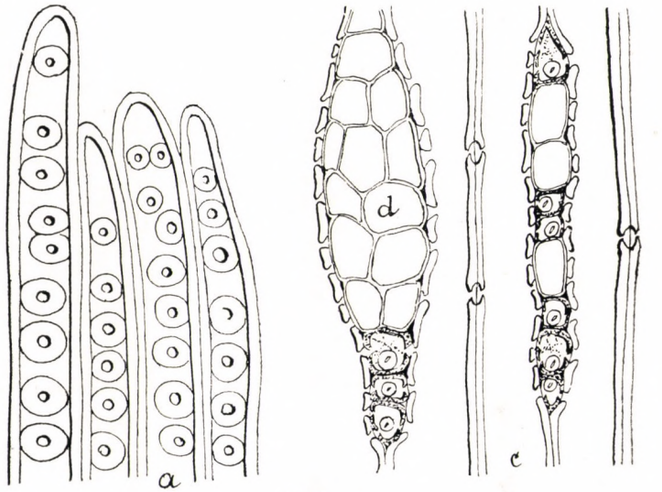
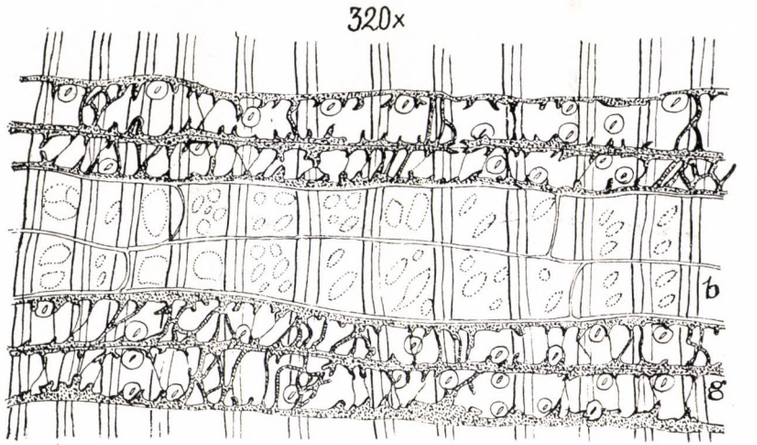
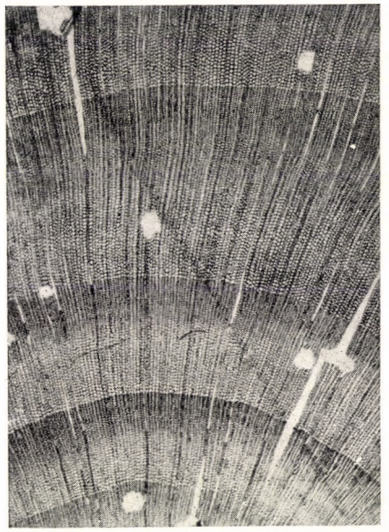
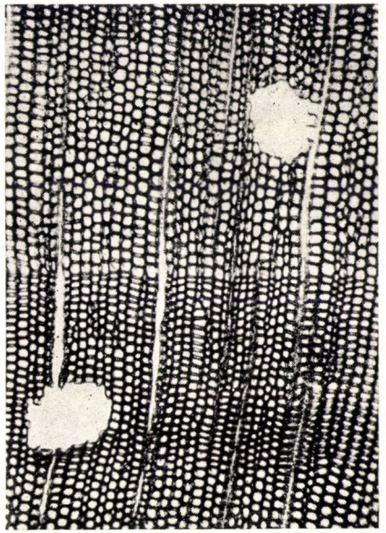




300. Pinus leiophylla SCHLECHTENDAL et CHAMISSO var. chihuahuana SHAW.



1. (30×)



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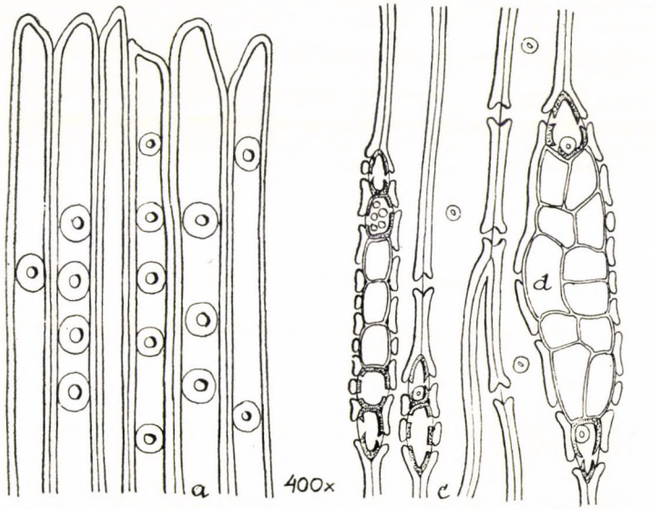
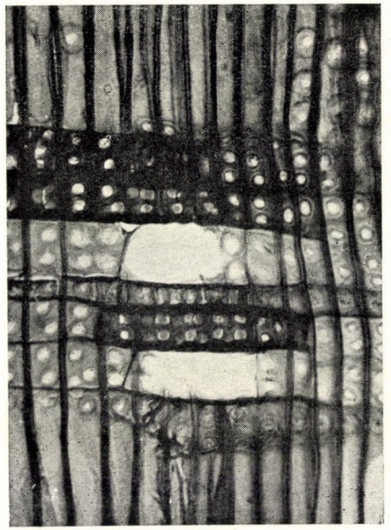
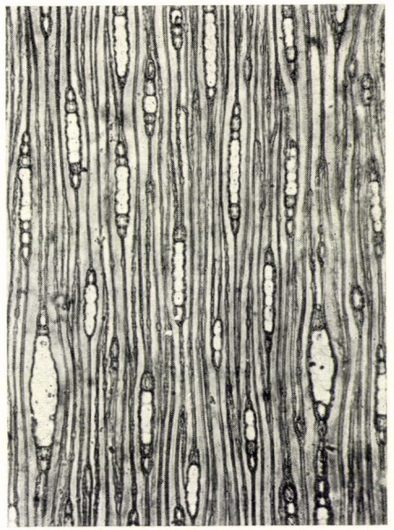
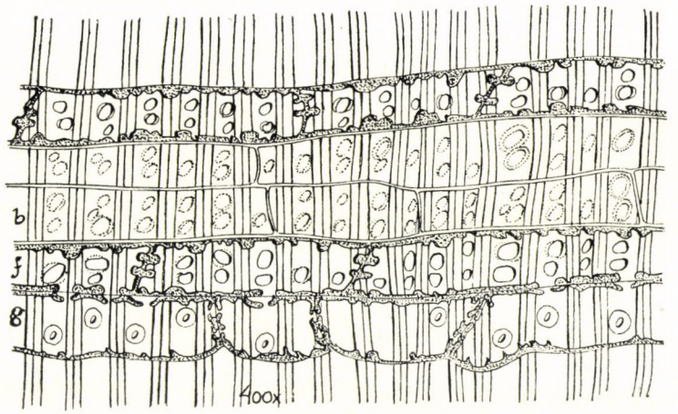




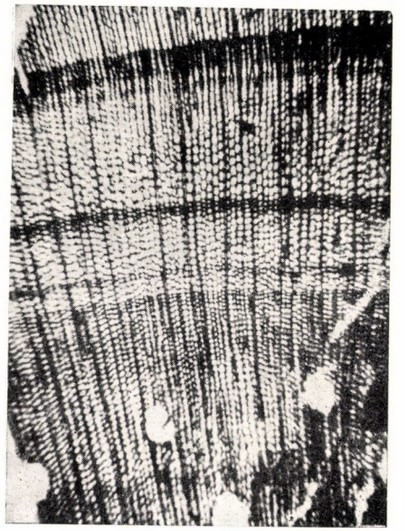
3. (300×)



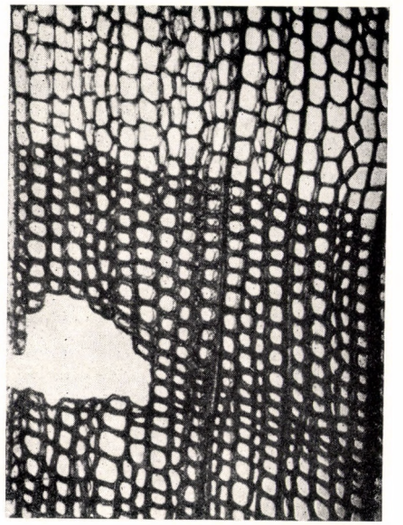
4. (100×)



301. Pinus leucodermis ANTOINE



1. (30×)



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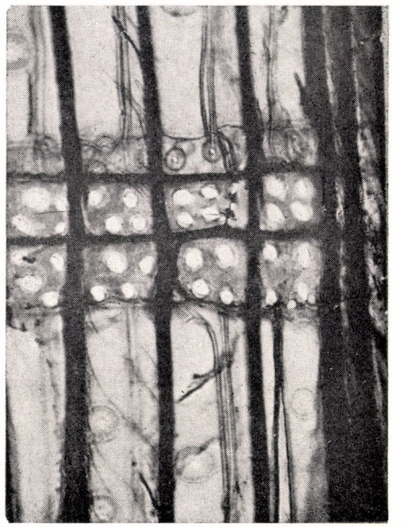
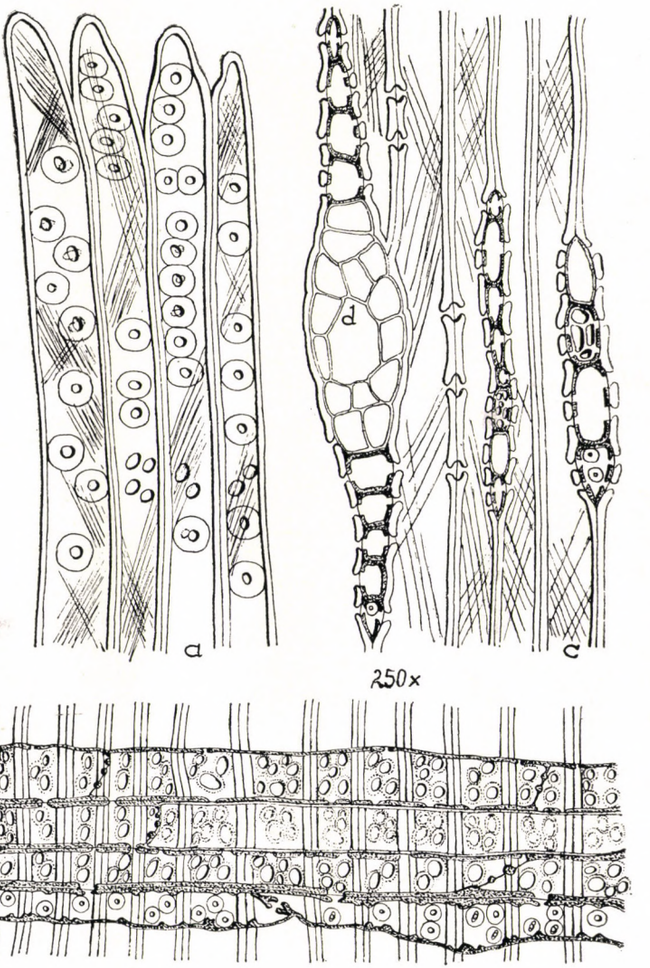


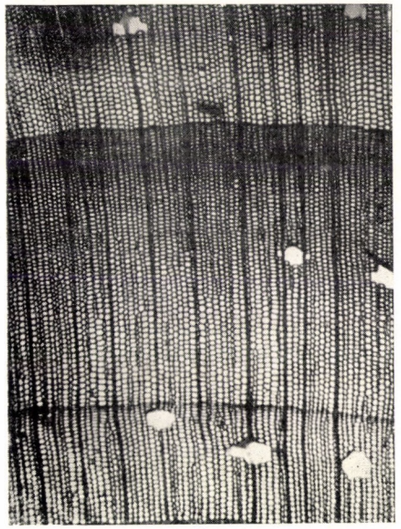
3. (300×)



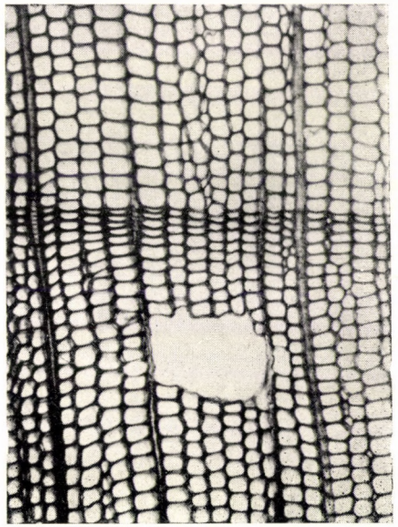
4. (100×)



302. Pinus longifolia ROXBURGH



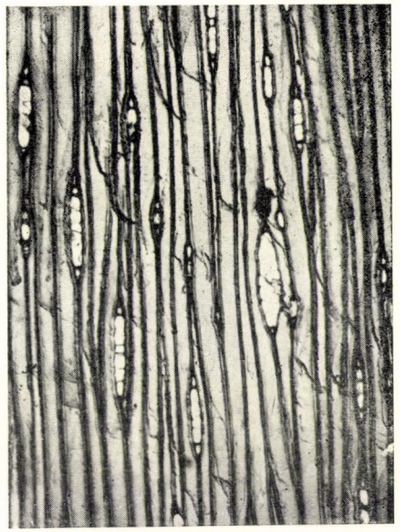
1. (30×)



2. (100×)



3. (300×)



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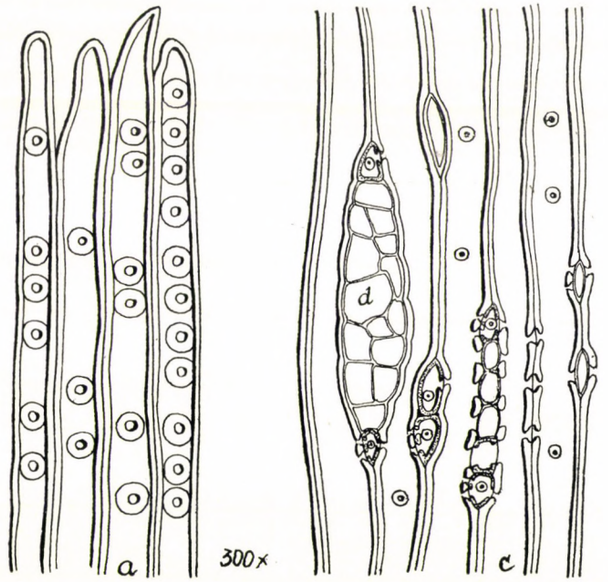
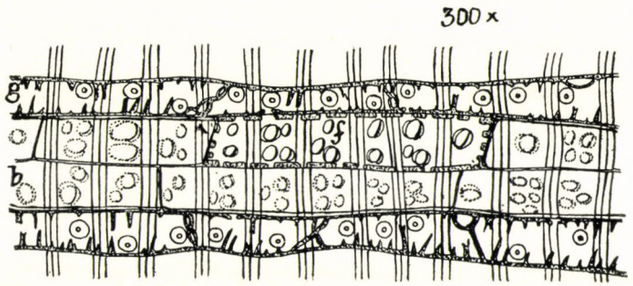
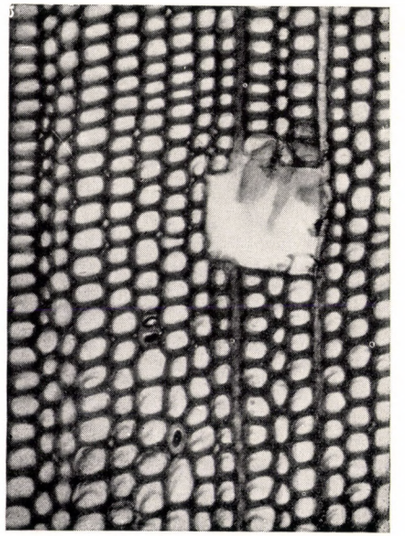




303. Pinus maritima LAMBERT



1. (30×)



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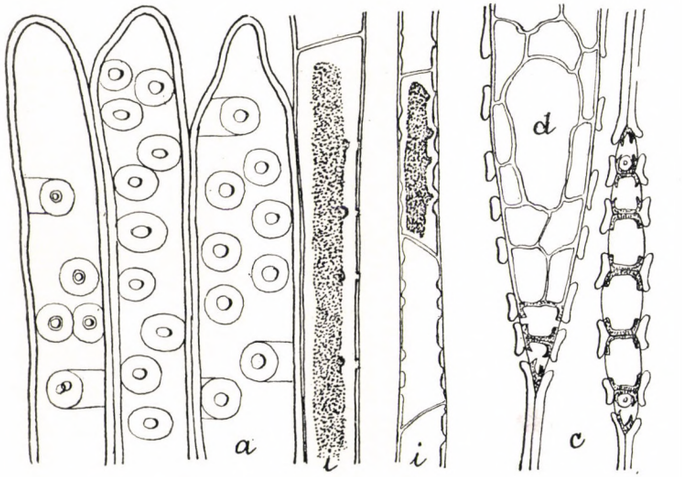

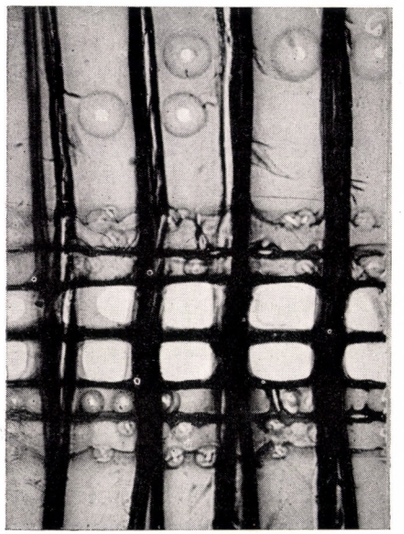

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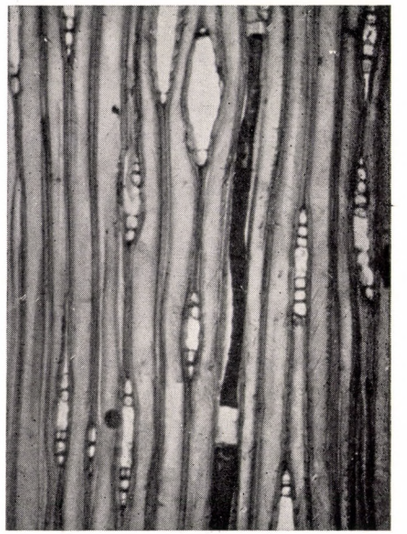
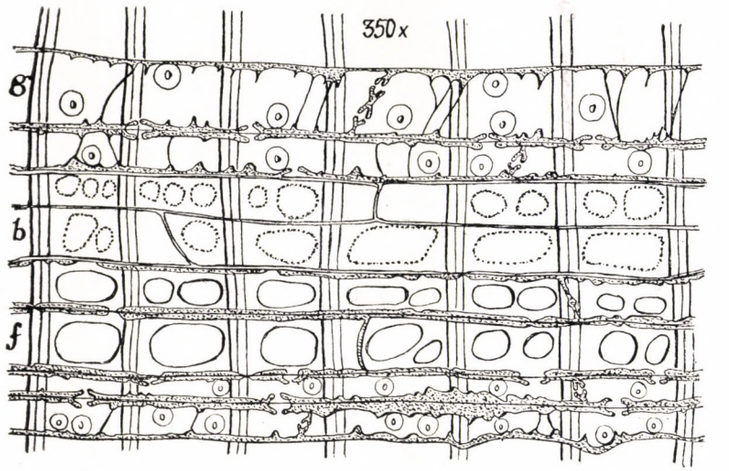
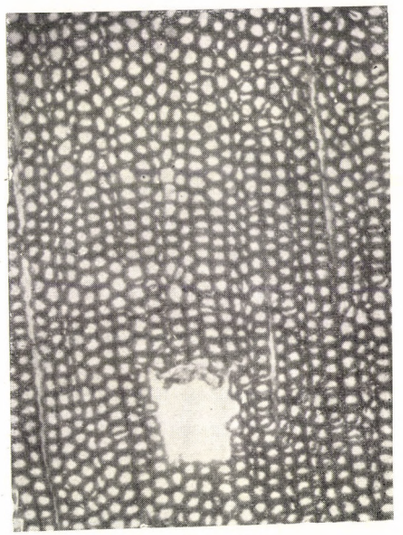


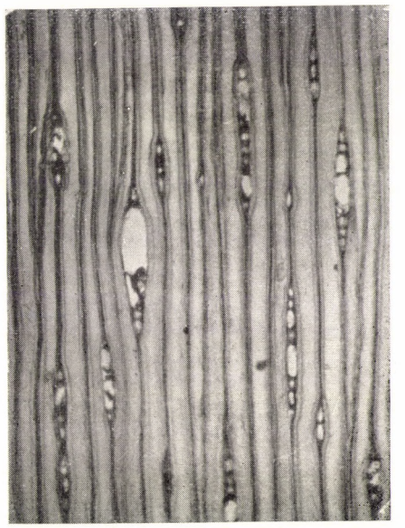
4. (100×)



304. Pinus Massoniana LAMBERT



1. (100×)



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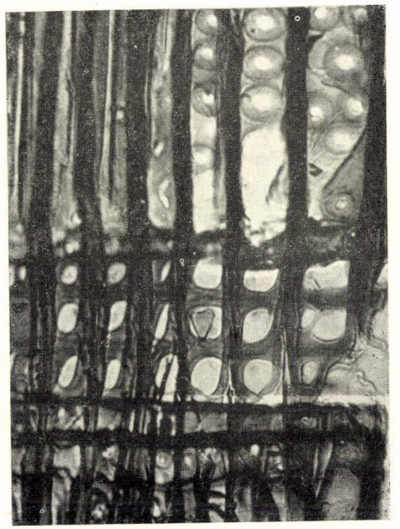
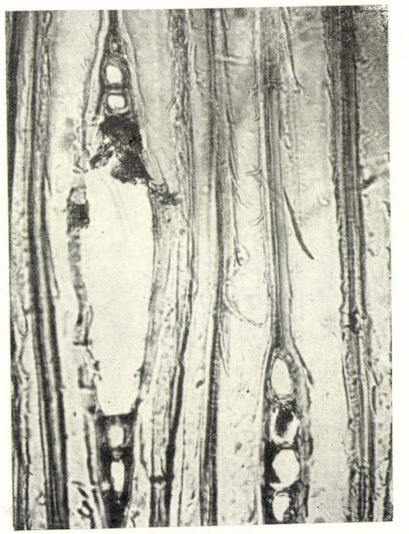
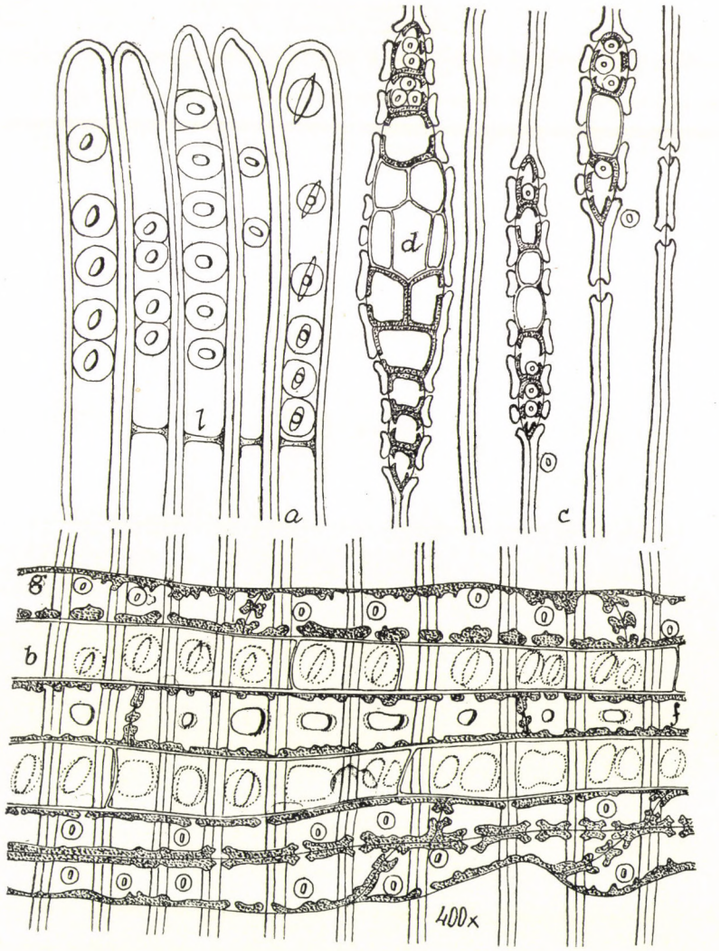


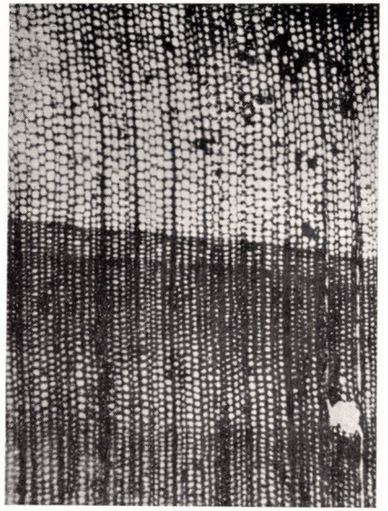
3. (300×)



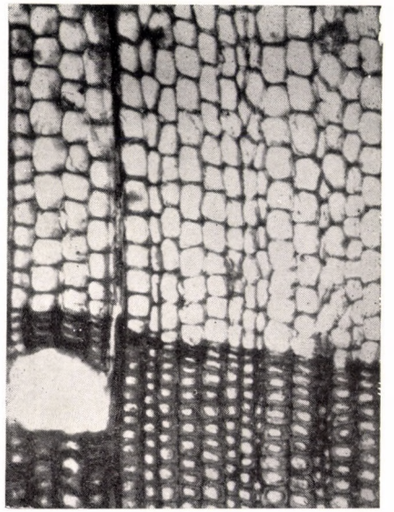
4. (300×)



305. Pinus Merkusii JUNGH et de VRIESE



1. (30×)



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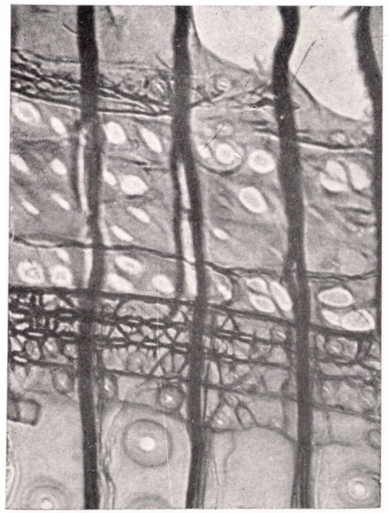
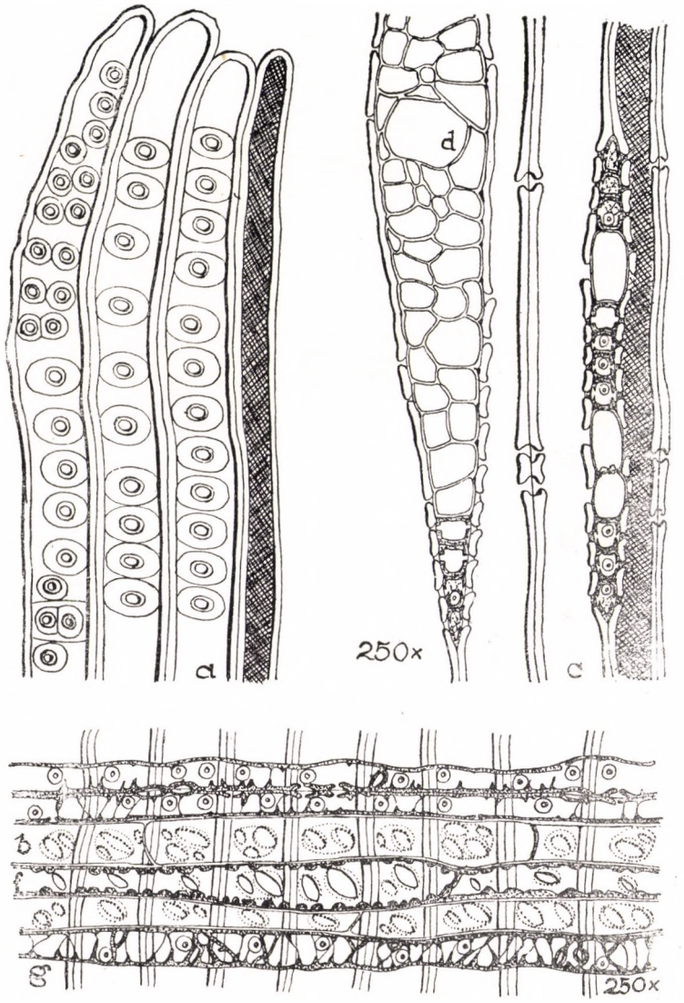


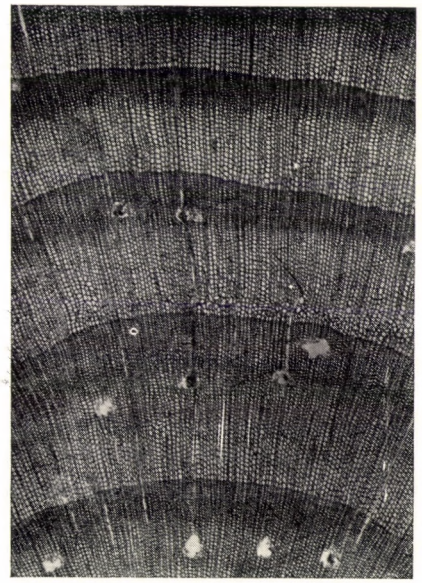
3. (300×)



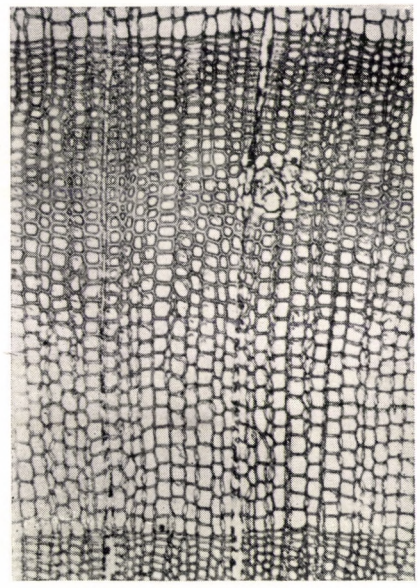
4. (100×)



306. Pinus Mitis Michx.



1. (30×)



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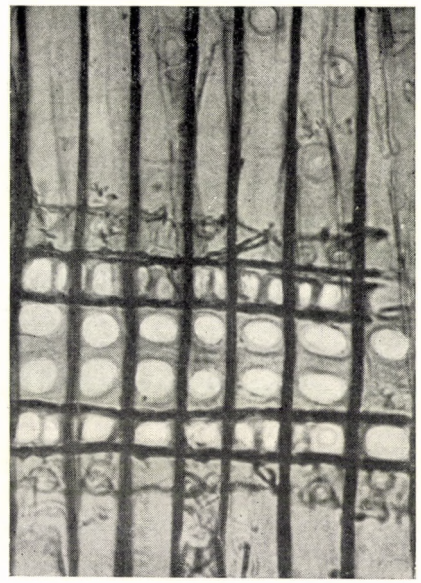

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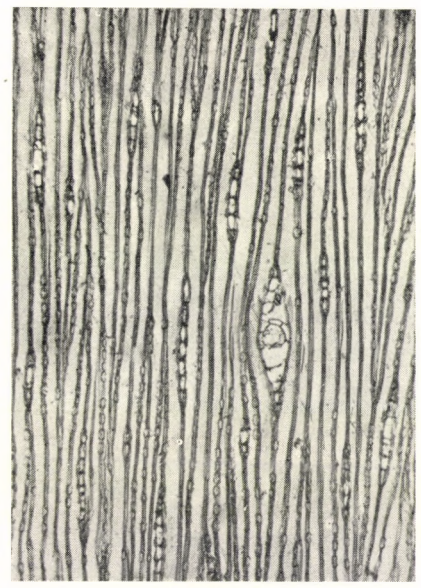
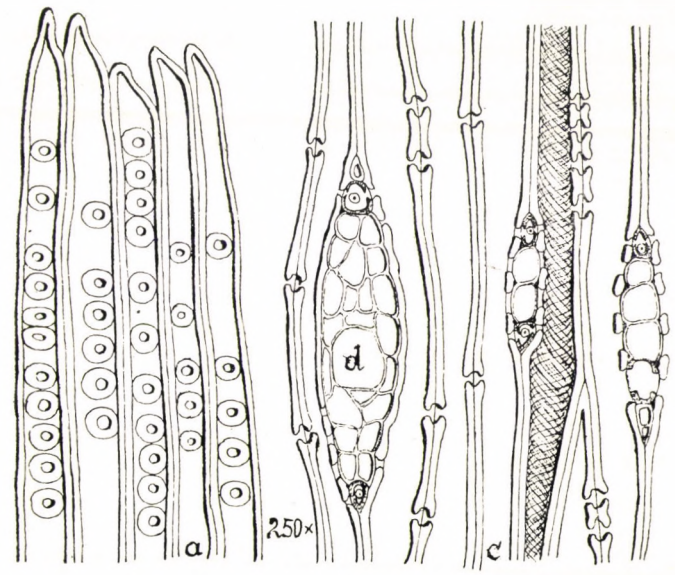
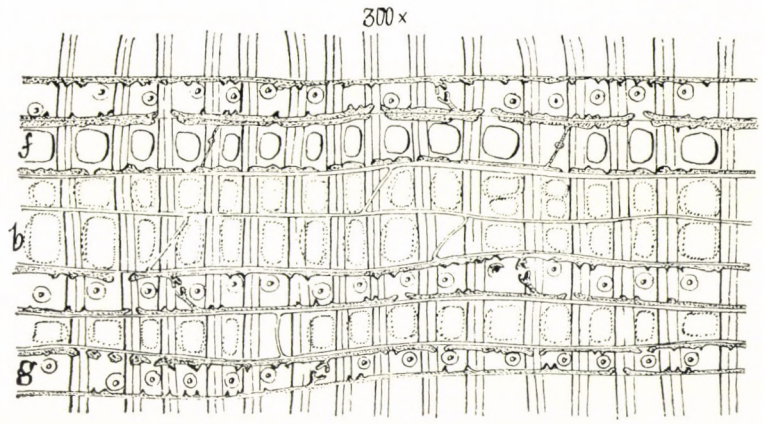
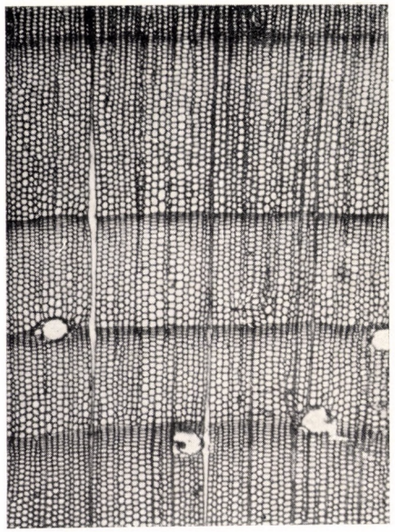


4. (100×)

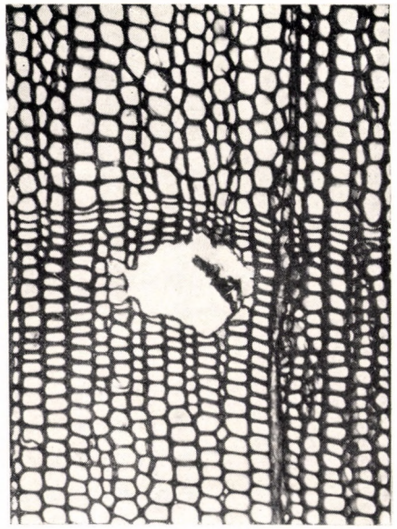




307. Pinus montana v. Mughus WILLK.



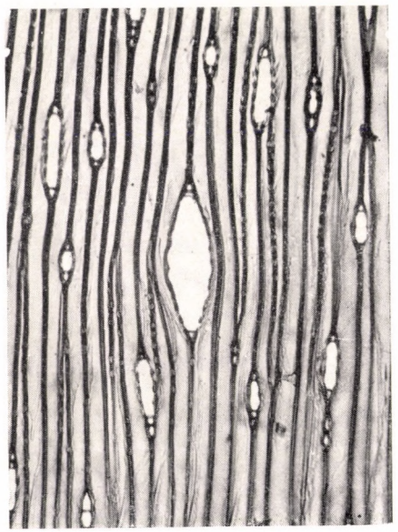
1. (30×)



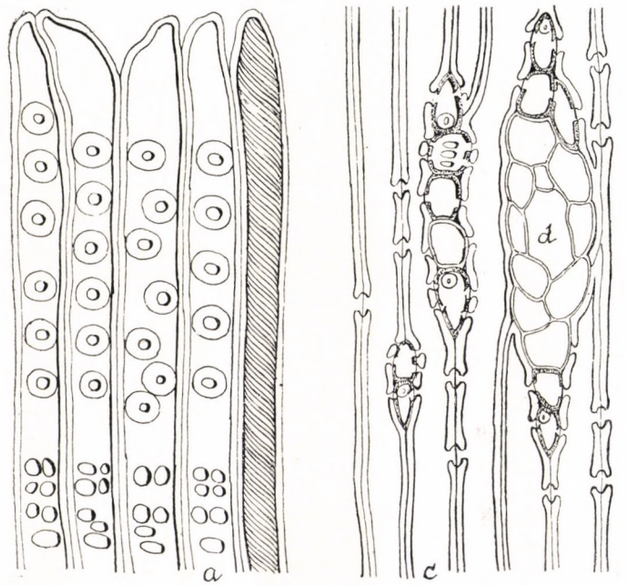
2. (100×)



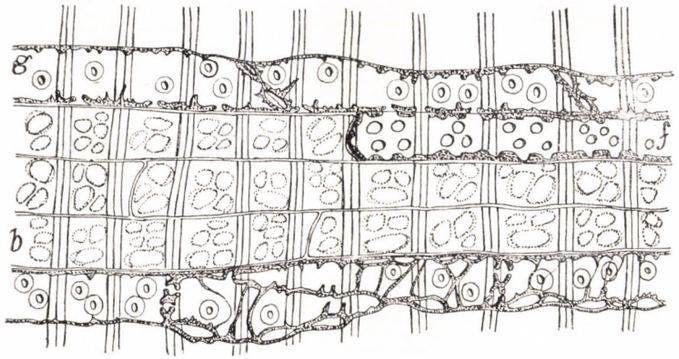
3. (300×)



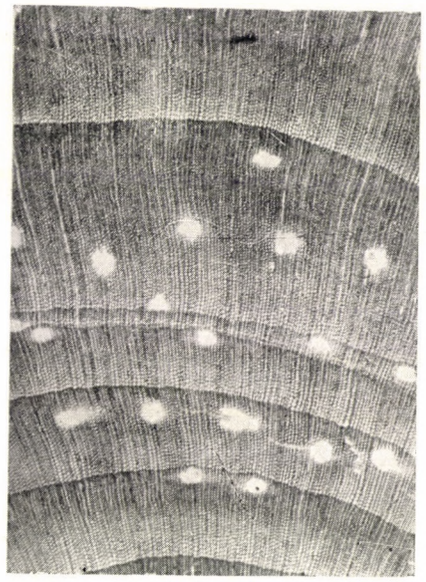
4. (100×)



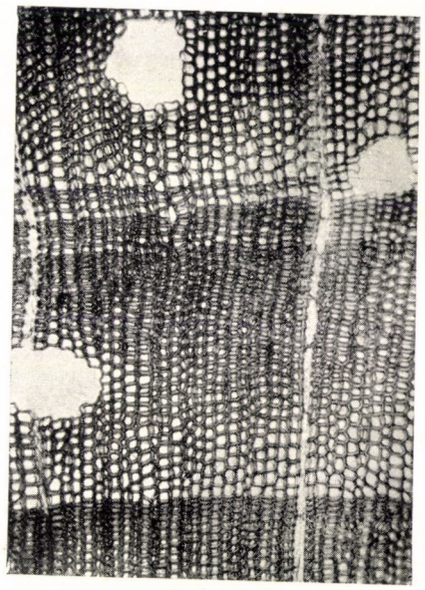
300×



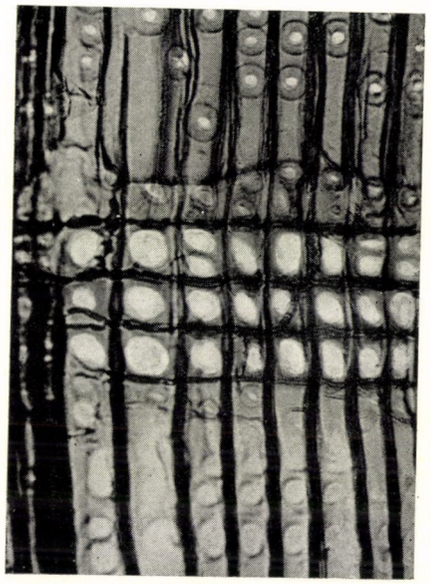
308. Pinus Montezumae LAMBERT



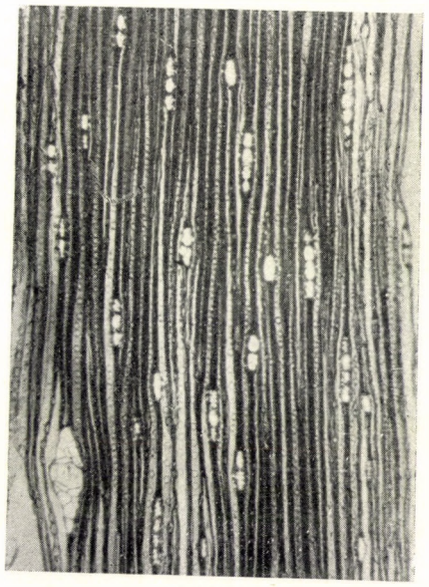
1. (30×)



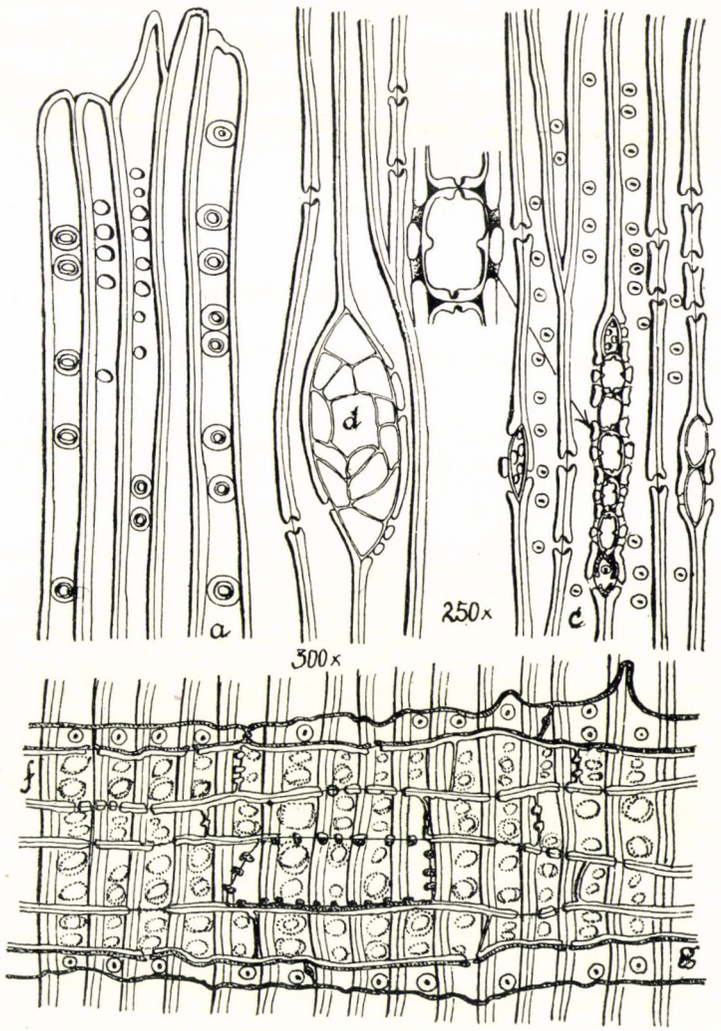
2. (100×)



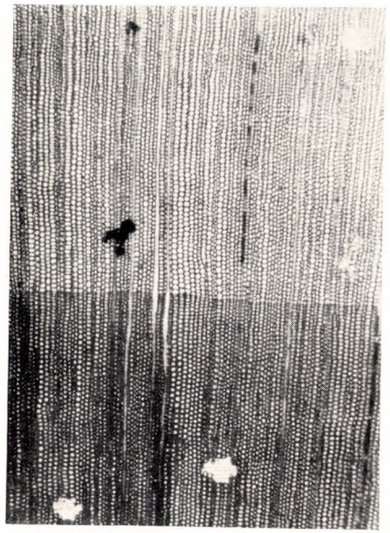
3. (300×)



4. (100×)



309. Pinus monticola DOUGLAS et LAMBERT



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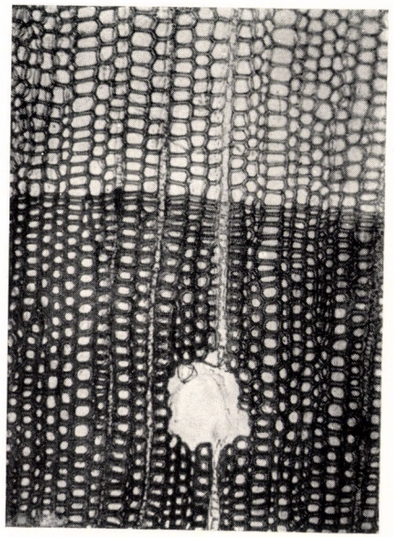

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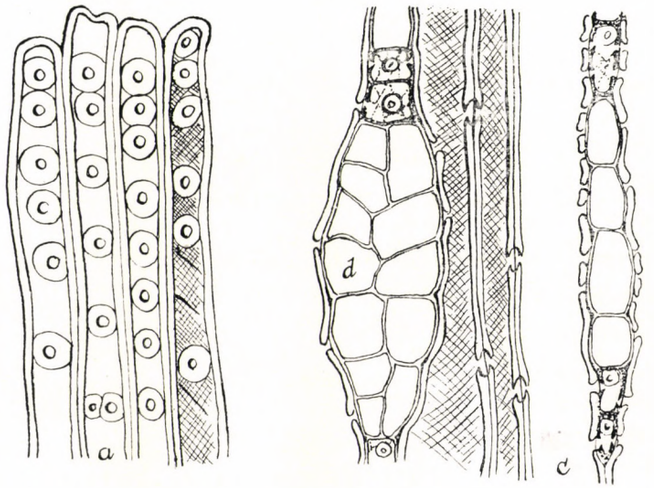

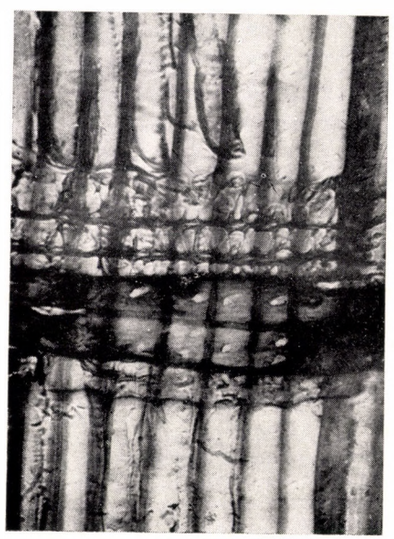

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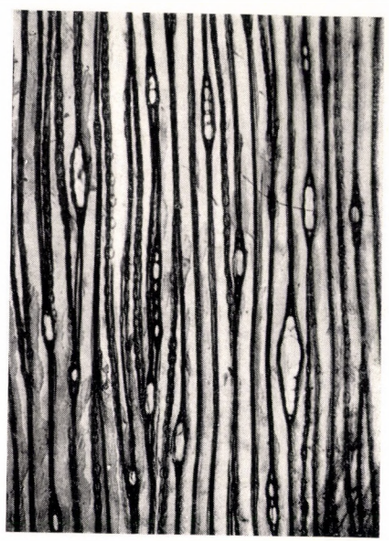

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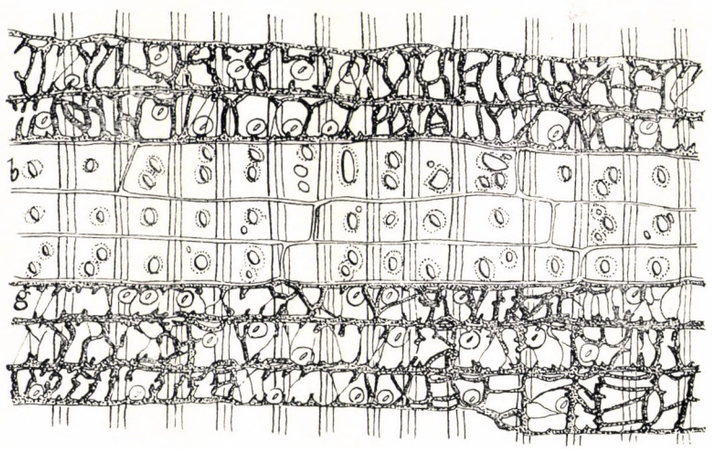
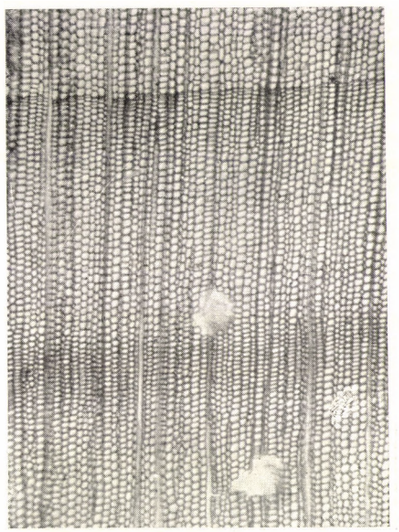


310. Pinus Murrayana Balf.



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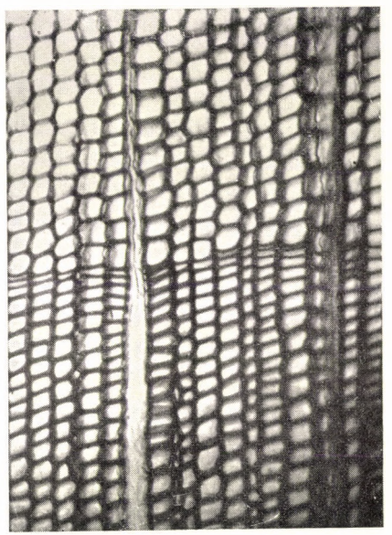

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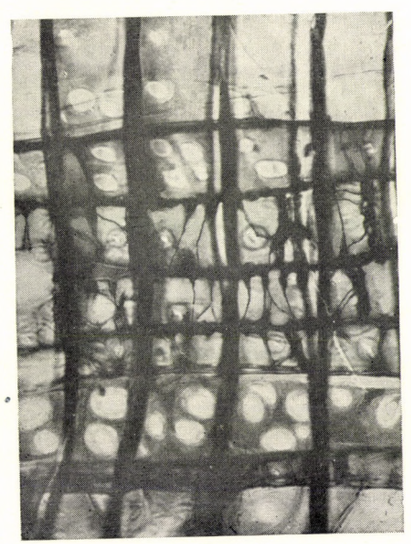

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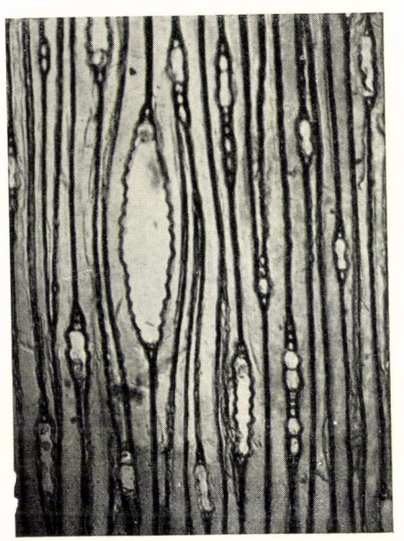

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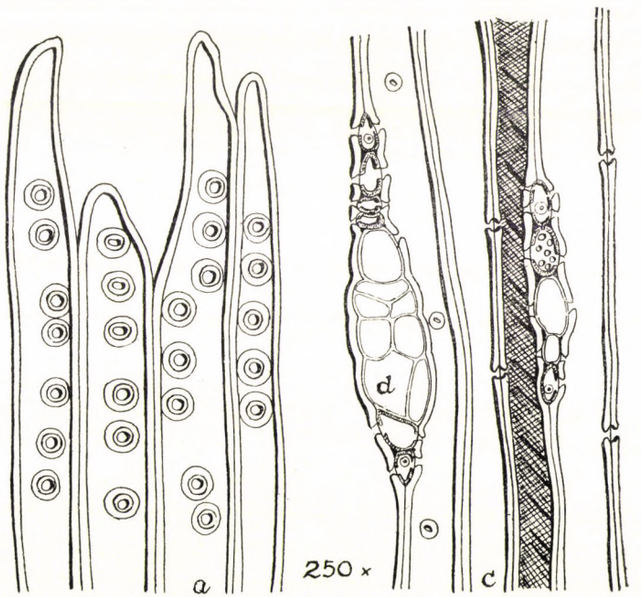
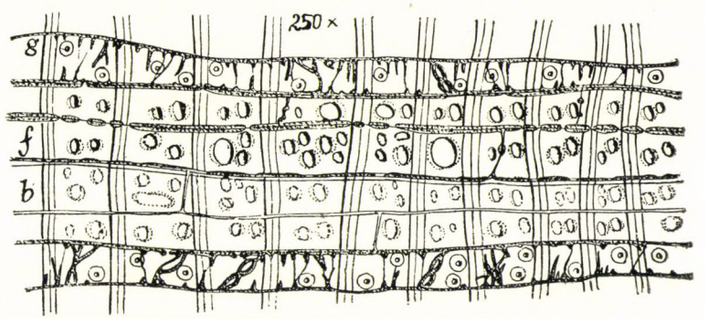
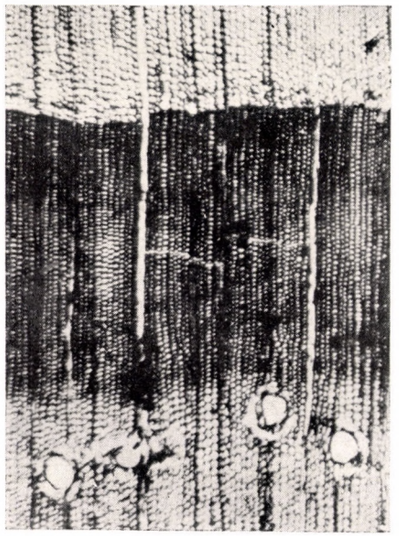
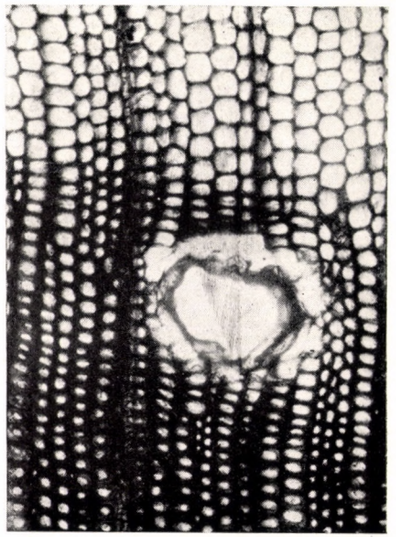




311. **Pinus muricata D. Don**



1. (30×)



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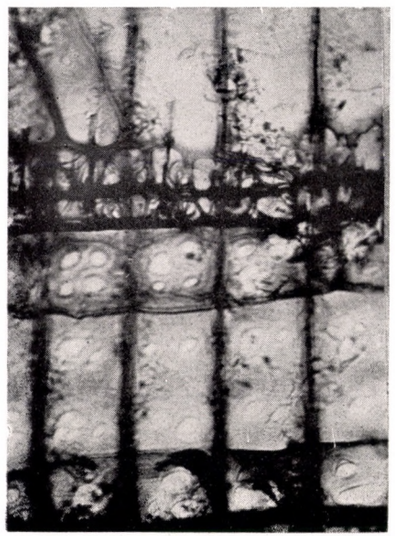
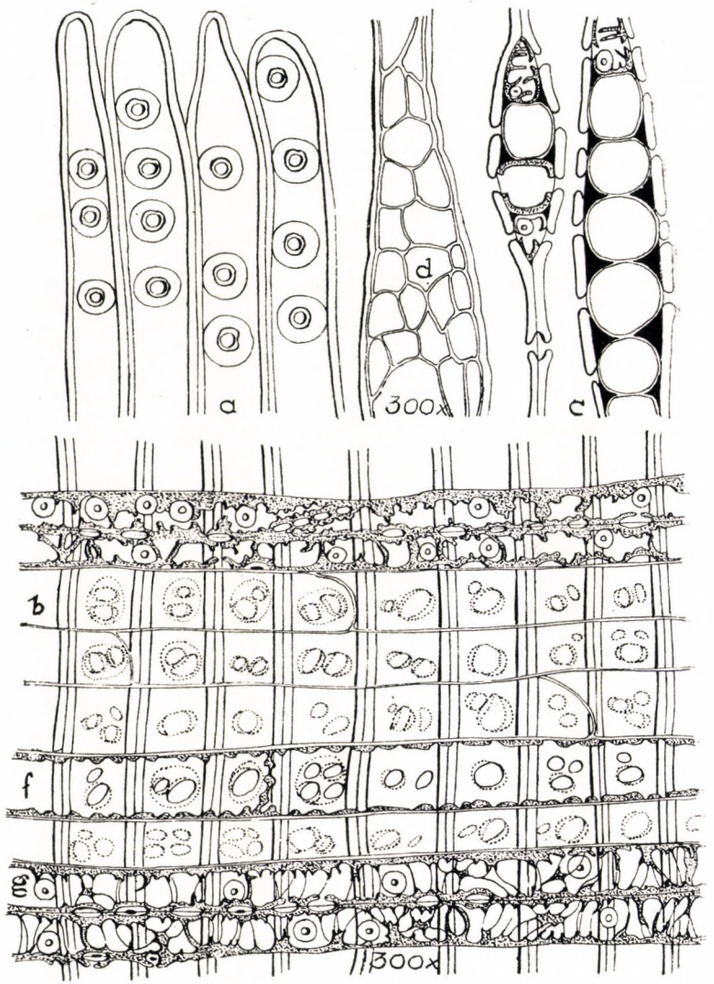


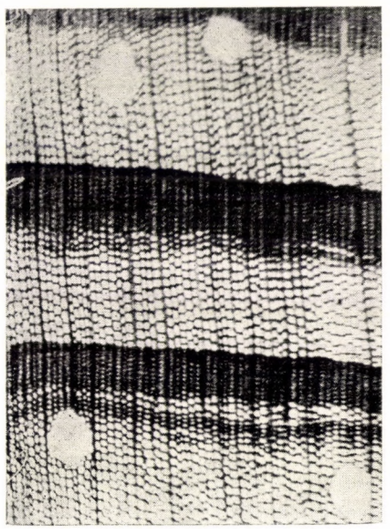
3. (300×)



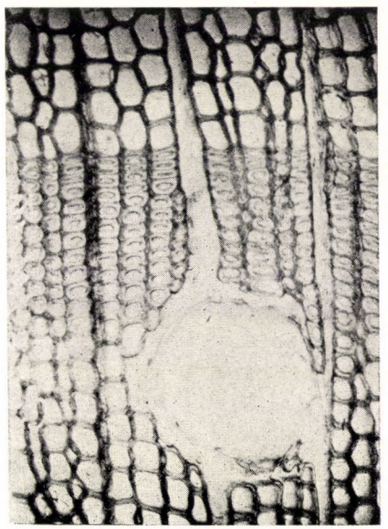
4. (100×)



312. Pinus occidentalis SWARTZ



1. (30×)



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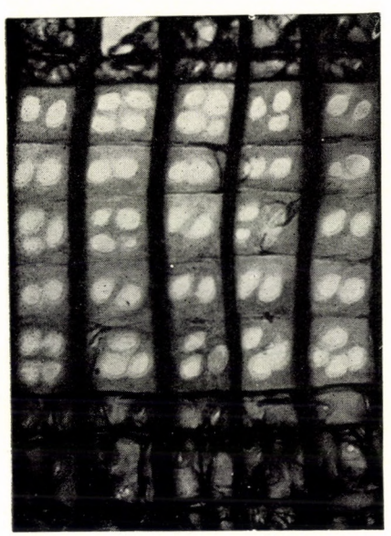

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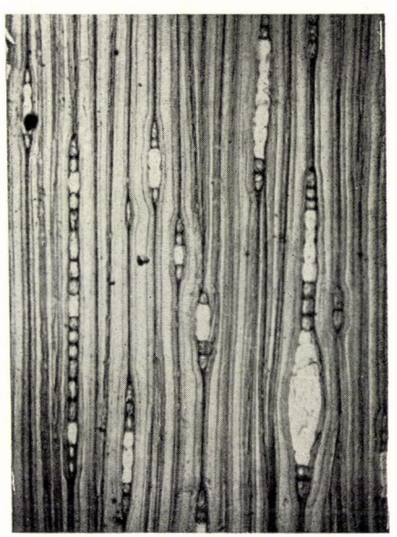

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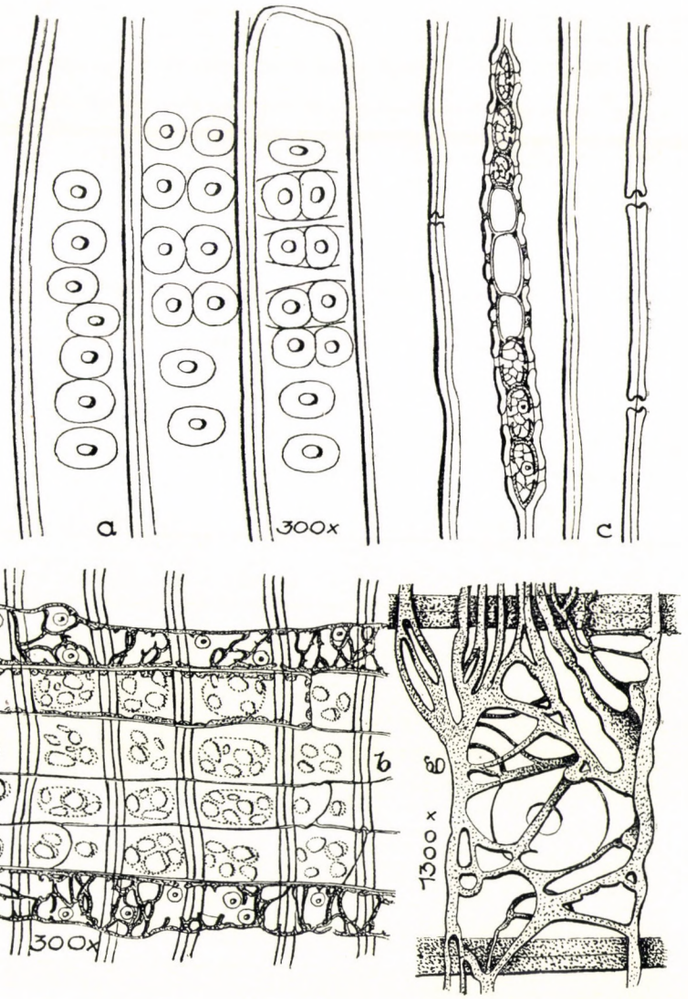
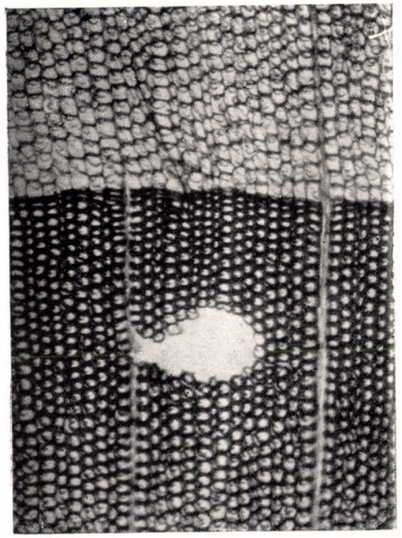
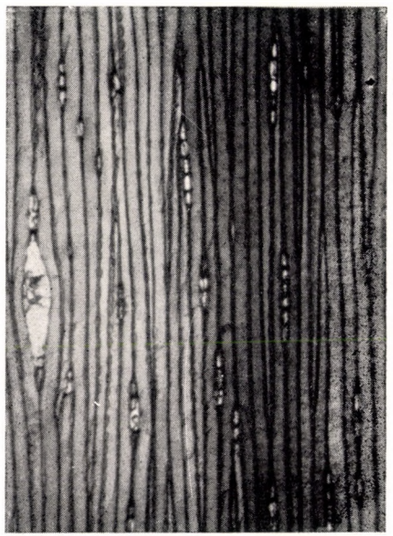


313. Pinus palustris MILLER



1. (100×)



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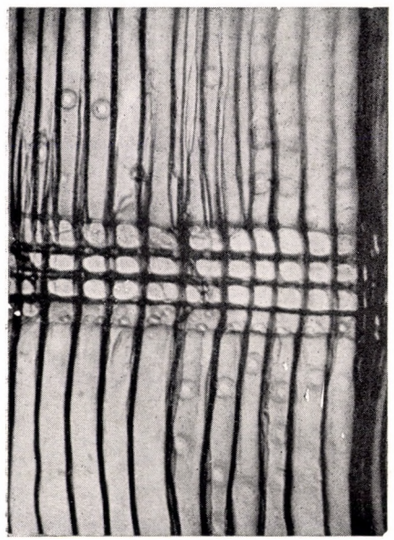
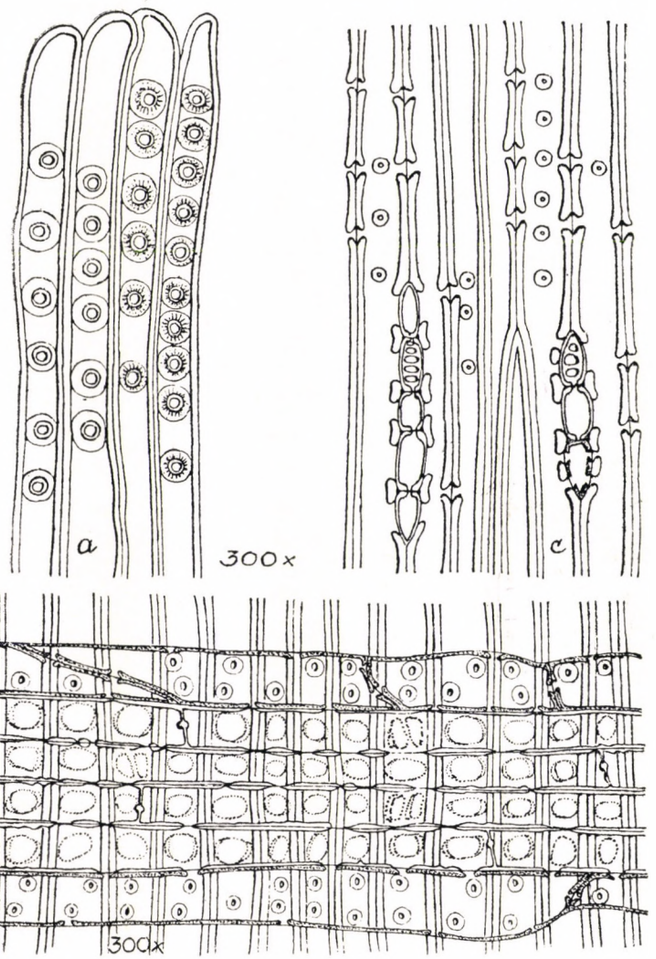


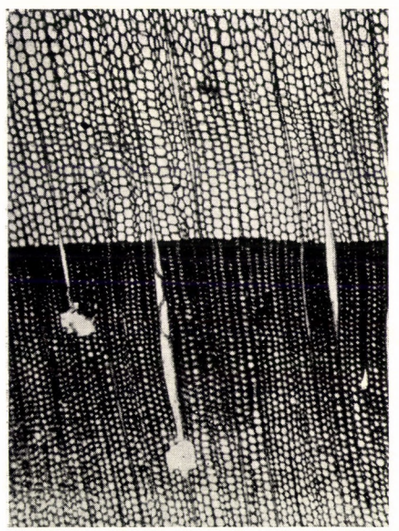
3. (200×)



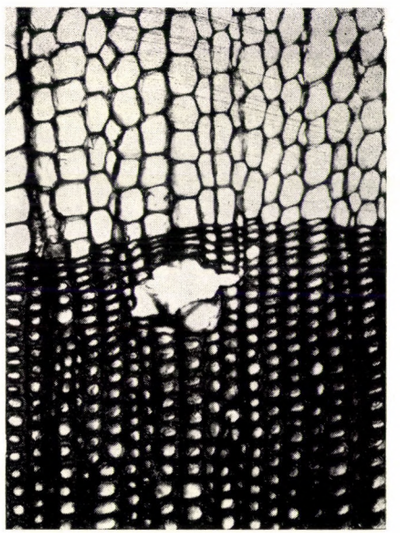
4. (300×)



314. Pinus parviflora SIEB. et ZUCC.



1. (30×)



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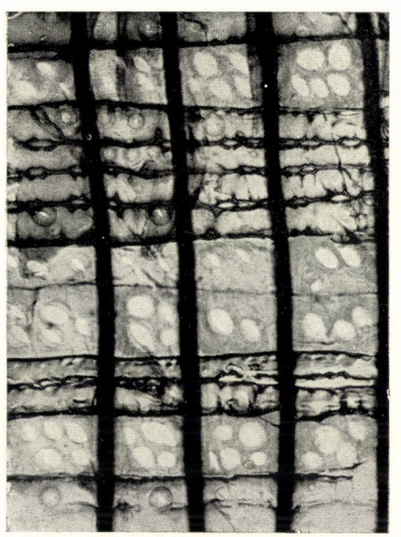

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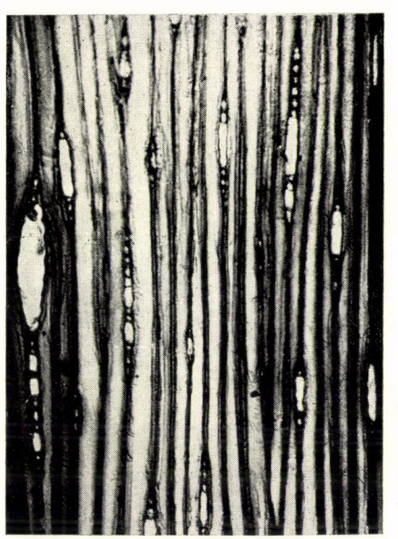
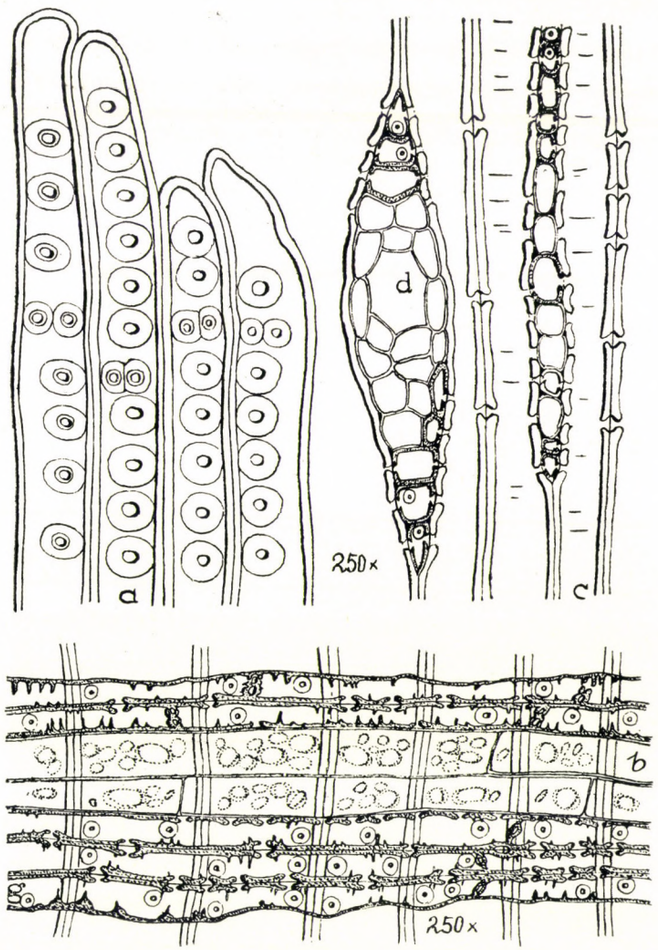
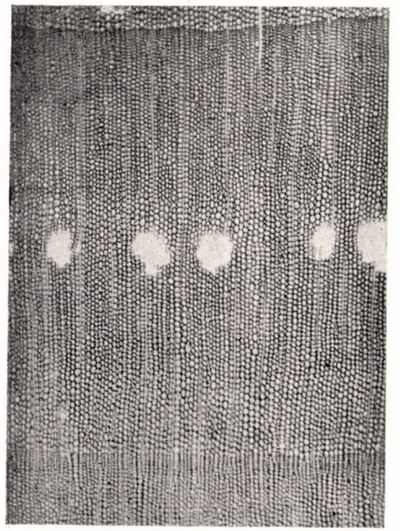


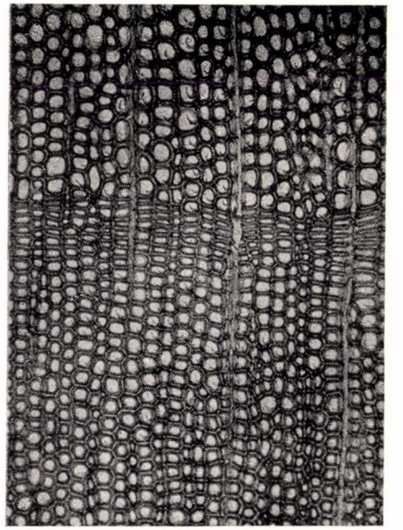
4. (100×)



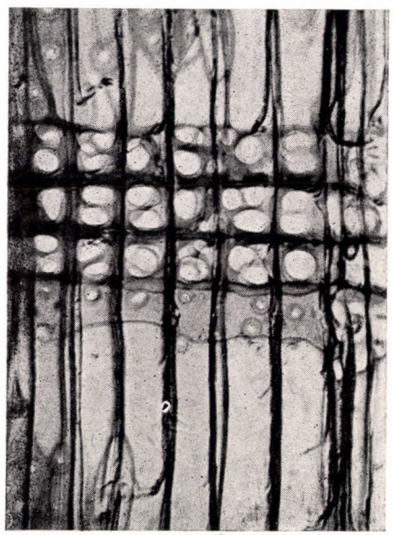
315. Pinus patula SCHLECHTENDAL et CHAMISSO



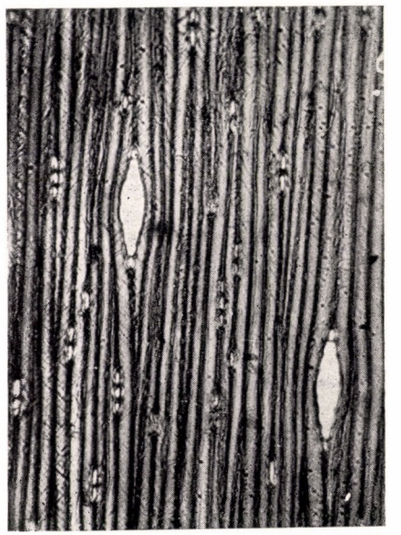
1. (30×)



2. (100×)



3. (300×)



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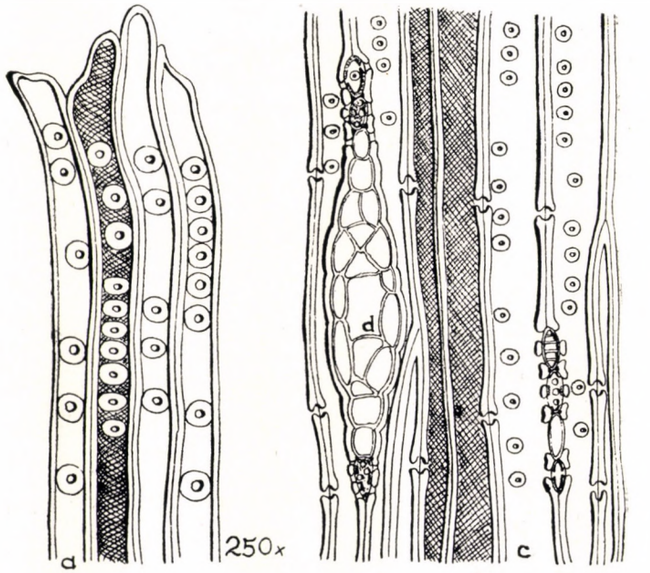
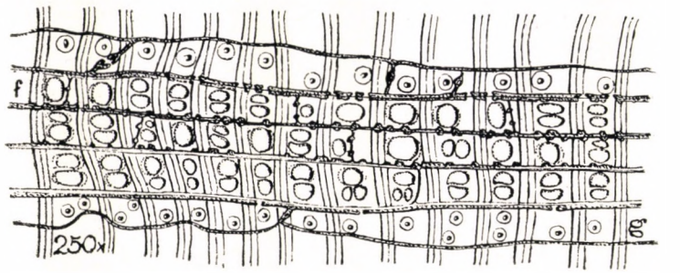
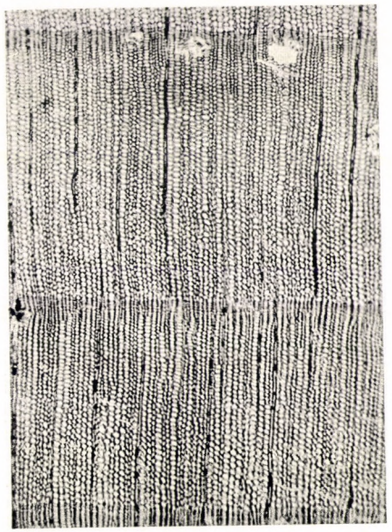
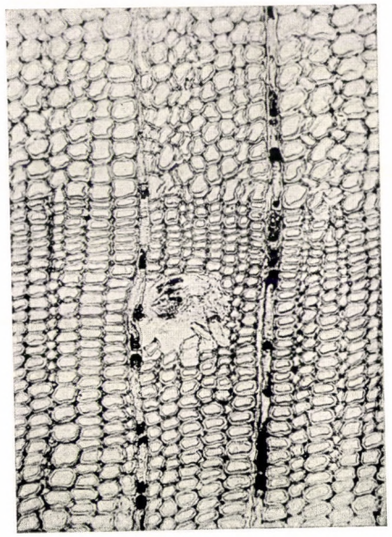




316. Pinus Peuce GRIESEBACH



1. (30×)



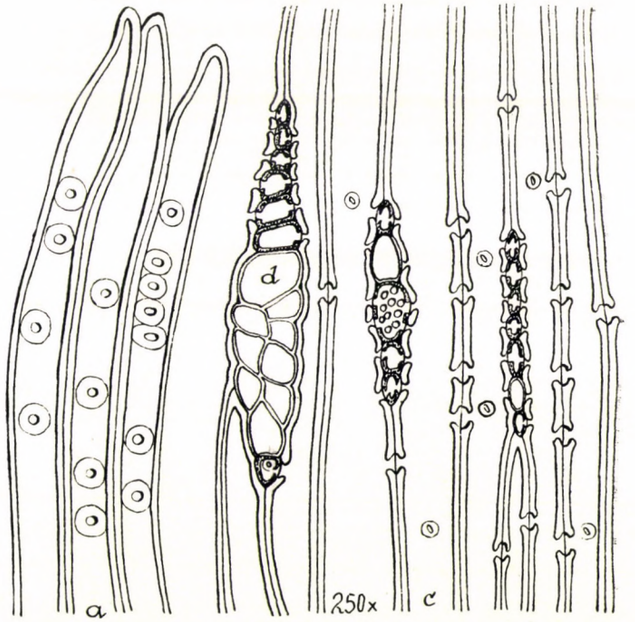
2. (100×)

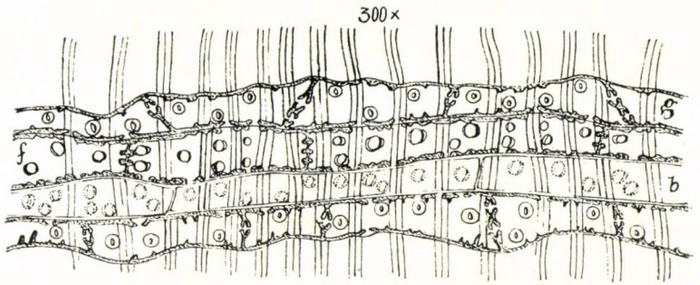


3. (300×)

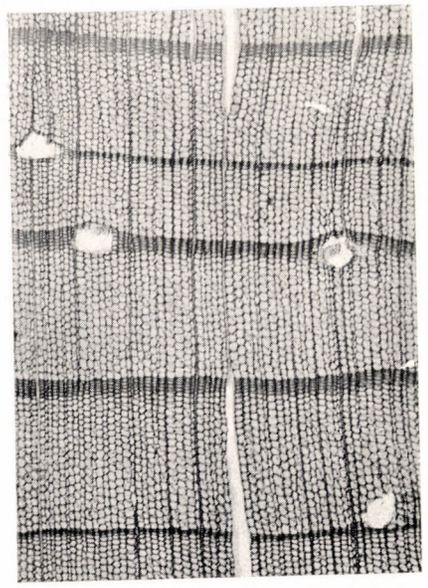


4. (100×)

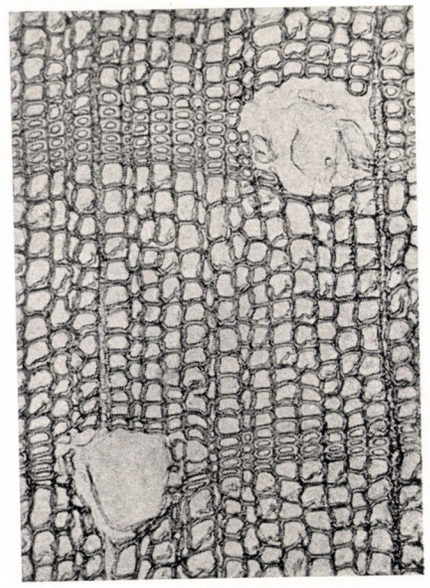




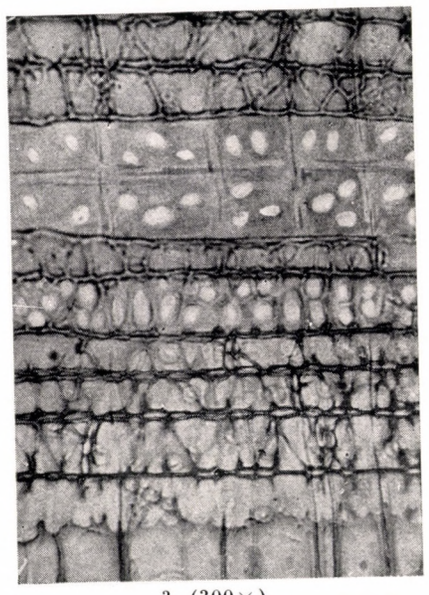
317. Pinus Pinea L.



1. (30×)



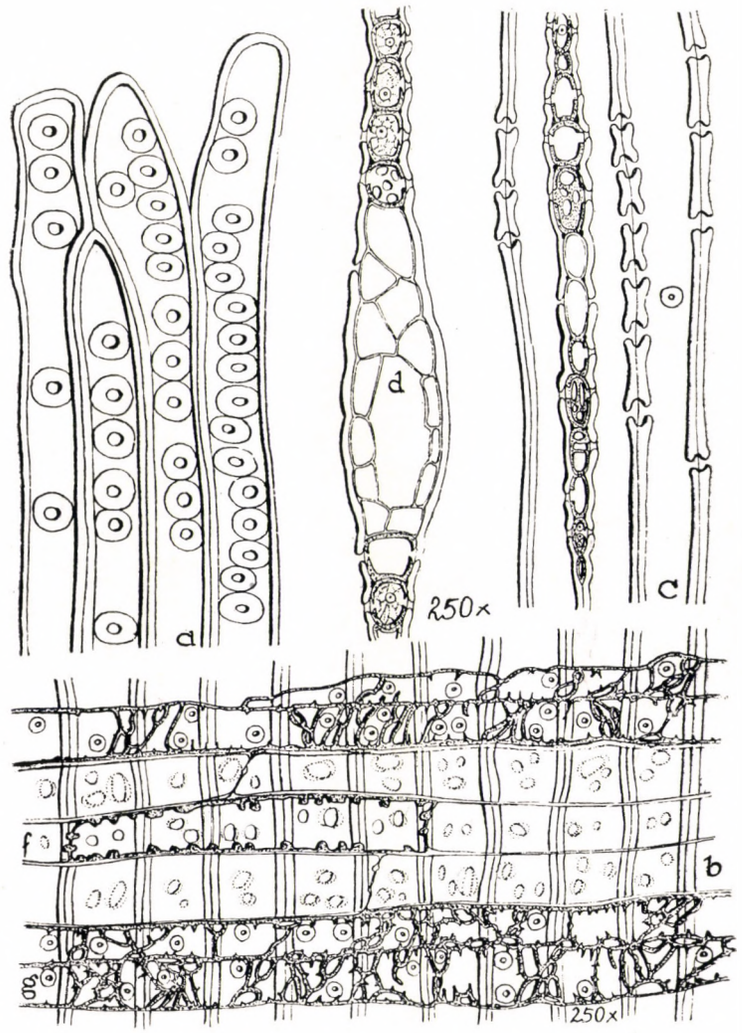
2. (100×)



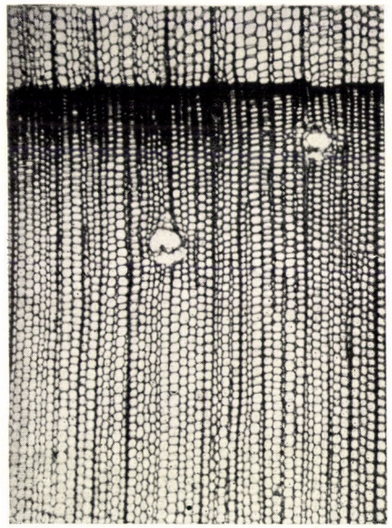
3. (300×)



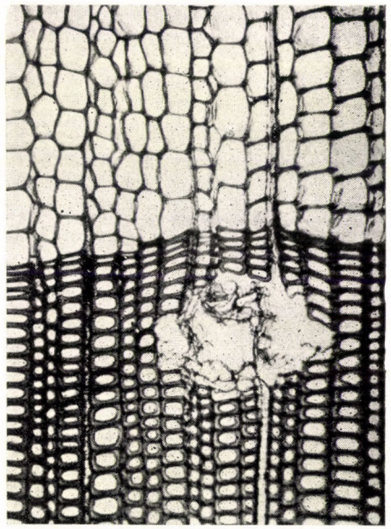
4. (100×)



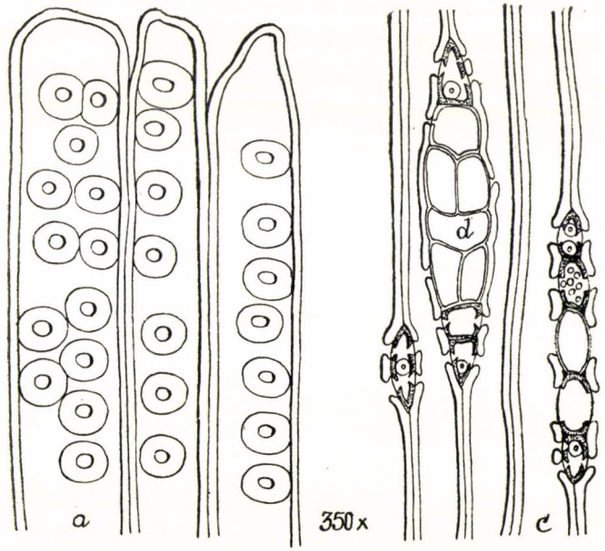
318. Pinus ponderosa DOUGLAS

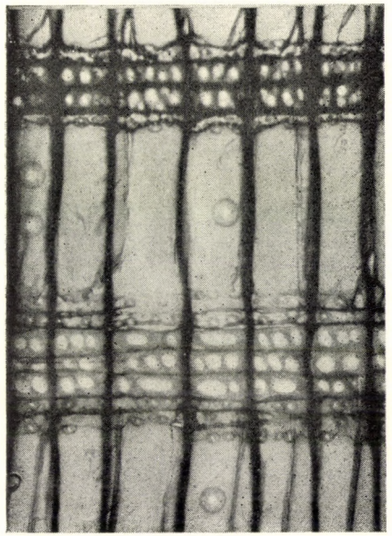


1. (30×)

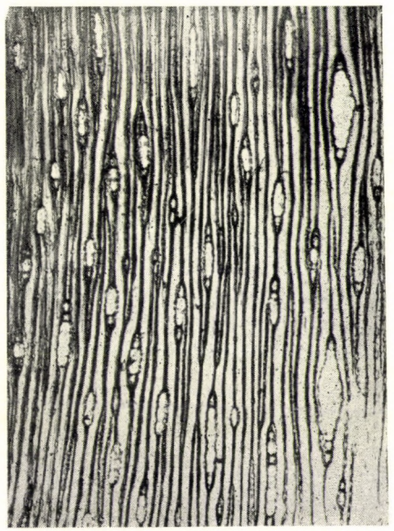


2. (100×)

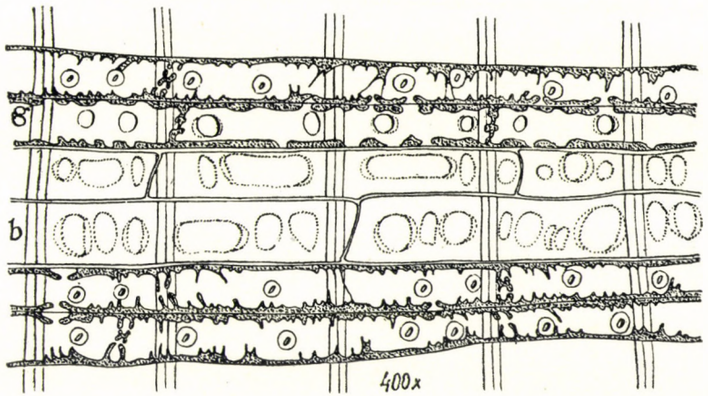




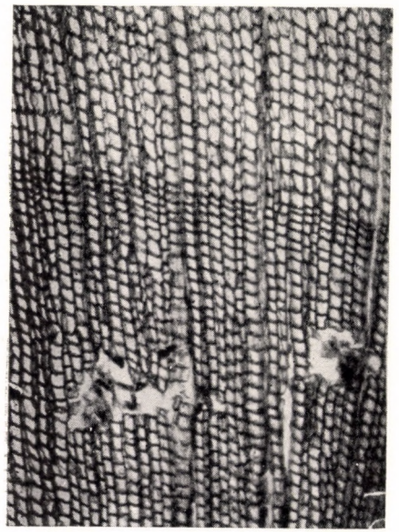
3. (200×)



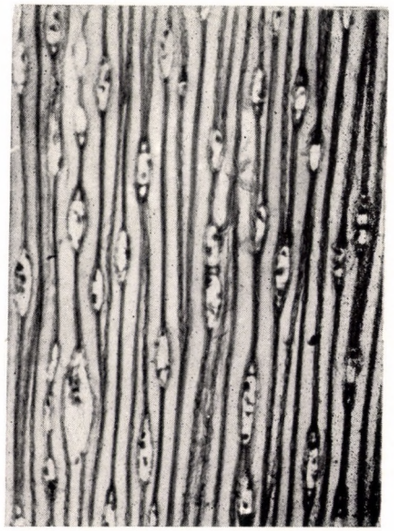
4. (100×)



319. Pinus ponderosa v. Jeffreyi VASEY



1. (100×)



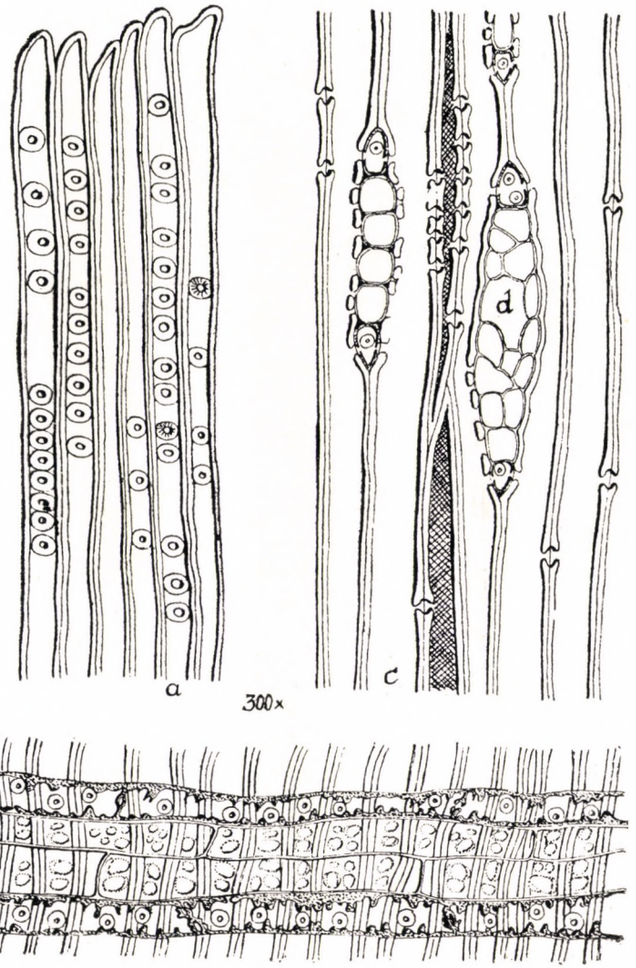
2. (100×)



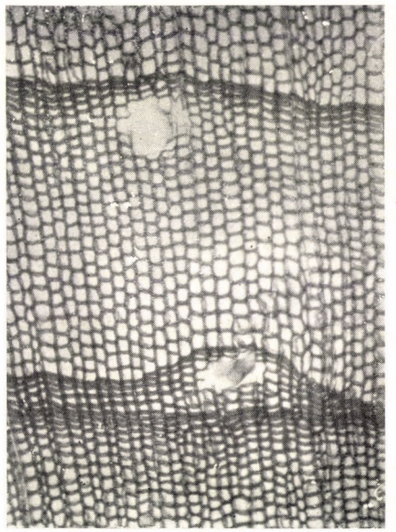
3. (300×)



4. (300×)



320. Pinus pseudo-strobus LINDLEY



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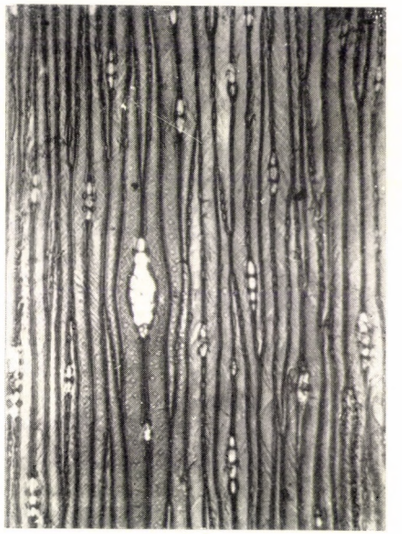

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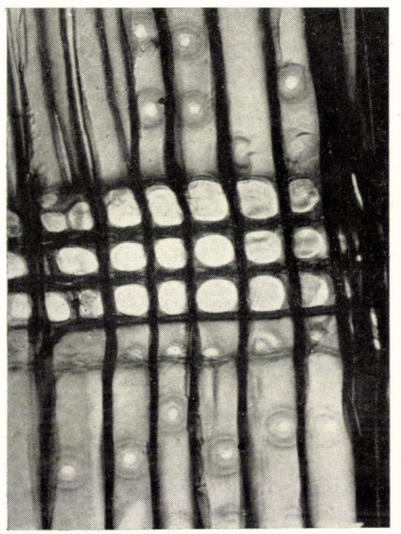

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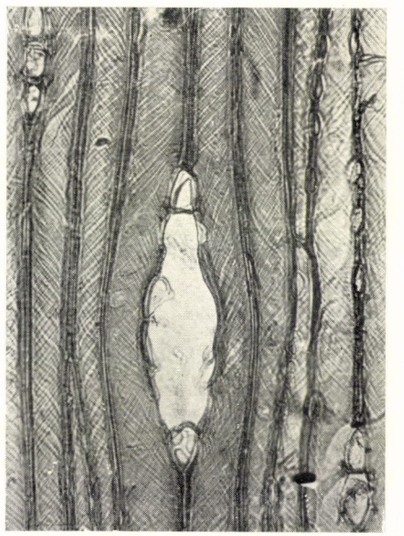

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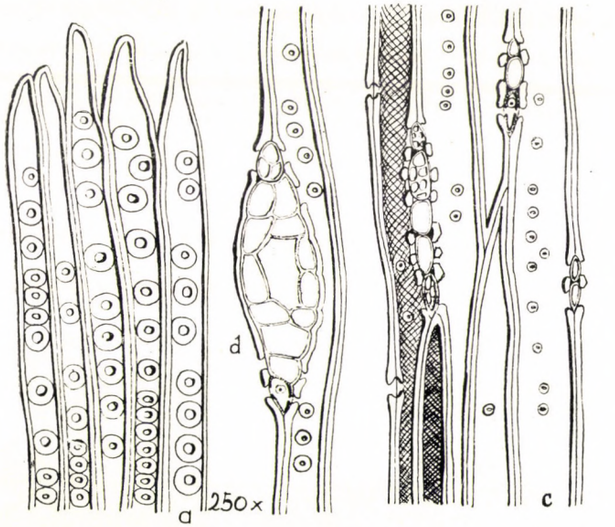
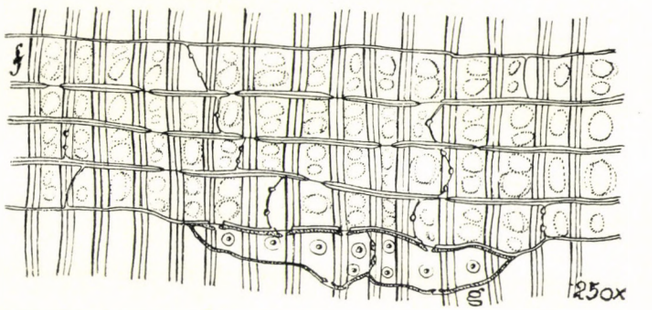
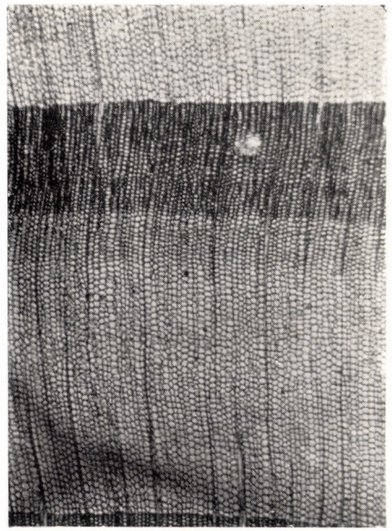




321. Pinus pumila REGEL



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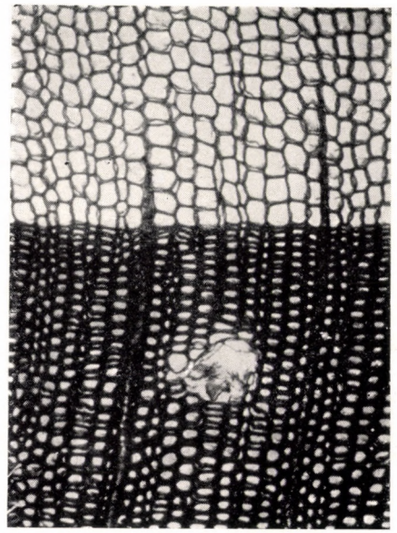

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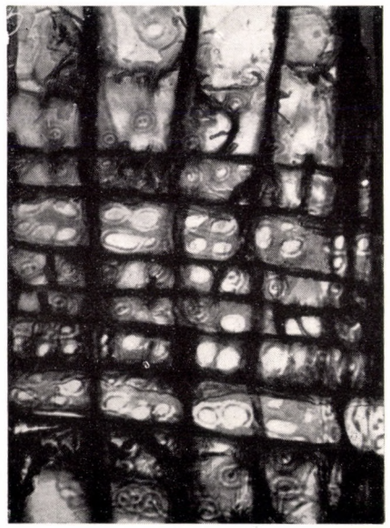

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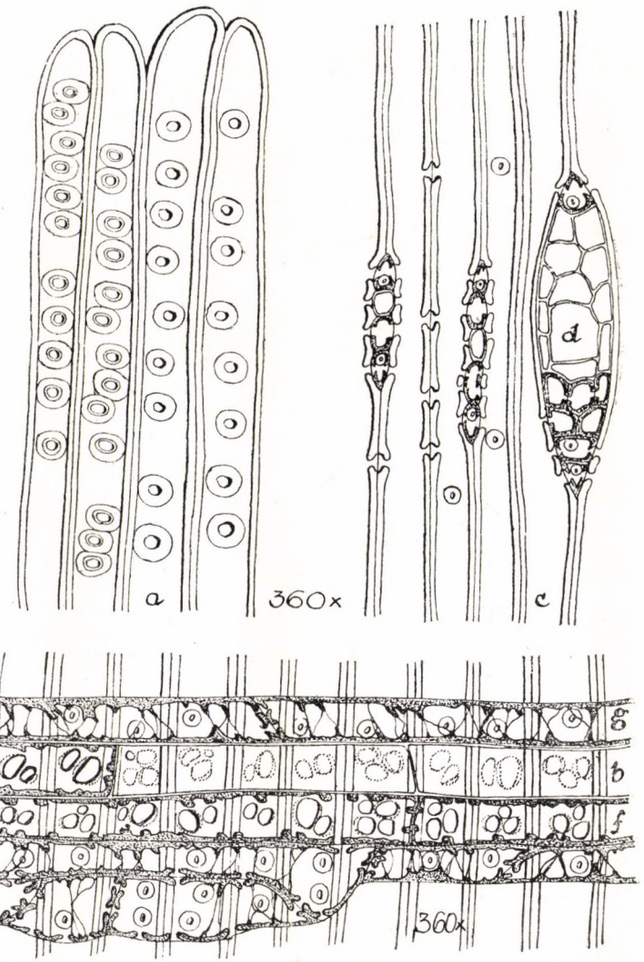
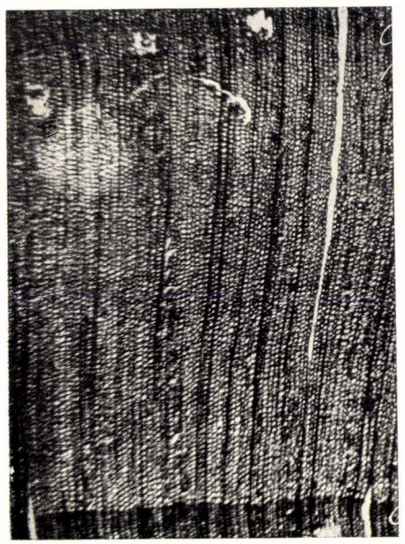
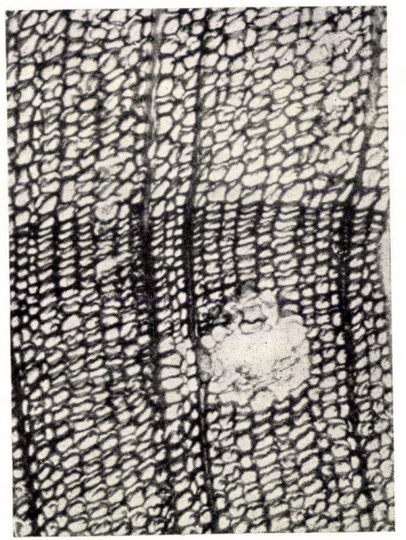
4. (100×)



322. Pinus pungens LAMBERT et MICHEAUX



1. (30×)



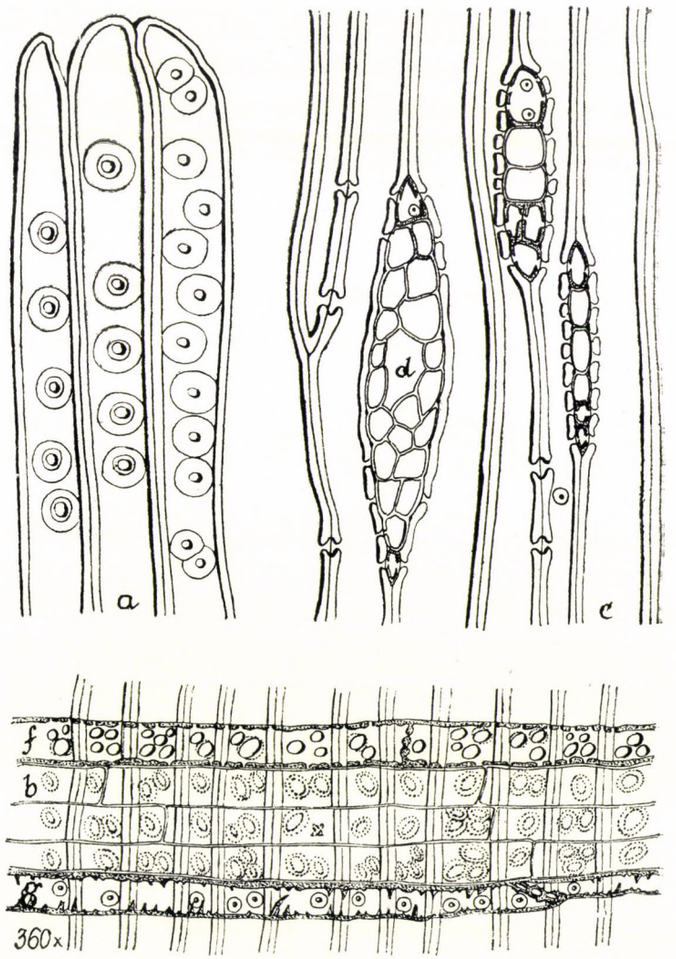
2. (100×)



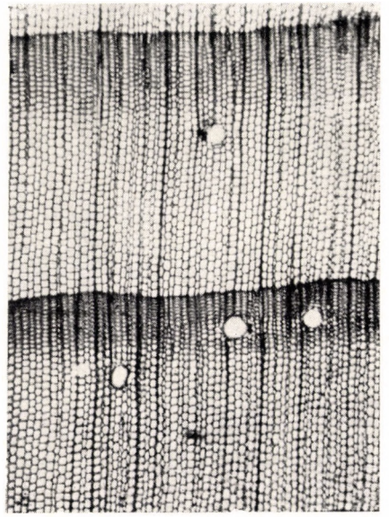
3. (300×)



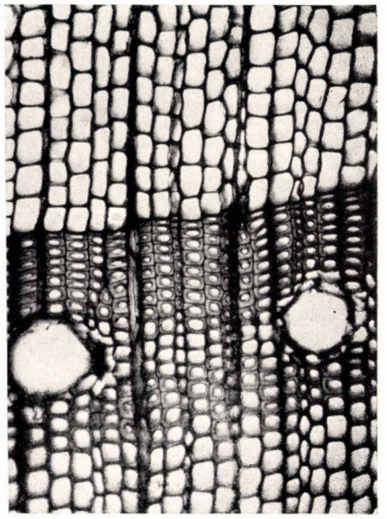
4. (100×)



323. Pinus radiata D. Don



1. (30×)



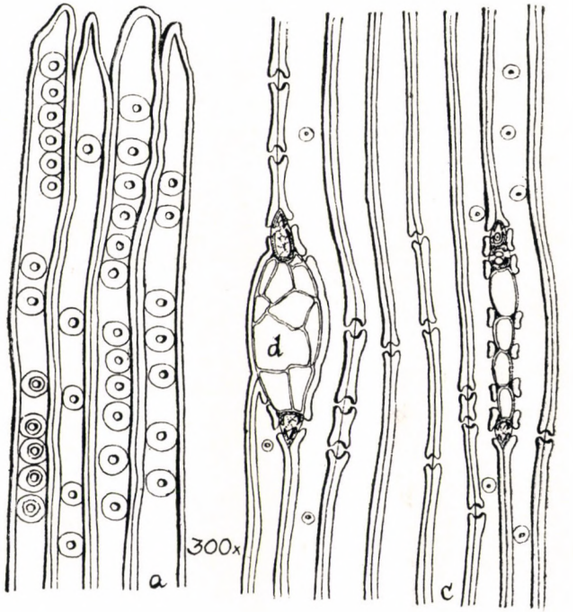
2. (100×)

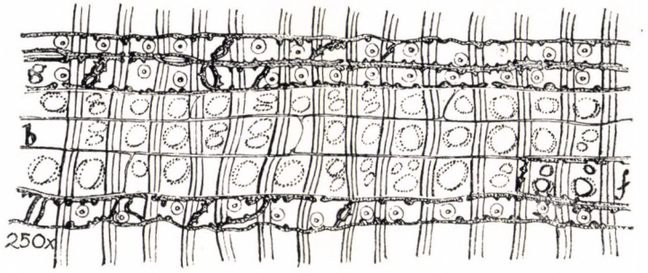


3. (300×)

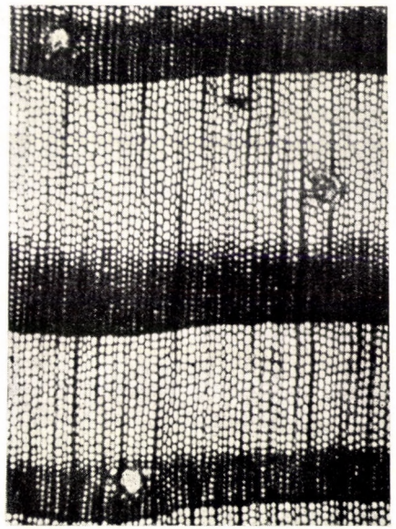


4. (100×)

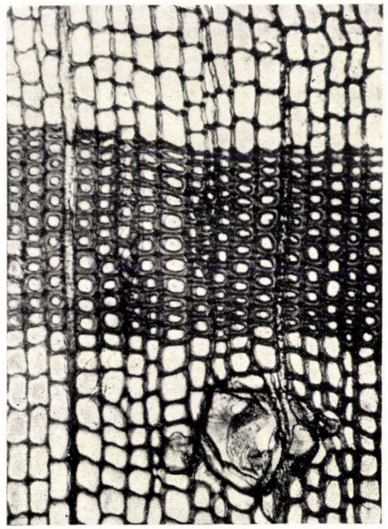




324. Pinus resinosa Aiton



1. (30×)



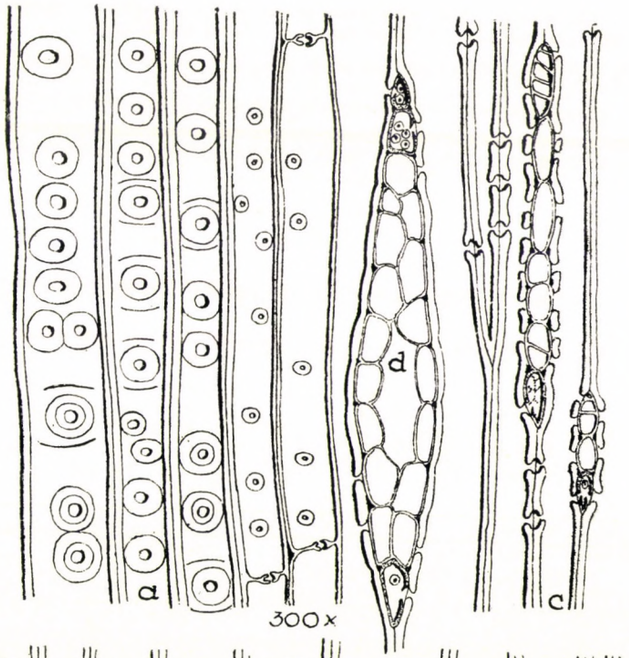
2. (100×)

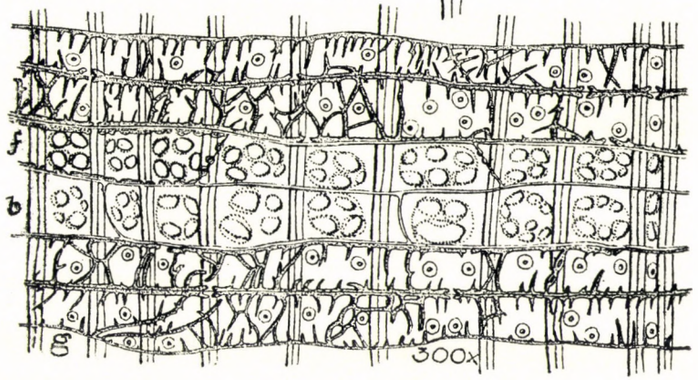


3. (300×)

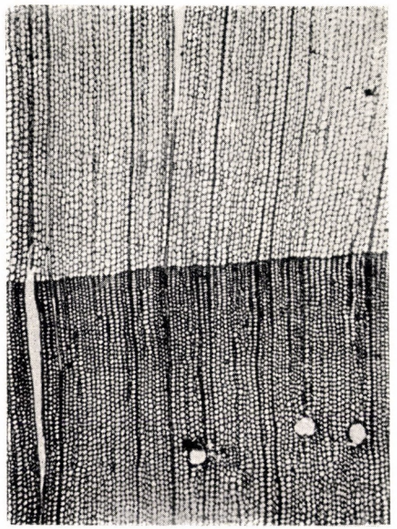


4. (100×)

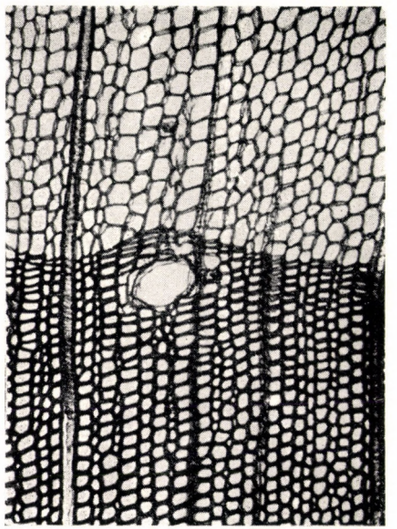




325. Pinus rigida MILLER



1. (30×)



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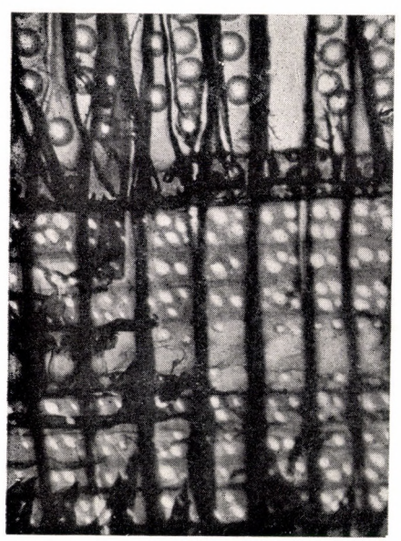
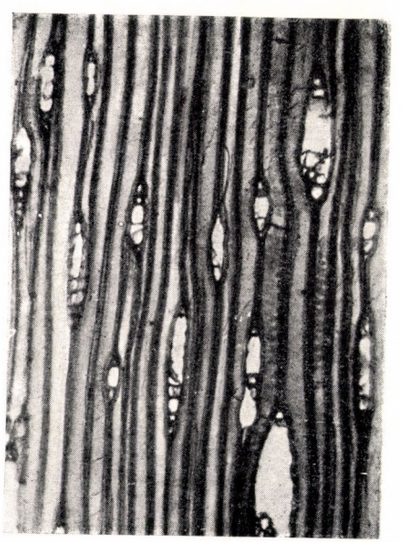


3. (300×)



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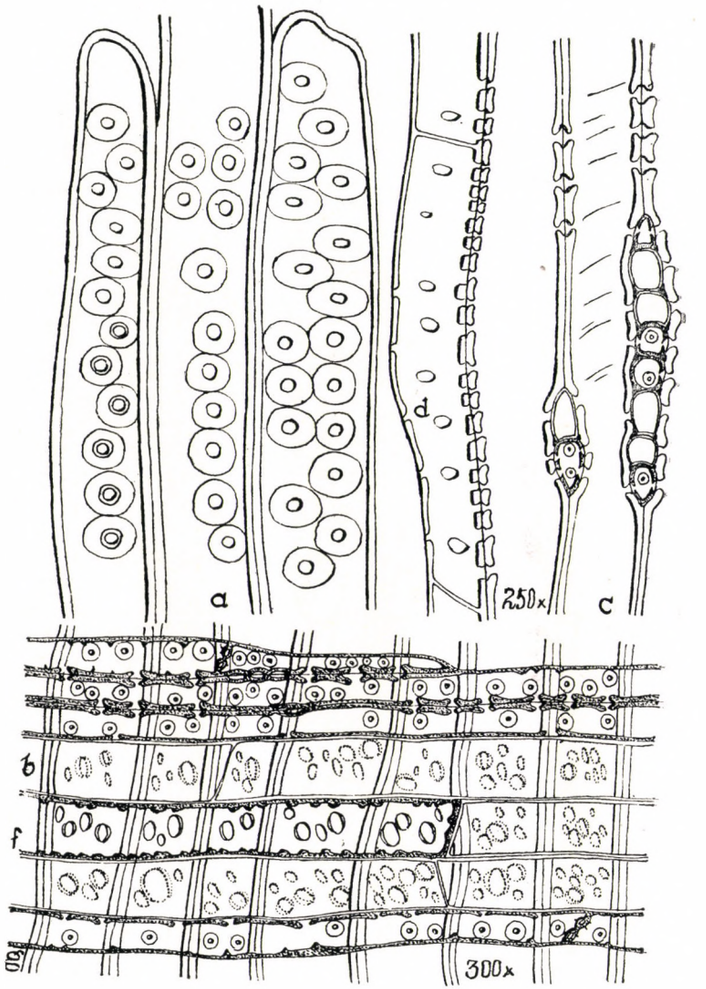
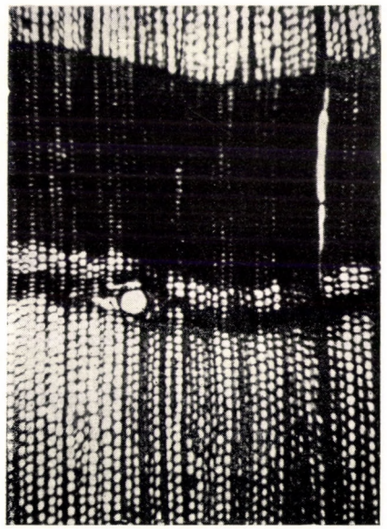


326. Pinus Sabiniana DOUGLAS



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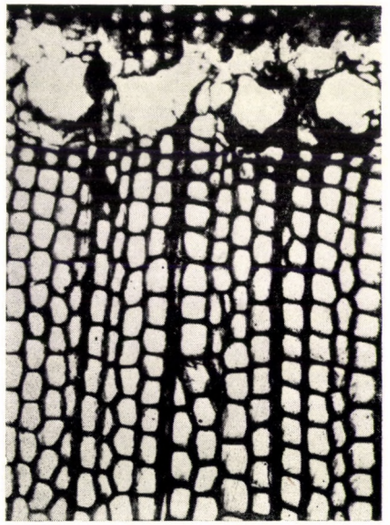
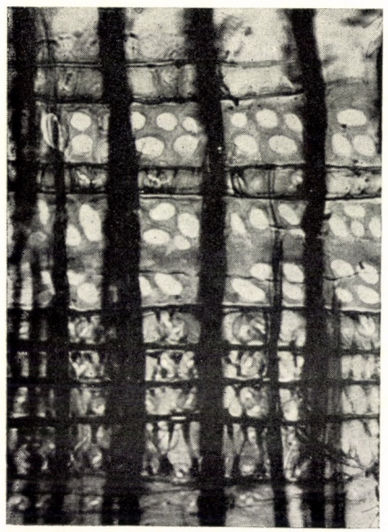


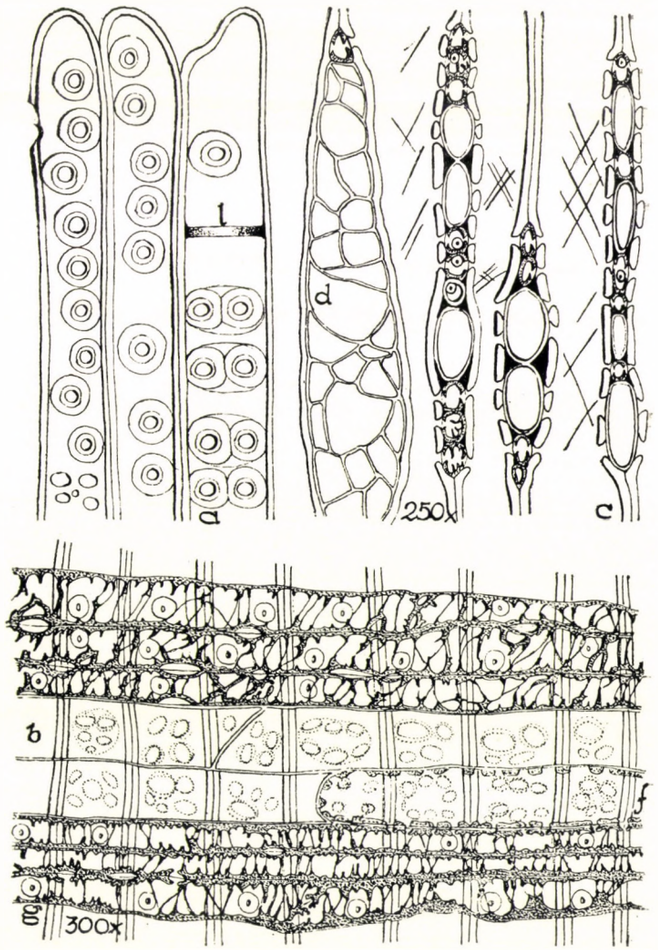
2. (100×)



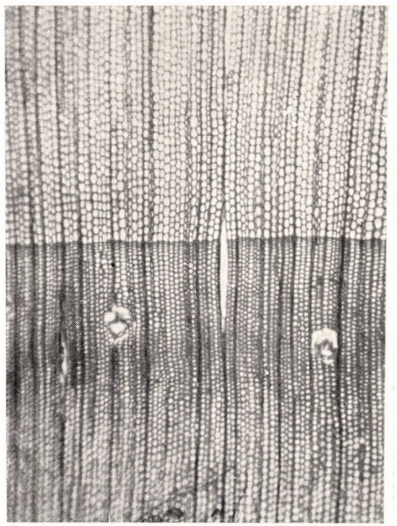
3. (300×)



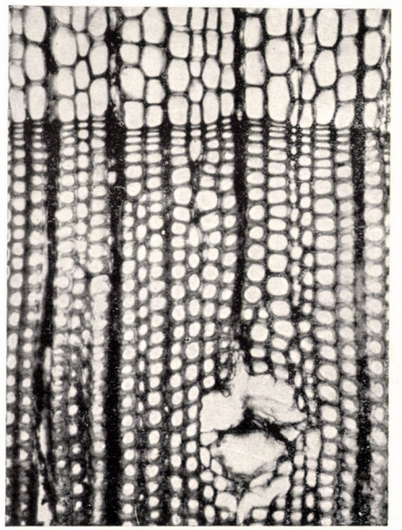
4. (100×)



327. Pinus serotina MICHAUX



1. (30×)



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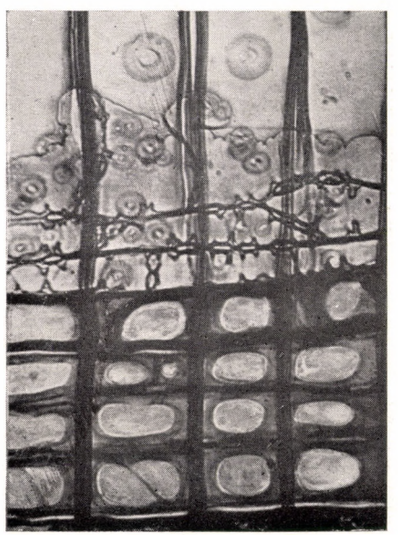
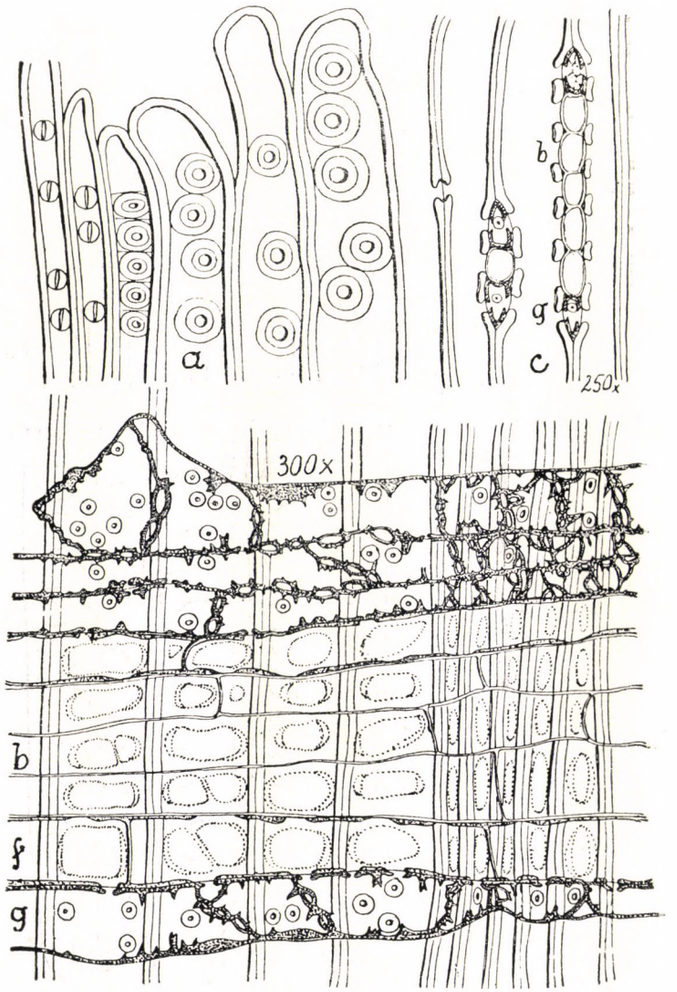


3. (300×)



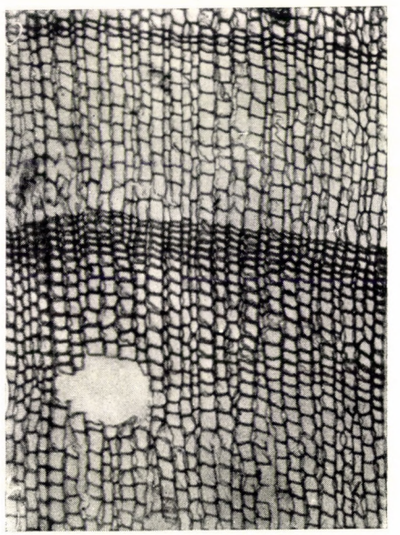
4. (100×)



328. Pinus silvestris L.



1. (30×)



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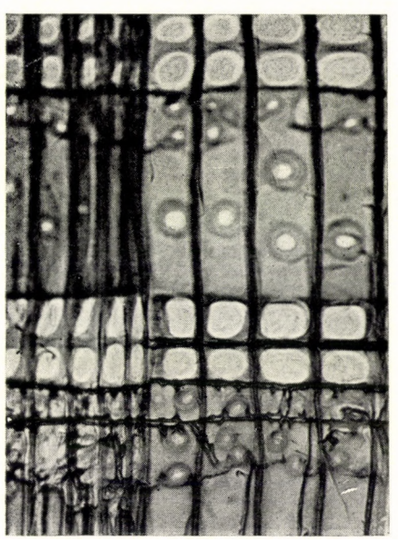
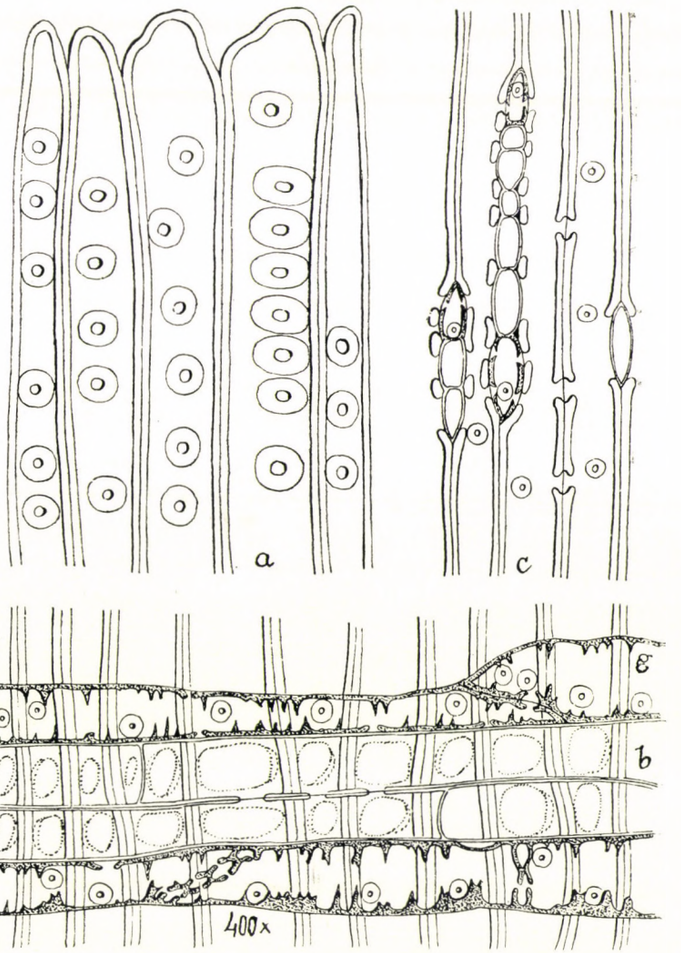


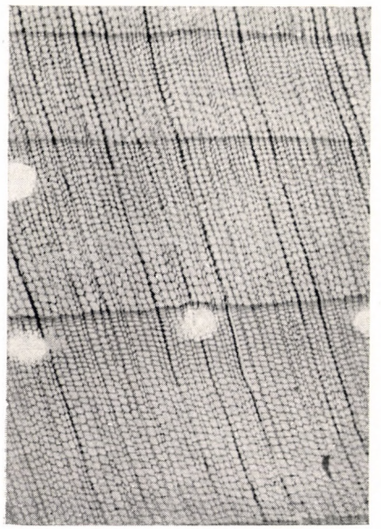
3. (300×)



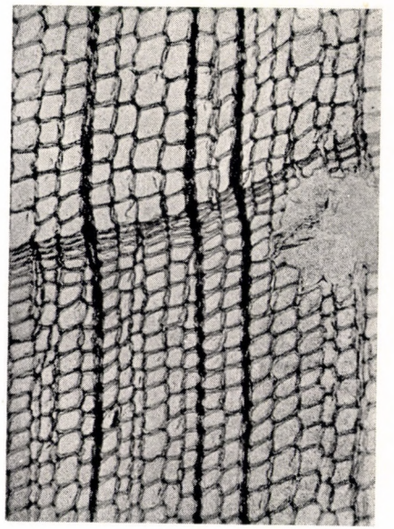
4. (100×)



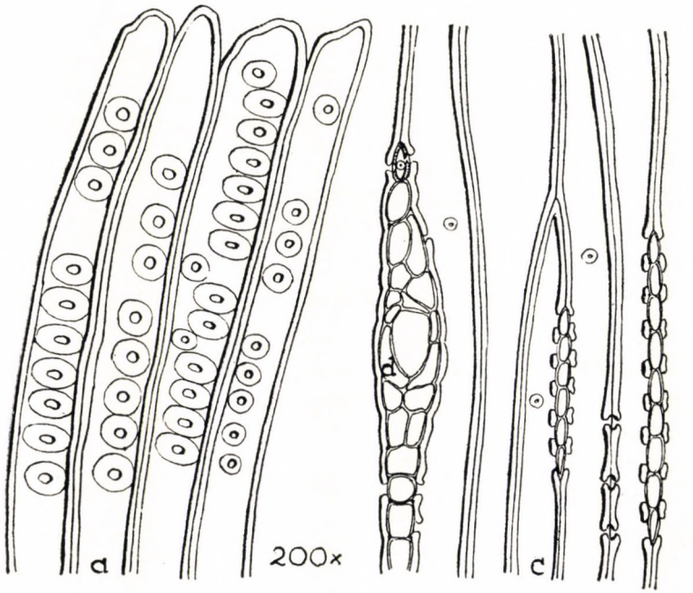
329. Pinus sinensis LAMBERT



1. (30×)



2. (100×)

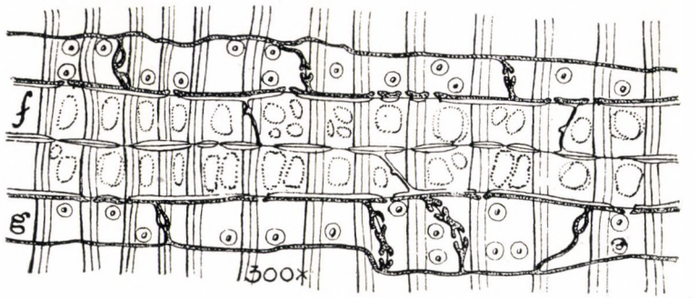




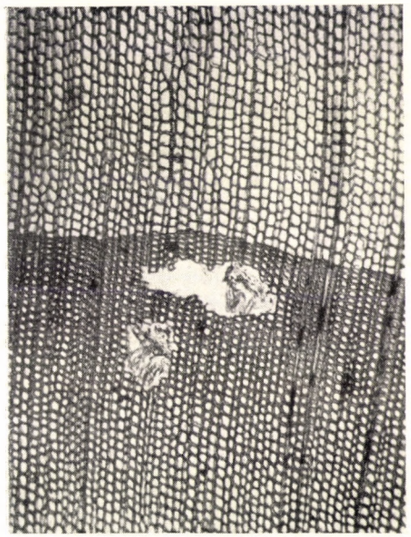
3. (300×)



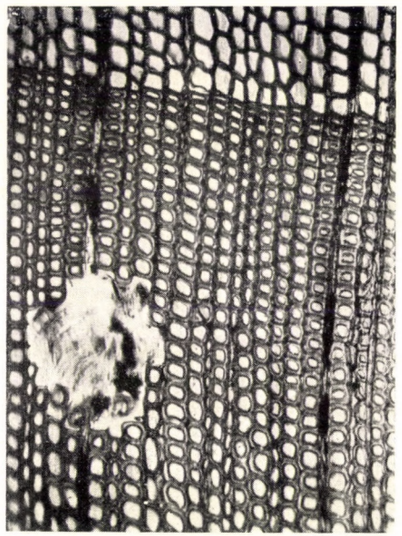
4. (100×)



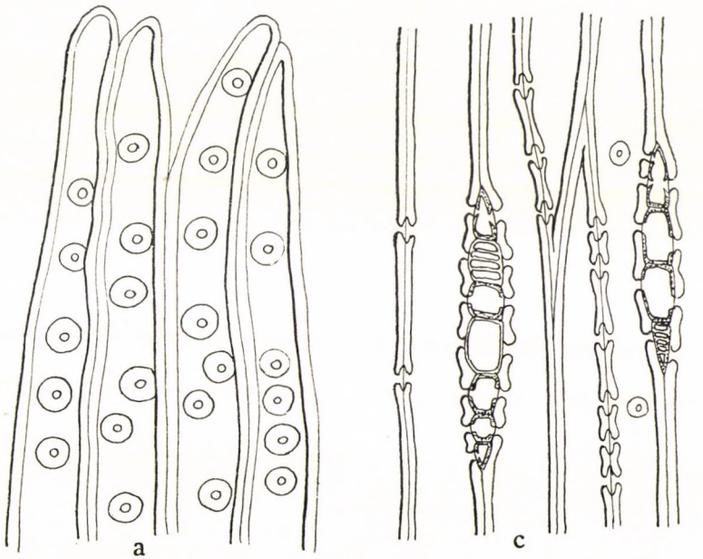
330. Pinus Strobus L.



1. (30×)



2. (100×)

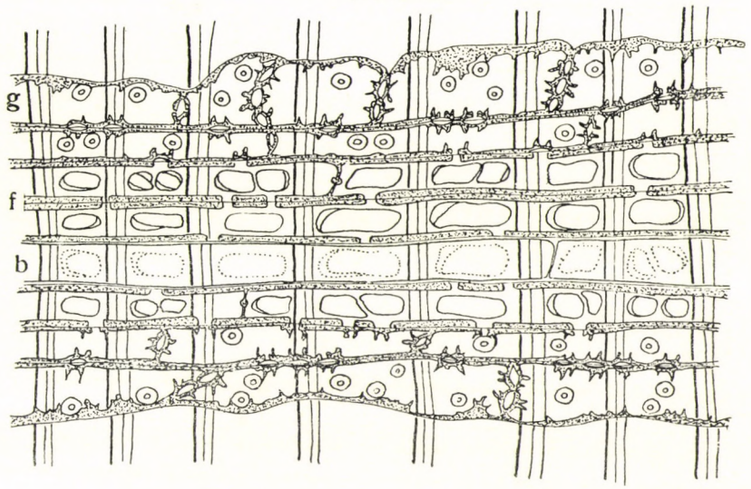




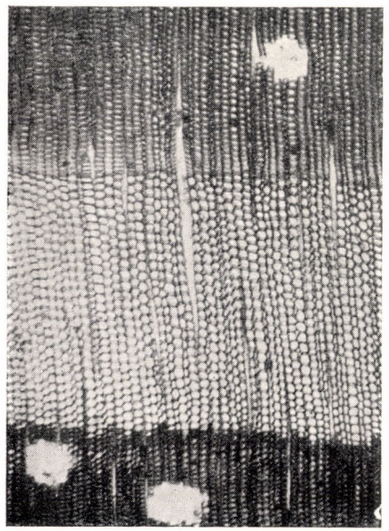
3. (300×)



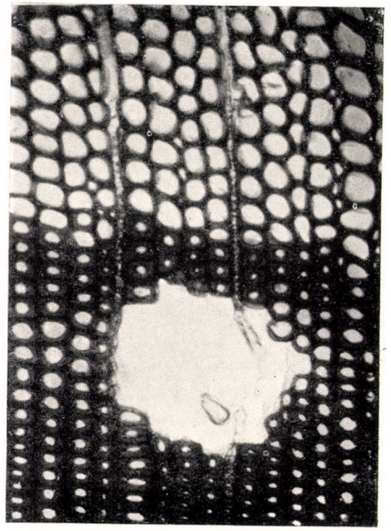
4. (100×)



330a Pinus tabulaeformis v. yunnanensis (Shaw) DALLIMORE



1. (30×)



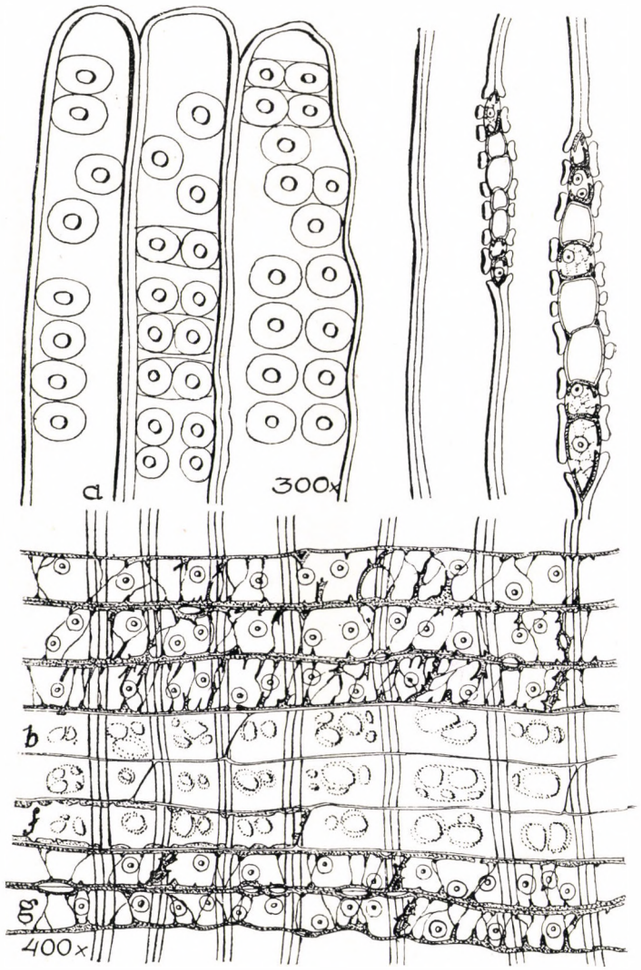
2. (100×)



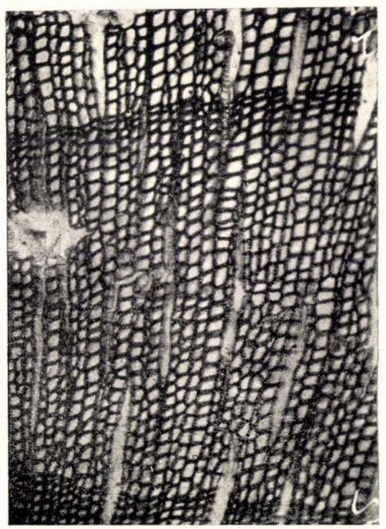
3. (300×)



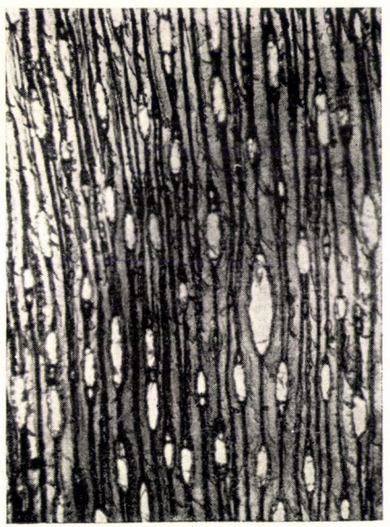
4. (100×)



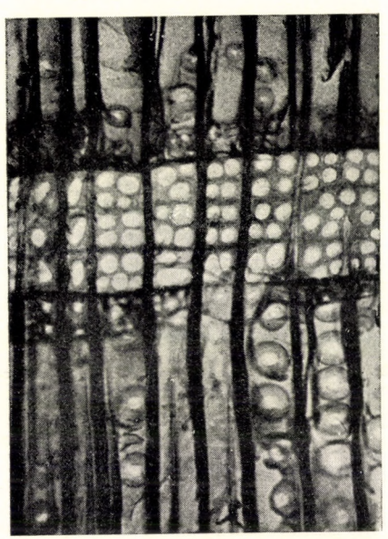
331. Pinus Taeda L.



1. (100×)



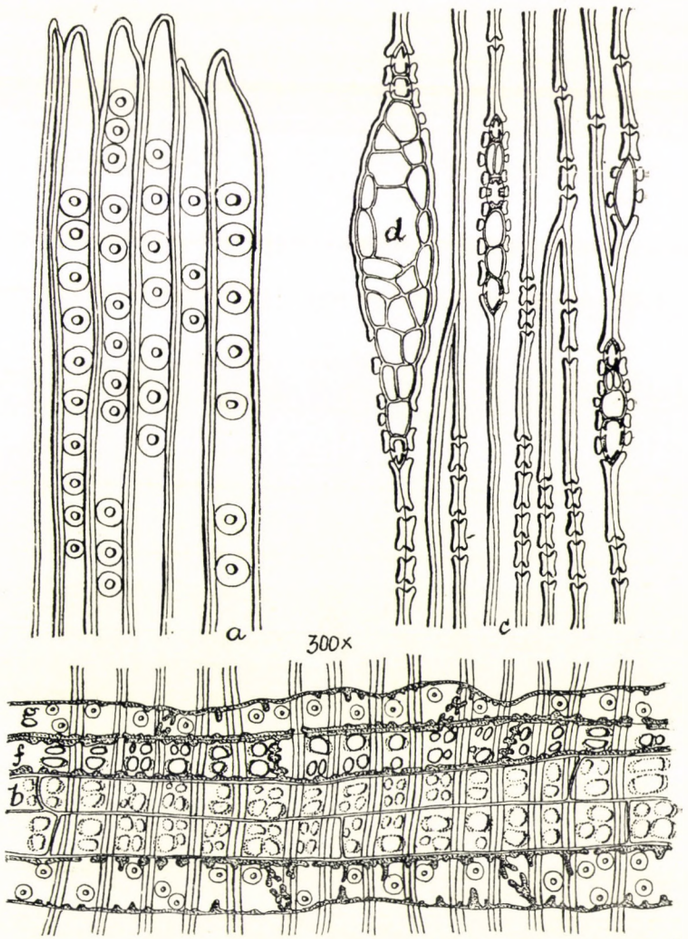
2. (100×)



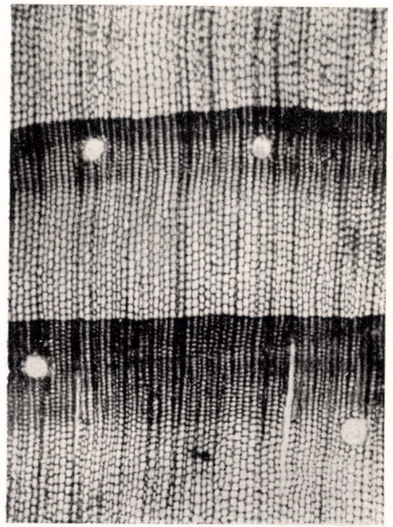
3. (300×)



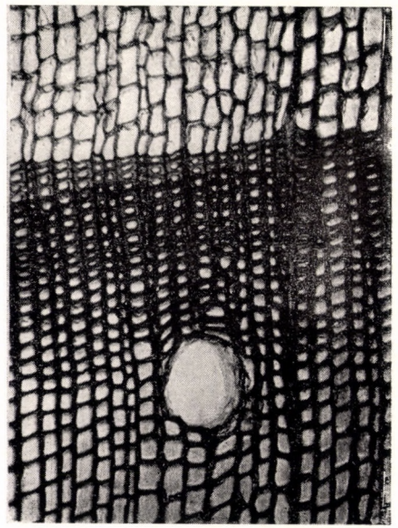
4. (300×)



332. Pinus Teocote SCHLECHTENDAL et CHAMISSO



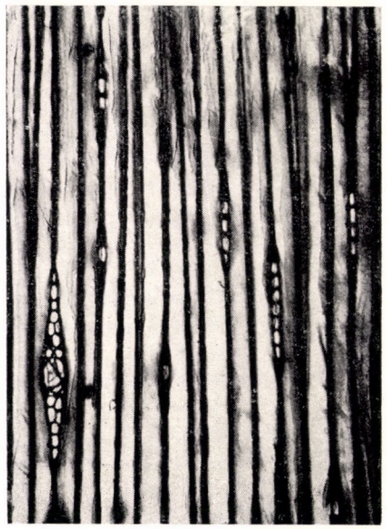
1. (30×)



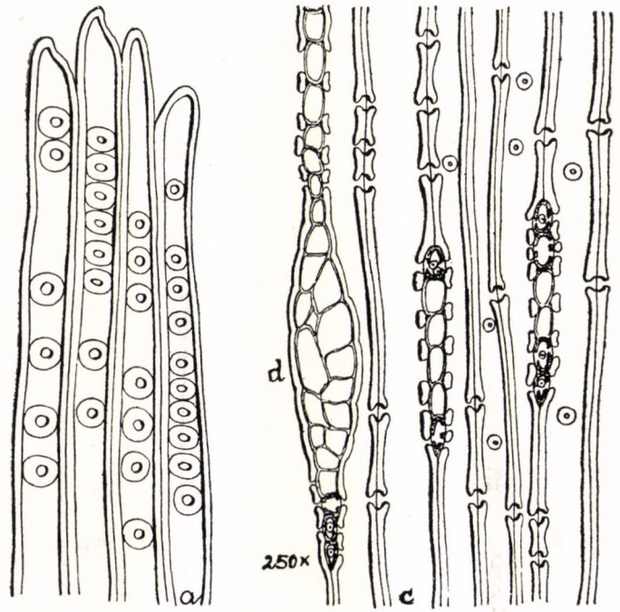
2. (100×)

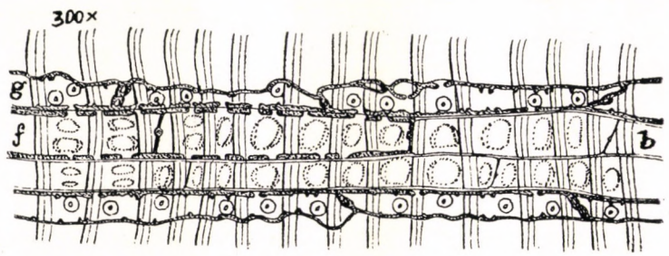


3. (300×)

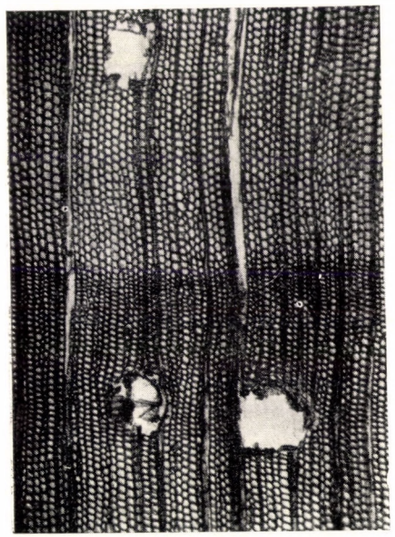


4. (100×)

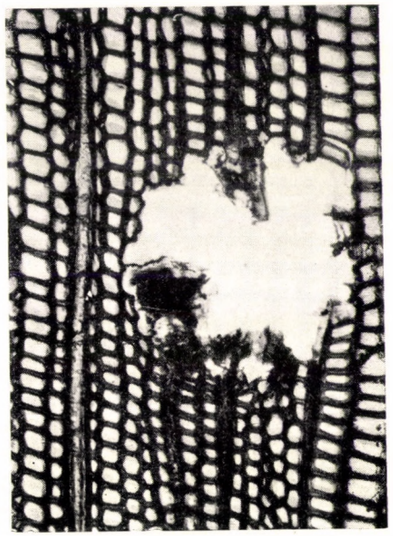




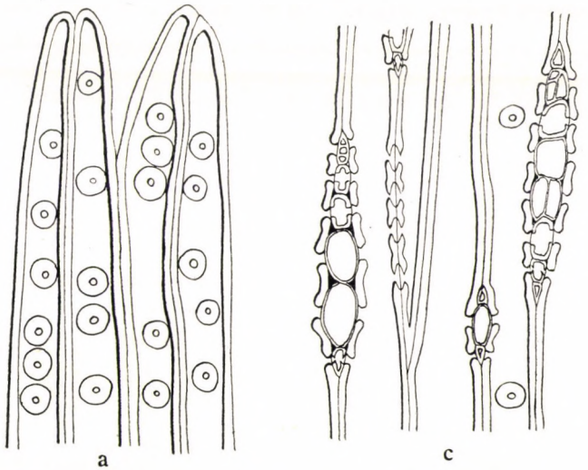
333. Pinus Thunbergii PARL.



1. (30×)



2. (100×)

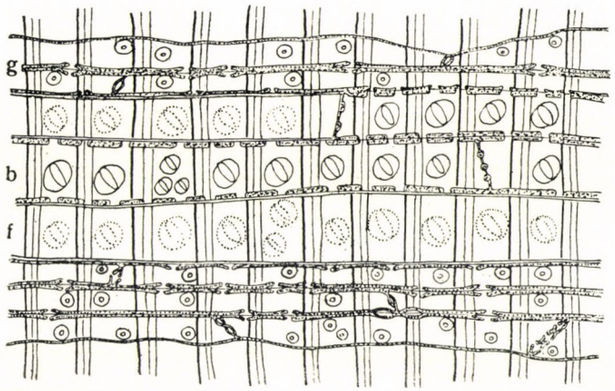




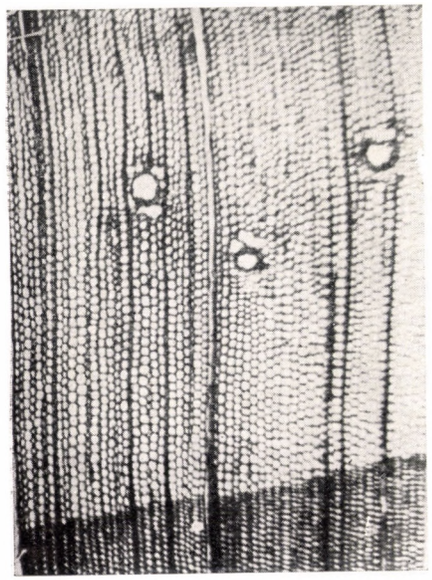
3. (300×)



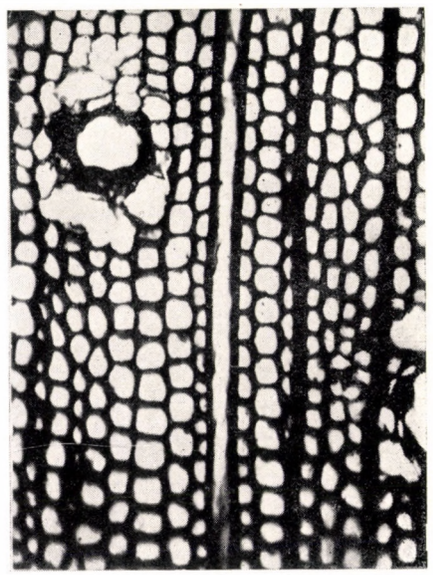
4. (100×)



334. Pinus **tonkinensis** A. CHEV.



1. (30×)



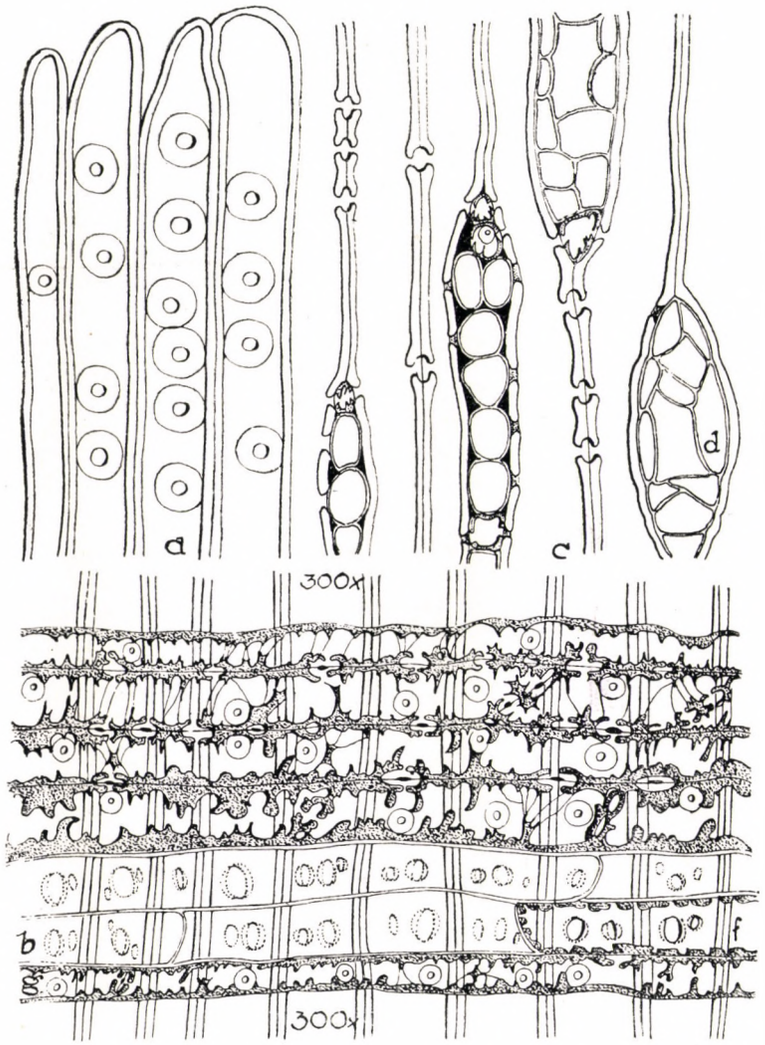
2. (100×)



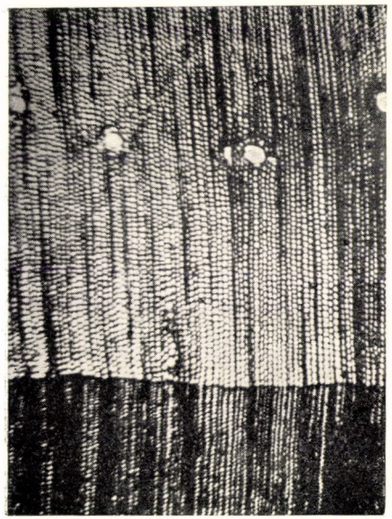
3. (300×)



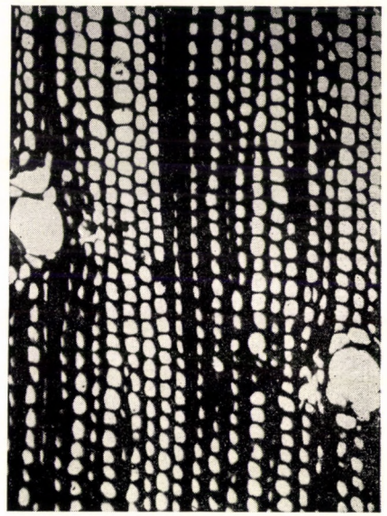
4. (100×)



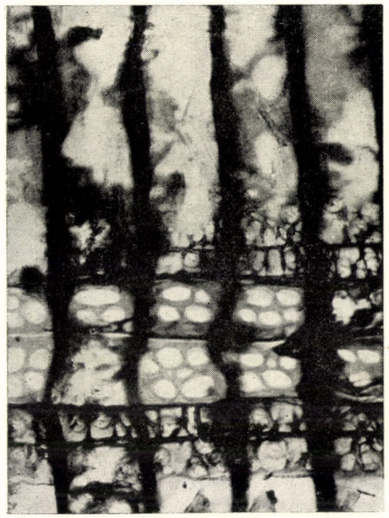
335. Pinus Torreyana PARRY



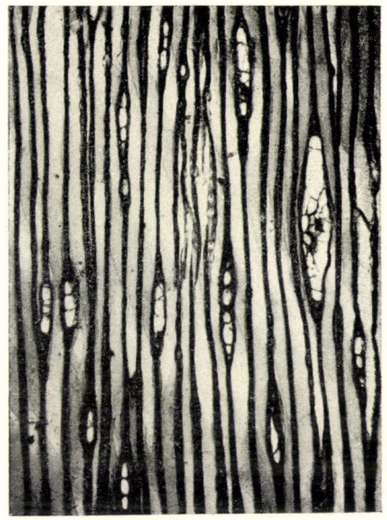
1. (30×)



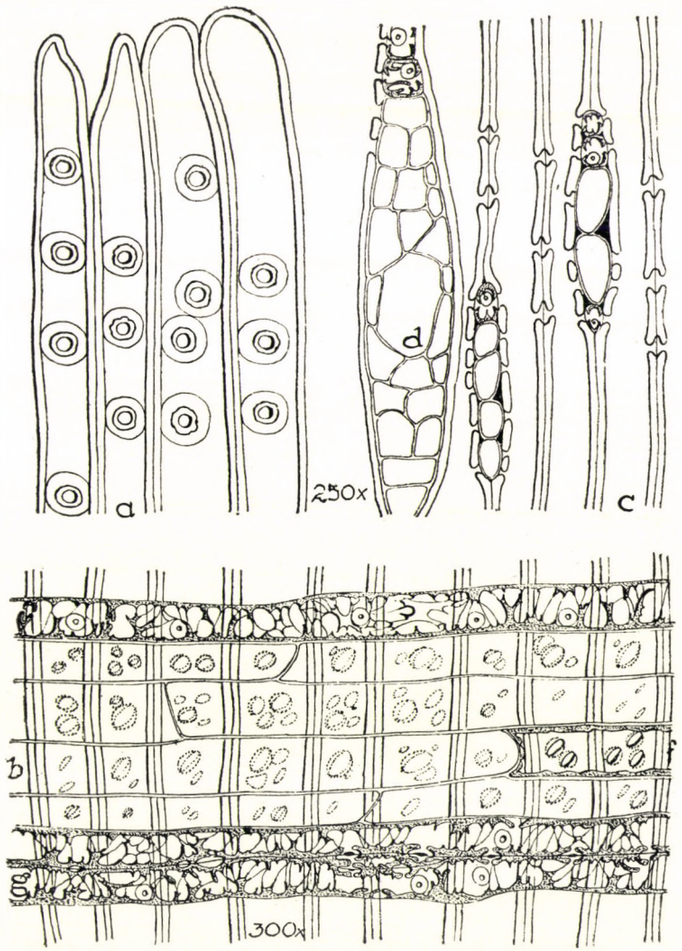
2. (100×)



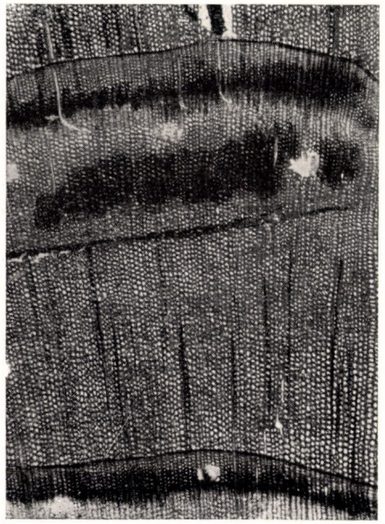
3. (300×)



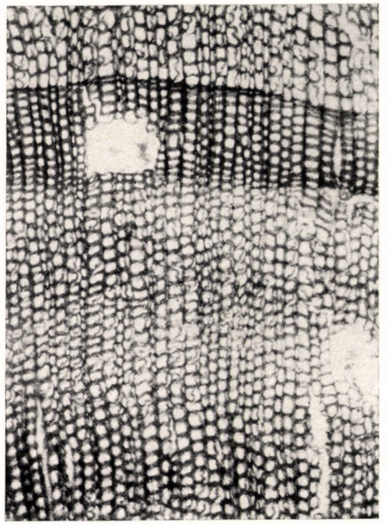
4. (100×)



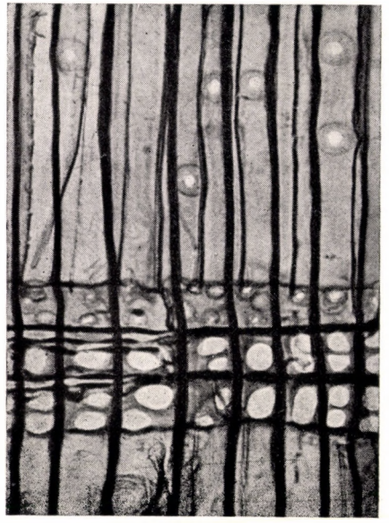
336. Pinus virginiana MILLER



1. (30×)



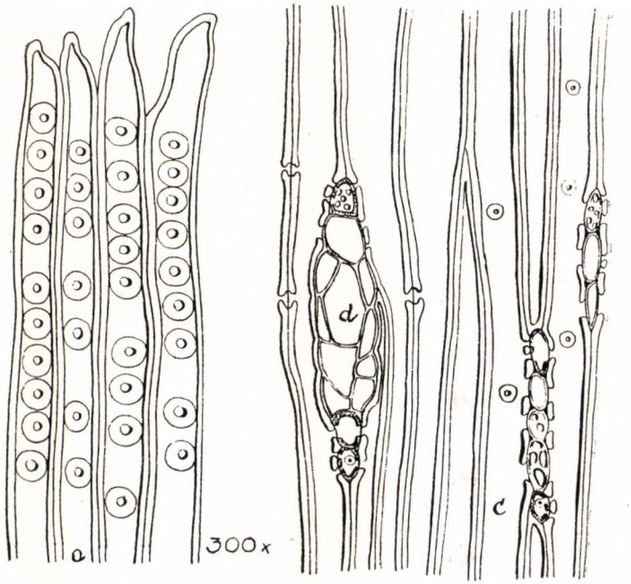
2. (100×)

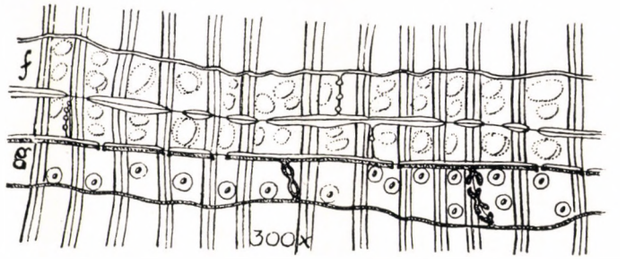


3. (300×)

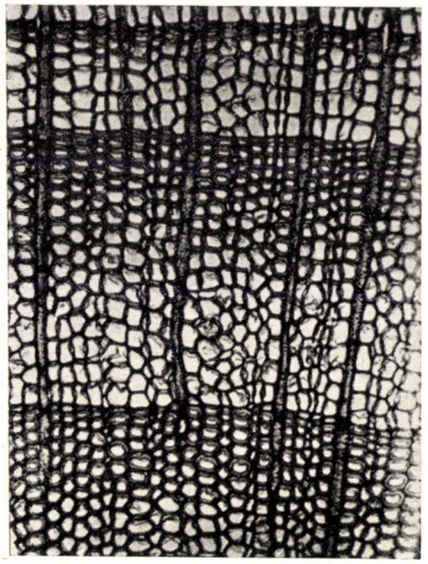


4. (100×)

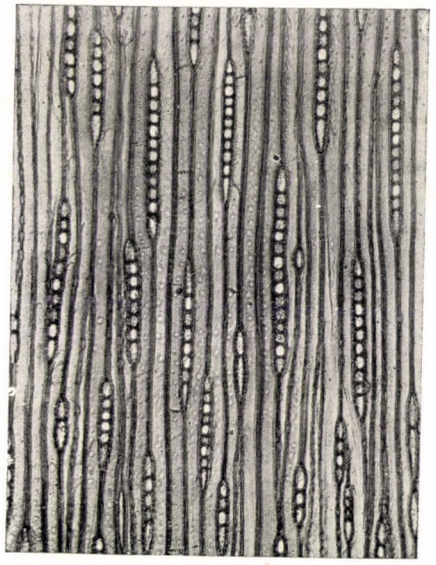




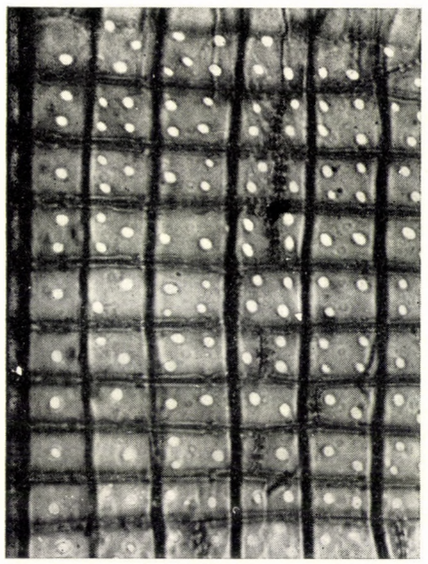
337. Pinus Wallichiana A. B. Jackson



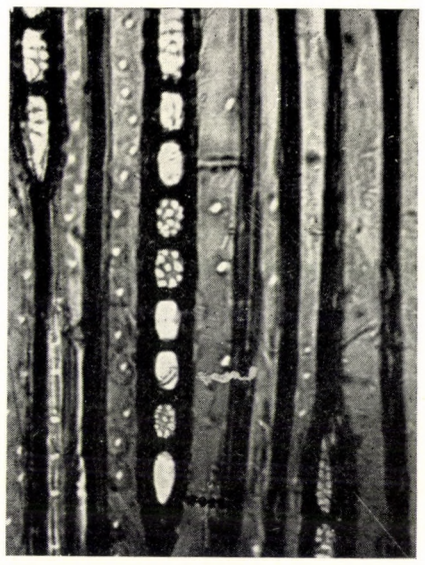
1. (100×)



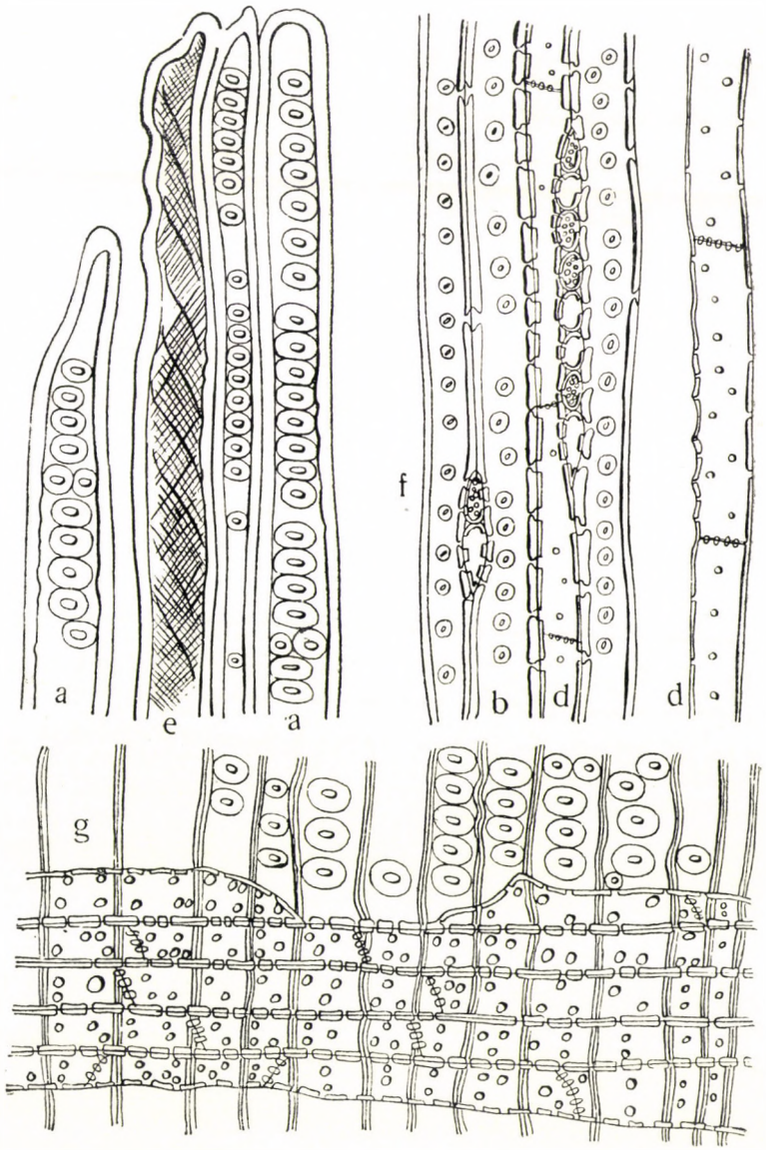
2. (100×)



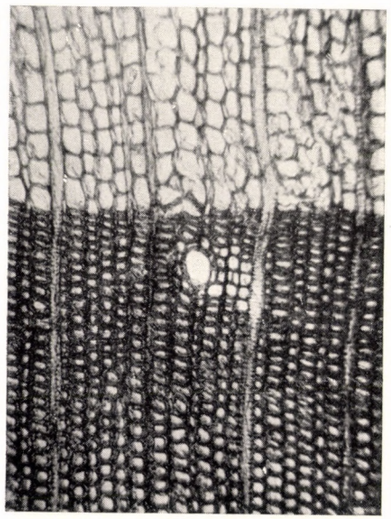
3. (300×)



4. (300×)



338. Pseudolarix amabilis Rehd.



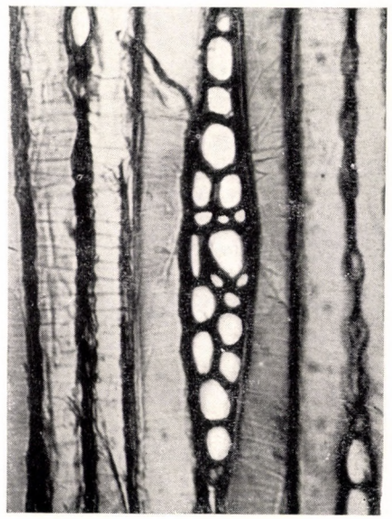
1. (100×)



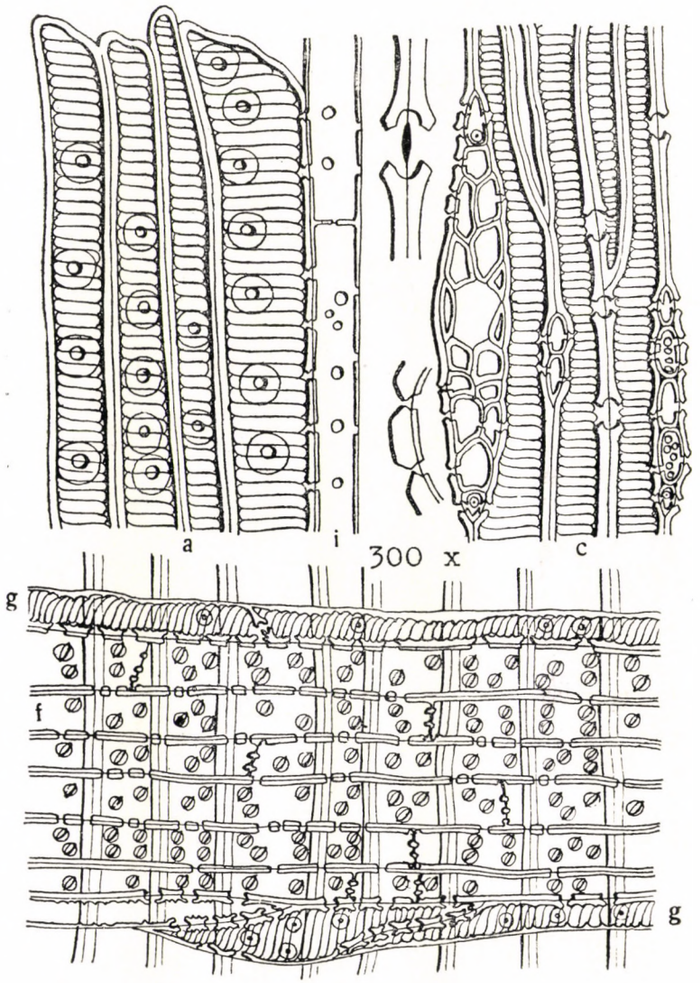
2. (100×)



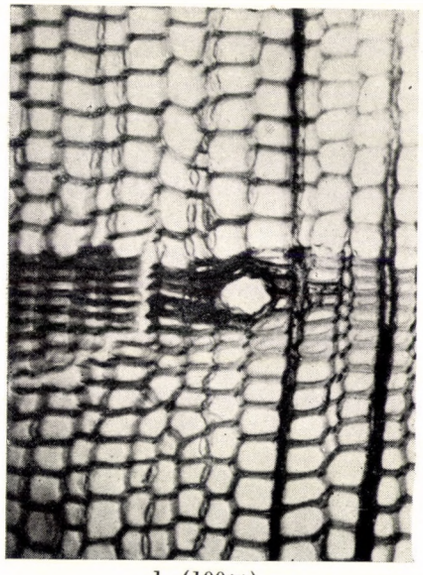
3. (300×)



4. (300×)



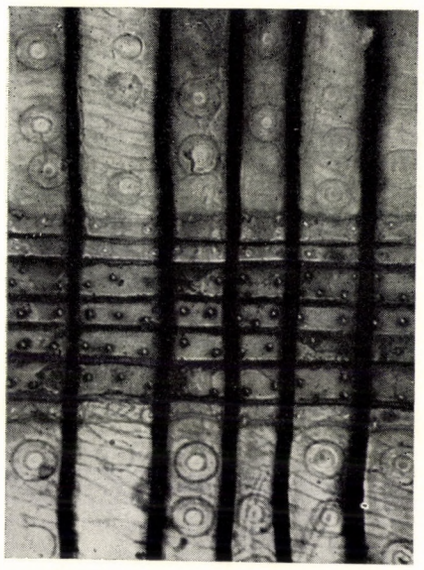
339. Pseudotsuga macrocarpa MAYR.



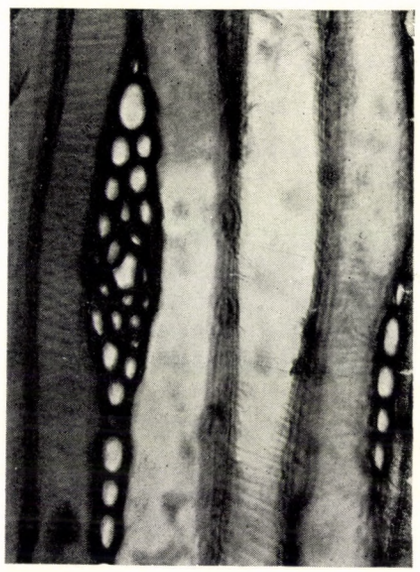
1. (100×)



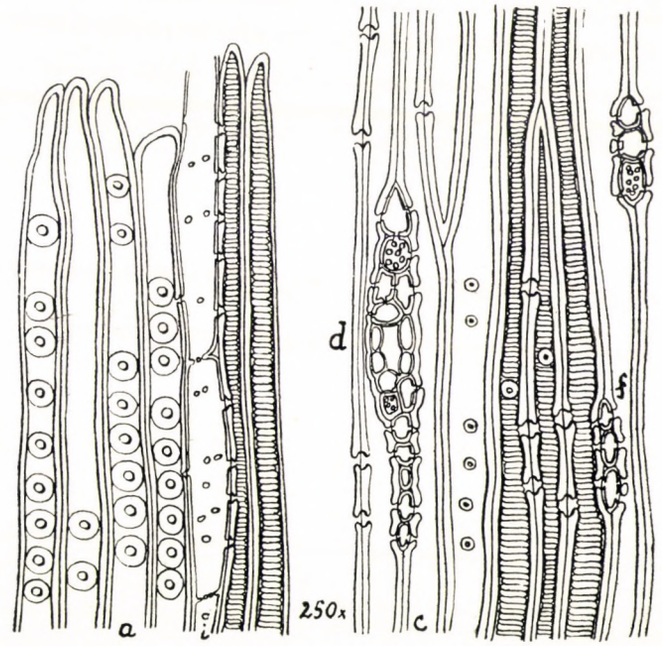
2. (100×)

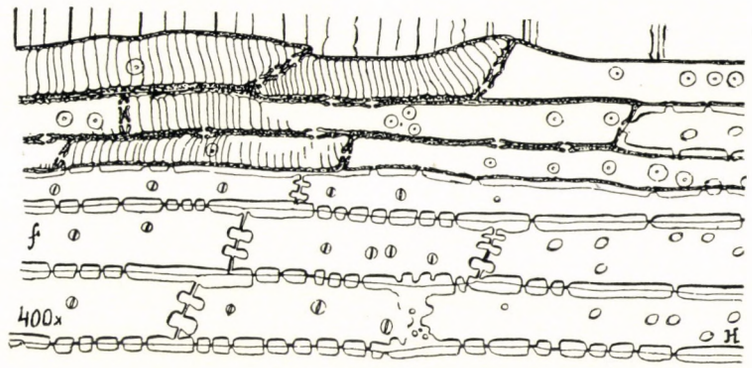


3. (300×)

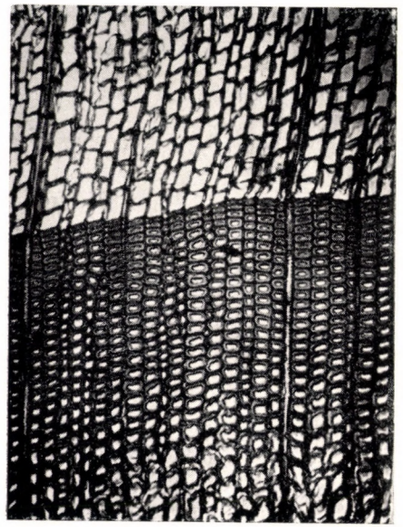


4. (300×)

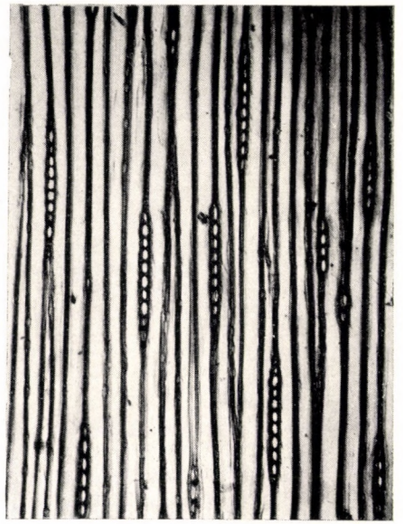




340. **Pseudotsuga taxifolia** Britt.



1. (100×)



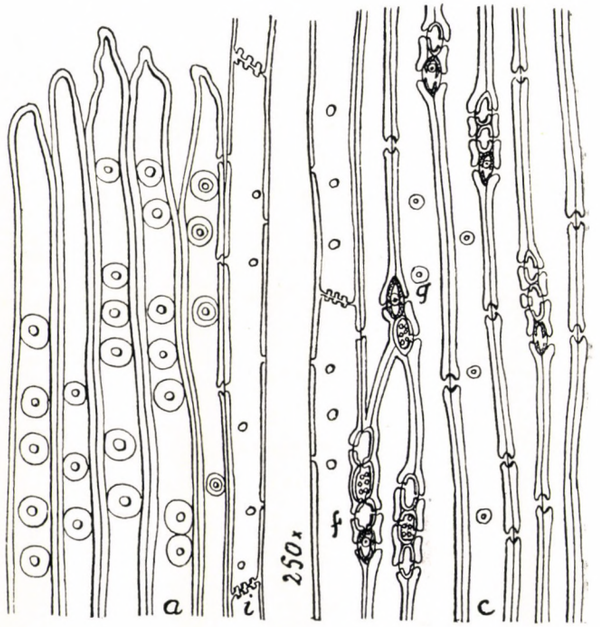
2. (100×)

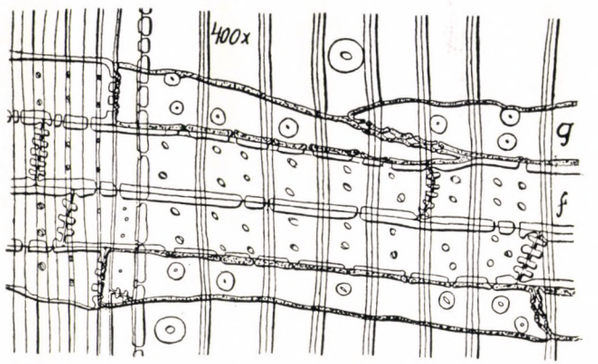


3. (300×)

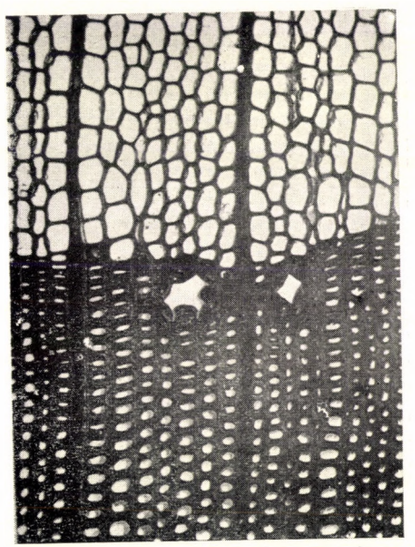


4. (300×)





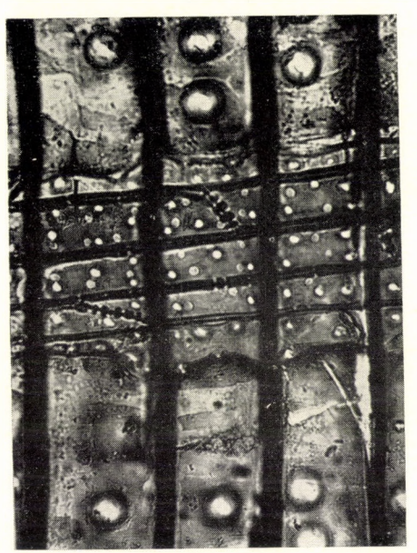
341. Tsuga canadensis (L) CARR.



1. (100×)



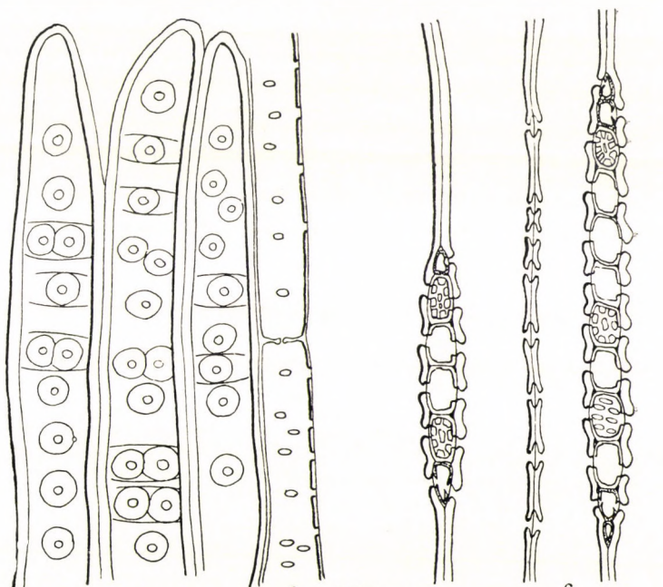
2. (100×)

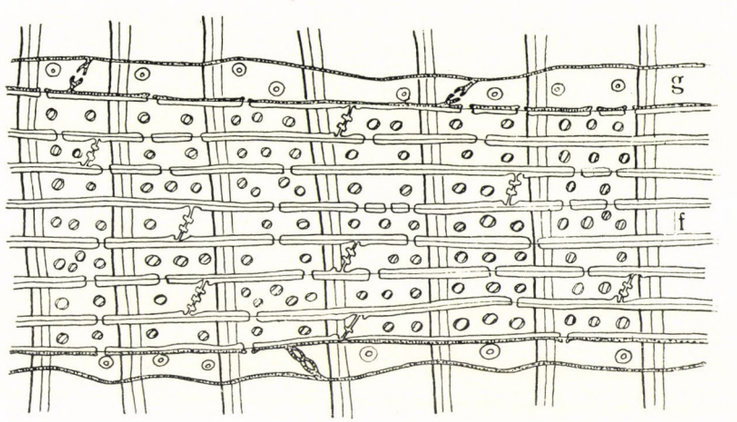


3. (300×)

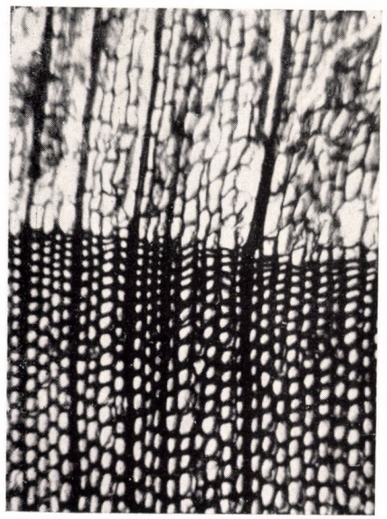


4. (300×)

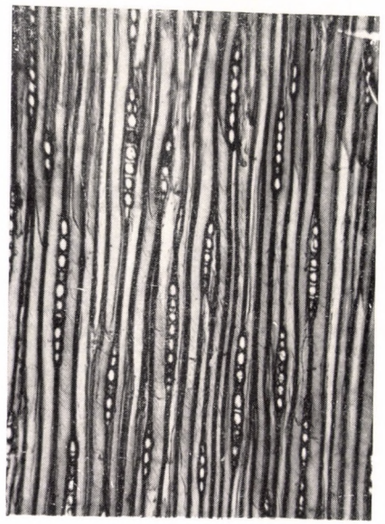




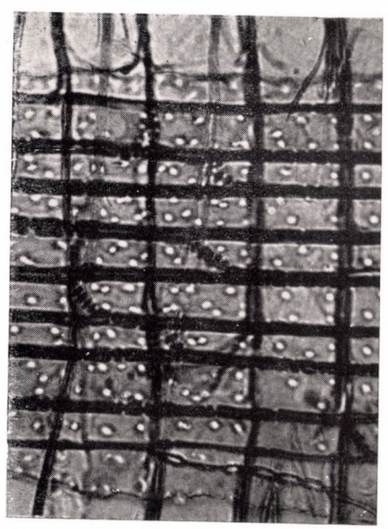
341a Tsuga chinensis PRITZEL



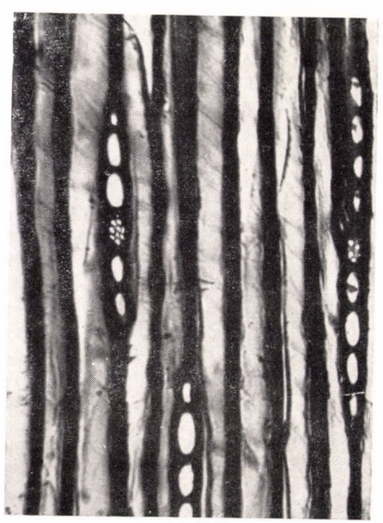
1. (100×)



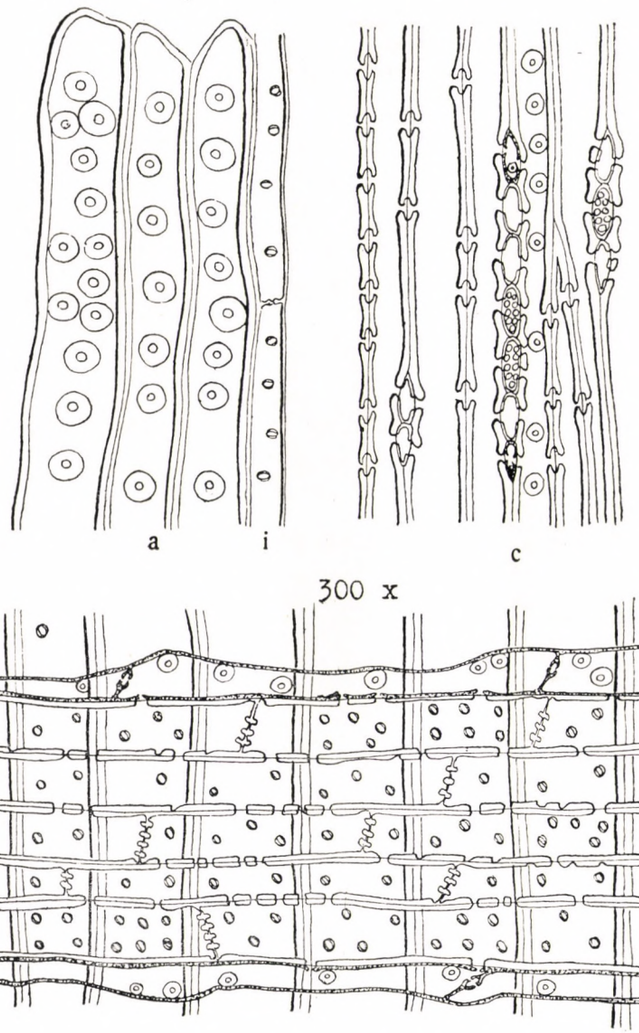
2. (100×)



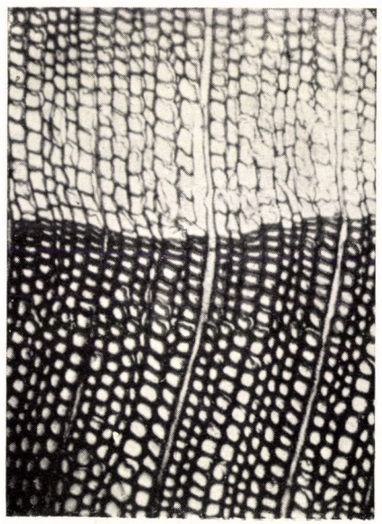
3. (300×)



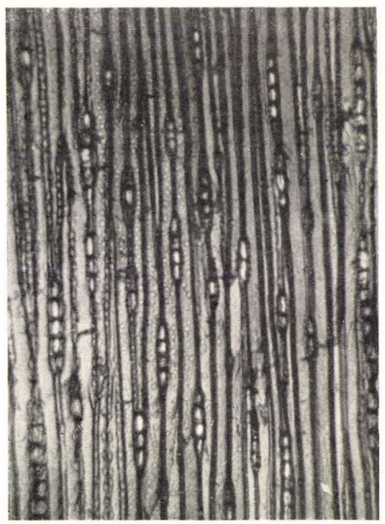
4. (300×)



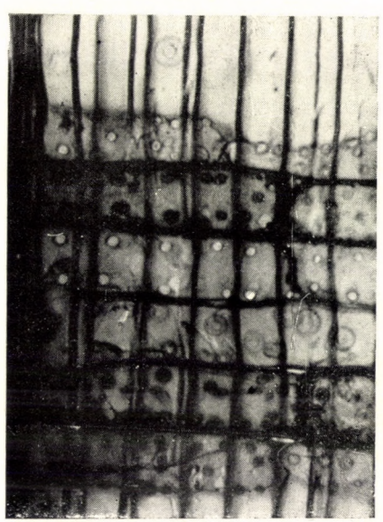
342. Tsuga diversifolia (Maximowicz) MAST.



1. (100×)



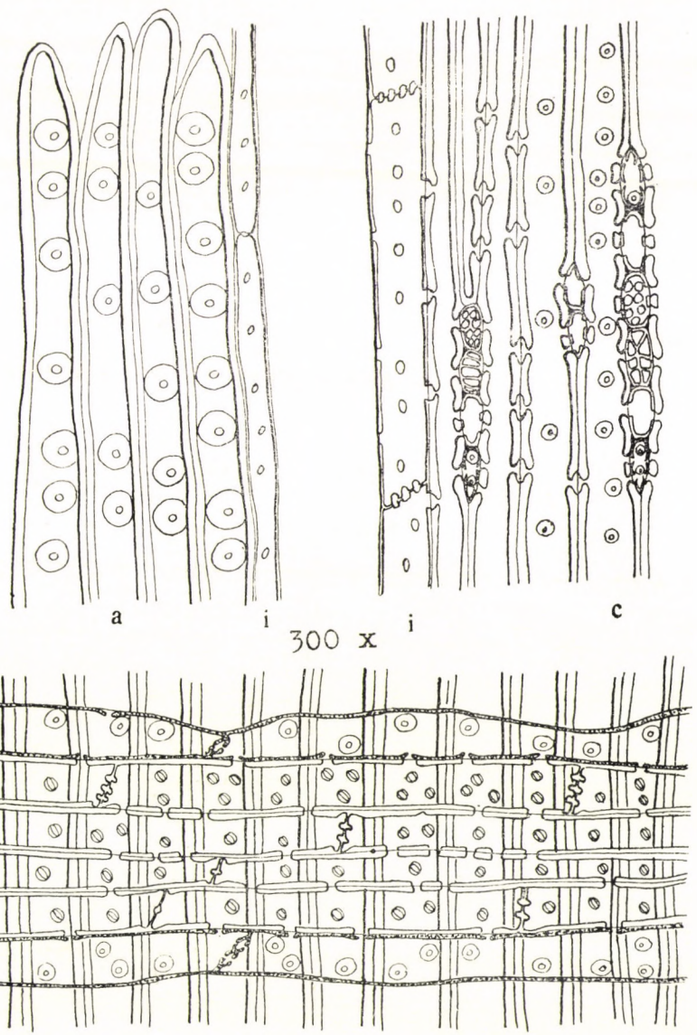
2. (100×)



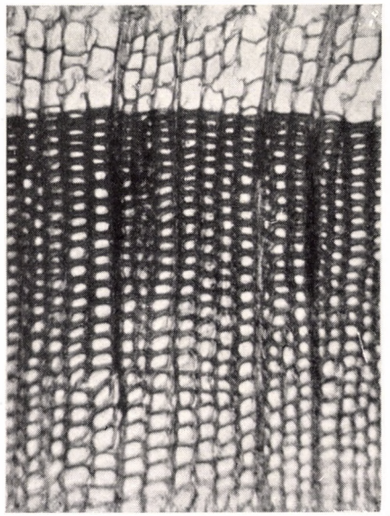
3. (300×)



4. (300×)



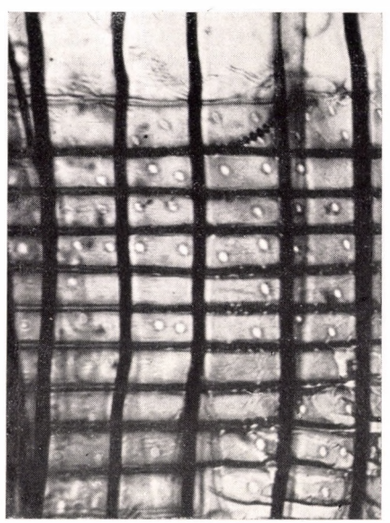
343. Tsuga dumosa (D. Don) EICHLER



1. (100×)



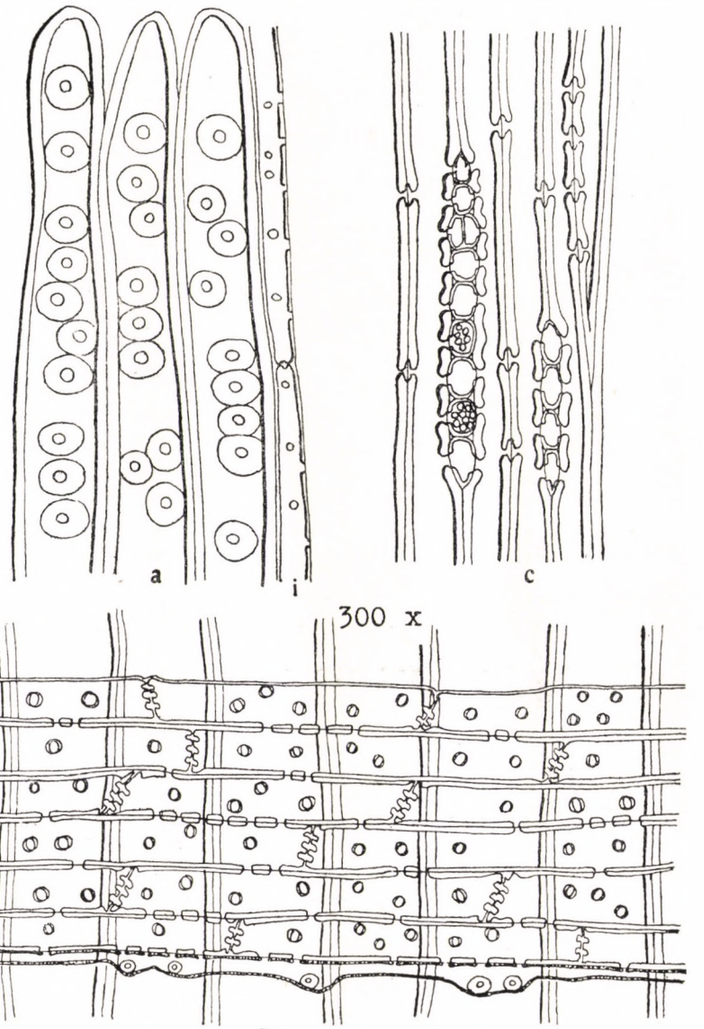
2. (100×)



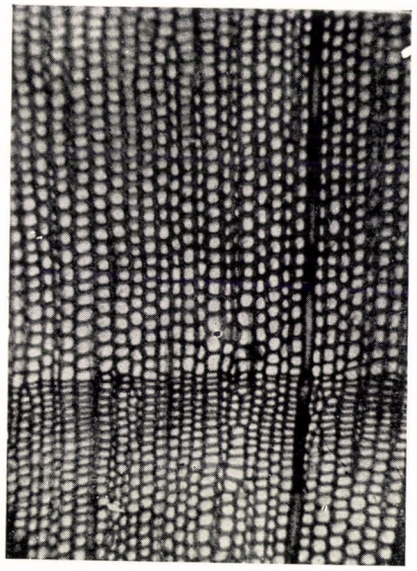
3. (300×)



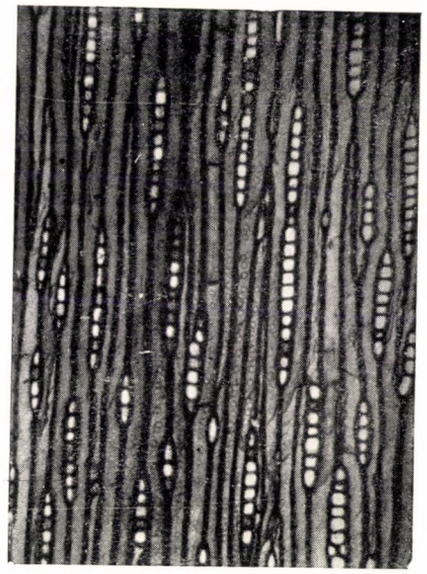
4. (300×)



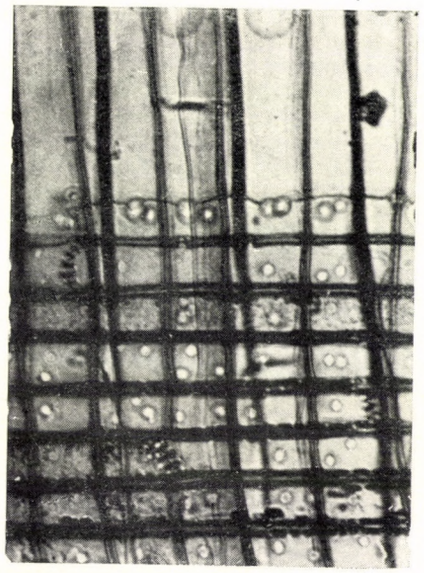
344. Tsuga heterophylla (Rafinesque) SARGENT.



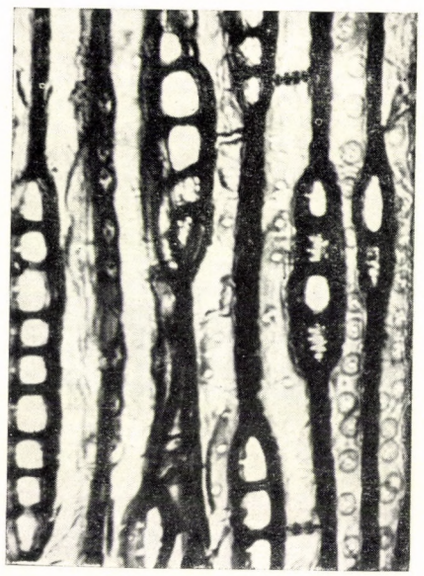
1. (100×)



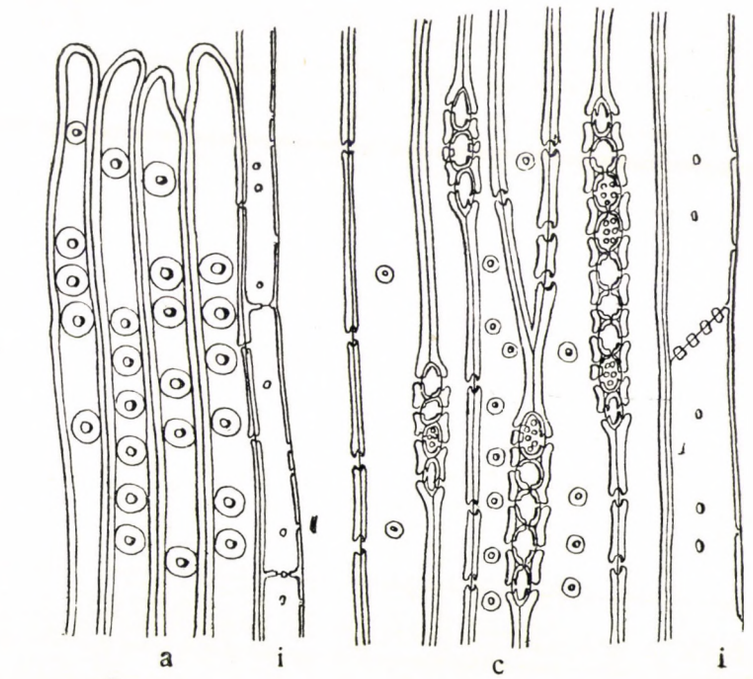
2. (100×)

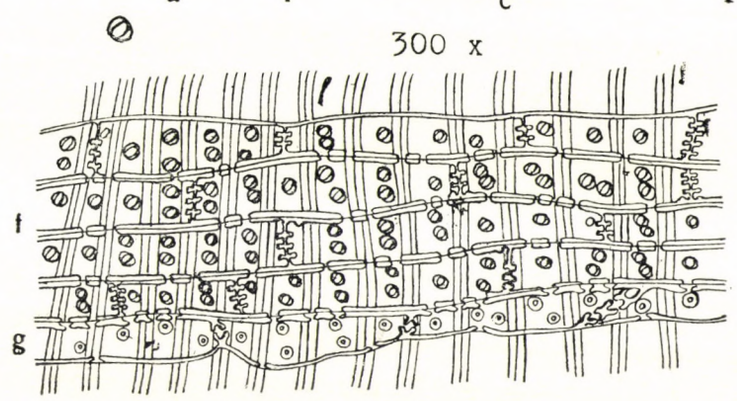


3. (300×)



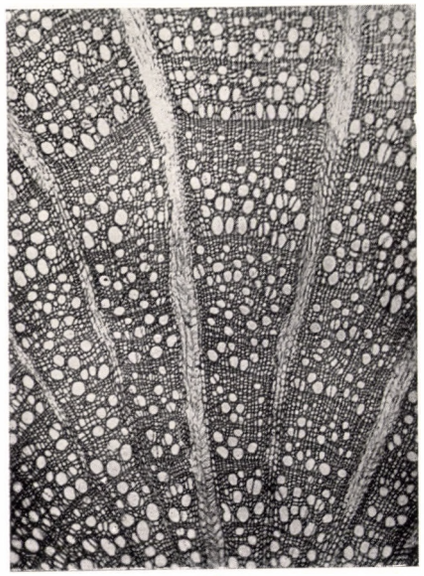
4. (300×)



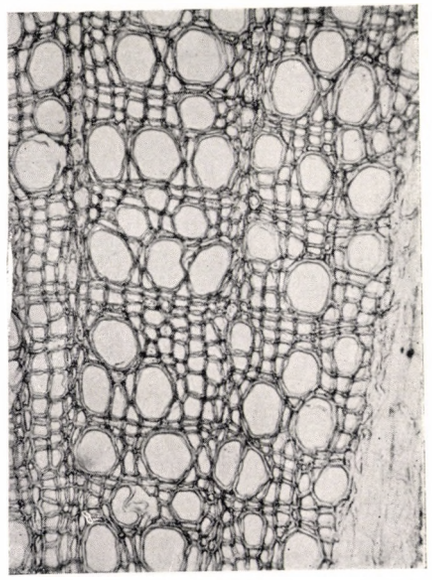


345. Tsuga Mertensiana (Bongard) CARR.

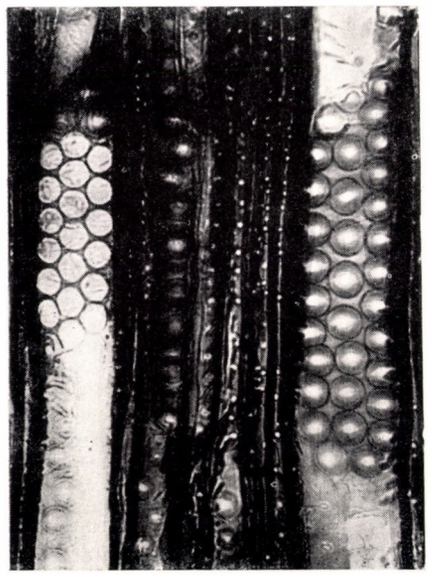
CHLAMYDOSPERMAE



1. (30×)



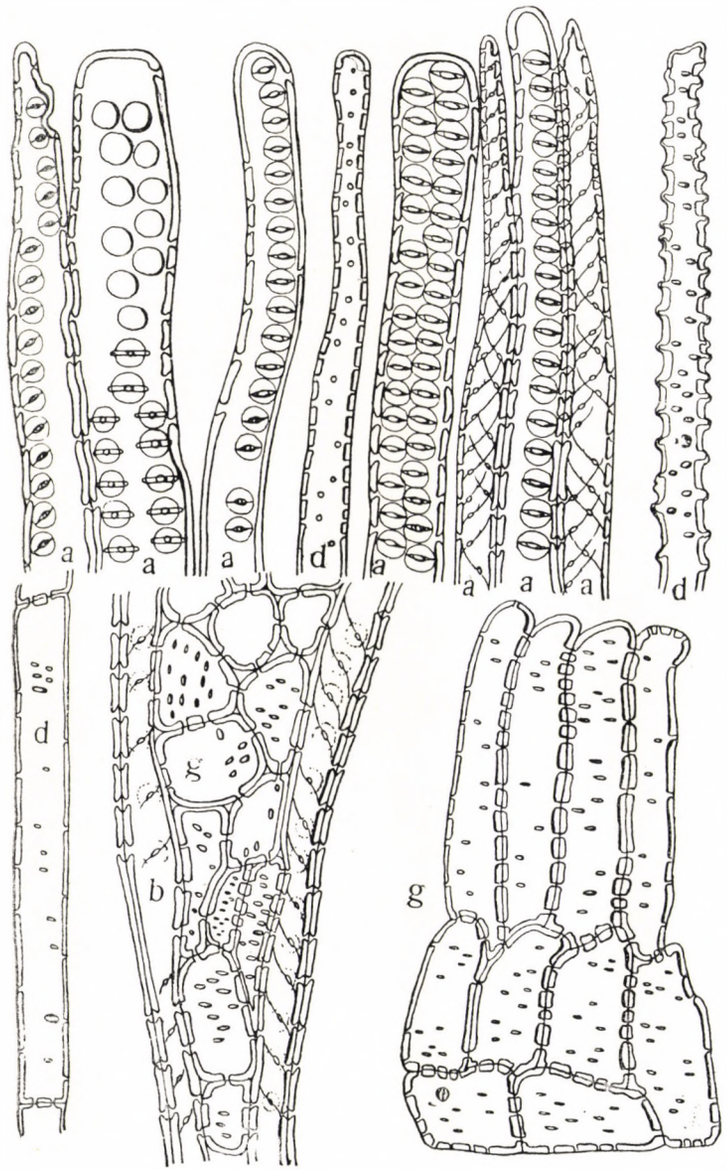
2. (100×)



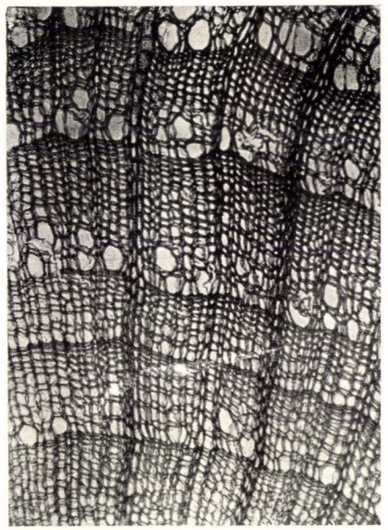
3. (300×)



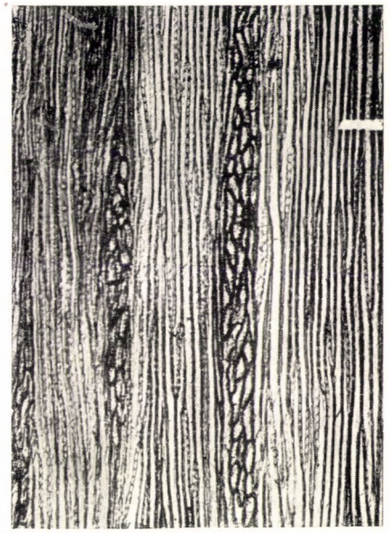
4. (100×)



346. Ephedra distachya L.



1. (100×)



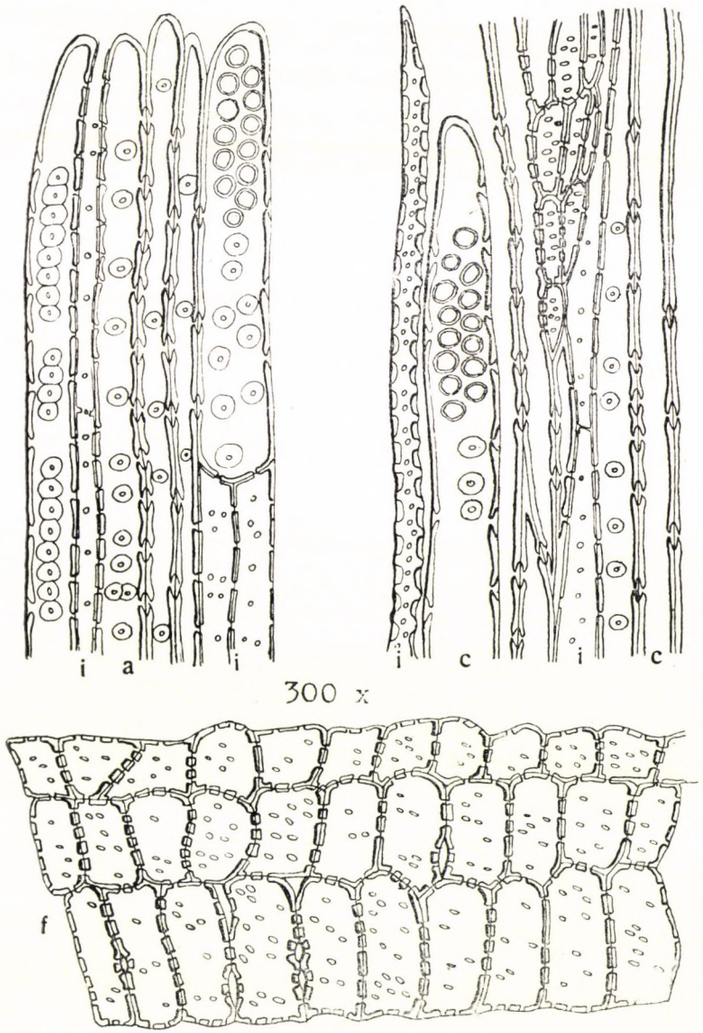
2. (100×)



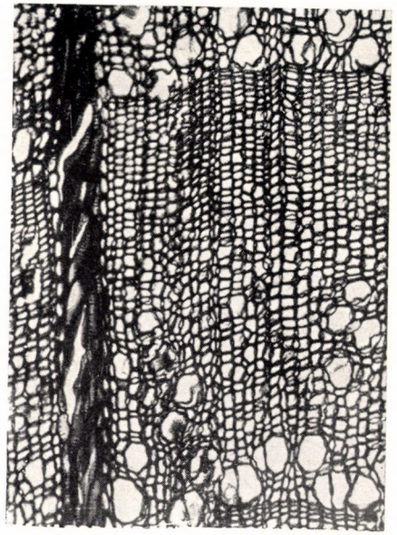
3. (300×)



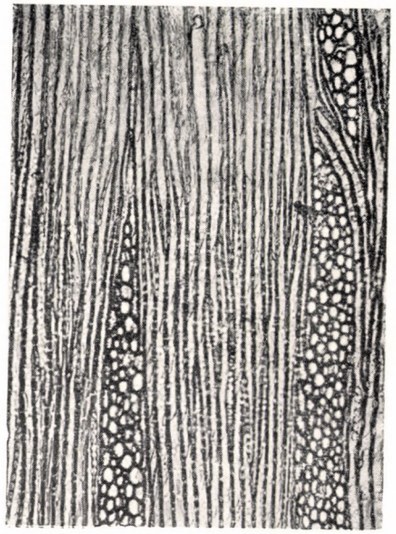
4. (300×)



347. Ephedra major HOST.



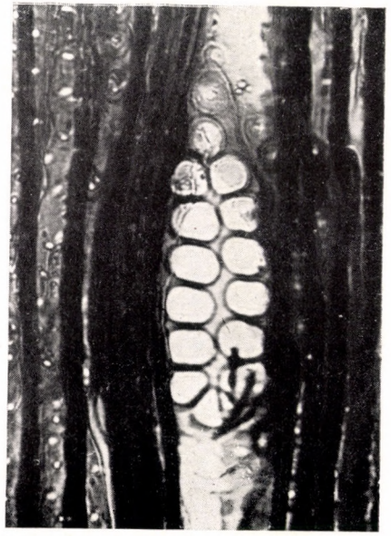
1. (100×)



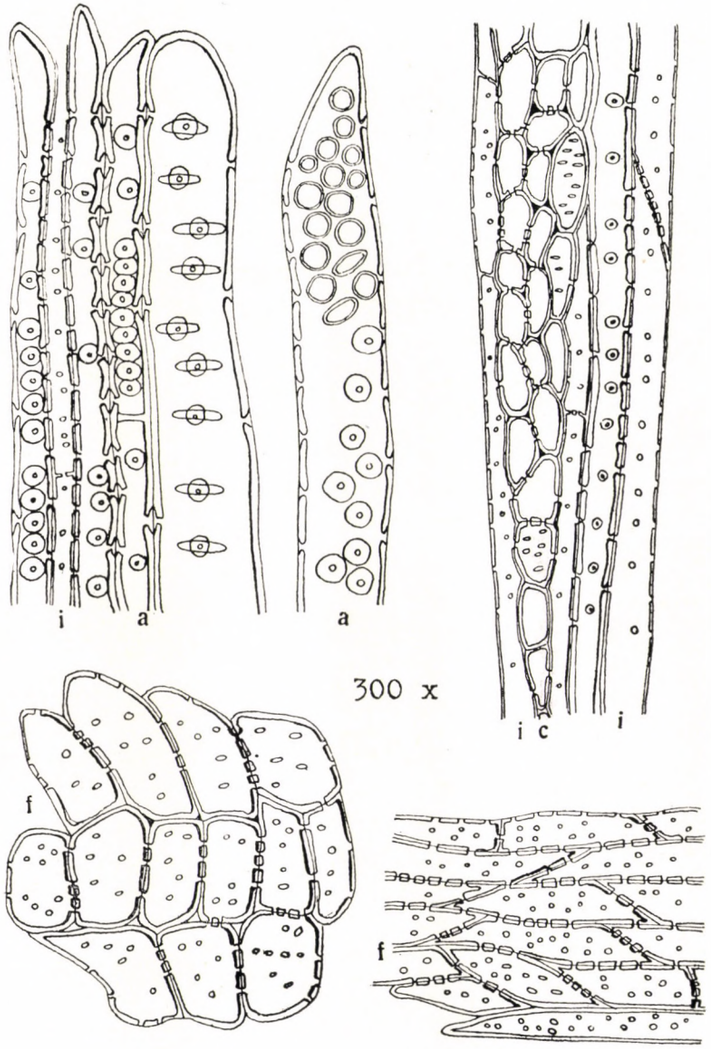
2. (100×)



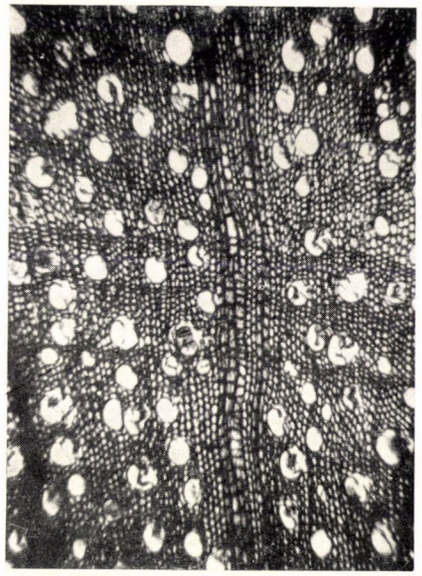
3. (300×)



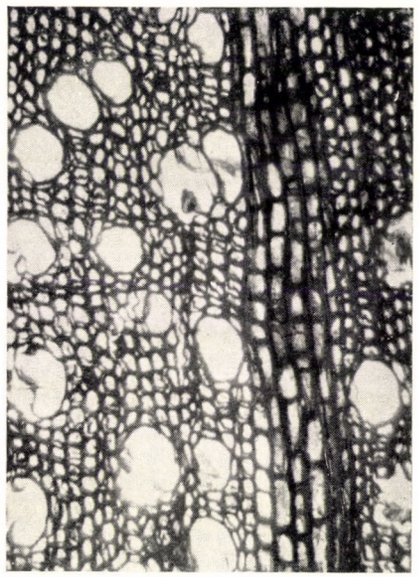
4. (300×)



348. Ephedra viridis COVILE



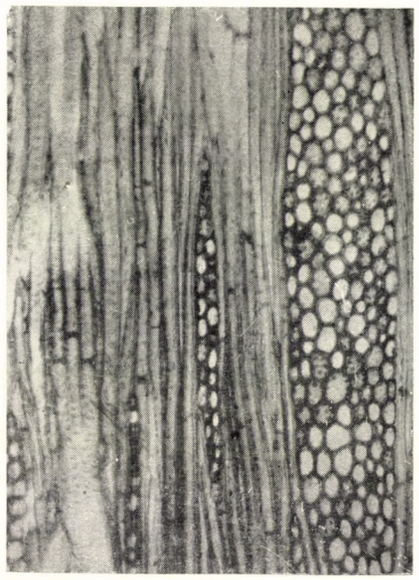
1. (30×)



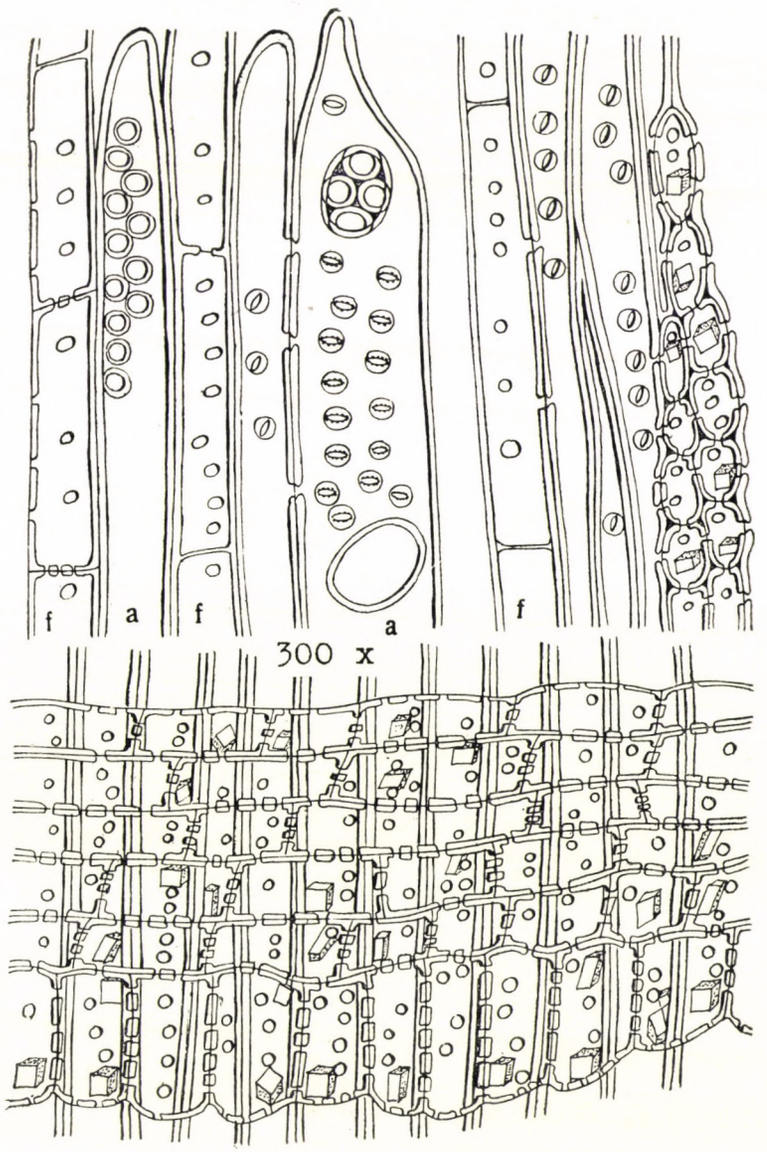
2. (100×)



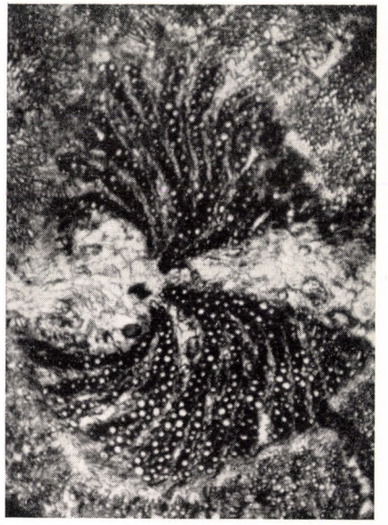
3. (300×)



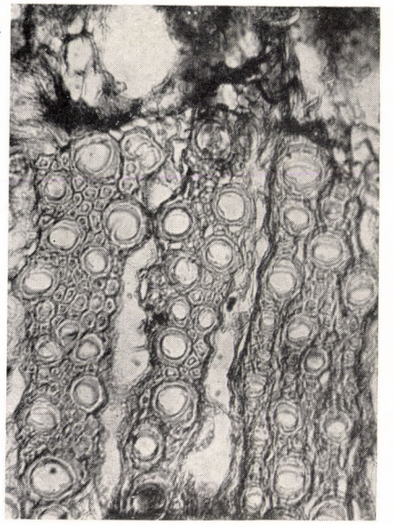
4. (100×)



349. Gnetum gnemon L.



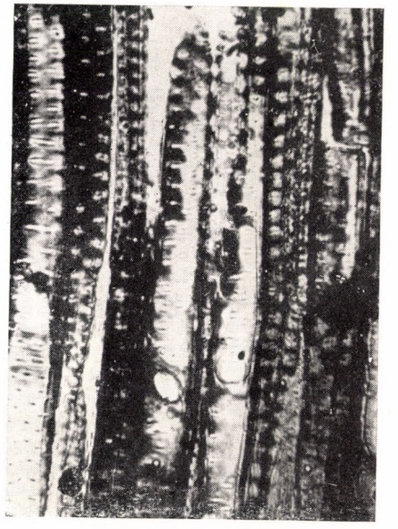
1. (30×)



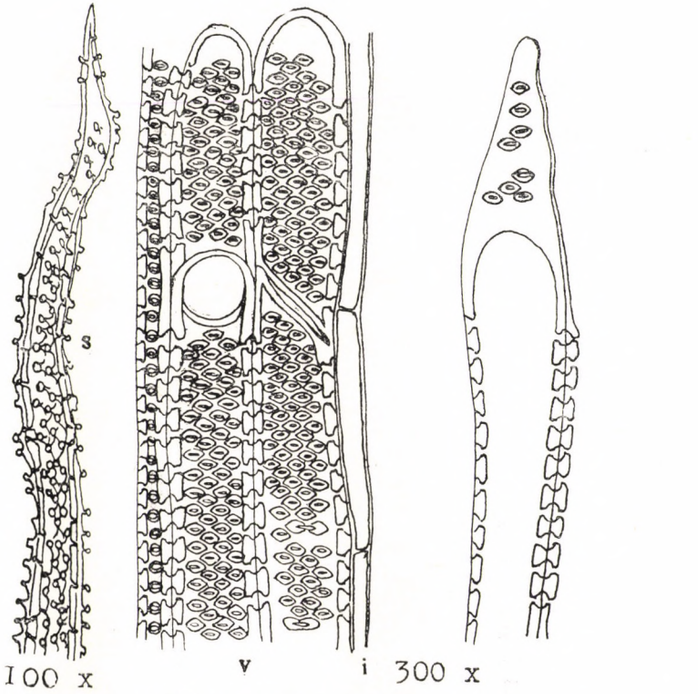
2. (100×)



3. (100×)



4. (300×)



350. Welwitschia mirabilis Hook f.

II.

SUMMARY

+ = present; yes
− = absent; no
× = from occasional to rare; indistinct

| Serial No. | Families and genera | Serial No. of plates | Tranverse surface: Tracheids: square or angular | Tranverse surface: Tracheids: rounded | Tranverse surface: resin ducts or cysts | Tranverse surface: mucilage ducts | Tranverse surface: wood parenchyma | Tranverse surface: Growth rings: distinct | Tranverse surface: Growth rings: indistinct | Tangential surface: Rays: height in cells | Tangential surface: Rays: width in cells | Tangential surface: Rays: Tangential walls: smooth or delicately verrucose | Tangential surface: Rays: Tangential walls: sievelike | Tangential surface: Rays: Tangential walls: scalariform | Tangential surface: Tracheids: smooth | Tangential surface: Tracheids: verrucose | Tangential surface: Tracheids: bordered pits | Tangential surface: Resin ducts and epithelial cells: thin | Tangential surface: Resin ducts and epithelial cells: thick: with 5—7 cells | Tangential surface: Resin ducts and epithelial cells: thick: with 7—10 cells | Tangential surface: Resin ducts and epithelial cells: thick: with 7—12 cells | Radial surface: Tracheids: Radial walls: number of pits | Radial surface: Tracheids: Radial walls: spiral thickenings | Radial surface: Tracheids: Radial walls: delicately verrucose | Radial surface: Transverse tracheids: present | Radial surface: Transverse tracheids: thin-walled | Radial surface: Transverse tracheids: dentate to couter of lumen, or with spiral bars | Radial surface: Transverse tracheids: reticulate | Radial surface: Wood parenchyma: Horizontal walls: smooth | Radial surface: Wood parenchyma: Horizontal walls: pitted or nodular | Radial surface: Wood parenchyma: crystalliferous | Radial surface: Ray-parenchyma cells: Horizontal walls: thin: smooth | Radial surface: Ray-parenchyma cells: Horizontal walls: thick: pitted | Radial surface: Ray-parenchyma cells: Horizontal walls: thick: smooth | Radial surface: Ray-parenchyma cells: Tangential walls: thin and smooth | Radial surface: Ray-parenchyma cells: Tangential walls: thick: headlike | Radial surface: Ray-parenchyma cells: Tangential walls: thick: dentate | Radial surface: Ray-parenchyma cells: Indentures | Radial surface: Ray-parenchyma cells: Pits: number of | Radial surface: Ray-parenchyma cells: Pits: diameter of | Radial surface: Wessel perforation: ephedroid | Radial surface: Wessel perforation: simple and ephedroid | Radial surface: Wessel perforation: simple | Radial surface: Cross field: Type of pitting: araucaroid | Radial surface: Cross field: Type of pitting: podocarpoid | Radial surface: Cross field: Type of pitting: dacrydioid | Radial surface: Cross field: Type of pitting: cupressoid | Radial surface: Cross field: Type of pitting: piceoid | Radial surface: Cross field: Type of pitting: taxodioid | Radial surface: Cross field: Type of pitting: glyptostroboid | Radial surface: Cross field: Type of pitting: pinoid |
|---|---|---

III.

ARAUCARIACEAE

+ = present ; yes
— = absent : no
× = from occasional to rare; indistinct

Serial No.	Species	Serial No. of plates	Transverse surface: Tracheids. per sq. mm. about	Transverse surface: Tracheids. squarish	Transverse surface: Tracheids. rounded	Transverse surface: Growht-rings. distinct	Transverse surface: Growht-rings. indistinct	Tangential surface: Rays. per sq. mm. about	Tangential surface: Rays. number of cells per sq. mm. about	Tangential surface: Rays. height in cells	Tangential surface: Rays. width in cells	Tangential surface: Ray cells. height in μ	Tangential surface: Ray cells. width in μ	Tangential surface: Tang. walls of tracheids. pits	Tangential surface: Tang. walls of tracheids. pit diameter in μ	Radial surface: thick-walled ray parenchyma	Radial surface: transverse tracheids	Radial surface: Tracheids. pit diameter in μ	Radial surface: Tracheids. number of alternate pits	Radial surface: wood parenchyma	Radial surface: Ray cells. horizontal walls smooth and thin	Radial surface: Ray cells. tangential walls smooth and thin	Radial surface: Ray cells. indentures	Radial surface: Cross field. number of bordered pits	Radial surface: Cross field. diam. of bordered pits in μ
1.	Agathis alba (Rumphius) Warb.	3	3600—3700	—	+	+	×	80—90	150—160	1—7 (8)	1	18—24	14—16	×	8—9	—	—	8½—10	1—2	×	+	+	—	1—3 (4—10)	4—7½—9
2.	« australis Salisb.	4	700—800	×	+	+	×	29—30	180—190	1—8—10 (1—20)	1	20—35	18—22	+	9—10	—	—	4—7 (14—16)	1—4	×	+	+	—	3—6 (10—12)	10—11
3.	« Beccarii Warb.	5	700—800	—	+	×	+	12—15	60—65	2—4 (12)	1	21—27 (40)	8—16	+	10—13	—	—	13—16	1—3	—	+	+	—	2—5 (12)	5—8
4.	« borneensis Warb.	6	950—1000	×	×	+	×	12—15	80—85	4—6 (12)	1	16—27	8—16	+	10—13	—	—	13—17	1—2	—	+	+	—	2—4 (5)	8—10
5.	« celebica Warb.	7	970—1000	×	+	×	×	25—30	120—125	3—6 (15)	1	16—35	13—18	+	13—14	—	—	16—18	1—2	—	+	+	—	1—5	6—8
6.	« hypoleuca C. Moore	8	2500—2600	+	×	+	×	80—90	120—130	1—2 (4)	1	18—30 (32)	16—18	×	8—9	—	—	12—13 (14—16)	1—2 (3)	+	+	+	—	4—6	7—8
7.	« lanceolata (Pancher) Warb.	9	450—500	+	×	+	—	12—15	120—130	1—10 (40—45)	1(2)	20—30	8—18	×	12—14	—	—	19—20	1—4 (5)	+	+	+	—	6—12 (20—22)	9—11
8.	« macrophylla (Lindl.) Mast.	10	850—900	×	×	—	+	25—30	80—90	1—18	1	20—(32)	20—22	+	11—12	+	—	13—14	1—2	+	+	+	—	(1) 3—6 (6—8)	7½—8 (11)
9.	« microstachya Bailey et White	11	500—550	×	×	+	×	18—20	115—120	1—25 (40)	1(2)	20—30	18—20	+	11—14 (16)	—	—	10—12 (14)	1—3 (5)	+	+	+	—	2—4 (12)	7—9
10.	« Moorei (Lindl) Mast.	12	2000—2100	×	×	+	×	52—55	125—130	1—5 (8)	1(2)	22—30	24—30 (12—14)	×	11—12	—	—	12—18	1—2 (3)	×	+	+	—	0—3—4 (6)	10—12
11.	« ovata Warb.	13	1700—1800	×	+	+	—	70—80	180—190	1—8	1	20—28	15—17	+	8½—10	—	—	10—12	1—2	×	+	+	—	1—8 (8—16)	6—7
12	« Palmerstonii F. v. Müll.	14	480—500	×	×	+	—	20—25	100—120	1—24	1	12—30 (26—34)	18—30	+	11—12	—	—	11—14	1—4 (5)	+	+	+	—	4—10 (12)	7½—9
13.	« robusta (Moore) F. v. Müll.	15	2200—2300	—	+	×	+	110—120	180—190	1—8	1	20—26	16—17	×	8—10	—	—	8—10	1—2 (3)	+	+	+	—	1—5 (6—18)	7—9
14.	Araucaria angustifolia(Bertoloni) O. Kuntz.	16	1200	+	+	—	+	28—30	110—125	1—10 (15)	1	20—21	15—18	+	10—11	—	—	10—11	1 (2)	—	+	+	—	1—5 (7—9)	7—9 (11)
15.	« araucana (Molina) K. Koch	17	1900—2000	×	×	×	×	70—75	170—180	1—8	1	24—35	17—18 (20)	×	10—11	—	—	10—11	1 (2)	—	+	+	—	1—6 (8)	4½— 5 (6)
16.	« Balanse Br. et. Gr.	18	1700—1800	×	×	—	+	27—30	52—53	1—6	1	25—26 (30—40)	16—18	+	5½—6	+	—	9—11	1—2	—	+	+	—	6—8 (10—14)	6½—7
17.	« Beccarii Warb.	19	1000—1100	×	+	—	+	15—20	70—80	1—6 (20)	1	21—27 (40)	13—27	—	—	—	—	13—14	1 (2)	—	+	+	—	3—5 (9—12)	6—8
18.	« Bidwillii Hook.	20	1900—1950	×	×	—	+	18—20	30—40	1—8	1	22—24 (26)	15—16	+	9—10	—	—	10—13	1 (2)	—	+	+	—	1—6 (8)	4—11
19.	« columnaris (Forst) Hook.	21	550—600	—	+	—	+	15—18	90—95	1—10 (16)	1	28—35 (40)	17—18	+	12—13	—	—	10—13 (16—17)	1—2 (3)	—	+	+	—	2—4—12	9—11
20.	« Cunninghamii Sweet	22	2300—2400	—	+	×	×	25—27	60—65	1—7 (8)	1	20—22 (40)	14—16	+	8—9	—	—	13—14 (10—11)	1—2	—	+	+	—	4—8 (12)	7—8
21.	« Cunninghamii var. glauca Antoine	23	1900—	×	+	×	×	55—60	180—190	1—8—10	1(2)	22—24 (35—40)	16—18	+	10—11	—	—	10—12	1—2	—	+	+	—	3—5 (7)	7—7½
22.	« excelsa (Lamb.) R. Br.	24	3400—3500	×	+	—	+	80—90	260—270	1—8	1	20—25 (28)	16—18	+	7—7½	—	—	8—10	1—2	—	+	+	—	1—4 (7)	8—10
23.	« Humboldtiensis Buchh.	25	1300—1400	×	×	—	+	55—60	100—110	1—4 (7)	1	20—30	17—18	+	6—7	—	—	11	1 (2)	—	+	+	—	2—4 (5—6)	6½—7
24.	« Klinkii Lauterb.	26	700—800	×	+	—	+	12—13	65—70	1—16 (20)	1	20—35	14—18 (20)	+	7½—8 (9)	—	—	15—18	1—2	—	+	+	—	2—3 (4—6)	10—12
25.	« montana Br. et Gr.	27	550—650	×	+	—	+	25—30	90—100	1—8 (12)	1	30—40 (42)	12—15 (13—14)	×	11—12	—	—	11—12	1—3	—	+	+	—	8—9 (14)	10—11
26.	« Muelleri Br. et Gr.	28	2100—2200	+	—	—	+	50—52	115—120	1—10	1	22 (30—32)	16—18	+	9—11 (10—12)	—	—	10—12	1—2	—	+	+	—	4—6 (6—8)	6—7
27.	« Rulei F. v. Müll.	29	2900—3000	×	+	—	+	32—33	60—62	1—4 (5—6)	1	18—20	9—10	×	12—13	—	—	8—10	1—2	—	+	+	—	1—8(9) (10—12)	5—6

IV.

PODOCARPACEAE

+ = present; yes
— = absent; no
× = from occasional to rare; indistinct

Serial No.	Species	Serial No. of plates	Transverse surface: Tracheids: per sq. mm about	Tracheids: squarish	Tracheids: rounded	Wood parenchyma	Growth rings: distinct	Growth rings: indistinct	Rays: per sq. mm. about	Rays: number of cells per sq. mm. about	Rays: height in cells	Tangential surface: Ray cells: width in cells	Ray cells: height in μ	Ray cells: width in μ	Tangential walls of tracheits: pits	Tangential walls of tracheits: pit diameter in μ	Horizontal walls of wood parenchyma smooth	Radial surface: Tracheids: pit diameter in μ	Tracheids: number of pit rows	Horizontal walls of wood parenchyma smooth	Ray cells: horizontal walls smooth	Ray cells: tangential walls smooth	Ray cells: indentures	Cross field: number of pits	Cross field: diameter of pits in μ
1	Acmopyle Pancheri Pilger	**30**	**2500**	+	×	+	+	—	100	170	**1–3 (6)**	1	20–28	10–12	+	11–12	×	**13–14**	1	+	+	+	—	1–(2)	8–11
									110	175							+								(14–15×**9–6**)
2	Austrotaxus spicatus Compt.	**31**	3300	+	×	+	—	+	75	100	1–3	1	18–22	7–12	+	7–8	+	13–14	1	+	+	+	—	1–2	8–10
									80	110	(4–5–7)		(30–34)	(12–15)		10–12		10–12						(3–4)	
3	Dacrydium araucarioides Br. et Gr.	**32**	3200	+	×	+	—	+	100	230	1–5 (7)	1	14–18 (27)	8–10 (14)	+	7–8 (10)	+	13–16	1	+	+	+	—	1–2	8–10
									120	240	1–9 (25)	1	13–16	5–8	+	7–8	+	8–13	1(2)	+	+	+	—	(3–4)	(11)
4	« Balansae Br. et Gr.	**33**	1800	+	—	+	—	+	45	330														1–2(3)	5–8
									50	335	1–10 (20)	(2)	17–20	13–16	+	13–14	+	8–9	1–2	+	+	+	—	1–2	8–9
5	« Colensoi Hook.	**34**	3000	+	—	—	+	×	90	340	1–12	1	14–16	9–10	×	7–8	0	11–14	1	**0**	+	+	—	1	16–24
									100	360	(16–18)		(18–20)	(13)		(8–10)								(2)	
6	« cupressinum Sol.	**35**	1200	+	×	+	—	+	65	280	1–10	1	14–16	10–16	×	14–15	+	16–18	1	+	+	+	—	1	10–13
									70	300	(20–22)		(20–22)											(2)	
7	« elatum Wall.	**36**	900	×	+	+	—	+	90	400	1–10	1	12–18	8–10	×	11–12	+	16–17	1–2	+	+	+	—	0—1—2	10–11
									100	420	15–17		(20)												
8	« Franklinii Hook. f.	**37**	2000	+	—	+	+	—	50	190	1–8	1	17–20	7–11	×	7–8	+	**18–20**	1	+	+	+	—	1 (2)	**16–20**
									55	200	(10–20)			(13)		13									**10–14**
9	« pierrei Hickel	**37a**	1700	+	—	+	+	—	70–75	300	1–(17)	1	13–18	8–13	+	12–13	+	12–14	1	+	+	+	—	1–2	6–8
10	« taxoides Br. et Gr.	**38**	2200	+	—	+	—	+	80	240	1–7–8	1	10–14	7–9	?	?	+	14–18	1	+	+	+	—	1 (2)	10–14
									85	250	(10)	(2)	(18–20)												
11	Microcachrys tetragona Hook. f.	**39**	3700	+	—	×	+	—	100	300	**1–8**	1	14–17	6–8	+	7–8	×	12–14	1	+	+	+	—	1–(3–4)	7–14
									110	310	12	(2)	(18)	(9)											
12	Phyllocladus alpinus Hook. f.	**40**	2600	+	—	**0**	+	—	90	290	1–10	1	13–18	7–9	+	6–8	0	11–13	1	**0**	+	+	—	1	11–17
									100	300	(10–11)		(22–27)	(12)											
13	« glaucus Carr.	**41**	2900	+	—	**0**	+	—	120	400	1–18	–(2)	14–17	4–6	+	4–6	0	9–11	1	**0**	+	+	—	1	10–14
									130	410	(15)		(18–22)	(7–8)		(8)		(16)							(16)
14	« rhomboidalis Rich.	**42**	1850	+	—	**0**	+	—	75–80	320	1–8	–2	10–14	6–8	+	8–10	0	10–13	1	**0**	+	+	—	1	16–24
										330	(14–16)		(18–20)	(12)				(17)							
15	« trichomanoides D. Don.	**43**	1700	+	—	**0**	+	—	50	280	1–12	1	12–16	7–8	+	8–10	0	**13–18**	1	**0**	+	+	—	1–2	14–18
									52	290	(20–22)		(18–20)	(10–12)		(13)									(20–22)
16	Podocarpus Blumei Endl.	**44**	1300	+	×	+	—	+	75	240	1–10	(2)	14–16	10–12	+	14–16	+	18–22	1–2	+	+	+	—	1 (2)	14–20
									80	250	(8–9)		(20–22)												
17	« coriaceus A. Rich.	**45**	1800	×	×	+	—	+	110	240	1–6	1	18–20	4–7	+	12–13	+	15–16	1	+	+	+	—	0–1–(2)	10–13
									115	250	(8)		(22–24)	(9)											
18	« dacrydioides A. Rich.	**46**	1400	+	×	+	×	+	70	660	1–60	(2)	15–17	9–10	?	?	+	14–16	1–2	+	+	+	—	0–1–2	6–7
									75	670			(20–24)	(12)			×							(3)	
19	« elatus R. Br.	**47**	2500	×	+	+	—	+	110	230	1–9	1	11–13	8–10	+	11–12	+	16–18	1	+	+	+	—	1 (2)	9–14
									120	240	(10)			13		(8–10)	×								
20	« elongatus L. Hér.	**48**	5600	×	×	+	—	+	260	540	1–6	1	14–15	8–10	+	11–13	+	12–13	1	+	+	+	—	1 (2)	6–8
									270	550	(7)		20–24 (32)												
21	« falcatus R. Br.	**49**	2300	+	—	+	×	+	230	500	1–6	1	13–14	7–10	×	10–11	+	8–13	1–2	+	+	+	—	1–(2)	7–9
									240	510	(7–10)		(27)					(11–16)							
22	« ferrugineus D. Don.	**50**	2900	×	×	+	—	+	85	280	1–10	–2	12–16	12–13	×	8–10	+	8–12	1	+	+	+	—	1 (2)	$5^1/_2$–7
									90	290	(15)	(3)	(21)												
23	« ferruginoides Compt.	**51**	2300	×	+	+	—	+	140	220	1–6	1	18–22	8–9	×	7–8	+	16–22	1–2	+	+	+	—	0–1	10–12
									150	230	(20)		26	(13–14)		9–10								(2)	16–17
24	« glomeratus D. Don.	**52**	4300	+	×	+	—	+	210	380	1–3	1	13–18	6–10	+	8–9	+	12–16	1	+	+	+	—	0–1	7–8
									220	390	(10)														
25	« gracilior Pilger.	**53**	1050	×	×	+	—	+	110	450	1–8	1	16–17	7–8	×	9–10	+	13–14	1	+	+	+	—	1 (2)	8–14
									120	460	(16)		(20)	(10)		(13)									
26	« Henckelii Stapf.	**54**	1200	+	×	+	×	×	100	340	1–12	(2)	14–20	8–10	×	10	+	16–20	1 (2)	+	+	+	—	1–2	7–8
									110	350	(18)		(27)	(14–15)				(21)							(10)
27	« javanicus Bl.	**55**	2900	+	—	+	—	+	200	630	1–7 (15)	–2	8–12	11–12	×	8–10	+	12–14	1 (2)	+	+	+	—	1–2	7–8
									210	640			(27)	(16)		(11)	×							(3)	
28	« latifolius R. Br.	**56**	4200	×	×	+	—	+	170	330	1–8	(2)	16–18	10–15	+	8–10	+	15–18	1	+	+	+	—	1–2	6–8
									180	335								(19)						(3)	
29	« longifoliatus Pilger	**57**	2500	+	×	+	×	+	90	200	1–11	(2)	16–18	7–10	×	11–12	+	15–22	1–2	+	+	+	—	0–1	8–12
									95	210	(12)		(22)	(12)										(2)	
30	« lycopodioides	**58**	3300	×	×	+	—	+	75	150	1–6	1	16–17	8–10	×	8–10	+	11–12	1	+	+	+	—	1–(2)	8–10
									80	155			(20)			(11)									(12)
31	« macrophyllus D. Don	**59**	2500	+	—	+	+	—	160	580	1–20	(2)	15–18	9–10	+	6–8	+	13–14	1 (2)	+	+	+	(×)	0–1	6–7
									170	590	(24)		(22)	(12)			×			×	×			(2)–3	(10)
32	« macrostachyus Parl.	**60**	3200	+	×	+	—	+	140	280	1–3	(2)	10–20	5–9	+	10–13	+	13–21	1 (2)	+	+	+	—	1 (2)	8—10
									150	290	(9)		(29–30)												(12)
33	« Mannii Hook.	**61**	1900	+	×	+	—	+	150	420	1–8	1	12–14	8–10	+	13–14	+	13–16	1	+	+	+	—	1	6–9
									160	430	(12)		(22–24)	(11)										(2)	(12)
34	« milanjianus Rendle	**62**	4800	+	×	+	—	+	150	370	1–4	(2)	10–18	4–8	+	13–16	+	13–18	1		+	+		1	6–12
									160	380	(16)		(31)	15										(2)	
35	« minor Parl.	**63**	720	+	—	+	+	—	60	330	1—20	1	18–20	12–16	+	13–14	+	13–14	1–2	+	+	+	—	2–3	10–12
									65	340	(35–40)	(2)	(24–30)						3					(5–6)	
36	« montanus Lodd.	**64**	2200	×	+	+	—	+	50	290	1–8	1 (2)	10–21	5–9	+	11–13	+	12–22	1–2	+	+	+	—	0–1	6–8
									55	295	(14–16)		(29–30)											(2)	
37	« neriifolius D. Don.	**65**	1500	—	+	+	—	+	72	210	1–8	1	18–22	9–11	+	11–13	+	19–22	1–2	+	+	+	—	1	10–13
									75	220	(12)		30–38	(13)											
38	« oleifolius D. Don.	**66**	890	×	×	+	—	+	90	170	1–5	1	13–20	5–10	+	8–10	+	18–24	1–2	+	+	+	—	0–1	5–10
									95	180	(20)		(27)	(13)				27						2	
39	« spicatus R Br.	**67**	1600	×	×	—	+	×	65	380	1–15	1–2	15–17	10–12	×	11–13	0	15–18	1–2	**0**	+	+	—	1 (2)	13–18
									70	390	(38)		20–22												
40	« Totara D. Don.	**68**	1100	×	×	+	—	+	50	490	1–40	1	16–18	5–6	+	14–16	+	16–18	1–2	+	+	+	—	0–1–2	8–10
									60	500	50–60		20–22	(7–9)				(20)	(3)					(3)	(11)
41	« usambarensis Pilger	**69**	730	—	+	+	—	+	90	640	1–18	1–2	10–20	6–12	+	16–18	+	16–20	1–2	+	+	+	—	0–1–2	8–12
									100	650	30–35	(3)	(24–26)					(22)							(14)
42	« Wallichianus C. Presl	**70**	720	+	×	+	×	×	65	470	1–15	1	12–18	8–10	+	16–20	+	18–22	1–2	+	+	+	—	1–(2)	10–16
									68	480	(40–50)		(22–28)	(11)											(18)
43	Prumnopitys elegans Philip.	**71**	4800	+	×	+	×	+	240	520	1–6	1	13–15	8–10	×	7–8	+	13–16	1–2	+	+	+	—	1–(2)	7–11
									250	530	(8–10)		(18–20)	12–13											
44	Sciadopitys verticillata Sieb. et Zucc.	**72**	2000	+	—	**0**	+	—	32	110	1–7	1	14–20	12–18	×	8–9	0	9–13	1	**0**	+	+	—	1 (2)	15–20
									35	115	(9–10)		(24)												(22)

V.

TAXALES AND TAXODIACEAE

+ = present; yes
− = absent: no
× = from occassional to rare ; indistinct

Serial No.	Species	Serial No. of plates	Transverse surface: Tracheids: per sq. mm. about	Tracheids: quadratic	Tracheids: rounded	Transverse surface: parenchyma	Transverse surface: resin ducts or cysts	Growth rings: distinct	Growth rings: indistinct	Tangential surface: Rays: per sq. mm. about	Rays: cells per sq. mm. about	Rays: height in cells	Rays: width in cells	Ray cells: height in μ	Ray cells: width in μ	Tangential-walls of tracheids: pit diameter in μ	Tangential-walls of tracheids: space between spirals in μ	Radial surface: Tracheids: pit diameter in μ	Tracheids: number of bord. pits	Horiz. walls of wood parenchyma cells: smooth	Horiz. walls of wood parenchyma cells: thickened or nodular	transverse tracheids	Ray cells: horiz. walls: smooth	Ray cells: horiz. walls: coarse	Ray cells: horiz. walls: pitted	Ray cells: tang. walls: smooth	Ray cells: tang. walls: nodular	Ray cells: indentures	Cross field: number of pits	Cross field: pit diameter in μ	Type of pitting: cupressoid	glyptostrob.	taxodioid	podocarpoid	pinoid
	Taxales		1900																																
1.	Amentotaxus argotaenia Pilger	73	2000	×	×	+	+	−	+	50–55	155–160	1–10	1 (2)	18–20	10–18	?	3–5	12–15	1	×	+	−	+	−	−	+	−	+	1–2 (3–4)	6–8 (10)	+				
2.	Cephalotaxus drupacea Sieb. et Zucc.	74	2400	+	×	+	+	×	+	110–120	250–260	1–14	1	12–13 18–20	8–10	?	4–7	4–5	1	×	×	−	−	×	+	+	−	+	1 (2) 2–4	6–7	+				
3.	« Fortunei Hook.	75	4000	+	×	+	×	+	−	150–160	250–260	1–8	1 (2)	18–20	7–9	?	4–6	12–13	1	×	+	−	−	×	+	+	−	+	1–2 (2–4)	5–6	+				
4.	« Oliveri Mast.	76	2300	×	×	?	?	+	−	65–70	220–225	1–4 (13)	1 (2)	13–18 (21)	5–13	12–13	4–6	12–13	1	?	?	−	−	×	+	+	−	+	1–2 (4)	5–6	+				
5.	« pedunculata Sieb. et Zucc	77	4300	×	×	+	+	+	×	170–180	370–380	1–7	1	16–18 30–38	8–9	5–6	3–6	5–6	1	×	+	−	−	×	+	+	−	+	1 (2) 3–4	4–5	+				
6.	Nothotaxus Chienii (Cheng) Florin.	78	4900	+	×	−	−	×	+	120–130	165–170	1–7 (10)	1	15–20 22–28	6–7 7–12	8–10	3–6	11–14	1	−(?)	−(?)	−	−	−	+	+	×	×	2–3 (6)	4–5 (6)	+				
7.	Taxus baccata L.	79	2700	×	×	− −(×)	×?	+	×	80–85	190–200 (30)	1–15	1 (2)	14–16 20–22	6–9	5–6	3–20	12–13	1	—	− ×?	−	−	+	+	+	−	×	1–2 (3–4)	5–6	+				
8.	« brevifolia Nuttal	80	3100	+	×	−	−	+	−	90–95	260–270 (30)	1–14	1	12–14 20–24	4–6	5–6	15–20	12–14	1	−	−	−	−	+	+	+	−	+	1–2 (2–4)	4–6	+				
9.	« canadensis Marshall	81	3000	+	×	−	−	+	−	90–100	410–420 (14)	1–12	1	12–16 20–22	5–6	5–6	16–18	13–16	1	−	−	−	×	×	×	+	−	×?	1–3 (4)	16–18 (6–8)	+			×	
10.	« chinensis Rehder	82	1700	+	×	−	−	+	−	70–75	240–245 (14)	1–12	1	16–20 13–14	7–9	8–9	12–18	16–18	1	−	−	−	−	+	+	+	−	+	2–3 (4)	4–5	+				
11.	« cuspidata Sieb. et Zucc.	83	1600	+	−	−	−	+	−	50–55	270–280	1–18 1–32	1	16–17 24–26	5–11	8–10	16–30	16–18	1–2	−	−	−	−	+	×	+	−	+	(0—1) (2–4)	5–6	+				
12.	« speciosa Florin.	84	4600	+	−	−	−	+	−	120–130	270–280	1–10	1 (2)	17–18 24–26	6–7	6–7	7–8 10–15	13–14	1	−	−	−	−	+	×	+	−	+	1–3 (3–4)	5–6	+				
13.	« Wallichiana Zucc.	85	2000	+	−	−	−	+	×	280–290	680–690	1–10 9–15	1	14–18 22–28	8–9	5–6	7–8	11–13	1	−	−	−	×	×	×	+	−	+	1–2 (2–3)	5–6	+				
14.	Torreya californica Torrey	86	3600	−	+	×	×	+	×	70–75	130–140	1–4 (6–9)	1	18–24 35–40	9–10	6–7	6–8 20–22	9–11	1	×	×	−	−	×	+	+	−	+	1–4	4–4,5	+				
15.	« grandis Fortune	87	3600	+	×	×	×	+	−	95–100	251–260	5–8 (10)	1	14–20	15–18	6–7	8–10 22–26	9–11	1	×	×	−	−	×	+	+	−	+	1–5	5	+				
16.	« nucifera Sieb. et Zucc.	88	1200	+	×	+	×	+	−	60–65	115–120	1–6 (8)	1	22–26	7–8	6–7	5–7 20–22	11–14	1 (2)	×	×	−	−	×	+	+	−	+	2-3-5	4–5	+				
17.	« taxifolia Arnott	89	1150	+	−	?	?	+	×	20–22	210–220	1–8 15-18(36)	1	22–30	9–12	4–5	6–10 20–25	14–16	1 (2)	?	?	−	−	×	+	+	−	+	3–6	4–5	+				
	Taxodiaceae																																		
1.	Athrotaxis selaginoides D. Don.	183	1600	+	−	+	+	+	−	50–60	235–240	1–12 (14)	1 (2)	20–24	9–11	10–12	−	11–15	1–2	+	×	−	+	×	−	+	−	−	1–3 (4–6)	5,5–7 (10)			+		
2.	Cryptomeria japonica D. Don.	184	3600	+	−	+	×	+	−	40–45	150–160	1–20 (24)	1 (2)	18–22	9–11	9–12	×−	13–14	1–2 (3)	×	+	−	×	×	− (×)	+	−	−	1–2 (5)	6,5–8	×	+	×		
3.	Cunninghamia lanceolata Hook.	185	1200	+	×	+	×	+	−	100–105	180–185	1–7 20–30	1 (2)	20–24 (36)	11–13 9–10	6,5— 9–11	−	13–14 9–11	1–2	×	+	−	+	×	−	+	−	−	1–3 (5)	5–6		+	×	+	
4.	Glyptostrobus pensilis K. Koch.	186	2200	+	−	+	×	+	−	85–90	330–335	1–18 (30)	1 (2)	18–20	7–9	10–11	−	12–13	1–2	×	+	−	−	+	+	+	−	−	1–4	6,5–8	×	+	×		
5.	Metasequoia glyptostroboides Hu et Cheng.	187	1300	+	−	+	×	+	−	45–50	260–280	1–16 (20)	1 (2)	20–22 (24)	8–12	9–10 (13)	-	20–22	1–2	+	×?	×	×	×	×	×	+	−	1–2 (2–4)	11–13	×	×	+		
6.	Sequoia gigantea (Lindl). Decne.	188	2200	+	×	+	+	+	− (×)	40–45	200–210	1-5-12 (30)	1 (2)	20–24 (18)	13–15 (7–8)	11–13	−	14–17	1–2 (3)	+	×	×	+	−	×	+	−	−	1–2 4–6	4,5–8	×	×	+	×	
7.	« sempervirens Endl.	189	1150	+	×	+	+	+	−	30–40	290–300	1–20 (30)	1 (2)	18–22 13–26	11–14 (16)	14–16	−	15–17	1–2	+	×	×	+	−	×	+	×	−	1-2-3 (5)	5–6	×	×	+	×	
8.	Taiwania cryptomerioides Hayata	190	5000	+	−	+	−	+	−	85–90	200–210	1–7 (10)	1	15–18 (24)	7–9	7–8	−	10–11	1–2	+	−	−	+	−	−	+	−	−	1-2-3 (7)	6,5–7,5	×	×	×	×	
9.	Taxodium ascendens Brongn.	191	2300	+	−	+	+	+	− (×)	75–80	310–360	1–9 (11)	1	17–22 (11)	10–12	8,5—9	−	10–12	1 (2)	×	+	−	+	−	+	+	−	−	1–3 (4–6)	5,5–9	×	×	+	×	
10.	« distichum Rich.	192	1000	+	−	+	×	+	−	50–60	350–360	1–24 (60)	1 (2)	18–20	11–12	9–10	−	12–14	1–3 (4)	×	+	−	+	−	+	+	−	−	1–3 (4–8)	5,5–8	×	×	+	×	
11.	« mucronatum Tenore	193	1800	+	−	+	×	+	−	65–70	270–280	1–15 (18)	1	20–22 (36)	10–11 (18)	9–11	−	13–15	1–2	×	+	−	+	×	+	+	−	−	1–4	8–11	×	×	+	×	
12.	**Pherosphaera Hookeriana Archer	194	8500	+	−	+	−	+	−	250–260	460–470	1–4 (8)	1	10–18	8–13	6–8	−	9–10	1	−	+	−	−	×	+	−	+	−	1–2 (3–4)	5–6	+				
13.	Saxegotheae conspicua Lindl.	195	4000	+	−	+	−	+	−	250–260	370–380	1–4 (6)	1	8–16 (27)	2–6	6–8	−	8–12	1	×	+	−	−	−	+	×	×	+	1–2 (6)	2–8	+				
13a.	Saxegotheae gracilis Hort. (Podocarpus nubigenus Lindl).	195a	3400	+	×	+	+	+	−	125–130	270–280	1–3 (10)	1 (2)	13–20	8–13	8–9	−	9–10	1–2	(×)	×	−	−	−	+	+	(×)	+	1–2 (4)	4–5	+				

VI.

CUPRESSACEAE

+ = present ; yes
— = absent ; no
× = from occasional to rare ; indistinct

Serial No.	Species	Serial No. of plates	Transverse surface: Tracheids: per sq. mm. about	Tracheids: squarish	Tracheids: rounded	Wood parenchyma	Resin contents	Growth rings: distinct	Growth rings: indistinct	Tang. surface: Rays: per sq. mm. about	Rays: number of cells per sq. mm. about	Rays: height in cells	width in cells	Ray cells: height in μ	Ray cells: width in μ	Tangent. walls of tracheids: pits	Tangent. walls of tracheids: pit diameter in μ	Radial surface: Wood parenchyma: Radial walls: pit diameter in μ	Wood parenchyma: horizontal walls: smooth	Wood parenchyma: horizontal walls: thickend	Wood parenchyma: horizontal walls: nodular	Ray cells: horisont. walls: smooth	Ray cells: horisont. walls: pitted	Ray cells: tang. walls: smooth	Ray cells: tang. walls: nodular	Ray cells: Indentures	Transverse tracheids	Cross field: number of pits in μ	Cross field: pit diameter in μ	Cross field: type of pitting: cupressoid	Cross field: type of pitting: taxodioid	Cross field: type of pitting: podocarpoid	Cross field: type of pitting: piceoid
	I.																																
1	Actinostrobus acuminatus Parl.	90	5000	+	×	+	+	×	×	100— 110	120— 130	1—6	1	16—37 (80)	8—13	+	6—13	12—13 (2×6)	+	—	—	+	—	+	—	—	—	1—8 (10)	5—8	+			
2	« pyramidalis Miquel	91	4700	+	×	+	+	+	×	95— 100	280— 290	1—8 (14)	1	13—24 (36)	10—13 (15)	+	8—12	11—13	+	—	—	+	—	+	—	—	—	2—5	6—8	+			
3	Callitris cupressiformis Vent.	94	900	×	+	+	+	+	—	25— 30	220— 240	1—35 13—16	1	8—22	4—18	+	6—13	15—17	+	—	—	+	—	+	—	—	—	1—2 (4—8)	6—7	+			×
4	« glauca R. Br.	95	2600	—	+	+	+	—	+	60— 70	480— 490	1—8 (13)	1	14—24	8—12	+	8—12	13—16	+	—	—	+	×	+	—	—	—	1—2 (3—4)	6—9	+			+
5	« intratropica Bent. et Hook. f.	96	4200	×	+	+	+	—	+	230— 240	420— 430	1—4 9—10	1	15—37	6—13	+	5—9	11—13	+	—	—	+	—	+	—	—	—	1—2 (3—4)	7—8	×			+
6	« oblonga Rich. et Mirb.	97	8000	×	+	+	+	—	+	110— 120	410— 420	1—5 (15)	(2)	11—17 (24)	6—13	+	6—8	7—8	+	—	—	+	—	+	—	—	—	1—2 (3)	3—4	×			+
7	« robusta R. Br.	98	2000	×	+	+	+	—	+	50— 55	100— 105	1—10 (24-26)	(2)	11—17	9—11	+	13—21	17—21	+	—	—	+	—	+	—	—	—	2—3	8—9	+			
8	« sulcata Schlechter	99	1200	—	+	+	+	—	+	15— 20	65— 70	1—5 (9)	1	13—26	12—18	+	13—15	13—21	+	—	—	+	—	+	—	—	—	1—2 (3—4)	8—13	+			
9	« verrucosa R. Br.	100	3000	×	+	+	+	—	+	60— 65	260— 265	1—8 (14)	1	17—22	5—13	+	11—13	13—14	+	—	—	+	—	+	—	—	—	1—2 (3—4)	6—9	+			
10	Callitropsis araucarioides Compt.	101	1500	+	—	×	+	—	+	35— 40	110— 115	1—4 12	1	13—24 (35)	6—13 (22)	+	11—13	13—18	+	—	—	+	—	+	—	—	—	1—2 (4—6)	7—13	+			
11	Tetraclinis articulata Mast.	172	1500	×	×	+	+	+	—	170— 180	260— 265	1—6 (17)	(2)	13—40	6—13	+	8—13	13—18	+	—	—	+	—	+	—	—	—	2—3 (4)	6—12	+			×
12	Widdringtonia cupressoides Endl.	178	2000	+	×	+	+	—	+	30— 35	210— 220	1—8 (16)	1	16—27 (35)	10—18	+	12—14	12—14	+	—	—	+	—	+	—	—	—	1—2 (3)	5—8	+			×
13	« dracomontana Stapf.	179	2800	+	×	+	+	+	—	80— 85	320— 340	1—8 (15)	1	10—18 32	5—10	+	12—13	12—13	+	—	—	+	—	+	—	—	—	(1)2-3 (4—6)	6—8	+			
14	« juniperoides Endl.	180	4500	×	×	+	+	—	+	100— 110	230— 240	1—6 30	(2)	16—24 (44)	13—21	+	5—6	10—14	+	—	—	+	—	+	—	—	—	2—4 (6)	4—8	+			×
15	« schwarzii Marl.	181	820	+	—	+	+	—	+	10— 20	150— 160	1-8-17 (33)	(2)	13—27 (29)	8—21	+	16—17	13—18	+	—	—	+	—	+	—	—	—	1—2 (3—7)	5—8 (10)	+			×
16	« whytei Rendle	182	5400	+	—	+	+	—	+	60— 70	180— 190	1—4 8	1	16—32	5—17	+	5—8	13—16	+	—	—	+	—	+	—	—	—	2-4-6	6—8	+			
	II.																																
17	Biota orientalis Endl.	95	3200	+	—	+	—	+	—	120— 125	410— 420	1—4 (16)	1	10—21 22	4—9	+	8—12	7—8	×	+	—	—	+	+	—	×	—	1—2 3—4	5—8	+			
18	Chamaecyparis formosensis Matsumura	102	1800	+	—	+	—	+	—	30— 35	120— 125	1—6 (12)	(2)	10—13 (18)	10—13	+	10—14	12—14	+	—	×	+	—	+	—	—	—	1—2 (4)	5—8	×	+		
19	« lawsoniana Parl.	103	7500	+	×	+	+	+	×	110— 120	200— 210	1-2-6 (10-25)	(2)	11—17 (22)	8—13	+	9—13	9—13	×	×	+	—	+	+	×	—	—	1—2 (4-5-7)	4—5	×	+		
20	« nootkatensis (Lambert) Spach.	104	4300	+	—	+	×	+	—	100— 110	290— 300	1—4 (16)	1	11—22 (37)	5—10	+	7—10	9—13	×	×	+	—	+	+	—	—	—	1—2 (3—4)	5—6	+			
21	« obtusa (Sieb. et Zucc.) Endl.	105	4500	+	—	+	+	+	—	60— 70	190— 200	1—3 (9)	(2)	11—18 (44)	4—8 (13)	+	12—13	8—13	×	×	+	—	+	+	—	×	—	1—2 (4—6)	4—6	+			
22	« pisifera (Sieb. et Zucc) Endl	106	8600	+	—	+	—	+	—	160— 170	340— 350	1—4 (6)	1	11—17 (33)	4—8	+	5—8	6—10	×	×	+	—	+	+	—	×	—	1—3 (4)	4—5	+			
23	« taiwanensis Masamune et Sufuki	107	2500	+	—	+	—	+	—	75— 80	230— 240	1—8 (12)	1	13—22	8—13	+	8—11	10—13	×	—	+	×	—	+	—	—	—	1—3 (4)	5—6	+			
24	« thyoides I. Britton	108	1700	+	—	+	—	+	—	80— 90	240— 250	1—5 (12)	1	11—16 (33)	5—8	+	8—16	17—18	+	×	×	×	—	+	—	+	—	2—3 (4—6)	5—6	+			
25	Fokienia hodginsii Henry et Th.	123	4100	+	—	+	×	+	—	60— 65	150— 160	1—6 (9)	1	13—22 (27)	6—13	+	6—9	8—10	×	+	×	×	—	+	—	×	—	1—2 (3—6)	5—6	+			
26	« kawai Hayata	124	1300	+	—	+	×	+	—	50— 55	165— 170	1—7 (30)	(2)	15—18	10—13	+	5—8	13—14	×	—	+	×	—	+	—	—	—	1—2 (3)	5—8	+			
27	Microbiota decussata Kom.	170	9800	+	×	+	—	+	—	90— 100	310— 320	1—5 (8)	1	13—21 (35)	5—8	+	10—13	10—13	+	—	—	—	+	+	—	—	—	1—2 (4)	4—6	+	×		
28	Thuja koraensis Nakai	173	8000	+	—	+	—	+	—	120— 130	400— 410	1—4 (10)	1	8—18 (24)	5—10	+	6—8	6—8	+	—	—	—	+	+	×	+	—	2—3 (3—6)	4—5	+			
29	« occidentalis L.	174	4600	+	×	×	—	+	—	70— 75	230— 240	1—4 (12)	(2)	8—18 (24)	4—8	+	6—8	10—13	+	—	—	—	+	+	×	+	—	2—3 (4)	4—6	+	×		
30	« plicata D. Don.	175	4800	+	—	×	×	+	—	90— 95	250— 260	1—6 (15)	1	8—13	2—5	+	8—11	9—13	+	—	+	—	+	+	—	+	—	1—2 (4)	6—8	+			
31	Thujopsis dolabrata Sieb. et Zucc.	176	5000	+	—	+	—	×	×	55— 60	130— 140	1—2 (5)	(2)	10—22 (48)	5—10	+	5—8	6—10	+	—	—	—	+	+	×	+	—	1—3	5—8	+			
32	« standishii (Gord.) Carr.	177	1500	+	—	+	+	+	—	100— 110	240— 250	1—5 (15)	1	9—22	3—11	+	4—5	10—14	+	—	+	—	+	+	×	×	+	1—2 (6)	4—6	+			
	III.																																
33	Arceuthos drupacea Antoine	92	7000	+	×	+	—	+	—	220— 230	510— 520	1—8 18	(2)	11—27 (37)	5—13	+	6—10	8—12	×	—	+	—	+	×	+	×	—	1—2 —3 (4)	5—6	+			
34	Cupressocyparis Leylandii Dallimore	109	4900	+	—	+	—	+	—	80— 85	225— 230	1—4 (11)	1	10—21	10—13	+	8—10	8—10	—	—	+	—	+	×	+	×	—	1—2 3—4	4—6	+			
35	Cupressus arizonica Greene	110	3500	×	×	+	—	—	+	110— 120	210— 220	1-3-8 (33)	(2)	13—22 (28)	5—13	+	8—10	8—13	×	×	+	—	+	×	+	×	—	1—2 (4)	5—8	+			
36	« duclouxiana Hickel.	111	6800	+	—	+	+	+	—	170— 180	470— 480	1-3-5 (15)	(2)	13—18	9—16	+	8—10	9—12	×	—	+	—	×	+	×	—	—	2—3 (5)	4—6	+			
37	« funebris Endl.	112	4700	+	—	+	—	×	×	100— 105	220— 225	1-3-4 (9)	1	13—20	6—12	+	8—12	9—16	×	×	+	—	+	×	+	—	—	2—3 (4)	4—6	+			
38	« goveniana Gord.	113	4000	+	—	+	—	+	—	65— 70	230— 240	1—4 (17)	(2)	12—22	7—12	+	8—12	9—18	×	+	×	—	+	×	+	×	—	1—2 3—4	5—6	+			
39	« lusitanica var. Benthami Carr.	114	5500	+	—	+	—	×	×	100— 110	160— 170	1-2-16 (25)	(2)	11—17 (22)	6—11	+	11—13	10—16	×	×	+	—	+	×	+	+	—	1—2 (3—4)	5—9	+			
40	« macnabiana Murr.	115	4600	+	—	+	+	+	+	80— 85	170— 175	1—4 (16)	1	13—21	10—12	+	8—9	10—12	×	—	×	—	+	×	+	+	—	1—2 (3—4)	2—5	+			
41	« macrocarpa Hartweg	116	5100	+	×	+	—	×	×	100— 110	170— 180	1—6 (10)	(2)	13—18 (22)	5—13	+	8—9	9—12	+	—	+	—	+	×	+	×	—	1—2 (3)	4—7	+			
42	« macrocarpa v.guadalupensis Mast.	117	4200	+	—	+	—	+	—	85— 90	230— 240	1—5 (15)	1	13—24	6—13	+	7—11	9—13	+	—	×	—	+	+	+	×	—	1—2 (4)	5—9	+			
43	« sempervirens L.	118	5200	×	+	+	—	×	×	100— 110	170— 175	1-3-8 (24)	(2)	13—27 (37)	6—15	+	6—8	8—13	+	—	—	—	+	×	+	×	—	1—2 —3 (6)	4—7	+			
44	« torulosa D. Don.	119	2400	×	×	+	—	×	×	70— 75	430— 450	1-6-12 (45)	(2)	8—17 (24)	4—11	+	6—8	8—12	+	—	+	—	+	—	+	×	—	1—2 (3)	6—8	+			
45	« whitleyana Carr.	120	3300	×	×	+	—	+	—	100— 110	240— 250	1—5 (12)	(2)	10—24	6—9	+	8—13	7—11	+	—	+	—	+	—	+	×	—	2—3 (4)	4—8	+			
46	Diselma archeri Hook.	121	5500	+	×	+	—	+	×	160— 170	330— 340	1-3-8 (10)	1	10—24 27	8—17 (21)	+	6—8	6—11	×	×	+	—	+	—	+	×	—	1—2 (3—4)	4—5	+			
47	Fitzroya cupressoides Johnston	122	1200	+	—	+	—	+	—	40— 45	120— 130	1-3-10 (19)	(2)	13—24 (43)	4—11 17	+	10—13	13—16	×	×	+	—	×	—	+	×	—	2—3 (5—8)	6—8	+			
48	Juniperus arenaria (Wils.) Florin	125	10000	+	—	+	—	+	—	100— 110	280— 290	1—6 (24)	1	11—24	5—10	+	6—8	6—8	+	—	+	—	+	—	+	+	—	2—3 (4)	2—5	+			
49	« ashei Buchh.	126	3300	+	—	+	+	+	—	100— 110	300— 310	1—4 (7)	1	13—18 (27)	5—8	+	5—8	10—13	—	—	+	—	+	—	+	+	—	1—2 (4)	4—5	+			
50	« bermudiana L.	127	4500	+	×	+	×	+	—	100— 110	240— 280	1—4 (6)	1	11—21	5—8	+	7—8	9—11	+	—	—	—	+	—	+	×	—	1—2 (3—4)	5—7	+			
51	« californica Carr.	128	5500	+	—	+	—	+	—	130— 140	250— 260	1—4 (8)	1	10—28	8—18	×	6—9	11—13	+	—	—	—	—	+	×	+	—	1—2 (3)	4—6	+			
52	« chinensis L.	129	6500	+	—	+	—	+	—	80— 90	260— 270	1—4 (11)	1	10—27	5—9	+	5—10	8—11	+	—	+	—	+	—	+	×	—	2—3 (5—6)	4—6	+			
53	« communis L.	130	4500	+	—	+	×	+	—	90— 95	350— 360	1—6 (13)	1	13—22	4—6	+	4—5	11—13	+	—	—	—	+	—	+	+	—	1—2 (3)	6—8	+			
54	« communis var. saxatilis Pall.	131	7800	+	—	+	×	+	—	170— 175	350— 360	1—4 (12)	1	11—18 (43)	4—8	+	6—9	11—13	+	—	—	—	+	×	+	+	—	1—2 (3)	5—7	+			
55	« conferta Parl.	132	3800	+	—	+	+	+	—	50— 60	170— 180	1—6 (10)	1	13—20 (33)	5—9	+	5—9	8—10	+	—	+	—	+	×	+	×	—	1—2 (3—6)	5—8	+			
56	« distans Florin	133	4000	+	—	+	—	+	—	130— 140	310— 320	1—4 (20)	1	16—20 (27)	10—13	+	5—8	8—10	—	—	+	—	+	+	—	+	—	2—3 (5—6)	4—6	+			
57	« excelsa Bieb.	134	8000	+	—	+	—	+	—	200— 210	420— 425	1—6 (8)	1	11—24	5—8	+	5—7	5—8	+	—	×	—	+	+	—	+	—	1—2 (3)	3—5	+			
58	« formosana Hayata	135	6500	+	—	+	×	+	—	70— 75	210— 220	1—6 (13)	1	13—30	8—10	+	6—8	6—13	+	—	—	—	+	—	+	+	—	1—2 (3)	4—6	+			
59	« foetidissima Willd.	136	6500	+	—	+	—	+	—	260— 265	420— 430	1—10 (20)	(2)	10—27	5—10	+	6—8	6—10	+	—	+	—	+	—	+	+	—	1—4 (6)	4—5	+			
60	« glaucescens Florin	137	9000	+	—	+	×	+	—	130— 135	340— 350	1—4 (12)	(2)	13—21	6—8	+	6—8	8—10	—	—	+	—	+	—	+	+	—	2—3 (4)	4—5	+			
61	« horizontalis Moench.	138	7200	+	—	+	—	+	—	170— 180	350— 360	1—4 (17)	1	8—17 (26)	4—8	+	5—7	8—11	+	—	—	—	+	—	+	×	—	1—3 (4)	5—6	+			
62	« lemeeana Lev. et Blin.	139	4500	+	—	+	—	+	—	120— 125	255— 260	1—5 (12)	(2)	13—18 (27)	5—10	+	8—10	10—13	+	—	+	—	+	—	+	×	—	2—4 (6)	2—5	+			
63	« macrocarpa Sibt. et Sin.	140	7000	+	—	+	—	+	—	170— 180	390— 400	1—4 (10)	1	8—27	5—8	+	8—10	8—12	+	—	—	—	+	—	+	+	—	1—2 —3 (4)	5—6	+			
64	« macropoda Boiss.	141	6000	+	—	+	—	+	—	80—90	240— 250	1—9 (13)	(2)	16—24	8—17	+	8—10	10—16	×	×	+	—	+	—	+	+	—	1—2 (3—4)	2—4	+			
65	« mexicana Schlech.	142	8500	+	—	+	+	+	—	160— 170	310— 320	1—8 (21)	(2)	13—21 (44)	10—14 (21)	+	5—8	11	+	—	+	—	+	—	+	×	—	1—2 (4)	5—7	+			
66	« monosperma Sarg.	143	5600	+	—	+	+	+	—	120— 130	420— 430	1—6 (14)	1	6—8	6—8	+	6—8	7—13	+	—	+	—	+	—	+	+	—	1—2 (4)	4—6	+			
67	« occidentalis = monocarpa Hook.	144	2000	+	—	+	+	+	—	60— 65	340— 345	1—6 (14)	(2)	8—12 (26)	5—7 (8)	+	5—10	9—16	+	—	+	—	+	×	+	+	—	1—2 (4)	5—7	+			
68	« oxycedrus L.	145	6900	+	—	+	—	+	—	100— 110	290— 300	1—12 (14)	1	9—33	2—11	+	7—10	9—13	+	—	+	—	+	—	+	+	—	1—2 (3—4)	4—8	+			
69	« pachyphloea Torr.	146	9500	+	—	+	—	+	—	150— 155	260— 270	1—6 (12)	1 (27)	13—21 (32)	5—8	+	4—5	11—12	—	—	+	—	+	—	+	+	—	1—2 (3)	4—5	+			
70	« phoenicea L.	147	8100	+	—	+	—	+	—	100— 110	330— 340	1—6 (13)	1	10—24	5—10	+	8—11	8—12	+	—	+	—	×	—	+	×	—	1—2 (3)	4—7 (8)	+			
71	« pinchoti Sudw.	148	3500	+	—	+	—	+	—	130— 140	320— 330	1—3 (7)	1	10—18 (27)	5—10	+	8—10	10—13	+	—	+	—	+	—	+	+	—	1—2 (3)	4—6	+			
72	« pingii Cheng]	149	6900	+	—	+	—	+	—	210— 220	500— 510	1—6 (18)	1	10—18 (27)	5—10	+	6—8	9—13	+	—	+	—	+	×	+	+	—	1—2 (3)	4—5	+			
73	« procera Hochst.	150	5500	+	×	+	—	+	—	110— 120	210— 220	1—3 (9)	1	13—30 (40)	6—13	+	6—8	8—11	+	—	+	—	+	×	+	×	—	1—2 (4—3)	4—5	+			
74	« przewalskii Kom.	151	10000	+	—	+	—	+	—	110— 115	210— 220	1—7 (15)	1	13—18 (32)	5—6	+	5—6	6—9	+	—	+	—	+	—	+	×	—	2—3 (4)	4—5	+			
75	« ramulosa Florin	152	10500	+	—	+	×	+	—	120— 130	300— 310	1—7 (12)	1	13—21 (43)	8—10	+	5—6	8—10	—	—	+	—	+	—	+	×	—	2—3 (4)	5—8	+			
76	« recurva Buchh-Ham.	153	2300	+	—	+	×	+	—	85— 90	250— 255	1—5 (11)	1	13—22 (26)	4—6 (8)	+	9—12	11—13	+	—	+	—	+	—	+	×	—	1—2 (3—4)	3—4	+			
77	« rigida Sieb. et Z.	154	3500	+	—	+	+	+	—	95— 100	280— 290	1—10 (24)	1	8—23	4—8	+	7—11	12—17	—	—	+	—	+	—	+	+	—	1—2 (3—4)	5—8	+			
78	« sabina L.	155	6000	+	—	+	×	+	×	120— 125	260— 265	1—8 (11)	1	8—17	4—11	+	8—10	8—11	+	—	+	—	+	—	+	+	—	1—2 (4)	5—8	+			
79	« saltuaria Rehd. et Wils.	156	8200	+	—	+	×	+	—	160— 165	310— 320	1—5 (13)	(2)	13—18 (29)	8—16	+	6—8	6—8	+	—	+	—	+	—	+	×	—	2—3 (5)	4—5	+			
80	« scopulorum Sarg.	157	2400	+	—	+	×	+	—	80— 85	350— 360	1—8 (16)	1	10—18 (27)	8—10	+	10—13	10—13	—	—	+	—	+	—	+	+	—	1—2 (3—4)	4—5	+			
81	« silicicola Bailey	158	5800	+	—	+	+	+	—	65— 70	200— 210	1—8 (24)	(2)	10—16 (33)	5—9	+	10—13	13—14	+	—	+	—	+	×	+	+	—	1—2 (3—4)	4—6	+			
82	« squamata Buchh.-Ham.	159	6500	+	—	+	×	+	—	160— 170	600— 610	1—5 (8)	1	10—17	4—8	+	9—11	7—10	+	—	+	—	+	—	+	+	—	1—2 (3)	4—5	+			
83	« thurifera L.	160	8000	+	×	+	×	×	×	190— 200	300— 310	1—4 (6)	1	10—18	4—8	+	10—12	6—11	+	—	—	×	×	+	—	—	—	1—3 (4)	4—6	+			
84	« tibetica Kom.	160a	6000	+	×	+	×	×	×	200— 210	310— 325	(6) 1—3 (14)	(2)	16—21	13—14	+	10—12	10—12	+	—	—	×	×	+	+	+	—	1—2 (3—4)	5—8	+			
85	« virginiana L.	161	3800	+	—	+	×	+	—	115— 120	330— 380—	(14) 1—4 (12)	1	10—22	3—8	+	4—6	10—13	+	—	×	—	+	×	+	+	—	1—2 (8)	4—6	+			
86	« zoidamensis Kom.	162	5600	+	—	+	—	+	—	145— 150	350— 360	1—3 (10)	1	13—18 (37)	8—10	+	4—6	9—10	+	—	—	—	+	—	+	+	—	1—2 (3)	4—5	+			
87	Libocedrus austro-caledonica Br. et Gr.	163	3200	+	×	+	+	×	×	40— 45	70— 75	1—3	1	22—37	6—16	+	9—10	10—13	+	—	—	+	—	×	—	—	—	1—2 (4)	8—12	+			
88	« bidwillii Hook.	164	2800	+	—	+	+	+	—	20— 30	50— 60	1—3 (8)	(2)	18—43	16—27	+	4—6	8—10	+	—	—	+	—	+	—	—	—	1—3 (6)	4—5	+			
89	« chilensis Endl.	165	1700	+	—	+	+	+	—	30— 35	160— 170	1—10 (20)	1	13—18 (27)	10—13	+	10—12	10—13	+	—	—	+	—	+	—	—	—	1—2 (3—6)	4—5	+			
90	« decurrens Torr.	166	5500	+	—	+	—	+	—	115— 120	330— 340	1—6	1	10—22	4—13	+	6—10	8—10	+	—	+	—	+	—	+	+	—	2—4 (6—7)	4—5	+			
91	« formosana Florin	167	3000	+	×	+	+	+	—	85— 90	200— 210	1—10 (15)	(2)	16—21 (27)	10—13	+	10—14	10—13	—	—	+	—	+	—	+	—	—	1—2 (5)	5—8	+			
92	« macrolepis Benth. et Hook.	168	2600	—	+	+	—	—	+	110— 115	210— 230— 240	1—4 (6)	1	10—20	5—10	+	8—10	8—10	+	—	—	—	+	—	+	+	—	1—2 (4)	4—6	+			
93	« plumosa Druce	169	2600	+	—	+	+	×	×	110— 115	280— 290	1—4 (8)	1	13—26	6—15	+	8—11	8—10	+	—	—	+	—	+	—	—	—	1—4 (6)	5—9	+			
94	Pilgerodendron uviferum Florin	171	1800	+	—	+	+	+	—	70— 75	220— 230	1—4 (12)	(2)	13—37 ..	13—16	+	8—10	12—16	—	—	+	—	—	—	+	—	—	1—2 (3—4)	5—7	+			

VII.

PINACEAE

+ = present; yes
− = absent; no
× = from occasional to rare; indistinct

Serial No.	Species	Serial No. of plates	Transverse surface: approx. number of tracheids per sq. mm.	Transverse surface: diameter of resin ducts in μ	Transverse surface: wood parenchyma	Tangential surface: Rays: per sq. mm about	Tangential surface: Rays: approx number of cells per sq. mm.	Tangential surface: Rays: height in cells	Tangential surface: Rays: width in cells	Tangential surface: Ray cells: height in μ	Tangential surface: Ray cells: width in μ	Tangential surface: diameter of pits in	Radial surface: diameter of pits in tracheids in μ	Radial surface: Wood parenchyma: horiz. walls: smooth	Radial surface: Wood parenchyma: horiz. walls: nodular	Radial surface: Wood parenchyma: horiz. walls: pitted	Radial surface: Ray cells: horiz. walls: smooth	Radial surface: Ray cells: horiz. walls: pitted	Radial surface: Ray cells: tang. walls: smooth	Radial surface: Ray cells: tang. walls: dentate	Radial surface: Ray cells: tang. walls: nodular	Radial surface: Walls of transverse tracheids: smooth	Radial surface: Walls of transverse tracheids: with minute dentations up to 2,5 μ	Radial surface: Walls of transverse tracheids: denations extending to center of lumen	Radial surface: Walls of transverse tracheids: reticulate or with spiral bars	Radial surface: indentures	Radial surface: Cross field: number of pits	Radial surface: Cross field: pit diameter in μ	Radial surface: Cross field: Tipe of pitting: cupressoid	piceoid	podocarpoid	pinoid	taxodioid	araucaroid
1.	Abies alba Mill.	196	2100	−	×	50−55	370−380	1−12 (40)	1	10−21 (27)	5−10	6	13−16	−	−	+	−	+	−	+	−	−	−	−	−	+	1−2 (3)	6−8		+			+	
2.	« amabilis Forbes	197	5000	−		140 150	410 420	1−6 (14)	1	13−18 (27)	6−8	5	8−14				−	+	−	+	−	−	−	−	−	+	1−2 3	2−5		+				
3.	« balsamea Mill.	198	2000	−		45−50	180−210	1−6 (10)	1 (2)	10−21 (27)	6−8	5	10−16				−	+	−	+	−	−	−	−	−	+	1−2 (6)	5−6		+				
4.	« cephalonica Loud.	199	6500	−	×	115−130	370−380	1−6 (12)	1 (2)	10−21 59	8−13	8	9−13	−	−	+	−	+	−	+	−	−	−	−	−	+	1−2 (3−4)	5−8		+				
5.	« chensiensis Van Tiegh.	200	4200	−	×	85−90 115−	360−370	1−8 (12)	1 (2)	13−18 (21)	8−13	8	10−13	−	−	+	−	+	−	+	−	−	−	−	−	+	1−2 (6)	5−10		+				
6.	« cilicica Carr.	201	3600	−	×	120	370−380	1−6 (13)	1	13−21 (54)	8−13	6	9−15	+	−	+	−	+	−	+	−	−	−	−	−	+	1−2 (3−5)	5−8		+				
7.	« concolor Lindl. et Gord.	202	4500	−		60−65	285−290	1−4 (12)	1	8−13 (27)	4−8	6	10−12	−	−	−	−	+	−	+	−	−	−	−	−	+	1−2 (3)	3−8		+				
8.	« Fabri Craib.	203	4800	−	×	100−110	270−280	1−7 (20)	1 (2)	13−18 (21)	8−13	6	10−13	+	−	+	−	+	−	+	−	−	−	−	−	+	1−2 (3)	4−6		+				
9.	« firma Sieb. et Zucc.	204	6500	−		40−50	270−280	1−6 (10)	1 (2)	10−21 (32)	7−10	8	8−13	−	−	−	−	+	−	+	−	−	−	−	−	+	2−3 (4)	4−5		+				
10.	« Fraseri Poiret	205	6000	−		60−70	180−200	1−6 (10)	1	10−16	5−8	6	10−13	−	−	−	−	+	−	+	−	−	−	−	−	+	1−2 (4)	5−6		+				
11.	« grandis Lindley	206	2800	−	×	40−45	250−260	1−6 (14)	1−2	10−21	8−12	5	12−18	×	−	+	−	+	−	+	−	−	−	−	−	+	1−2 (3)	4−6		+				
12.	« holophylla Maximowicz	207	6200	−		110−120	280−290	1−8 12	1	13−18 (27)	4−10	5	8−10	−	−	−	−	+	−	+	−	−	−	−	−	+	1−2 (3)	4−6		+				
13.	« homolepis v. umbellata (Mayr) Wilson	208	6000	−		130−135	340−345	1−5 (8)	1	13−21 (30)	8−16	10	10−13	−	−	−	−	+	−	+	−	−	−	−	−	+	1−2 (3−5)	4−5		+				×
14.	« Kawakamii Ito.	209	4000	−		17−18	120−130	1−8 (18)	1	9−12	10−16	8	10−13				−	+	−	+	−	−	−	−	−	+	1−2 (4)	4−8		+				
15.	« koreana Wilson.	210	4000	−	×	80−90	340−350	1−6 (10)	1	10−20 (32)	5−10	5	10−15	−	−	+	−	+	−	+	−	−	−	−	−	+	1−2 (4)	4−5		+				
16.	« lasiocarpa Nuttal	211	2000	−		35−40	450−460	1−20 (49)	1	10−26	8−10	5	12−16	−	−	−	−	+	−	+	−	+	−	−	−	+	1−2 (4)	4−6		+				×
17.	« lasiocarpa v. arizonica Lem.	212	8000	−	×	110−120	400−410	1−5 (10)	1	10−18 (25)	4−8	4	10−13	×	−	+	−	+	−	+	−	−	−	−	−	×	1−2 (4)	4−7		+				
18.	« Lowiana A. Murray	213	3800	−		70−80	240−250	1−8 (10)	1	15−16 (18)	6−8	9	10−13	−	−	−	−	+	−	+	−	+	−	−	−	+	1−2 (4)	5−6		+				
19.	« magnifica A. Murray	214	5000	−	×	80−90	390−400	1−8 (27)	1	10−18 (27)	5−12	8	8−13	−	−	−	−	+	−	+	−	−	−	−	−	+	1−2 (4)	4−5		+				
20.	« nephrolepis Maximowicz	215	5000	−		130−140	460−465	1−7 (12)	1	13−21	4−8	5	8−12				−	+	−	+	−	−	−	−	−	+	1−2 (4)	4−6		+				
21.	« Nordmanniana Spach.	216	5000	−	×	150−160	510−520	1−8 (15)	1	10−18 (27)	5−8	5	9−13	−	−	+	−	+	−	+	−	−	−	−	−	+	1−2 (4)	2−5		+				
22.	« numidica De Lannoy	217	6000	−	×	110−120	320−330	1−7 (12)	1	10−18 (32)	5−13	6	10−15	+	−	×	−	+	−	+	−	−	−	−	−	+	1−2 (5)	4−6		+				×
23.	« pindrow Spach.	218	4300	−		50−60	120−125	1−4 (6)	1	13−18 (50)	5−10	6	8−10				−	+	−	+	−	−	−	−	−	+	1−2 (4)	2−5		+				
24.	« Pinsapo Boisser	219	8000	−	×	130−140	460−470	1−8 (10)	1	13−18 (27)	6−13	6	8−13	−	−	+	−	+	−	+	−	−	−	−	−	+	1−2 (5)	4−5		+				
25.	« procera Rehder.	220	2800	−		60−65	490−500	1−16 (45)	1 (2)	10−16 (25)	8−13	6	13−18				−	+	−	+	−	−	−	−	−	+	1−2 (3)	4−6		+				
26.	« sachalinensis Mast.	221	10,000	−		21−22	340−345	1−6 (12)	1	13−18 (27)	4−8	5	10−12				−	+	−	+	×	−	−	−	−	+	2−3 (4)	2−4		+				
27.	« sibirica Ledebour	222	7500	−	×	100−110	860−870	1−12 (18)	1	13−18 (40)	5−10	5	10−13	−	−	+	−	+	−	+	−	−	−	−	−	+	1−2 (4)	4−5		+				
28.	« spectabilis Spach.	223	2300	−	×	65−70	630−640	1−12 (32)	1 (2)	10−18 (27)	8−15	8	16−21	−	−	+	−	+	−	+	−	−	−	−	−	×	1−2 (3)	5−6		+				
29.	« squamata Mast.	224	6600	−		80−90	410−420	1−8 (20)	1 (2)	13−18 (25)	6−10	6	10−13				−	+	−	+	−	−	−	−	−	×	1−2 (4−5)	2−6		+				
30.	« Veitchii Lindley	225	7000	−	×	140−150	390−400	1−6 (12)	1	13−18 (48)	4−8	5	10−13	×	−	+	−	+	−	+	−	−	−	−	−	+	1−2 (6)	4−7		+				
31.	« venusta K. Koch.	226	1100	−	×	25−30	200−210	1−9 (36)	1 (2)	13−27	10−20	13	16−21	−	−	+	−	+	−	+	−	−	−	−	−	+	1−2 (3−4)	5−9		+				×
32.	« Vilmorinii Mast.	227	3300	−		70−80	160−170	1−6 (11)	1	16−27 (50)	8−15	9	10−16				−	+	−	+	−	−	−	−	−	+	1−2 (3−4)	4−8		+				
33.	Cedrus atlantica Manetti	228	3000	×	+	65−70	390−400	1−12 (30)	1	13−16	8−13	10	13−16	×	−	+	−	+	−	×	+	+	−	−	−	×	2−3 (4−5)	4−6		+				
34.	« brevifolia Henry	229	1400	50×90	+	30−35	230−235	1−5 (15)	1 (3)	15−30	12−16	10	13−21	−	−	+	−	+	−	+	×	+	−	−	−	×	2−3 (4)	4−6		+				
35.	« Deodara Loudon	230	3200	×	+	35−40	270−280	1−14 (32)	1 (2)	13−24	5−18	10	10−18	−	−	+	−	+	−	×	+	+	−	−	−	×	1−2 (4)	5−6		+				×
36.	« libani Loud.	231	5000	×	+	100−110	390−400	1−8 (18)	1 (2)	10−27 (54)	8−16	9	9−13	−	−	+	−	+	−	+	−	+	−	−	−	×	1−2 (3)	4−6		+				
37.	Keteleeria Davidiana Beissner	232	2000	−	+	32−35	270−280	1−12 (32)	1 (2)	13−18 (43)	5−18	8	10−16	×	−	+	−	+	−	+	−	−	−	−	−	+	1−2 (5−6)	5−8		+				
38.	« Fortunei Carr.	233	2400	−	+	65−70	250−260	1−6 (15)	1 (2)	10−27	10−18	9	12−16	−	−	+	−	+	−	+	−	−	−	−	−	+	1−2 (4−5)	4−5		+				×
39.	Larix decidua Miller	234	3000	40×54	×	90−100	320−330	1−8 (20)	1 (2)	13−18 (40)	6−10	5	10−21	+	−	+	−	+	−	+	−	+ (×)	×	−	−	+	3−4 (6)	4−6		+				+
40.	« Gmelinii Litvinov	235	1300	50×60	×	35−40	270−280	1−12 (26)	1	13−24	4−6	8	18−27	−	−	+	−	+	−	+	−	+	−		−	+	3−4 (6)	6−7		+				×
41.	« Gmelinii var. japonica Pilg.	236	3400	30×40	×	75−80	220−230	1−10 (20)	1 (2)	13−27 (40)	6−8	8−	13−16	−	−	+	−	+	−	+	−	+	−	−	−	+	4−6 (6)	2−6		+				×
42.	« laricina K. Koch.	237	5400	31×37	×	50−60	190−200	1−12 (24)	1	16−24	5−16	5	13−18	−	−	+	−	+	−	+	−	+ (×)	×	−	−	+	3−4 (7)	4−6		+				×
43.	« leptolepis Murray	238	3000	54×54	×	50−60	280−290	1−12 (30)	1 (2)	13−20 (32)	4−8	9	13−21	−	−	+	−	+	−	+	−	+	−	−	−	+	2−4 (5)	4−6		+				
44.	« Lyalii Parl.	239	2100	40×40	×	60−65	300−310	1−16 (30)	1	13−18	8−13	5	13−21	−	+	−	−	+	−	+	−	+	−	−	−	+	3−4 (6)	4−6		+				×
45.	« occidentalis Nuttal	240	800	67×81	×	25−30	150−160	1−10 (26)	1	10−13 (18)	4−6	6	16−24	−	−	+	−	+	−	+	−	+	−	−	−	+	6−10	5−6		+				×
46.	« pendula Salisb.	241	5000	35×40	×	70−75	310−320	1−10 (14)	1	10−16 (27)	4−13	4	10−13	−	−	+	−	+	−	+	−	+ (×)	×	−	−	+	2−4 (6)	4−5		+				
47.	« Potanini Batalin	242	3100	32×40	+	40−50	310−320	1−16 (30)	1 (2)	10−16 (21)	5−13	5	13−18	−	−	+	−	+	−	+	−	+ (×)	×	−	−	+	1−2 (3)	4−5		+				×
48.	« sibirica Ledebour	243	5000	29×35	+	50−60	200−210	1−8 (16)	1 (2)	10−16 (22)	5−10	5	8−16	+	−	+	−	+	−	+	−	+ (×)	×	−	−	+	2−3 (4)	4−6		+				
49.	Picea Abies Karst.	244	5000	32×40	−	50−60	210−220	1−10 (26)	1 (2−3)	13−18 (27)	6−8	5	10−13	−	−	−	−	+	−	+	−		+	−	−	+	1−2 (5)	4−6		+				×
50.	« albertiana Stew. Br.	245	1800	45×54	−	25−30	210−220	1−10 (24)	1 (2−3)	13−21 (29)	5−8	6	13−21	−	−	−	−	+	−	+	−	−	+	−	−	+	2−3 (4)	4−5		+				
51.	« asperata Mast.	246	5400	35×40	−	90−100	280−290	1−10 (20)	(2−4) 1	15−20 (27)	4−6	6	13−17	−	−	−	−	+	−	+	−	−	+	−	−	+	2−4 (6)	4−5		+				
52.	« bicolor Mayr.	247	8000	27×35	−	140−150	460−470	1−10 (12-16)	1 (2−3)	14−18 (27)	8−13	6	9−10	−	−	−	−	+	−	+	−	−	+	−	−	×	2−3 (6−8)	4−5		+				
53.	« brachytyla Pritzel.	248	5900	27×40	−	80−90	210−220	1−6 (12-16)	1 (2−4)	14−18 (25)	8−10	5	9−10	−	−	−	−	+	−	+	−	−	+	−	+	+	1−2 (6−8)	4−5		+				
54.	« Breweriana S. Wats.	249	3200	25×40	−	80−90	360−365	1−6 (8-16)	1 (4)	10−18 (32)	5−9	7−	8−9 (14)	—	—	—	−	+	−	+	−	+	−	−	−	+	2−4 (6)	3−5		+				
55.	« Engelmannii Engel.	250	9200	21×29	−	110−120	300−310	1−7 (12)	1 (2−4)	16−18 (30)	6−9	6	9−14	−	−	−	−	+	−	+	−	+	−	−	−	+	2−3 (4)	3−6		+				
56.	« glauca Voss	251	8000	45×51	−	160−170	460−470	1−10 (28)	1 (2−3)	10−16	4−8	6	10−13	−	−	−	−	+	−	+	−	−	+	−	−	+	1−2 (4)	4−5		+				
57.	« Glehnii Mast.	252	5600	48×54	−	80−90	220−230	1−12 (16)	1 (2−3)	13−18 (40)	4−8	6	8−16	−	−	−	−	+	−	+	−	−	+	−	−	+	2−4 (6)	4−6		+				
58.	« jezoensis Carr.	253	8000	27×35	−	140−150	380−390	1−10 (12)	1 (2−4)	14−20 (35)	5−8	6	10−13	−	−	−	−	+	−	+	+	−	×	−	−	×	1−2 (3−4)	3−6		+				
59.	« junnanensis Hort	254	6800	29×29	−	100−110	300−310	1−10 12−20	1 (2−3)	13−18 (30)	6−9	6	10−13	−	−	−	−	+	−	+	−	−	+	−	−	+	2−4 (6)	4−6		+				
60.	« Koyamai Shiras.	255	7200	27×32	−	150−160	350−360	1−8 (18)	1 (2−3)	15−18 (27)	6−8	6	10−13	−	−	−	−	+	−	+	−	−	+	−	−	+	2−3 (8)	5−7		+				
61.	« likiangensis Pritzel	256	2000	54×65	−	85−90	390−400	1−10 (18)	1−2 (3−4)	13−18 (27)	8−18	6	12−14	−	−	−	−	+	−	+	−	−	+	−	+	+	3−4 (7)	4−8		+				
62.	« var. purpurea Dall. et Jacks.	257	2000	35×40	−	150−160	470−480	1−8 (14)	1 (2−3)	15−18 (27)	8−10	6	10−13	−	−	−	−	+	−	+	−	−	+	−	+	×	3−4 (6)	4−6		+				
63.	« mariana Britt. et. St. Pogg.	258	2300	27×45	−	45−50	200−210	1−20 (25)	1 (2−3)	10−16	4−5	5	15−18	−	−	−	−	+	−	+	−	−	+	−	−	+	1−4 (6)	3−6		+				
64.	« Maximowiczii Regel	259	6100	40×45	−	110−120	345−350	1−8 (16-18)	1 (2−3)	13−18 (30)	4−13	5	10−13	−	−	−	−	+	−	+	−	−	+	−	×	+	4−6	3−6		+				
65.	« morrisonicola Hayata	260	5900	32×37	−	130−140	260−270	1−16	1 (2−3)	13−18 (40)	8−13	8−	10−13	−	−	−	−	+	−	+	−	−	+	−	×	+	2−4 (6)	5−7		+				
66.	« Neoveitchii	260a	1200	37×37	−	42−45	400−410	1−6 (12-32)	1 (2−3)	8−16	5−8	5	18−21	−	−	−	−	+	−	+	—	—	+	—	+	+	2−4 (7)	4−6		+				
67.	« obovata Ledeb.	261	7000	37—37	−	100−110	300−310	1−8 (8-12)	1 (2−3)	12−20 (40)	7−12	6	10−15	−	−	−	−	+	−	+	−	−	×	−	−	+	2−3 (7−8)	4−5		+				
68.	« Omorika Bolle	262	5500	32×40	−	50−55	250−260	1−6 (12)	1 (2−3)	15−20	5−10	6	10−16	−	−	−	−	+	−	+	−	−	+	−	−	+	2−4 (6)	4−6		+				
69.	« orientalis Carr.	263	5600	54×70	−	60−70	630−640	1−16 (40)	1 (2−4)	13−18	4−5	6	16−18	−	−	−	−	+	−	+	−	−	×	−	−	+	1−2 (3−5)	4−6		+				
70.	« polita Carr.	264	9400	32×40	×	80−85	280−290	1−10 (18)	1 (2−3)	15−20 (30)	7−10	6	8−13	−	−	+	−	+	−	+	−	−	+?	−	−	+	1−2 (6)	4−6		+				
71.	« pungens Engel.	265	7000	37×48	−	100−110	350−360	1−10 (14)	1 (2−3)	14−20 (25)	8−13	8	10−14	−	−	−	−	+	−	+	−	−	+	−	−	+	2−4 (6)	3−6		+				
72.	« Schrenkiana Fisch. et May.	266	6500	27×40	−	200−210	550−560	1−8 (14)	1 (2−4)	14−20 (27)	7−13	8	8−16	−	−	−	−	+	−	+	−	−	+	−	−	×	2−3 (4)	4−5		+				
73.	« sitchensis Carr.	267	5000	21×27	−	75−80	320−330	1−8 (16)	1 (2−3)	13−18 (32)	4−13	5	13−16	−	−	−	−	+	−	+	−	−	+	−	−	+	2−3 (5)	4−6		+				
74.	« Smithiana Boiss.	268	7000	30×30	−	75−80	200−250	1−10 (20)	1 (2−4)	13−21 (27)	5−13	6	13−18	−	−	−	−	+	−	+	−	−	×	−	+	×	2−4 (6)	4−6		+				
75.	« Wilsonii Mast.	269	6000	29×28	×	120−130	330−340	1−8 (16-20)	1 (2−3)	14−18 (28)	5−8	6	10−14	−	−	+	−	+	−	+	−	−	+	−	−	+	2−4 (6)	4−6		+				
	Pinus. See Table VIII. 76—145.																																		
146.	Pseudolarix amabilis Rehder	338	2700	−	+	75−80	470−480	1−10 (24)	1 (2)	13−18 (56)	10−16	12	13−18	−	−	+	−	+	−	+	−	−	−	−	−	+	2−4 (8)	4−6		+				
147.	Pseudotsuga macrocarpa Mayr.	339	2700	41×45	+	45−50	220−230	1−5 (20)	1 (2−3)	13−21 (27)	6−13	6	16−21	−	−	+	−	+	−	+	−	−	−	−	+	+	2−4 (6)	4−8		+				
148.	« taxifolia Britton	340	3500	40×50	+	90−100	320−330	1−4 (10)	1 (2−3)	13−18 (27)	4−8	6	10−16	−	+	−	−	+	−	+	−	+	×	−	+	+	2−4 (7)	2−6		+				
149.	Tsuga canadensis Carr.	341	2500	−	+	35−40	200−210	1−6 (12)	1	13−18 (22)	5−10	8	13−16	—	−	+	−	+	−	+	−	+	−	−	−	+	2−4 (7)	2−5		+				
150.	« chinensis Pritzel	341a	1600	−	+	50−55	370−375	1−14 (34)	(2)	13−27	8−16		13−18		−	+	−	+	−	+	−	+	−	−	−	+	2−3 (4−5)	4−5		+				
151.	« diversifolia Mast.	342	2500	−	+	65−70	400−410	1−6 (18)	1 (2)	10−18 (27)	4−8	9	13−17	−	×	+	−	+	−	+	−	+	−	−	−	+	3−4 (8)	2−6		+				
152.	« dumosa Eich.	343	2800	−	+	70−75	270−280	1−6 (14)	1 (2)	13−21 (40)	5−13	8	10−13	−	−	+	−	+	−	+	−	+	−	−	−	+	2−4 (6)	5−6		+				
153.	« heterophylla Sarg.	344	1700	−	+	30−35	380−390	1−12 (26)	1	13−18 (27)	4−8	8	13−18	−	−	+	−	+	−	+	−	+	−	−	−	+	1−2 (4)	4−6		+				
154.	« Mertensiana Carr.	345	3600	—	+	85−90	530−540	1−12 (27)	1 (2)	10−18 (29)	10−16	8	10−16		−	+	−	+	−	+	−	+	−	—	−	+	1−2 (3)	4−5		+				

VIII.

PINUS-SPECIES

+ = present; yes
− = absent; no
× = from occasional to rare; indistinct

Serial No.		Species	Serial No. of plates	Transverse surface: Tracheids: tang. diameter in μ	Transverse surface: Tracheids: radial diam. in μ	Transverse surface: Tracheids: diam. of resin ducts in μ	Tangential surface: Rays: pit diameter in μ	Tangential surface: Rays: height in cells	Tangential surface: Rays: width in cells	Tangential surface: ray cells	Radial surface: Rays: width in μ	Radial surface: Pits in tracheids: pit diam. in μ	Radial surface: Pits in tracheids: number of	Radial surface: Ray parenchyma: cross-field pits: piceoid	Radial surface: Ray parenchyma: cross-field pits: pinoid	Radial surface: Ray parenchyma: cross-field pits: number of	Radial surface: Ray parenchyma: cross-field pits: diameter in μ	Radial surface: Ray parenchyma: walls: thin	Radial surface: Ray parenchyma: walls: 1,5-2 μ in thickness	Radial surface: Ray parenchyma: walls: 2—4 μ in thickness	Radial surface: Transverse tracheids: smooth	Radial surface: Transverse tracheids: dentations up to 2,5 μ	Radial surface: Transverse tracheids: dentations to center of lumen	Radial surface: Transverse tracheids: with reticular thickening
		A. HAPLOXYLON																						
76.	I.	Pinus Armandi Franch.	**272**	15—20	15—25 6—8	80 100	8—10	1—8	1	20	26	8—12	18—20 10—12	1		+	1—2 (3)	14—20		+		+			
77.		« Ayacahuite Ehrenb.	**274**	12—25	15—25 8—10	100 130	6—8	1—10	1	15	20	8—10	18—20 10—14	1		+	1—2 (3)	12—24		+		+			
78.		« cembra L.	**279**	30—40	30—50 10—20	80 100	8—10	1—15	1	20	22	8—10	20—25 12—15	1—2		+	1—2 (3)	16—24		+		+			
79.		« flexilis James.	**288**	10—20	15—25 5—8	70 80	8—10	1—10	1	17	25	7—15	15—18 5—10	1		+	1—2 (3—4)	12—20		+		+			
80.		« monticola Dougl. et. Lamb.	**309**	15—20	12—20 8—10	100 125	8—10	1—10	1	18	30	8—10	12—15 10	1		+	1—2	10—20		+		+			
81.		« Peuke Griseb.	**316**	17—25	20—30 10—15	120 250	8—10	1—12	1	20	25	7—12	16—18 10—12	1		+	1—2 (3)	16—20	+	+		+			
82.		« pumila Regel.	**321**	15—25	20—25 6—8	60 80	8—10	1—8	1	15	20	10—15	15—18 10—12	1		+	1—2 (3)	10—16		+		+			
83.		« Wallichiana A. B. Jack	**337**	12—25	12—25 8—10	70 100	8—10	1—6	1 (2)	15	20	8—12	15—20 10—12	1		+	1—2 (3)	10—16		+		+			
84.	II.	« albicaulis Engelm.	**270**	15—25	25—30 8—10	70— 100	8—10	1—10		15	20	8—10	18—20 10—12	1		+	1—2	16—24		+		+			
85.		« koraiensis Sieb. et Zucc.	**295**	25—35	25—50 8—10	100 130	8—10	1—15	1	20	30	10—18	20—25 8—12	1		+	1—2 (3—4)	20—34		+		+			
86.		« Lambertiana Dougl.	**296**	25—50	25—60 10—15	150 220	10—12	1—20	1	20	30	8—12	25—30 14—16	1—2		+	(1) 2 (3—4)	20—36		+		+			
87.		« parviflora Sieb. et Zucc.	**314**	20—25	20—30 8—10	90 100	10—12	1—8	1	18	35	10—15	20—22 10—12	1		+	1—2	12—20			+	+	×		
88.		« strobus L.	**330**	30—35	35—40 10—20	90 140	8—10	1—14	1	20	25	6—8	15—22 10—15	1 (2)		+	1—2	20—32		+		+			
89.		« tabulaeformis v. yunnanensis Dallimore	**330a**	20—40	30—45 10—27	160 200	10—12	1—4 (16)	1 (2)	13	21	8—10	16—18	1		+	1—2	10—32		+		+			
90.	III.	« aristata Engelm.	**271**	15—25	20—30 5—8	60 120	6—8	1—14	1	15	20	4—8	14—15 7—8	1 (2)	+	×	1—4	4—5			+	+			
91.		« cembroides Zucc.	**280**	20—30	20—35 6—10	100 120	8—10	1—25	1—2	18	24	10—20	16—18 8—10	1	+	×	1—4	4—6			+	+			
92.		« cembroides v. edulis Voss.	**281**	14—16	10—20 4—8	100 120	6—8	1—20	1	15	17	10—12	10—14 8—10	1	+	×	1—4	4—5			+	+			
93.		« cembroides v. monophylla Voss.	**282**	20—30	25—20 5—8	100 120	8—10	1—20	1	20	26	12—15	14—18 10—12	1	+	×	1—4	4—6			+	+			
94.		« cembroides v. Parryana Voss.	**283**	20—30	20—25 8—10	100 120	8—10	1—16	1	10	25	14—20	16—18 10—12	1	+	×	1—4	5—7			+	+			
95.		« Balfouriana Jeffr. et. Murr.	**275**	20—40	20—40 8—10	80 120	8—10	1—45	1—2	15	25	7—10	20—22 14—16	1	+	×	1—4	4—5			+	+	×		
96.		« Bungeana Zucc.	**277**	10—25	20—30 6—10	80 120	6—8	1—8	1	15	25	8—12	12—14 8—10	1	+	×	1—4	4—5			+	+	×		
97.		« Gerardiana Wallich	**290**	8—12	18—24 6—10	80 100	6—8	1—8	1	20	24	12—14	12—16 8—10	1	×	×	3—4 (6)	7—8	+		+	+	×		
		B. DIPLOXYLON																						
98.	IV.	Pinus massoniana Lam.	**304**	40—48	50—55 10—12	160 300	—	1—15	1	20	24	20—22	24—26 8—10	1—2		+	1—2	40×20 10×12	+		+		+		
99.		« Merkusii Jungh. et de Vries	**305**	25—35	20—40 15—20	100 150	6—8	1—15	1	15	25	10—15	18—20 6—8	1—2		+	1—4	16—26	+		+		+		
100.		« tonkinensis A. Chev.	**334**	27—40	27—40 10—21	160 300	13—16	1—8 (40)	1 (2)	16	27	13—18	18—22 13—16	1		+	1—2 (3)	8—21	+	+			+		
101.	V.	« leiophylla v. chihuahuana Schaw.	**300**	32—40	30—40 12—16	200 230	—	1—10	1	18	22	16—18	26—28 8—10	1		+	1—3 (4)	8—12	+		+		+		
102.		« patula Schlecht. et Cham.	**315**	25—50	25—60 10—20	150 200	—	1—25	1	10	30	10—15	20—25 8—10	1—2		+	1—8	4—20	+				+		
103.		« ponderosa v. Jeffreyi Vasey	**319**	20—45	25—70 10—15	150 160	—	1—15	1 (2)	10	25	10—15	20—25 6—8	1—2		+	1—6	2—16	+		+		+		
104.		« radiata D. Don	**323**	20—40	20—40 8—15	100 125	—	1—10	1—2	10	25	10—20	24—26 10—12	1 (2)		+	1—6	4—16	+		+		+		
105.		« sabiniana Dougl.	**326**	20—30	20—60 10—15	100 110	—	1—20	1	15	25	10—15	20—25 8—10	1—2		+	1—6	4—16	+		+		+		
106.	VI.	« canariensis C. Sm.	**278**	20—30	20—30 8—15	100 150	6—8	1—12	1	10	20	10—18	18—20 8—12	1		+	1—3	6—9	+		+		+		
107.		« halepensis Mill.	**292**	15—25	15—20 8—12	80 100	10—12	1—10	1	25	35	10—15	14—18 8—10	1		+	1—3 (4)	6—8	+		+		+		
108.		« halepensis v. Brutia Elwes et H.	**293**	20—30	20—30 8—12	100 150	5—7	1—12	1—2	10	30	8—15	20—22 8—10	1		+	1—3 (4)	6—12	(+)		+		+		
109.		« Laricio Poiret	**297**	20—24	20—24 8—12	120 200	—	1—10	1	16	28	12—14	12—14 8—10	1		+	1—2 (2—4)	6—10	+		+		+		
110.		« leucodermis Antoine	**301**	10—20	10—20 8—10	80 100	—	1—16	1—2	15	20	10—18	14—16 6—8	1	×	+	1—2 (3)	6—8	+		+		+		
111.		« longifolia Roxb.	**302**	20—35	20—40 15—20	100 150	8—10	1—10	1 (2)	20	40	10—20	20—25 10—12	1	×	+	1—5 (6)	4—8	+		+		+		
112.		« pinea L.	**317**	20—30	15—25 6—10	100 150	8—10	1—10	1—2	15	25	10—15	18—20 8—10	1	×	+	1—3 (4)	4—8	+		+		+		
113.	VII.	« densiflora Sieb. et Zucc.	**287**	10—15	15—25 5—10	50 80	—	1—10	1	15	25	10—18	14—16 8—10	1		+	1—2	10—18	+	+		×	+		
114.		« funebris Kom.	**289**	15—20	15—25 6—10	70 100	—	1—10	1	18	20	8—14	18—20 6—8	1		+	1—2	10—24	+	+		×	+		
115.		« khasya Royle.	**294**	10—20	15—25 6—8	80 100	6—8	1—8	1	15	25	5—8	12—15 8—10	1		+	1—2	8—14		+		+	×		
116.		« Laricio v. nigricans Parl.	**298**	15—25	15—25 6—10	100 150	—	1—10	1	15	25	15—20	18—20 8—10	1		+	1—2	10—20	+	+			+		
117.		« Laricio v. Pallasiana Endl.	**299**	20—35	20—30 10—15	100 120	—	1—15	1	15	25	8—12	18—20 8—10	1		+	1—2	10—20	+	+			+	×	
118.		« montana v. mughus Willk.	**307**	15—20	15—30 5—10	100 125	—	1—12	1	20	30	10—15	15—18 8—10	1		+	1—2	20—34	+	+			+		
119.		« resinosa Ait.	**324**	14—18	15—20 5—10	110 120	—	1—10	1	15	20	10—20	16—18 6—10	1		+	1—2	12—20	+		+		+		
120.		« silvestris L.	**328**	15—35	25—50 5—19	100 150	10—12	1—12	1 (2)	20	30	10—15	20—25 6—8	1		+	1—2	20—36	+	+			+		
121.		« sinensis Lam.	**329**	15—25	20—30 5—10	110 120	—	1—8	1	15	25	5—14	18—20 6—8	1		+	1—2	20—40		+			+		
122.		« Thunbergii Parl.	**333**	20—25	15—30 5—10	110 120	—	1—10	1	15	30	10—18	15—18 6—8	1		+	1—2	14—22	+	+			+		
123.	VIII.	« attenuata Lemmon.	**273**	20—25	20—30 6—10	100 150	—	1—25	1	15	25	10—18	18—20 8—10	1		+	1—6	6—10	+		+		+		
124.		« Banksiana Lam.	**276**	15—30	20—40 5—10	80 100	—	1—12	1	10	20	10—15	18—20 6—8	1 (2)		+	1—6	10—16	+		+		+		
125.		« Coulteri D. Don	**286**	30—50	20—25 8—16	150 200	—	1—15	1	20	40	8—18	18—20 8—12	1—2		+	1—4 (6)	6—16	+		+		+		
126.		« maritima Lam.	**303**	20—30	20—40 8—12	80 120	5—7	1—15	1	15	25	14—16	20—24 8—10	1		+	1—5	6—10	+		+		+		
127.		« Montezumae Lam.	**308**	20—25	20—25 10—15	100 150	—	1—12	1	10	26	10—18	18—20 6—8	1—2		+	1—5	6—12	+		+		+		
128.		« muricata D. Don	**311**	25—40	20—40 10—15	100 150	—	1—15	1—2	15	35	15—30	20—22 14—18	1		+	1—4	8—14	+		+		+		
129.		« pseudostrobus Lindl.	**320**	20—25	20—30 15—20	80 100	—	1—15	1	20	25	10—16	18—20 10—14	1		+	1—6	8—14	+				+		
130.		« teocote Schlecht. et Cham.	**332**	20—25	20—25 8—15	80 100	—	1—10	1	15	25	15—20	18—20 10—15	1		+	1—6	6—8	+		+		+		
131.	IX.	« caribaea Moore	**278a**	25—40	20—55 10—20	120 160	—	1—7 14—34	1 (2)	18 (32)	27	13—24	21—27	1—2		+	1—8 (10)	5—22	+		+				+
132.		« clausa Vasey	**284**	20—40	25—50 8—20	80 100	—	1—20	1	20	30	8—12	20—25 8—10	1—2		+	1—6	6—20	+		+				+
133.		« contorta Dougl.	**285**	10—20	10—20 6—10	80 100	6—8	1—10	1	10	20	10—15	14—18 5—8	1		+	1—4	14—15	+	(+)	+				+
134.		« Murrayana Bay	**310**	30—35	25—30 8—10	120 140	—	1—10	1—2	20	30	30—34	12—13 10	1		+	1—2 (3)	20—10	+						+
135.		« glabra Walt.	**291**	20—40	25—50 8—10	100 120	—	1—15	1	15	25	10—20	16—18 10—20	1		+	1—6	8—16	+		+				+
136.		« mitis Michx.	**306**	25—50	25—50 10—20	100 150	—	1—20	1	15	30	15—20	20—26 10—12	1—2		+	1—6	8—24	+		+				+
137.		« occidentalis Schwartz	**312**	25—50	30—50 10—15	140 180	10—12	1—20	1—2	20	30	25—30	20—25 8—10	1—2		+	1—4	8—18	+		+				+
138.		« palustris Mill.	**313**	30—40	25—60 10—20	150 250	—	1—20	1	20	25	10—20	20—25 8—12	1—2		+	1—7	8—22	+		+				+
139.		« ponderosa Dougl.	**318**	20—40	20—50 8—16	150 200	—	1—30	1 (2)	15	30	10—18	20—26 8—10	1		+	1—6	6—12	+		+				+
140.		« pungens Lamb et Michx.	**322**	20—35	20—40 6—10	100 150	—	1—12	1	20	25	10—15	18—20 6—8	1 (2)		+	1—5	4—16	+		+				+
141.		« rigida Mill.	**325**	20—40	20—50 6—10	100 150	—	1—15	1 (2)	15	35	10—18	20—25 6—8	1—2		+	1—6	8—20	+	+					+
142.		« serotina Michx.	**327**	25—50	25—50 10—20	150 180	—	1—20	1	20	30	10—20	22—25 10—12	1—2		+	1—6	8—14	+		+				+
143.		« taeda L.	**331**	25—50	40—60 15—20	200 250	—	1—15	1	15	30	10—20	20—22 8—10	1—2		+	1—6	16—24	+		+				+
144.		« Torreyana Parry.	**335**	20—50	25—60 15—20	90 100	—	1—12	1—2	20	30	20—25	25—30 10—12	1		+	1—3 (4)	10—16	+		+				+
145.		« virginiana Mill.	**336**	25—30	25—30 8—18	100 120	10—12	1—10	1	15	30	10—20	20—25 10—15	1		+	1—4	12—22	+		+				+

Ára : 300,— Ft