HISTORY OF HUMAN LIFE SPAN AND MORTALITY

by
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This monograph is the result of co-operation between anthropologist and demographer. The novelty of their approach lies in the fact that by co-operating their existing methods and devising specific new techniques, they created a sound basis for the objective demographic analysis of anthropological series.

The book consists of three major parts. The first one deals with theoretical and methodological problems of life span and mortality from both the biological and demographical points of view.

The second part discusses the process of increasing of human life span and the history of human mortality throughout the one million years' history of mankind, i.e. from prehistoric ages to modern times. Special importance is lent to these chapters by the completeness of the anthropological series studied. Both Hungarian and foreign anthropological materials are analysed. Based on these data different historical types of mortality are established.

In the third part palaeodemographic tables are submitted, contributing to further research in this field.

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PREFACE

It is an inevitable problem of our individual existence as well as a determining factor of social life that the span of human activities is limited and the duration of life finite. The end of human existence is death, so we may draw conclusions from the length of individual lives on human mortality and, conversely, from mortality on the length of human life. Thus the span of life and mortality are two aspects of the same problem.

We do not think that the study of the history of mankind is a task complete in itself. Man is passionately interested in his past, in the motive and driving force behind historical changes. It may be that he is interested in the drama of the story to a certain extent, but above all a knowledge of his past helps him to understand his present and forecast his future.

We know relatively little about the historical trends in the span of human lives as there are major difficulties which have to be overcome when investigating in this field. It is true that written sources including occasional mortality statistics are available covering a few hundreds of years in modern times. These sources have formed the rough basis of demographic research, but when we consider ancient times we are confronted with a number of unsolved problems and have very few facts to start our investigations. If we consider the results of historic demography it is evident that such investigations would be highly instructive.

The achievements of historic demography show that in the last few centuries the human life span and mortality have undergone profound changes never experienced before. These changes are of such epoch-making importance that they are known as a 'demographic revolution'. This may not be a precise scientific definition but it is a very expressive term. One factor promoting the series of demographic changes was the decrease in mortality. This decrease assumed such proportions in Europe that life expectancy at birth increased from 30–40 years to some 70 in one or two centuries. This process is still continuing in Europe and is the most characteristic feature of the populations of developing countries. Increase in life expectancy is apparent throughout the Asian, African and Latin American continents; within the last few decades changes have taken place very rapidly.

In countries where the decrease in the rate of mortality has not been followed by some form of birth control, the population increase is causing major concern. The problems of maintaining increasing numbers in the maximum age groups, of creating possibilities of future employment and of raising investment funds to promote economic growth are well known throughout the world.

Even in countries with highly developed economies where the decrease in the mortality rate has decreased such changes have modified ways of thinking. Less than a century ago few children survived infancy even in Europe and frequent epidemics made people aware of the fact that life and death are inseparable realities. Today the birth of a child is a rare and solemn event, the experience of a lifetime for many people and death before old age has become an exceptional event. Possibly as a reaction to mediaeval thinking, our civilization has virtually dismissed the idea of death and the average European does not wish to realise that he is mortal; at least not before he grows old. However, although it has been possible to control epidemics and medicine has accomplished much in curing a variety of diseases, modern man is still not safe. Overcoming the selective blows of infant mortality, he is increasingly threatened by various viral diseases, by cancer which is claiming more and more victims, by circulatory diseases and diseases of the nervous system. Famine has not disappeared from the world, and wars may yet lead to the destruction of the whole of mankind.

Doubtless, the characteristics of the present length of human life are the result of some form of evolution. What was the trend of this evolution? In what manner, and as a consequence of what events did it take place? These are the questions we are trying to answer. The lesson of half a million years may tell us what we can expect from the future.

We have said that in our own time human mortality has undergone changes never experienced before. To be exact this was a stylistic analogy rather than a scientific statement, for what can we know about changes that took place in the past of mankind? We only have sporadic data which cannot be generalized or adjusted to fit into the framework of some historic process. There are hypotheses but no attempt has been made to support them with facts.

However it is not impossible to reconstruct history. Fossil bones of historic man, unequalled proofs of mortality, have emerged from many places and epochs. In addition other sources such as archaeological, comparative-ethnographic, etc., have formed a basis from which conclusions can be drawn. It is possible to reconstruct the history of mortality if the various branches of science cooperate, if their methods and achievements are coordinated on the basis of a comprehensive international scheme.

From the various branches of science, archaeology supplies the material to be studied, the chronology of the finds, the socio-economic and ethnical characteristics. The role of anthropology is still more important because it has to determine the characteristics derived from the skeletal finds, while demography has the responsibility of analysing the material. Biology and several branches of the social sciences have to be called upon for a well-founded and authentic interpretation of the phenomena discovered.

Twenty years ago the authors of this book, a demographer and an anthropologist, began to elaborate this subject. From the beginning of our enterprise we realised that we would have to rely not only on each other, but also on the support of others. References in literature available at the time and our own initial experiments have shown that studies of this kind are subject to particular difficulties and special conditions. Of these, three conditions are most important. As far as possible a completely uncovered series should be used, the sex and age at death of the anthropological finds should be ascertained with great accuracy and a comprehensive demographic analysis should be made covering every significant element. Naturally it is not an easy task to meet all these requirements.

In the first phase of our investigations we deliberately aimed at the comprehensive excavations of cemeteries, including the complete collection of material to provide the basis for well-founded demographic analysis. These Hungarian skeletal remains provided the basic material for our studies. Later on we initiated control examinations to check the methods employed for determinig sex and age at death and conducted our investigations on the basis of these results.

Throughout our work we received generous help from biologists, archaeologists and other experts. We believe that a task of this kind cannot be accomplished unless there is full cooperation and all reserves are pooled in order to shape the programme through each phase until the final analysis.

We have mentioned that our work is based primarily on the achievements of Hungarian archaeological and anthropological research, on finds actually available in Hungary.

We have also made use, to a certain extent, of other authors' works. Even so we could not have accomplished our task without wide international scientific support and cooperation, particularly in the examination of the remains of primitive man and other European, African and Asiatic collections of skeletons.

Acknowledgements are due to representatives of the various branches of science, particularly to Hungarian and foreign scientific institutions, for their generous assistance extended to the cause of science.

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We are aware that the hypothesis outlined in our book — although founded on concrete facts and on the results of investigations — is merely a framework that will be filled in by future research. Many problems on particular aspects still need elaboration, and it is probable that light will be thrown on facts on which hitherto data were unavailable. Again it may happen that subsequent investigations will modify the picture we have presented. Nevertheless, in laying the foundations for further research, we believe that it would be useful if we gave a synthesis of the results so far obtained, and put forth a hypothesis about the human lifespan and mortality. The reader using our book as a source is requested to take these considerations into account.

First we outline the concepts of life span and mortality, followed by discussion of the outcome of palaeodemographic investigations known to us. In our opinion familiarity with these subjects is indispensable for understanding and evaluating the results of our research. For the same reason, in Chapter III we describe in full our methods for determining sex and age. Later chapters summarize the conclusions drawn from our investigations. The life tables have been presented in a special chapter.

This volume is mainly concerned with hitherto unknown details of the history of mortality; events analysed by historical demography could be consulted only by way of reference.

The Authors

*Those whose names are thus marked are no longer living.

CHAPTER I

LIFE SPAN AND MORTALITY

LIFE SPAN AS A CONCEPT

Life span is a relatively simple chronological concept but its precise scientific definition raises difficulties. The first source of these difficulties is that the reproduction of certain organisms coincides with the end of individual life. As early as the first half of the last century it was a known fact that certain Protozoa maintain life through bipartition and Weismann used this as an argument for the immortality of unicellular organisms. Although biology is indebted to investigation into 'immortality' for a number of achievements, it is obvious that the individual is not immortal. Even when the death of an individual is equivalent to the birth of unicellular organisms and there is no dead organism, immortality cannot be conceded. Indeed it is not the infinity of individual life but rather the continuity of life itself that is apparent in the case of unicellular organisms.

The first point to be clarified is whether the term 'life span' is to be used to denote the chronological duration of life of a species or of the indivudal. Life of the individual lasts from its genesis until the end. The life span of the individual, therefore, is the time elapsing between conception and the final disappearance of all manifestations of life. In practice this time lapse is measured as the period between live birth and the complete cessation of vital functions without capability of resuscitation. On the other hand, the life span of a species can be interpreted in two ways, i.e.

(1) In the palaeontological sense, as the period of time beginning with the emergence of the species and ending with the stage of evolution (change) by which a new species has developed, or the former has become extinct;

(2) In the taxonomic and systematic sense, as the life span characteristic of the individuals of a species.

Obviously the latter interpretation is important when studying the length of human life. Although observations are limited to determining the actual age of human individuals and individual life spans completed at death, the eventual perspective is the acquisition of knowledge about man and the human race as a whole, and the deduction of rules governing human life.

However, even in view of the above considerations, the life span of the human race has no unequivocal concept. We have to decide whether we study the characteristic life span of man in specific circumstances or the potential characteristic life span of man in optimal circumstances. For any species it is essential to distinguish between these two viewpoints regarding either the actual life spans of individuals of a species, or life spans attainable under optimal conditions. Both elements of the above definitions, i.e. the specific or optimal circumstances and the actual or potential characteristic nature of life spans, are criteria that need further clarification.

Life cannot be detached from given circumstances; consequently the span of life can be studied only under specific environmental conditions. The multitude of natural conditions and those developed in social environments are constantly changing and there is no guarantee that the 'potential' life span of man, living in an interrelationship with his environment, will remain unchanged.

According to the theory of evolution, species differences in life span are the results of adaptation and differentiation, i.e. change. Quite apart from the fact that the optimal nature of the combination of factors connected with the span of life would be difficult to determine, it is problematic whether 'optima' can be considered at all in an absolute sense. To suppose the existence of an optimal metaphysical environment that would always ensure the largest possible life span would be equivalent to denying change and evolution. It is obvious, of course, that both man and his environment do change. The estimation of the potential life span of the human race makes sense only at a given stage of evolution in well-defined circumstances. We may then be able to determine the age that individual men attain or may attain under relatively optimal circumstances considering the specific environmental changes. In doing so, however, we actually arrive at the concept of life span usually characteristic of man in definite circumstances. We must also clarify the term 'characteristic' life span.

In most cases the characteristic span is interpreted as follows:

(1) As the average length of life attained by various individuals (mean value);

(2) As the probable length attained by half of the individuals (median value);

(3) The so-called normal age at death attained by most people disregarding those who died as children (modal value).

A more accurate definition of these concepts will be discussed in connection with the life tables later on.

The potential span of life, which the individual might attain under optimum conditions, is also characteristic. But this value can only be estimated. It would therefore be more suitable to use the maximum rather than the potential span of life as a concept, which could be derived from the longest individual life span found under specific conditions.

It is therefore obvious that the concepts of maximum and potential life spans are not identical. The maximum span of life is an individual value, while the potential span is not a property pertaining to the individual, but presumably belongs to the human race as a whole. The maximum span of life is a quantity that can be observed in a concrete manner, although the many sources of error could give rise to inaccuracies. The potential span cannot be clarified in practice, it would seem to exist as a logical concept only. Research into the optimal conditions for long life indicates that in connection with the 'external' socio-economic conditions, which normally show an equivocal relationship with mortality determining its rates and trends, contradictory results have been reported in the case of individuals with maximum life spans. In studying the environment of long-lived individuals, science today cannot add much to the conclusion of the physiologists of the last century. Pflüger, for instance, stated that the precondition of long life is an 'internal' factor that keeps evading an accurate definition. This conclusion is still valid today, at least for the time being.

Repeated attempts have been made to estimate, based on various formal criteria, the potential length of life, i.e. the specific biological period of man's existence. But, until the concept of old age, closely correlated with the potential length of life, has been clarified in all respects, these attempts are due to fail. Senescence is accompanied by reductive changes and pathological phenomena and it is difficult to differentiate between the symptoms of senescence and those of disease. Unfortunately, not only the layman but the scientific investigator as well finds that senescence and the accumulation of pathological signs determined by age are still synonymous. It is true that gerontology is concerned with this differentiation, but we cannot at the moment expect that these attempts can be used to determine the biological limits of the length of human life. If senescence cannot be identified with the accumulation of pathological phenomena, which are concomitant with the ageing process, there is little hope that man's 'natural' duration of life, terminated as a matter of biological necessity, can be measured empirically in the foreseeable future. Although 50 million people died every year in the last decade, biological death could not once be ascertained. Using adequate standards, examination always established some disease, injury or poisoning as the cause of death.

According to the present state of our knowledge, people die of diseases and of pathological processes. The possibility of long human life without pathological signs, and whether human death of a purely biological character without pathological changes is at all conceivable, is still an open question. It would, however, be of some interest to study the extraordinary life spans of some people, possibly achieved by the interaction of exceptionally favourable circumstances.

MAXIMAL HUMAN LIFE SPANS

The span of man's life, the actual life period, is not solely a scientific problem. It is a most personal affair for everyone although some of us are inclined to forget that life is finite. When the functioning of the organism is disturbed and when diseases that could be signs of senescence begin to afflict us, from the depths of human consciousness we ask the question 'how long are we able to live?' Obviously it is impossible to predict the life expectancy of the individual under existing scientific standards. A newborn babe may die after a few days without becoming a conscious being while others may meet their deaths in accidents. Yet many reach a ripe old age and even become centenarians. The length of human life therefore varies considerably. Nevertheless we may try to discover the longest individual life span ever attained by man. This is not a new question and science has been trying to find an answer for a long time. The limits to human life, senescence and the problem of prolonging life have absorbed thinkers ever since the earliest cultures. More than two thousand years have elapsed since Cicero published *De Senectute* in 44 B.C. His reflections on old age have their roots in the works of Pythagoras and Hippocrates. The problems of old age and long life are even older, probably as old as human culture itself. As shown by mediaeval literature, Christian belief in immortality in the next world caused the problem to recede into the background, but the men of the Renaissance were all the more eager to prolong their earthly existence. In 1498 Ficino wrote a book about prolonging life with the aid of magic and Cornaro (1558) discussed the 'art' of living long. Interest did not flag and even Bacon's attention (1633) was attracted by the subject. From Hufeland (1829) to Humphry (1889), the scholars of the nineteenth century amassed reports on modern Methuselahs. They collected details of the conditions necessary for a long life and vital statistics on the mortality and life expectancy of the human race itself.

In the twentieth century biological investigations were placed on a firmer foundation. They were extended to cover practically the entire realm of nature. Eventually, gerontology, a new and complex branch of science concerned with senescence emerged.

Observations over many centuries show evidence of the fact that individual spans of life may vary from the normal both by their brevity and by their exceptional length. Indeed many examples of longevity have been recorded in literature but there is little value in the reports. References to incredibly long lives were handed down to posterity from ancient times. In the Bible, for instance, Methuselah was credited with 969 years, but recent critical investigations into the source have reduced this figure to 74 as the original calculation was based on 28-day lunar years. The proverbial Nestor of the Iliad did not live long compared with the immortal gods but the three generation's life span attributed to him by Homer is certainly a poetical exaggeration. The authenticity of sources recording the lives of people in antiquity, Epimenides of Crete, 153 years old, Fullinius of Bologna, 150 years old, is not much better. Neither are the records of Pliny accurate; the age of Kentigern, the founder of Glasgow Abbey, who died at the age of 185 on January 5th, 600, is also highly suspect. Hungary might take pride in the fame of a Peter Zortay (Zorton?, Czártán?, Zart?), who died in 1724 at the age of nearly two hundred years, as he was said to have been born in 1539. Hungarian records from the 18th century, mentioning individuals of 172 and 164 years respectively (János Rovin and his wife Sára Desson, who were married for 147 years), are not much more credible (Fáy, 1854).

Recorders of exceptionally long life spans often fell victim to intentional or unintentional misrepresentations. There are still people the world over who do not keep exact evidence of their age; this human frailty may be excused especially in cases where 'very old' people believe that they actually experienced events told them by their parents in their childhood. This naive pretence to be 100, 120, 150 years old, may be due to the prestige which goes with very great age but not with a 'mere' 80 or 90 years. But possible interests attached to the appearance of very long lives might also be involved. People supposed to be 100 years old were often mentioned in the press about 1950; but it was discovered later that they attained such a high age not through the actual passing of time, but rather because of the respect due to aged people.

There are, on the other hand, more authentic observations, which though doubted by some people, are considered reliable by others. The best known among these is probably the life of the Danish Christen Jacobsen Drakenberg, the 'old man of the north' (Dublin et al., 1949). According to his contemporaries, Drakenberg was born on November 18, 1628, and died on October 9, in 1772, so he is said to have lived nearly one century and a half. He had been a sailor for 91 years, fought in the war against the Swedes, then became a merchant seaman. In 1694 he was taken prisoner by Algerian pirates, but was set free after 15 years of slavery and resumed his life as a seaman. In 1737, at the age of 110, he married a widow of 60, who died after some years. He is said to have unsuccessfully proposed marriage to several women when he was 130. Whether the C. J. Drakenberg, born in 1628, was identical with the man who escaped from the pirates' captivity, and whether he had lived all these years, can no longer be ascertained.

Another frequently quoted case is that of Thomas Parr, a Shropshire peasant, who claimed to have lived 152 years. He was autopsied after his death by Harvey, the famous physician. However we need not go back as far as that to find life spans lasting a century and a half. Mahmoud Nivazov of Azerbaidzhan, living among his 173 descendants, in 1959 was reported to convince Professor Panev, who examined him, that he was actually 150 years of age by producing written evidence of his date of birth.

There is no need to continue the enumeration of instances of individual longevity, as their possible authenticity is vitiated by hosts of legends, errors and deceptions. Official records exist according to which lives of over 100 years are no rarity. Let us have a look at these data.

THE STATISTICS OF MAXIMAL LIFE SPANS

A number of people who are 100 or older are being recorded at censuses in a variety of countries. Based on the official data submitted to the U.N. Statistical Office, we have drawn up a table showing the number of the oldest people in 36 countries in the years following World War II. Of the 617 million people living in the 36 listed countries, 14,326 men and 24,274 women appear to be 100 or more, which means that 6·26 of every 100,000 inhabitants are at least 100 years old.

Taking this into account, about 150,000 to 200,000 centenarians or even older people must have lived among the three thousand million inhibitants of the globe in the early 1960's.

TABLE 1

The number of oldest people according to censuses taken in various countries after World War II

Continent, country, population	Year of census	Population in 1,000	No. of those aged					Cente-narians per 100,000
			93	95	98	100 and more		
						males	females	
EUROPE								
Belgium	1947	8,512	579	266	45	4	13	0·2
Bulgaria	1956	7,614	724	742	357	252	402	8·6
Denmark	1960	4,585	559	218	72	0	0	0·0
England and Wales (U.K.)	1951	43,758	4,296	1,927	573	49	222	0·6
Finland	1950	4,030	193	66	17	3	2	0·1
France	1946	39,843	2,876	1,230	159	93	168	0·7
G.F.R.	1950	47,696	1,675	615	137	14	56	0·1
Greece	1951	7,633	429	823	217	447	1,152	20·9
Holland	1960	11,462	961	394	97	11	30	0·4
Hungary	1960	9,961	633	273	53	18	49	0·7
Ireland	1961	2,818	392	222	65	56	97	5·4
Jugoslavia	1948	15,772	972	999	225	492	701	7·6
Northern Ireland (U.K.)	1951	1,371	127	94	28	4	12	1·2
Norway	1960	3,591	722	339	108	15	34	1·4
Portugal	1960	8,889	1,045	766	471	143	367	5·7
Rumania	1956	17,489	681	646	257	103	384	2·8
Scotland (U.K.)	1951	5,096	442	172	48	6	8	0·3
Sweden	1960	7,495	1,100	562	128	28	60	1·2
Switzerland	1960	5,429	536	255	48	4	19	0·4
ASIA								
Ceylon	1946	6,657	225	733	372	207	286	7·4
Iran	1956	18,955	3,510	2,324	1,154	764	584	7·1
Iraq	1957	6,340	855	780	177	2,749	3,010	90·8
Israel	1948	717	21	29	21	2	—	0·3
Japan	1955	89,276	2,020	832	212	37	121	0·2
Thailand	1947	17,443	656	1,637	292	701	1,295	11·4
Turkey	1945	18,790	422	2,959	578	1,516	2,784	22·9
AFRICA								
Algeria, Moslems	1948	7,580	250	253	293	154	198	4·6
Algeria, Europeans	1948	932	58	28	17	3	12	1·6
Egypt	1947	18,967	71	2,693	102	2,181	2,954	27·1
Union of South Africa	1946	11,418	895	1,388	941	633	772	12·3

TABLE 1 (cont'd)

Continent, country, population	Year of census	Population in 1,000	No. of those aged					Cente-narians per 100,000
			93	95	98	100 and more		
						males	females	
SOUTH AMERICA								
Argentina	1947	15,894	815	676	259	214	649	5·4
Bolivia	1950	2,704	209	900	311	1,038	942	73·2
Brasil	1950	51,944	1,646	3,759	2,185	3,290	6,399	18·7
Venezuela	1950	5,035	207	683	357	215	426	12·7
NORTH AND CENTRAL AMERICA								
Costa Rica	1950	801	35	51	25	27	32	7·4
Dominican Republic	1950	2,136	151	493	212	477	679	54·1
El Salvador	1950	1,856	79	286	124	138	274	22·2
Guatemala	1950	2,791	63	361	106	330	326	23·5
Haiti	1950	3,097	173	671	264	234	481	23·1
Panama	1950	757	34	100	46	63	96	21·0
United States	1960	179,326	23,380	11.894	4,355	3,830	6,539	5·8
OCEANIA								
Australia	1961	10,508	1,222	602	179	40	91	1·2
Fiji Islands	1956	346	21	36	17	55	28	24·0
New Zealand, Europeans	1951	1,824	165	94	20	9	10	1·0
New Zealand, Maoris	1951	116	6	7	6	6	14	17·2

It is, however, questionable whether so many old people are actually alive today. It must be remembered that when a census is taken, no documentary evidence proving age is requested. Proof is not required in Hungary, or in any other country, and all data are based on the answers received from the population. In the case of young and adult age groups no substantial error results from this method of interviewing, but the accuracy of the data can certainly be challenged in the case of the aged and very old population. With this in mind, let us scrutinize the summary of the censuses taken about 1950 (Table 1).

Looking at the table superficially it would seem that Iraq and Bolivia are the 'paradise of centenarians', and that the chance of attaining a great age is most favourable in the Dominican Republic, Guatemala (in Central America in general), Egypt, Turkey, Greece, and even on the Fiji Islands, while the chances are exceptionally poor in most parts of Europe, Japan and Australia. Obviously, this result presents a misleading picture. In New Zealand, for example, there is a substantial difference between the data of the European and the Maori population: seventeen times as many centenarians were recorded among the Maoris, who are living in poorer conditions, than among the population of European origin. A similar difference appears in the post-war data of Algeria. The source of differences is therefore not to be sought in the geographical environment, as the ratio of centenarians or older individuals of different populations living in the same area is very different. Or is this discrepancy the manifestation of the biological differences between the various populations living in the same region? Again the table proves the contrary. In Belgium with a 'white' population the number of centenarians and older individuals out of 100,000 is the same as in Japan with its 'yellow' population, while there are more than hundred times as many in Greece, which is 'white'! There is no substantial difference in this respect between Haiti, which is 95 per cent 'black', and Guatemala or El Salvador which are inhabited by mestizos, while the data of South American countries with similar ethnical compositions are markedly different. Hypotheses exist setting out that people engaged in agricultural work, living in the open air, in 'natural' conditions, usually live longer than others, or at least longevity is more common among them. It is improbable, though, that mortality, which is closely correlated with living conditions, should show a more favourable pattern in populations living under poor conditions in backward countries. Although these theories are based on the data we have cited, they can be refuted with the same data. For instance, Finland, where half the population is agrarian, had a ratio of long-lived individuals only one-twelfth of that in highly industrialized Sweden where only 20 per cent of the employed population is engaged in agriculture. A lower ratio appears also in Switzerland and in the G.F.R. with a larger proportion of agrarian population than in Great Britain where the proportion of the agrarian population is only one-third of the former two. Even numerically fewer centenarians and old people were recorded in Jugoslavia when the country was of a distinct agrarian character than in Greece, with a much smaller population, only half of which was engaged in agriculture. The number of long-lived people recorded in the highly industrialized United States of America was also relatively much higher than that shown in the data of Denmark, Ireland, Norway or Rumania. (Nor would the data of a 1960 survey of the oldest people in Hungary render the aforesaid hypothesis tenable.)

The conclusion to be drawn from the contradictions in these data is that the high proportion of long-lived individuals in socially and economically less developed countries does not reflect the truth but is due to the characteristic inaccuracy of statistics relating to the maximum age groups. This is supported by investigations conducted in the Soviet Union and in Hungary.

In Brasil, with a population of about 50 million, the number of people aged 100 or more was given as nearly 10,000, in Egypt and Turkey, with populations less than 20 million each, the respective numbers were 5,000 and 4,000, in Iraq, with a population of 6 million, nearly 6,000. According to *Vestnik Statistiki* (Moscow, 1961), a scientific review, the number of people claiming to be this age was 28,015 at the time of the 1959 census in the Soviet Union with a population of more than 200 million. In the course of a verification, however, it appeared that 22·5 per cent of these were actually younger than 100, and that the probability of such long life could be established only for 21,708 people. And even this figure includes 1,277 persons whose age was uncertain. The report says in connection with 368 people allegedly 120 years old or even older that 'in many cases it was impossible to ascertain the exact age of these people'. From the data grouped according to republics, regions and districts it appears that the ratio per 100,000 of centenarians and older people shows considerable deviation. In the district of Moscow and Leningrad, in the Estonian S.S.R., the value of this index is 1, and is usually low in districts where population registration has been practiced for a considerable time, while it is very high, 50–70 per 100,000, in certain Asian republics, as well as in the Azerbaidzhan, Georgian and Armenian Soviet Socialist Republics (the relative number is 144 in the Nagorno-Karabakh Autonomous Region of Azerbaidzhan, and 112 in the Nakhichevan Autonomous Republic). The example of China may be referred to, where out of a population of 574 million only 3,384 centenarians were recorded, i.e. 0·6 per 100,000 inhabitants, although the oldest of these declared himself to be 155 years of age.

According to preliminary data collected at the 1960 census in Hungary, and recorded by the enumerators, 67 people gave their age as 100 or more (0·7 per 100,000). Yet subsequent checks revealed that in 53 of these cases the age was the result of mistaken declaration or careless recording. So on January 1, 1960, only 14 persons could be detected who had attained the age of 100 years and were able to prove it (0·1 per 100,000). The oldest person whose age could be proved by means of a birth certificate was a woman, aged 103, who died six months later. Ages higher than this proved to be errors. During the verification it was found that the age of 100 recorded in the course of the preliminary census proved to be correct in only 21 per cent of the cases, while 44 per cent of the declared age of 99 years proved to be correct (20 persons in all). This proportion was 84 per cent in case of people aged 95–98, and 97 per cent with people aged 85–94.

The 1960 investigations in Hungary showed that the census returns relating to the oldest recorded ages are inaccurate. It is obvious, therefore, that in countries where there is no registration of births and deaths, or where registration is relatively recent, the ratio of the oldest people is the highest, while for the same reason it is lower in European countries where the taking of censuses is traditional and available vital statistics are more dependable. Due to various factors there may be, and probably are, differences between various populations concerning the trends of such ratios. The considerable dissimilarities appearing in the scrutinized data, however, are not the consequences of such factors: they are more likely to be the result of the age-accumulation, a phenomenon which has long been known as a source of error that ought to be eliminated from censuses.

The relatively frequent declaration of exceptionally long life spans can therefore be put down to the fact that old people, when they have reached a certain age, (particularly after the age of 90) have a fondness for claiming to be older than they are. The fact that most of them insist on being a round 100 years old is in part due to the wide use of the decimal system. It has been found that ages ending in 0, or in 5 to a lesser extent, have a strong appeal on memory. It can be seen from Table 1 that in countries where the ratio of centenarians and older persons is over 7, the number of people aged 95 usually exceeds not only those aged 98, but also those aged 93. We have shown the number of people aged 93 and 98, as these two ages are relatively free from age-accumulation for this reason. They lend a certain reality to the other figures, and show clearly the rapid drop in the number of very old people for most countries.

The series of former Hungarian censuses show a trend that conforms with what has been said here. At the end of the last century, the number of centenarians and older people amounted to 1–2 per 100,000. Yet the ratio of 1·5 at the turn of the century continued to decrease despite the gradual increase in the length of life, and the number of recorded centenarians also dropped while the population grew considerably.

TABLE 2

The number of centenarians in Hungary according to censuses taken between 1869 and 1960

Year	Population in 1,000*	Aged 100 years and older			
		males	females	total	per 100,000
1869	5,011	30	28	58	1·2
1880	5,329	40	71	111	2·1
1890	6,009	28	31	59	1·0
1900	6,854	39	66	105	1·5
1910	7,612	32	90	122	1·6
1920	7,987	31	72	103	1·3
1930	8,685	28	72	100	1·2
1941	9,316	12	36	48	0·5
1949	9,205	21	55	76	0·8
1960	9,961	18	49	67	0·7
1960**	—	4	10	14	0·1

* Calculated to the present territory of Hungary. Data of 1869–1890 refer only to civil population.

** Revised and corrected data.

The fluctuation with time and decreasing trend of the figures in Table 2 are not an indication of an actual drop in the number of centenarians, but show the growing accuracy of statistical data. However, it is evident from these figures that there are, in fact, people who live to the centenary of their birth, and it is equally evident that there are very few of them. Other sources, such as insurance statistics which have been kept for a long time now, show the same. Early in this century Young (1905) studied life insurances and annuities of more than 800,000 persons and found only 22 cases where the completion of 100 years was proved. The investigations of Bowerman (1939), an American insurance statistician, yielded interesting results: he was able to record eight cases where the length of life was 108 years or more (the oldest among them was a Canadian man aged 113).

Studies of individual lifetimes show that the maximum length of human life exceeds 100 years. Yet it is difficult to establish the exact figure if the investigations are based on individual life spans as these are always open to doubt. Mortality statistics are far better suited to this purpose, as their extensive material discloses rules from which conclusions can be drawn on the maximum length of life.

Although the problems of mortality will be surveyed in more detail later on, conclusions relating to the length of life are discussed briefly below.

For a long time Hungarian demographers have been studying the probability of attaining the age of 100 and the trends of this probability can be followed and compared with the past on the basis of adequate life tables. At the beginning of the 20th century theoretically not one newborn out of hundred thousand had a chance to live to his hundredth birthday. The probability of attaining the age of 100 reached one per 100,000 by 1910, and the mortality rate of 1930–31 showed a pattern in which 6 out of hundred thousand newborn boys and 17 out of as many girls had a chance to live hundred years. By 1948 this probability rose to a respective 17 and 58 per 100,000 and has kept growing ever since, as can be seen from Table 3.

TABLE 3

The probability of becoming a centenarian in Hungary (based on life tables)

Year	No. of those who might live to 100 out of			
	100,000 newborn		10,000 seventy-year-old	
	males	females	males	females
1910–11	1	1	4	4
1920–21	1	2	4	7
1930–31	6	17	17	43
1941	6	20	14	41
1948–49	17	58	37	103
1958	23	70	42	106

It is interesting to study the hope of attaining 100 years not only for the newborn but for aged people as well. Table 3 shows how the probability changed so that people aged 70 should live another 30 years, i.e. attain the age of 100. Under the specific mortality conditions of 1958 ten times as many men of 70 had a chance to live 100 years and nearly 27 times as many women as they had earlier in the 1910's. It must be emphasized, however, that these figures are only probabilities and that these chances would come true only if the mortality rate laid down in the respective life table remained unchanged for hundred years. It should also be noted that the value of these figures is considerably affected by the methods applied for constructing and smoothing the life tables. (For instance, Hungarian life tables of 1959–60, collected with a different method, show the probability of attaining the age of 100 to be 4 per 100,00 in the case of newborn males, and 53 in the case of females.)

TABLE 4

The chance to attain maximum length of life

Age (years)	Survivors of ten million 98-year-old
98	10,000,000
99	5,680,000
100	3,030,000
101	1,515,000
102	699,000
103	296,000
104	122,000
105	37,000
106	10,900
107	2,500
108	420
109	48
110	3

On the basis of mortality data of the oldest people the maximum length of life can be estimated. Without anticipating any conceptual discussion of the life tables we should like to refer here to the studies of a French demographer, Vincent (1951), who studied the mortality of the oldest people in four countries: France, Sweden, Holland and Switzerland. He found that about every third person among those aged 98 attains the age of 100, while only every thousandth has a chance to live 106 years. And only three out of ten million people aged 98 have a chance to live 110 years.

It is easy to see that on the basis of the probabilities shown in Table 4 the age of 110 years can be regarded as the maximum length of human life at present. If the proportion of the centenarians is taken as 1 per hundred thousand, then—considering the 3 thousand million inhabitants of the globe—their number would be 30,000; if a ratio of 10 per hundred thousand is taken, the number of centenarians would be 300,000. Consequently, that of people aged 98 or more could at most range from hundred thousand to one million. But at least three million people aged 98 ought to be living for only one man to attain the age of 110. Even under the best mortality conditions known to us, 5–600 people out of the hundred million born every year today may attain the age of 105, and only 6 may attain 108.

So it is more or less generally accepted that man's maximum length of life can be counted at present to be 110±10 years. The confidence interval of 10 years shows that this limit is not an absolute, but rather a probable value. It is not impossible that somebody might live, say 114 years, and not impossible either that the external and internal preconditions of longevity should be somewhat different in other populations, maybe even better. It ought to be noted, however, that the given probabilities have been calculated on the basis of populations whose mortality is good even if regarded by world standards.

AGE AND MORTALITY

Death is not only man's individual destiny, it is as important a factor as birth in a population's reproduction. Regarded from the angle of a population, the concept of individual death is replaced by that of mortality which means the relative frequency of deaths referred to the number of population.

Considering the fact that the death of the human individual is a certainty (only its time being doubtful), fundamental rules can be laid down in the field of mortality. These rules are correlated first of all to age. But the natural order of the length of human life and mortality is considerably affected by social and economic factors and it is these very factors that are decisive in the development of trends and changes, and in the determination of levels. The explanation of specific mortality, of temporal and territorial differences in mortality is therefore to be found chiefly in these factors. They must not be neglected in studying mortality on the basis of biological features such as age or sex either because socio-economic aspects are always attached to these.

Human life may come to an end at any time, so mortality affects all age groups of the population, though not in the same manner. During a lifetime, the human organism is ceaselessly exposed to external influences and the capacity of resistance and adaptation changes with age. Senescence is accompanied by the weakening of these capacities, thus death occurs most often at old age; but external influences, diseases, or 'nonviability' may cause death to come earlier as well.

In the study of mortality the most important information is supplied by death rates. Their basic type is the crude or general death rate(m), which is an index suitable for first approximation. It is calculated by relating the number of annual deaths (D) in a given population to the mid-year number of this population (P):

$$m = \frac{D}{P}$$

The crude death rates are, as a rule, expressed per thousand population. Theoretically, the rate of general mortality can reach any upper limit up to the complete extinction of the population (1,000 per thousand), but cannot drop infinitely in the case of a larger population with a regular age structure. As long as life is terminated by death, and the length of life characteristic of man is determined by mortality, the mortality rate can be deduced from the length of life. The longer the span of life the fewer individuals die during a given period, and the general mortality rate is lower. Thus the average length of life (e^0) is inversely proportional to the mortality rate:

$$m = \frac{1}{e^0}$$

Under present conditions of mortality, a considerable part of the population attains the age of 80 in many countries. If everyone died at the age of 80, and the number of births did not change meanwhile, the mortality rate of such a population would become constant at 12·5 per thousand after some time. E.g. in a population of eight million people, made up of generations consisting of hundred thousand each, a hundred thousand people of 80 would die every year, yielding a death rate of 100,000 : 8,000,000, i. e. 12·5 per thousand. If people were able to reach the age of 120, the mortality rate would drop to 8·3 per thousand. Although life expectancy today barely amounts to two-thirds of this possibility, the crude death rate approximates 10 per thousand the equivalent of 100 years of age in a number of countries and is even as low as 7–8 per thousand in some. Such a low level of mortality is the result of recent changes, i.e. increase, in the span of life.

Although crude death rates are based on the actual values of mortality, they may often be misleading. Crude rates refer to the entire population, whereas the mortality of various sub-populations may be completely different, especially in subgroups classified by age, sex, social and economic conditions. Thus general mortality depends not only on the length of life but also on the structure of the population. Therefore, for the purposes of mortality analysis and comparative studies, the specific death rate has been introduced.

Among these the most important are the death rates according to age (age-specific death rates). Their general formula is:

$$m_x = \frac{D_x}{P_x}$$

where m_x = the mortality of people aged x,
D_x = the number of persons died at age x,
P_x = the mid-year number of the population aged x.

Age-specific death rates, too, are expressed per thousand.

There is a close correlation between the crude death rate and age-specific mortality. The crude death rate is, in fact, the weighted mean of the age-specific mortality. As, on the basis of the above formula, $D_x = m_x P_x$, if the highest age is ω, the general mortality rate can be stated also in the following way:

$$m = \frac{\sum_{x=0}^{\omega} m_x P_x}{\sum_{x=0}^{\omega} P_x}$$

It should be noted here that the probability of death at a certain age (q_x) is a value very similar to the respective age-specific mortality rate numerically, but of a different meaning. It is not a notion belonging to the sphere of probability theory, but rather an empirical index—like age-specific mortality—measuring the relative intensity of deaths. It differs from the former in that it shows the ratio of deaths between age x and $x + 1$ to the number of survivors at age x, thus in the denominator the number of the population at the beginning of the calendar year is used. Age-specific mortality rates, which in life tables are sometimes called central death rates, as well as probabilities of death represented graphically yield a somewhat distorted U-shaped curve. Infantile mortality—especially that of newborns—is very high (consisting one stem of the U-shaped mortality curve). Then mortality decreases gradually during childhood and reaches its lowest value at adolescence, between 10 and 20 years. In the past, mortality slightly increased at the beginning of adolescence (juvenile mortality), whereby a minor lateral mode was formed about the ages of 18–25 years, followed by a transient decrease. Beginning from the third decade of life, mortality shows a continuous increase (young and middle adult mortality). The rise is slow in the beginning, but from 60–70 years on (old-age mortality) it becomes gradually steeper resulting in the other, upward stem of the U curve which is higher than the first one.

The U-shaped curve of mortality expresses the age-dependent rules of mortality. The shape of the curve is basically determined biologically, but the vertical arrangement of its values, minor variations of this shape, and, to a certain extent, its horizontal extension are determined mainly by social and economic factors. The above-described shape of the curve is generally valid but the actual plotting was based on current Hungarian mortality data. Figure 1 shows the mortality in Hungary in 1930 and 1960. The figure, showing the difference between male and female mortality, indicates also a change of structure in addition to a general decrease.

During a period of only thirty years, mortality in Hungary underwent considerable changes. The rate decreased from 15·5 per thousand to 10·2 per thousand, and the shape of the curve changed as well. The most significant among the structural changes of mortality is that the side of the U curve that descends in childhood and starts from ever lower infantile mortality rates has become steeper despite the lower starting point. This is a consequence of the fact that child mortality, which was still relatively high in 1930, has practically been eliminated, and that the minimum ages-pecific mortality has shifted to a younger age (from 13 to 11 years in the case of males, from 12 to 11 in the case of females; but it is also very low at present during the entire infant II age).

The other change resulted from a more rapid decrease of mortality in the younger age groups, as a result of which the lateral mode of juvenile mortality became considerably reduced in the case of males, and vanished nearly altogether in the case of females. Thus the mortality of males in rising somewhat higher about the age of 20 shows hardly any change up to the age of about 30. With females, on the other hand, this stagnant transition does no longer appear, and, beginning from the minimum at the age of 11, their mortality rises gradually.

The mortality of adults between the ages of 30 and 60 is considerably lower at present than earlier. Considering, however, that the mortality minimum in childhood dropped to a very low level, and changed only little at old age, adult mortality is rising with age faster than before. At old age, where the decrease of mortality was slow, no substantial change took place in the mortality pattern.

Several attempts have been made to define the ‘law of human mortality’ and to determine analytically the shape of the U curve. The idea behind these attempts has been that mortality is a biologically determined phenomenon depending on age and should, therefore, be described by universal formulae. De Moivre, who published his calculations in 1724, assumed that mortality increased continuously, in the manner of an arithmetic progression from the age of 12 until the highest age limit (which he had set at 86). So the function of the probability of death looked like this:

$$q_x = \frac{1}{86 - x}$$

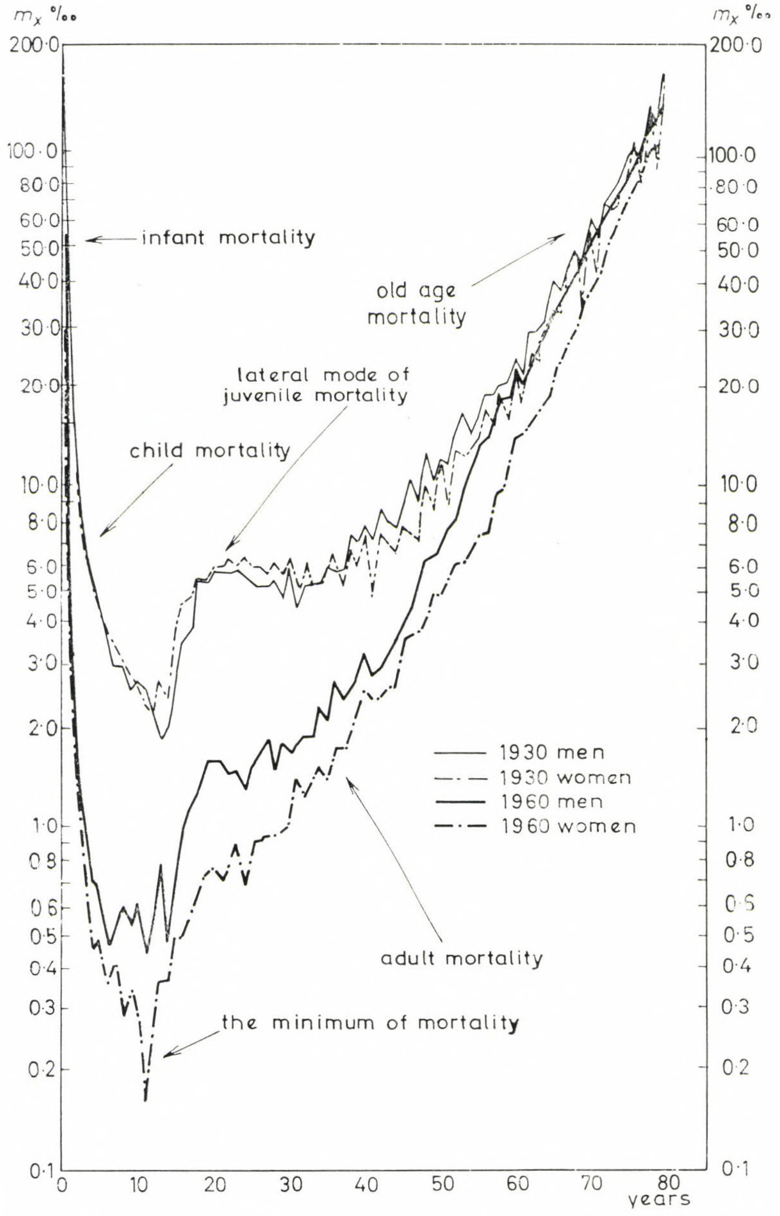


Fig. 1. Mortality in Hungary according to age and sex in 1930 and 1960.

But soon De Moivre's function proved to be untenable and at the beginning of the 19th century was replaced by Gompertz's formula having a sounder mathematical basis. According to Gompertz, the probability of death increases with age, from 10–15 to 55–60, like a geometrical progression. Therefore:

$$q_x = bc^x$$

Parameter c is sometimes called the wear coefficient of the organism. In the second half of the 19th century Makeham added to this theory a systemic factor (a) influencing the intensity of mortality independent of age. The Gompertz–Makeham formula is

$$q_x = a + bc^x$$

This form of exponential function presumes that in the course of life mortality is determined by two groups of factors; the effect of one is constant throughout, while that of the other is being intensified with growing age. The value of parameters a, b and c can be determined only approximately, and they are usually calculated by the method of minimum squares.

Today the Gompertz–Makeham formula still carries some importance in the field of biology, but more thorough studies of human mortality have shown that the interrelationship of mortality and age cannot be described by means of such simple mathematical formulae. Mortality does depend on age, but age is a complex notion including a temporal series of effects produced by a large number of factors on which mortality directly depends, so that any conceivable mathematical formulation of the relationship between age and mortality is illusory. As can be seen from Fig. 1, changes in social and economic factors—including the progress of medicine and hygiene—have no identical effect on the mortality of various ages. Consequently the function of mortality stated according to age is rendered invalid. The Gompertz–Makeham formula of human mortality has therefore only some historical significance, and is used in practice for smoothing, with careful limitations, of certain life tables.

The U.N. model life tables have been based on the relationship of age and mortality. These models are of great practical value and will be reverted to in connection with life tables, but it should be noted in anticipation that, like the Gompertz–Makeham formula, and for the same reasons, they are of no universal validity either.

LIFE TABLES

Mortality or life tables are the conventional means of the comparative description and analysis of mortality. They serve mainly for showing how many of the newborn reach their first, second, third, etc. birthday, and how many of those of a given age live to their next birthday. Thus the fundamental data of the life table determine the number (l_x) of survivors at given ages.

Data of such character are also directly supplied by censuses. On the basis of Hungarian censuses beginning from 1869, it is possible to follow up several generations (see 1960 census). The trends in the number of populations born in the same decades are shown in Table 5. The first generation shown in the table, born in 1851–1860, was at the time of the 1869 census 9–19 years old, and was 99 or more at the 1960 census (data are based on original age declarations). The survival

TABLE 5

Trends in the number of survivors in cohorts of birth from 1869 to 1960 (calculated for the present territory of Hungary)

Date	1851–1860	1861–1870	1871–1880	1881–1890
	Survivors in cohorts born in the above decades			
31. XII. 1869	1,056,750	1,176,971	—	—
31. XII. 1880	889,229	1,038,543	1,333,427	—
31. XII. 1890	837,804	917,819	1,170,107	1,544,527
31. XII. 1900	753,325	884,129	1,082,074	1,382,865
31. XII. 1910	640,793	779,180	960,485	1,225,120
31. XII. 1920	478,205	675,023	851,271	1,066,489
31. XII. 1930	264,036	527,664	755,334	986,684
31. I. 1941	73,629	309,720	608,796	895,633
1. I. 1949	8,067	108,689	386,611	722,664
1. I. 1960	113	8,477	125,881	463,744

Date	1891–1900	1901–1910	1911–1920	1921–1930
	Survivors in cohorts born in the above decades			
31. XII. 1869	—	—	—	—
31. XII. 1880	—	—	—	—
31. XII. 1890	—	—	—	—
31. XII. 1900	1,694,771	—	—	—
31. XII. 1910	1,580,662	1,818,164	—	—
31. XII. 1920	1,382,241	1,760,364	1,531,290	—
31. XII. 1930	1,280,898	1,587,826	1,447,309	1,778,892
31. I. 1941	1,215,832	1,535,103	1,361,974	1,740,105
1. I. 1949	1,058,673	1,358,226	1,230,530	1,581,685
1. I. 1960	888,460	1,257,457	1,173,161	1,512,086

and almost complete extinction of those born in the decade following 1850 as well as the emergence and survival of newer generations (up to 1930) can readily be observed. The principal interest in these data is perhaps that the loss in new generations diminishes gradually in the first ten years of life. This is evidently a consequence of the decrease in infantile mortality. It also appears that between 1910 and 1920, the decade of World War I, the cohorts born between 1881 and 1900, who were young (aged 10–40) in this war decade suffered graver losses than did the older cohorts born in 1851–1870 (of which some were 70 in 1920). So these data also prove the aforesaid experience that mortality depends not only on age but changes with time and is affected by other external factors as well.

Although Table 5 supplies fairly extensive information on the trends of survival, it cannot be regarded as a life table. The lucidity of the table is badly impaired by the fact that survivorship is shown according to long periods (of a ten years' birth cohorts) whereas the mortality at different ages is highly dissimilar. Another

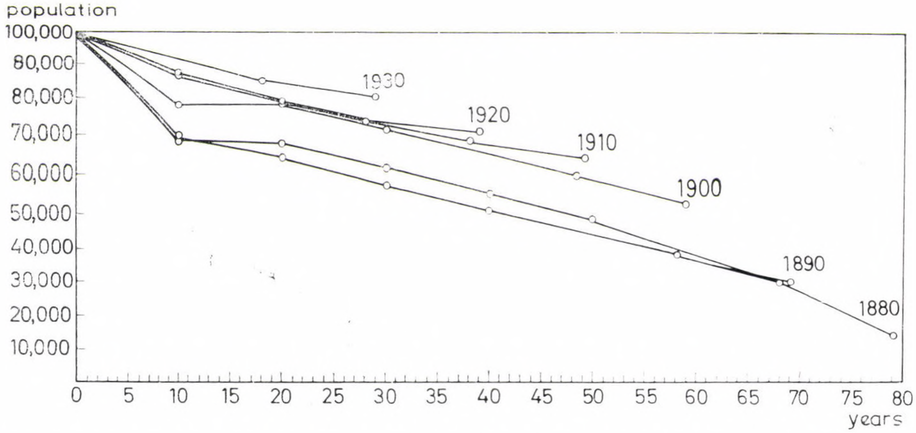


Fig. 2. Trends in the number of survivors in populations born in census years 1880–1930 examined up to 1960.

difficulty in comparing survivals is that the data of this table are absolute figures which inform us about the survival of cohorts of various size. These disturbing circumstances can be eliminated by observing the survivors of cohorts of one year only instead of one decade, and, for the sake of better comparison, taking them as some power of 10 (with 100, 1,000, 10,000, or, most often, with 100,000) and giving the proportion of survivors as related to this root of the life table.

Survival data determined in this way are shown in Fig. 2 which gives the trends of populations born in the years of censuses between 1880 and 1960, and refers the number of births and survivors to 100,000 population. Disregarding certain disturbing factors which will be discussed later, this way of representation informs us about the number of survivors of the individual cohorts at the time of subsequent censuses, i.e. shows the number of survivals to specific ages in the various cohorts.

It appears from Fig. 2 that the number of survivors to given ages increases in subsequent decades. For example, only 69 per cent of the people born in 1880 and 1890 were found alive 10 years later, while 78 per cent of those born in 1900, and 86 and 87 per cent respectively of people born in 1910 and 1920 were registered at the time of the following census.

Yet the improvement of the chances of survival appearing in this figure is equivocal. The fact that various cohorts were affected by temporal factors influencing mortality—e.g. epidemics, wars, etc.—at different ages explains this only in part. Part of the apparent inconsistencies must be ascribed to technical shortcomings in the observations on which the life tables were based.

The idea of following up the survival of generations by means of statistical methods came from Herrmann who starting from 1834–1835 attempted to construct life tables in Bavaria on this basis. Similar attempts were made by Bortkiewicz in Russia, and in Hungary József Kőrösy, a demographer of international reputation, urged the introduction of his method of calculating generation life tables. But the use of such life tables has not become general in international practice. During such a long period (about 100 years) from the time of birth to the death of the last member of a cohort, necessary registration and other work could not be carried out reliably, not even in European countries with highly developed vital statistics.

One practically insolvable problem is the keeping of records on the mortality of emigrants, or to eliminate the mortality of immigrants. Alterations in national boundaries and annexations of territories cause changes which present practically unsurmountable difficulties. These problems are not solved either in Table 5 and Fig. 2 where the data pertain to a population registered in the present territory of this country, irrespective of their place of birth, or of whether people born in the country and having emigrated later on, were still alive at the time of the census. Large-scale emigration at the turn of the century, extensive displacement of people during the World Wars, several changes of territory explain the inconsistencies of these data.

Another shortcoming of generation life tables is that by the time they are completed their value is merely historical. Not even the survival of the 1880 cohort of birth can be followed up to the end in Fig. 2, and the cohort of 1930 was only 29 years old at the time of the census on January 1, 1960. So this figure cannot give a picture of the survival conditions of a shorter period. For this reason life tables are usually drawn up not on the basis of following up the survivals in a population born at a given time, but rather by referring the actually observed mortality of a shorter period to a fictive population, the population of the life table.

The method employed in constructing tables based on the mortality of shorter calendar periods, e.g. one year, consists in determining the ratio of survivors after one year for each specific age. For doing so we must know the number of the living members of various cohorts at a specific time, the number of deaths occurring during the following year, or the number of survivors after one year. Naturally, the ratio of survival of various ages is characteristic in this case not of one cohort but of the survival conditions of the different cohorts at different ages. Supposing, however, that the observed rates of mortality do not change, the survivorship and the expectation of life, etc. can be calculated at this given mortality in a fictious cohort born at the same time, if its size were not affected by migration.

The calculation method of life tables is roughly as follows. Mortality according to ages is determined; next it is calculated how many of the population of 100,000, taken as a basis, would die according to the mortality rate of those aged 0, and how many would reach their first year; again, how many of this remainder would die in accordance with the mortality rate of those aged 1, and how many would live to their second year, and so on. In theory, this computation is carried on until the population of the table has become extinct; in practice the limit is usually 100 years. Life tables for males and females are usually drawn up separately but composite tables of the two sexes are occasionally prepared. The columns of figures, i.e. the life table functions, required for these computations are not only technical requisites but organic parts of the life tables at the same time. Each of them supplies valuable information on the nature of mortality, or may serve as the basis for drawing conclusions on the span of life.

DATA AND ESSENTIAL RELATIONSHIPS IN LIFE TABLES

The first column shows the age (x) given in years. Then follow the other columns showing the various data computed for every age, the first one being usually the probability of death (q_x). As has been said before, probability of death is a concept almost identical with the age-specific mortality rate (or central death rate) (m_x); actually, it is the ratio of l_x, the population of a given age alive at the beginning of the period (i.e. survivors at age x), and d_x, the number of people died of this population during the given period:

$$q_x = \frac{d_x}{l_x}$$

which is in practice computed by special methods adapted to the data available and the length of the period to be studied. Probability of death is the formal expression of the chances a person aged x has if dying before reaching the age of $x + 1$; in practice, however, it expresses not only the probability of the death of the individual to occur at a certain time, but also—which is equivalent—how many out of a population of a given age are likely to die in a year. Essentially the same, the relative death rate of a given age group referred to a specific period, is expressed by the age-specific mortality rates which refer the number of deaths to the midperiod population. Both indices are therefore justly called mortality rates at various ages, though it should be noted that they can be distinguished accurately in the course of life table computations, and that a relationship exists between them that can be expressed as follows:

$$q_x = \frac{2m_x}{2 + m_x}$$

Consequently, the probabilities of death have not been plotted in a separate figure, as they are adequately characterized in Fig. 1, by age-specific mortality. Smoothed probabilities of death, computed from Hungary's death registrations of 1959–1960, are shown in the second columns of Tables 6 and 7.

Death or survival are events exclusive of each other if related to the same given moment of time. In respect of a probability calculation the occurrence of one of these events, i.e. that the person in question will be either alive or dead at the given time, is a certainty, which means that its probability is equal to the sum of the probability of these events, which is 1. The counterpart of the probability of death (q_x), is the probability of survival (p_x), which can be derived from the probability of death:

$$p_x = 1 - q_x$$

but can be computed also directly as the quotient of the number of subjects aged x and those who reach the age of $x + 1$:

$$p_x = \frac{l_{x+1}}{l_x}$$

Using the number of survivors, the probability of death can be derived, as the number d_x of those died at age x is

$$d_x = l_x - l_{x+1}$$

therefore

$$q_x = \frac{l_x - l_{x-1}}{l_x} = 1 - \frac{l_{x+1}}{l_x}$$

The probability of survival expresses the chance of a person aged x to attain the age of $x + 1$. Making use of this index, it can be computed how many of a population of a given age will reach their next birthday.

On the basis of the Hungarian life table of 1959–1960 for men, the probability of death of those aged 0, i.e. the newborn, is

$$q_0 = 0{\cdot}055{,}83$$

Hence the probability of survival for age 0 is

$$p_0 = 1 - 0{\cdot}055{,}83 = 0{\cdot}944{,}17$$

By means of q_x or p_x the number of both the dead and the survivors can be derived, and a complete life table can be constructed by using either series of data. Let the radix, i.e. the number of those aged 0, be

$$l_0 = 100{,}000$$

from which the number of subjects attaining the age of 1 can be derived by using either probability q_0 or probability p_0:

$$l_1 = l_0 p_0 = 100{,}000 \times 0{\cdot}944{,}17 = 94{,}417$$

or since

$$d_x = l_x q_x \text{ and } l_{x+1} = l_x - d_x = l_x - l_x q_x$$

therefore

$$l_1 = l_0 - l_0 q_0 = 100{,}000 - 100{,}000 \times 0{\cdot}055{,}83 = 100{,}000 - 5{,}583 = 94{,}417$$

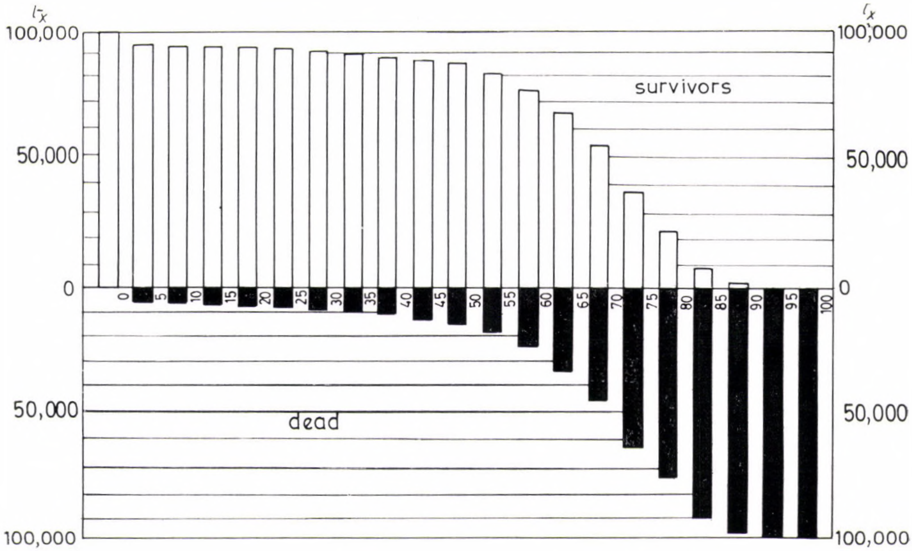


Fig. 3. Survivorship in Hungary based on male mortality in 1959–1960.

Similarly

$$l_2 = l_1 p_1 = 94{,}417 \times 0{\cdot}995{,}95 = 94{,}035$$

or

$$l_2 = l_1 - l_1 q_1 = 94{,}417 - 94{,}417 \times 0{\cdot}004{,}05 = 94{,}417 - 382 = 94{,}035$$

Consequently the number of people died at the age of 0 and 1 is

$$d_0 = 5{,}583$$

$$d_1 = 382$$

It appears from Tables 6 and 7 that the number of survivors decreases year by year.

Out of 100,000 newborn males, only 93,469 reach the age of 10, out of as many females 94,548, and the age of 80 will be attained only by 22,559 and 32,436 respectively. The series of survivors l_0, $l_1 \ldots l_x$, $l_{x+1} \ldots l_{\omega-1}$ at given ages is called the survivorship function (ω denotes the life span during which the population included in the life table becomes extinct, thus $l_\omega = 0$).

The pattern of survivorship and certain particularities of the life table are apparent from Fig. 3. At the top of the figure, divided into two horizontal sections, we have shown the number of survivals at certain ages out of 100,000 newborn, whereas in the lower section the number of deaths, based on male mortality in Hungary in 1959–1960. Ages are plotted in steps of five years on the horizontal axis. As can be seen from Fig. 3, the difference in height between two

TABLE 6

Life table based on the mortality of Hungarian male population in 1959–1960

Age (x)	Probability of death (smoothed values) (q_x)	Survivors (l_x)	No. of deaths (d_x)	Life expectancy (e^0_x)
0	0·055,83	100,000	5,583	65·18
1	0·004,05	94,417	382	68·00
2	0·001,53	94,035	144	67·28
3	0·000,96	93,891	90	66·38
4	0·000,77	93,801	72	65·44
5	0·000,66	93,729	62	64,49
6	0·000,59	93,667	55	63·54
7	0·000,53	93,612	50	62·57
8	0·000,50	93,562	47	61·61
9	0·000,49	93,515	46	60·64
10	0·000,50	93,469	47	59·67
11	0·000,53	93,422	50	58·70
12	0·000,59	93,372	55	57·73
13	0·000,66	93,317	62	56·76
14	0·000,75	93,255	70	55·80
15	0·000,89	93,185	83	54·84
16	0·001,11	93,102	103	53·89
17	0·001,25	92,999	116	52·95
18	0·001,40	92,883	130	52·01
19	0·001,52	92,753	141	51·09
20	0·001,60	92,612	148	50·16
21	0·001,63	92,464	151	49·24
22	0·001,61	92,313	149	48·32
23	0·001,57	92,164	145	47·40
24	0·001,53	92,019	141	46·47
25	0·001,53	91,878	141	45·54
26	0·001,57	91,737	144	44·61
27	0·001,62	91,593	148	43·68
28	0·001,69	91,445	155	42·75
29	0·001,77	91,290	162	41·82
30	0·001,85	91,128	169	40·90
31	0·001,93	90,959	176	39·97
32	0·002,01	90,783	182	39·05
33	0·002,10	90,601	190	38·13
34	0·002,20	90,411	199	37·21
35	0·002,31	90,212	208	36·29
36	0·002,43	90,004	219	35·37
37	0·002,56	89,785	230	34·45
38	0·002,70	89,555	242	33·54
39	0·002,87	89,313	256	32·63

TABLE 6 (cont'd)

Age (x)	Probability of death (smoothed values) (q_x)	Survivors (l_x)	No. of deaths (d_x)	Life expectancy (e^0_x)
40	0·003,06	89,057	273	31·72
41	0·003,28	88,784	291	30·82
42	0·003,50	88,493	310	29·92
43	0·003,75	88,183	331	29·02
44	0·004,07	87,852	358	28·13
45	0·004,46	87,494	390	27·24
46	0·004,94	87,104	430	26·36
47	0·005,47	86,674	474	25·49
48	0·006,07	86,200	523	24·63
49	0·006,77	85,677	580	23·78
50	0·007,56	85,097	643	22·93
51	0·008,46	84,454	714	22·11
52	0·009,44	83,740	791	21·29
53	0·010,51	82,949	872	20·49
54	0·011,70	82,077	960	19·70
55	0·013,01	81,117	1,055	18·93
56	0·014,42	80,062	1,154	18·17
57	0·015,94	78,908	1,258	17·43
58	0·017,58	77,650	1,365	16·70
59	0·019,35	76,285	1,476	16·05
60	0·021,19	74,809	1,585	15·30
61	0·023,31	73,224	1,707	14·62
62	0·025,41	71,517	1,817	13·96
63	0·027,68	69,700	1,929	13·31
64	0·030,23	67,771	2,049	12·67
65	0·033,16	65,722	2,179	12·05
66	0·036,40	63,543	2,313	11·45
67	0·039,89	61,230	2,442	10·86
68	0·043,71	58,788	2,570	10·29
69	0·047,97	56,218	2,697	9·74
70	0·052,74	53,521	2,823	9·20
71	0·057,95	50,698	2,938	8·69
72	0·063,53	47,760	3,034	8·19
73	0·069,62	44,726	3,114	7·71
74	0·076,32	41,612	3,176	7·25
75	0·083,76	38,436	3,219	6·81
76	0·091,00	35,217	3,205	6·39
77	0·099,96	32,012	3,200	5·98
78	0·109,77	28,812	3,163	5·59
79	0·120,48	25,649	3,090	5·21
80	0·132,17	22,559	2,982	4·86
81	0·144,93	19,577	2,837	4·52

TABLE 6 (cont'd)

Age (x)	Probability of death (smoothed values) (q_x)	Survivors (l_x)	No. of deaths (d_x)	Life expentancy (e_x^0)
82	0·158,80	16,740	2,658	4·21
83	0·173,88	14,082	2,449	3·91
84	0·190,23	11,633	2,213	3·62
85	0·207,93	9,420	1,959	3·36
86	0·227,06	7,461	1,694	3·11
87	0·247,65	5,767	1,428	2·87
88	0·269,79	4,339	1,171	2·65
89	0·293,50	3,168	930	2·45
90	0·318,82	2,238	714	2·26
91	0·345,76	1,524	527	2·08
92	0·374,30	997	373	1·92
93	0·404,41	624	252	1·77
94	0·436,00	372	162	1·63
95	0·468,99	210	98	1·51
96	0·503,21	112	56	1·38
97	0·538,49	56	30	1·27
98	0·574,57	26	15	1·16
99	0·611,20	11	7	1·05
100	0·648,02	4	3	1·03

neighbouring columns of survivors is identical with that between the corresponding two columns referring to the dead. Thus the number of deaths is

$$d_x = l_x - l_{x+1}$$

If this relationship is stated for every age

$$d_0 = l_0 - l_1$$

$$d_1 = l_1 - l_2$$

$$\cdots\cdots\cdots$$

$$d_{\omega-1} = l_{\omega-1} - l_\omega$$

$$d_\omega = l_\omega$$

and if the equations are summed up, we obtain

$$\sum_0^\omega d_x = l_0.$$

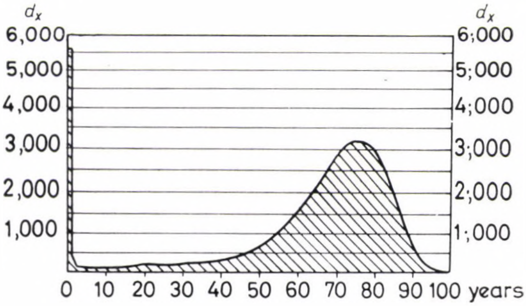


Fig. 4. Distribution of deaths in Hungary based on male mortality in 1959–1960.

Thus, the aggregate number of the dead gives the root of the life table, which is apparent also from Fig. 3 as survivorship follows the complete extinction of the population studied.

The curve resulting from the distribution of deaths differs considerably from those of the probability of death or the probability of survival. This curve commences very high as the number of deaths is usually the highest in the first year of life, then descends rapidly as the general death rate decreases subsequent to infantile mortality down to the minimum of child mortality appearing about the age of 10. Beginning from this point the curve rises with the increase in mortality slowly at first, then steeply beginning from the ages of 40–50 up to the maximum appearing between the ages of 70 and 80. Although mortality continues rising from this point, the curve descends rapidly down to zero, as the number of living population is similarly diminishing. The distribution curve of deaths is of course closely related to the curve of survivorship. At ages where the number of deaths is high compared with the number of survivors, the survivorship curve descends rapidly, and *vice versa*, where this number is low, the slope of the curve appears flat. Concerning the span of human life, one of the most important results can be obtained directly from the distribution of deaths. It is this distribution that tells us the lengths of life attained by most people; or, more directly, the age at which most people die. Although there is a generally experienced high mortality of infants, really important information on the normal age at death is derived from the number of deaths at a more advanced age. This old-age mode is called the normal age at death, or the modal value of life span. In Fig. 4 this value appears at the age of 75 (at 79 in the case of females). However, in addition to this at the age of 21 another minor lateral mode appears, hardly showing in the figure, which represents juvenile mortality rising more rapidly for a while from age infant II. This juvenile mode of death distribution was much more prominent not so long ago.

Like the normal age at death, the probable length of life, another index of the life table, is also a positional median value. It is the median value of the pattern of survivorship, i.e. it shows the age attained by half of the survivors aged x.

It should be noted incidentally that a distinction must be made between the terms age and length of life. Age means the number of time units lived (usually the number of years that passed since birth), while length of life shows the number of time units passed between two given ages.

The most important column of life tables is that showing the expectation of life (e_x^0), or life expectancy, which is the mean of possible lifetimes. Thus life expectancy shows the mean of years to be lived by the individual according to the life table.

TABLE 7

Life table based on the mortality of Hungarian female population in 1959–1960

Age (x)	Probability of death (smoothed values) (q_x)	Survivors (l_x)	No. of deaths (d_x)	Life expectancy (e_x^0)
0	0·045,95	100,000	4,595	69·57
1	0·003,89	95,405	371	71·90
2	0·001,52	95,034	144	71·17
3	0·000,82	94,890	78	70·28
4	0·000,62	94,812	59	69·34
5	0·000,56	94,753	53	68·38
6	0·000,49	94,700	46	67·42
7	0·000,43	94,654	41	66·45
8	0·000,37	94,613	35	65·48
9	0·000,32	94,578	30	64·50
10	0·000,29	94,548	27	63·52
11	0·000,29	94,521	27	62·54
12	0·000,31	94,494	29	61·56
13	0·000,37	94,465	35	60·58
14	0·000,47	94,430	44	59·60
15	0·000,48	94,386	45	58·63
16	0·000,52	94,341	49	57·66
17	0·000,57	94,292	54	56·69
18	0·000,63	94,238	59	55·72
19	0·000,69	94,179	65	54·75
20	0·000,74	94,114	70	53·79
21	0·000,77	94,044	72	52·83
22	0·000,80	93,972	75	51·87
23	0·000,83	93,897	78	50·91
24	0·000,86	93,819	81	49·95
25	0·000,89	93,738	83	49·00
26	0·000,92	93,655	86	48·04
27	0·000,96	93,569	90	47·08
28	0·001,00	93,479	93	46·03
29	0·001,05	93,386	98	45·17
30	0·001,10	93,288	103	44·22
31	0·001,15	93,185	107	43·27
32	0·001,20	93,078	112	42·32
33	0·001,27	92,966	118	41·37
34	0·001,35	92,848	125	40·42
35	0·001,45	92,723	134	39·47
36	0·001,59	92,589	147	38·53
37	0·001,76	92,442	163	37·59
38	0·001,94	92,279	179	36·66
39	0·002,14	92,100	197	35·73

TABLE 7 (cont'd)

Age (x)	Probability of death (smoothed values) (q_x)	Survivors (l_x)	No. of deaths (d_x)	Life expectancy (e^{0}_{x})
40	0·002,33	91,903	214	34·80
41	0·002,52	91,689	231	33·88
42	0·002,71	91,458	248	32·97
43	0·002,91	91,210	265	32·05
44	0·003,12	90,945	284	31·15
45	0·003,37	90,661	306	30·24
46	0·003,64	90,355	329	29·34
47	0·003,93	90,026	354	28·45
48	0·004,25	89,672	381	27·56
49	0·004,60	89,291	411	26·67
50	0·004,99	88,880	444	25·80
51	0·005,39	88,436	477	24·92
52	0·005,80	87,959	510	24·05
53	0·006,26	87,449	547	23·19
54	0·006,82	86,902	593	22·34
55	0·007,53	86,309	650	21·49
56	0·008,37	85,659	717	20·64
57	0·009,32	84,942	792	19·81
58	0·010,39	84,150	874	19·00
59	0·011,61	83,276	967	18·19
60	0·012,99	82,309	1,069	17·40
61	0·014,47	81,240	1,176	16·62
62	0·016,04	80,064	1,284	15·86
63	0·017,80	78,780	1,402	15·11
64	0·018,82	77,378	1,456	14·37
65	0·022,20	75,922	1,685	13·64
66	0·023,85	74,237	1,771	12·94
67	0·027,69	72,466	2,007	12·24
68	0·030,89	70,459	2,176	11·57
69	0·034,58	68,283	2,361	10·93
70	0·038,92	65,922	2,566	10·30
71	0·043,84	63,356	2,778	9·70
72	0·049,25	60,578	2,983	9·12
73	0·055,24	57,595	3,182	8·57
74	0·061,89	54,413	3,368	8·04
75	0·069,61	51,045	3,553	7·54
76	0·075,99	47,492	3,609	7·06
77	0·085,55	43,883	3,754	6·60
78	0·095,63	40,129	3,838	6·17
79	0·106,23	36,291	3,855	5·77
80	0·117,43	32,436	3,809	5·40
81	0·129,20	28,627	3,699	5·05

TABLE 7 (cont'd)

Age (x)	Probability of death (smoothed values) (q_x)	Survivors (l_x)	No. of deaths (d_x)	Life expectancy (e_x^0)
82	0·141,51	24,928	3,528	4·73
83	0·154,54	21,400	3,307	4·42
84	0·168,15	18,093	3,042	4·14
85	0·182,50	15,051	2,747	3·88
86	0·197,44	12,304	2,429	3·63
87	0·213,12	9,875	2,105	3·40
88	0·229,48	7,770	1,783	3·18
89	0·246,56	5,987	1,476	2·98
90	0·264,37	4,511	1,193	2·80
91	0·282,94	3,318	939	2·62
92	0·302,19	2,379	719	2·46
93	0·322,18	1,660	535	2·31
94	0·342,83	1,125	386	2·16
95	0·364,18	739	269	2·03
96	0·386,20	470	182	1·91
97	0·408,85	288	118	1·80
98	0·432,06	170	73	1·70
99	0·455,81	97	44	1·61
100	0·480,03	53	25	1·53

In Table 6 for instance the men who attained the age of 20 are likely to live another 50 years, i.e. to attain the age of 70.

Of lifetimes to be expected at various ages, the most often compared values are those of expectation of life at birth (e_0^0), and the mortality rate of the life table can also be derived from this value. Life expectancy at birth is illustrated graphically in Fig. 5. In this figure e_0^0 means age (or $0e_0^0$ means distance) where—at a given value of the former—the area limited by the survivorship curves l_0 and l_{100} is identical with the surface of rectangle $0e_0^0l_0A$. The section cut from the rectangle by the part between the survivorship curve l_0 and point A is exactly as large as the section to the right from line e_0^0B (both sections are shaded).

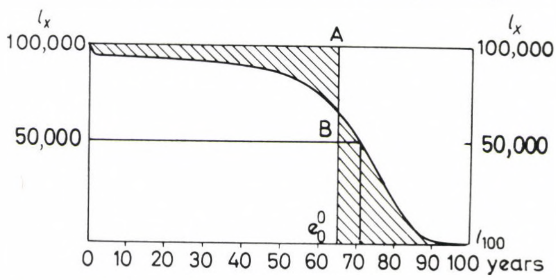


Fig. 5. Survivorship, the probable length of life and the expectation of life in Hungary based on male mortality in 1959–1960.

For computing life expectancy, the total number of years (T_x) lived by the population from age x must be determined first. This is the sum of the total number of years (L_x) lived by the surviving population of the life table at various ages:

$$T_x = \sum_{x}^{\omega}{}' L_x$$

Assuming that deaths are evenly distributed within age x and $x + 1$,

$$L_x = \frac{l_x + l_{x+1}}{2} = l_x - \frac{d_x}{2} = l_{x+1} + \frac{d_x}{2}$$

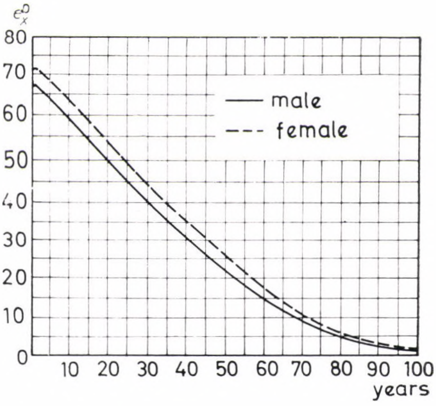


Fig. 6. Expectation of life at various ages by sex. Based on the Hungarian life table of 1959–1960.

Although experience does not verify this presumption particularly in the first year of life, its use in practice does not substantially distort the determination of T_x (even when a high accuracy is required, monthly corrections are usually applied only at the first year of life). If, therefore, the number of years to be lived by survivors l_x in the first year is $l_{x+1} + \frac{d_x}{2}$, and in the second year $l_{x+2} + \frac{d_{x+1}}{2}$, etc., the total number of years to be lived from age x to complete attrition is $l_{x+1} + \frac{d_x}{2} + l_{x+2} + \frac{d_{x+1}}{2} + \ldots + l_\omega + \frac{d_{\omega-1}}{2} = T_x$. Reducing this equation we obtain

$$T_x = l_{x+1} + l_{x+2} + \ldots + l_\omega + \frac{1}{2}(d_x + d_{x+1} + \ldots d_{\omega-1})$$

Considering that the term in brackets is equal with l_x, the total number of years to be lived is

$$T_x = \sum_{x}^{\omega}{}' L_x = \frac{l_x}{2} + l_{x+1} + l_{x+2} + \ldots + l_\omega$$

Expectation of life at birth is the quotient of the total number of years (T_0) to be lived by the entire population of the life table and its radix (l_0):

$$e_0^0 = \frac{T_0}{l_0}$$

and the expectation of life at the given age x is

$$e_x^0 = \frac{T_x}{l_x}$$

Graphic representation of the expectation of life for various ages results in a curve that shows a concave shape for a while after its origin, and is then tending toward the horizontal axis maintaining a convex character throughout (Fig. 6).

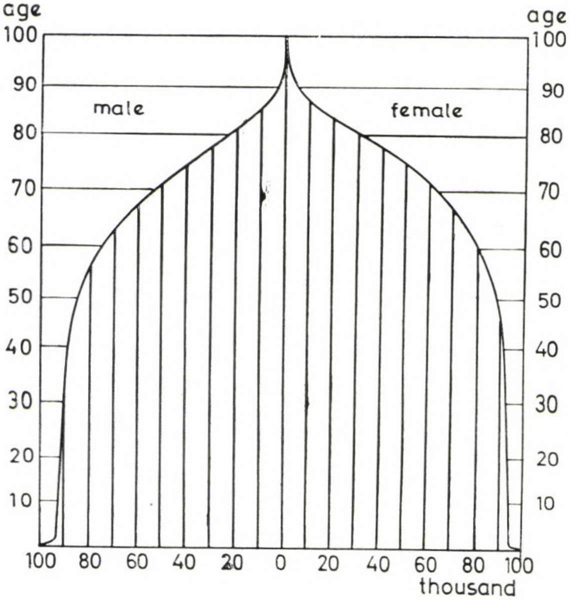


Fig. 7. Stationary population on the basis of Hungary's life table of 1959–1960.

Expectation of life increases for some time after birth and is considerably higher when reaching the 1st birthday than at birth (according to Hungarian life tables of 1959–1960, expectancy at the age of 1 was 68 years for men and 72 for women, 2–3 years more than at birth).

Life tables are suitable not only for illustrating mortality, but their survivorship can also be regarded as a model population. Namely if we regard the survivors of various ages of the table as a population living at a given time, a population structure is gained in which the number of births is the same as the number of deaths every year and is identical with the radix of the life table; consequently, as has been mentioned above:

$$l_0 = \sum_0^{\omega} d_x$$

Size and age structure of such a population remains unchanged if it is of a stationary character, and is therefore called a stationary population. The number of the stationary population is the equivalent of T_0. In the age structure of a stationary population the size of the various cohorts is given by the L_x values. (The various cohorts of a stationary population derived from the life tables broken down to sexes are computed on the basis of values l_0 corrected according to the sex ratio at birth.) The birth rate of the stationary population (the number of births related to the entire population) is

$$n_s = \frac{l_0}{T_0}$$

and the death rate, on the basis of the relationships $n_s = m_s$ and $e_0^0 = \frac{T_0}{l_0}$, is the reciprocal of life expectancy:

$$m_s = \frac{1}{e_0^0}$$

Figure 7 outlines a type of stationary population based on the Hungarian life table of 1959–1960. The two sides of the age pyramid consist of the curves of the male and female survival, with the difference, however, that in this figure the values of age are shown on the vertical, the values of l_x on the horizontal axis. Thus the age structure of the stationary population is determined by the survivorship, as can be seen clearly from this figure.

A stationary model population based on given mortality rates is not the only hypothetical model population to be used in demography. When investigating the complex and intricate processes of reproduction, theoretical demography often makes use of constructions that express the principal features and relationships of the various processes in a simplified, abstract manner. The model most frequently used is the stable population devised by Lotka, where in case of an unchanged rate of natural growth (this may be attrition as well!), the size of the population changes with an exponential character, and its age structure becomes stabilized.

Although the stationary population is only a marginal case of the stable model population (the rate of growth being zero), it plays a highly important part in respect of historico-demographic studies. Its importance lies in the fact that, with the exception of certain periods and areas, the rate of growth of human population was very slow even between 1 A.D. and the middle of the 17th century. According to estimates, the number of world population grew during these sixteen centuries from about 210–250 millions to nearly 550 millions, so the annual rate of natural growth may have been only 0·05–0·1 per thousand. Assuming that the first man using implements had appeared about half a million years ago, the size of the primordial population must have changed very little and its rate of growth must have been extremely low. It is obvious that in such circumstances—for lack of other data—the stationary model population is a hypothesis that approximates the one-time historical reality fairly well.

MODEL LIFE TABLES

With the intention of helping the developing countries where no mortality records have been kept (involving about two thirds of world population), the demographers of the United Nations Organization published a series of forty model life tables in 1956. If plans for social and economic development are drawn up, a demographic analysis is required in which the knowledge of mortality trends is indispensable. In such countries these models promote the theoretical determination of mortality levels according to sex and age, and may even be used for determining mortality trends. Since the U.N. model life tables have been prepared on the basis of 158 life tables coming from fifty countries with highly different populations, social systems, cultures and geographical situations, they are also suited for illustrating the wide range and extreme complexity of mortality conditions prevailing in the first half of the 20th century.

According to their authors, the forty model tables contain practically every possible variant of mortality ranging between the two extremes of life expectancy at birth of 18 and 72 years. Such a wide range has been considered necessary to meet the needs of developing countries, in many of which mortality conditions are very poor. However, quite frequently the model life tables meet these requirements only because there are no data available about the actual mortality conditions of the population concerned. In spite of the fact that these tables have been constructed based on large materials and are theoretically well founded, it is impossible to say that reality cannot differ from these schemes (see e.g. Fig. 10).

Starting from the mortality characteristic of our era, the model tables have been prepared for the purpose of analysing current demographic processes. Yet the rules employed in constructing the models are general enough to suggest the idea that the mortality types characterized by these tables could possibly be regarded as having historical validity as well. Considering the fact that on the basis of these models only approximate estimates can be made even for the present time, we are of the opinion that mortality factors of the past may, in all probability, have created conditions that could not be reflected in the tables on the basis of which these models have been prepared. This is why in the case of historical investigations no over-confidence in these models is justified, especially if other authentic data are not available. Nevertheless, these models can be used to advantage for comparison with comprehensive historical data, for completion of inadequate information, and for checking various conclusions derived from an insufficient number of observations.

The practical experiences underlying the construction of the U.N. model life tables was that the mortality of two adjoining age groups or cohorts does not differ considerably—apart from demographic catastrophes—whatever the level of mortality may be. In other words, only minor, accidental fluctuations of the mortality curve plotted according to age are to be expected, and no major breaks.

With view to an easier use of the data of the life tables the probability of death was computed for five-year age groups according to the following formula:

$$_5q_x = \frac{l_x - l_{x+5}}{l_x}$$

where $_5q_x$ is the probability of death in the five-year age group, and l_x is the number of survivors taken from the life tables. Seventeen scatter diagrams were prepared from the probability of death in consecutive age groups by plotting the probability of death in the youngest age group ($_5q_x$) against the horizontal axis, and the probability in the next group ($_5q_{x+5}$) against the vertical axis. The data were smoothed with a second-degree parabola ($y = a + bx + cx^2$; the constants were determined with the method of least squares). Such a curve, comparing $_5q_{10}$ and $_5q_{15}$, is shown in Fig. 8. Here the curve fits the low values of the 158 life tables well, but the higher values show a considerable scatter around the parabola.

The parabolas of the scatter diagrams express the characteristic relationship between the mortality of consecutive age groups. The model tables were prepared on the basis of this relationship, by means of 17 parabolas; 40 different values were

Fig. 8. Relation between mortality of two successive age groups at different mortality levels.

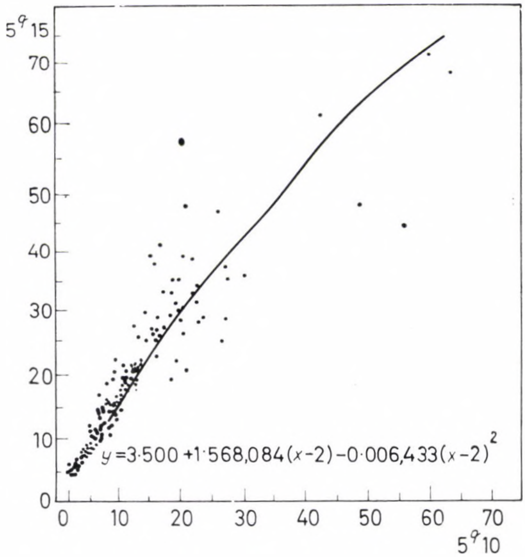
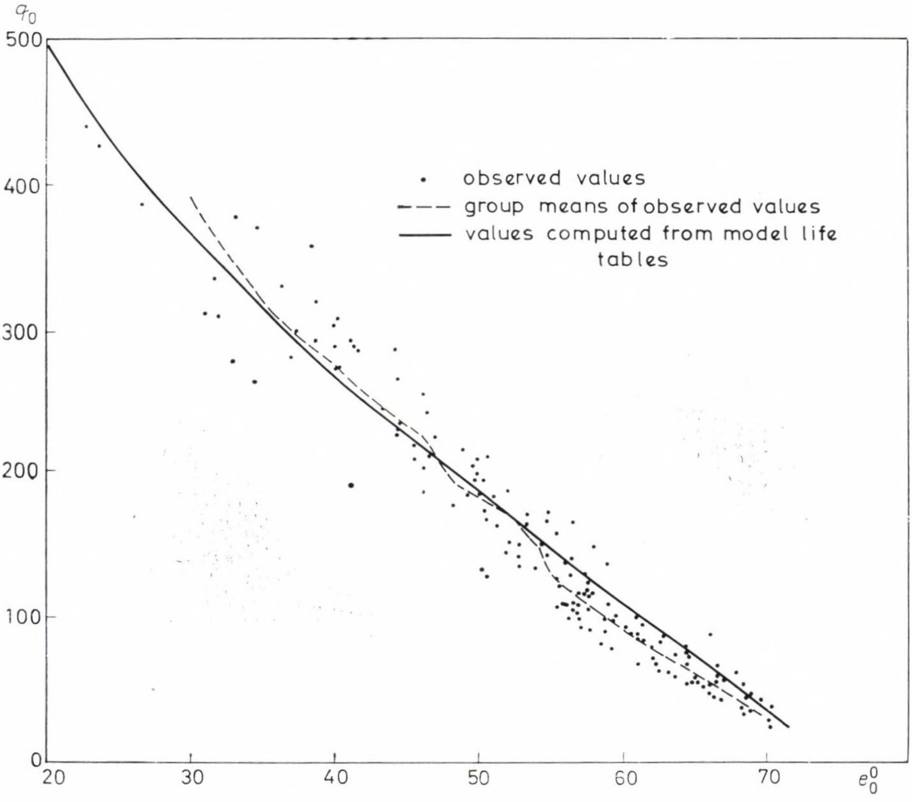


Fig. 9. Relation between the mortality and expectation of life at birth of the age group under five.



given to the mortality of the first age group (mortality at age 0 was given the following values: $q_0 = 20, 25, 30, \ldots 95, 100, 110, \ldots 320, 330$). On the basis of the values ${}_5q_x$ the other columns of the life tables can be determined. The mortality levels of the forty model tables correspond to forty expectations of life of different values. Although these values depend actually on what mortality values of the youngest group we take as a starting point, the method by which the U.N. experts have constructed the model tables cannot be considered arbitrary. Namely, the correlation appears from the collected 158 life tables that the lower the mortality under the age of five, the longer the expectation of life at birth, which depends after all on the mortality of all age groups, i.e. on the general level of mortality. This correlation is outlined in Fig. 9, where both the values actually found and the values computed from the model tables are shown.

The relationship between the values ${}_5q_0$ and e_0^0 is a consequence of the fact that the high infantile and child mortality appearing at the beginning of human life affects the largest cohorts and therefore influences the expectation of life considerably. This relatively close relationship between mortality under the age of five and expectation of life appears also in Fig. 9, in which the data show no major scatter even at extreme values. It is characteristic, too, that in the figure the curve computed from the model life tables runs almost parallel to the dotted line connecting the age intervals that have actually been observed in life tables.

TABLE 8

Probability of death in model life tables

Level	1	6	24	28	32	36	40
e_0^0	71·71	67·38	42·91	35·67	29·19	23·59	18·83
e_0^0	13·95	14·84	23·30	28·03	34·26	42·39	53·11
Age							
0	20·00	45·00	170·00	210·00	250·00	290·00	330·00
1–4	3·91	13·71	90·63	127·43	171·76	224·89	288·39
0–4	23·83	58·09	245·22	310·67	378·82	449·67	523·22
5–9	2·66	5·05	28·75	41·24	56·59	75·04	96·93
10–14	2·28	3·95	20·13	28·40	38·33	49·91	63·16
15–19	3·94	6·53	29·81	40·41	51·98	63·86	75·34
20–24	5·03	8·87	41·22	54·66	68·40	81·51	93·20
25–29	5·70	9·52	44·39	60·33	77·49	94·71	110·72
30–34	7·03	10·71	47·41	65·91	87·01	109·43	131·42
35–39	9·21	12·87	52·03	73·40	99·10	128·00	157·81
40–44	13·43	17·31	60·18	84·48	114·63	149·70	187·16
45–49	21·33	25·71	74·04	101·55	135·75	175·82	218·85
50–54	33·28	38·49	94·63	125·67	163·35	206·19	250·69
55–59	50·73	57·21	124·66	160·11	201·18	245·46	288·68
60–64	80·86	89·22	171·55	211·56	255·29	299·12	338·58
65–69	129·10	139·93	240·32	284·95	330·61	373·12	408·58
70–74	205·86	219·77	341·60	391·62	440·18	483·19	517·20
75–79	315·73	332·24	470·26	523·66	575·36	616·55	649·41
80–84	459·65	477·63	625·79	681·56	734·78	776·59	809·50

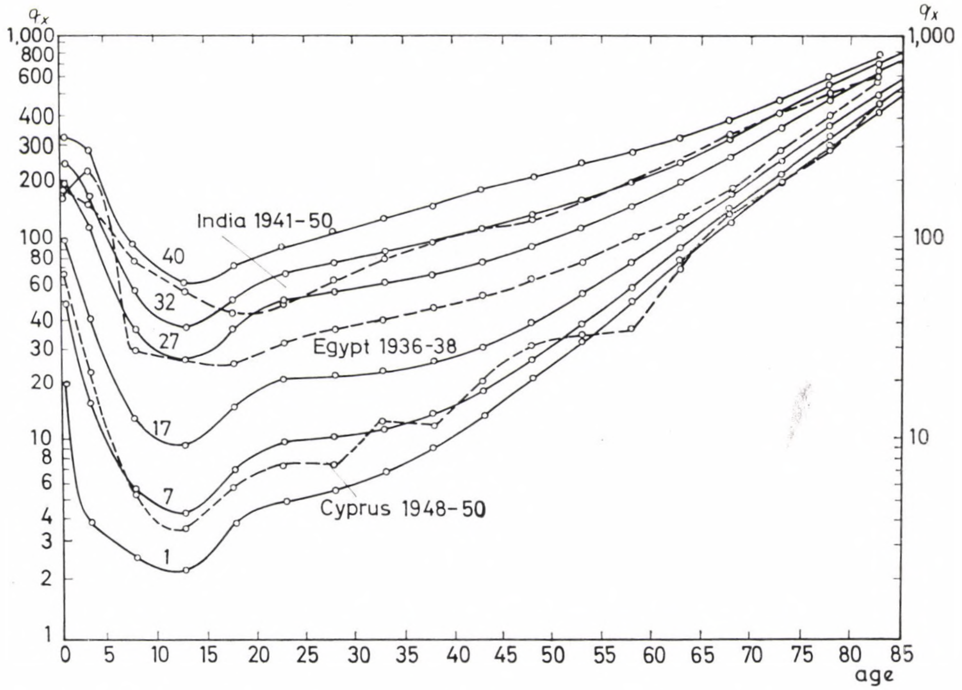


Fig. 10. Probabilities of death in some model life tables and in empirical life tables.

The U.N. model life tables have a variety for both sexes combined, and one in which the sexes are shown separately. The probability of death as given by some of the model tables for both sexes combined is shown in Table 8. It contains level 1 representing the lowest mortality, level 6 that corresponds to the mortality in Hungary, as well as the data of every fourth level between nos 24 to 40. The probability of death of the various age groups is expressed per thousand (1,000 $_5q_x$).

The probabilities of death in five-year groups cannot be compared directly with the data of Hungarian life tables, as the latter show probabilities in single years of age. To illustrate the construction of model life tables we present Fig. 10, in which the hypothetical data of a few models are compared with actual data. The curves of actual data from India (1941–1950), Egypt (1936–1938) and Cyprus (1948–1950) correspond to the data of a different model at practically every age. For instance, the Cyprus curve starts higher than model 7, intersects the latter several times, then assumes lower values on the average which even drop below the curve of model 1 at two points. The outset of the Egyptian curve expresses a type of mortality that differs from that of the model tables, then shows a more favourable adult mortality than could be expected on the basis of the initial values. The minimum of the Indian mortality curve, which approximates model 32, is considerably shifted on the age axis as compared with the minima shown in the model tables.

It should be noted that prior to the publication in 1955 of the model life tables discussed here, U.N. demographers had used such models for their population forecasts in Latin America. They concluded that the validity of the tables holds mainly for mortality levels corresponding to a life expectancy at birth of 50 and 60 years, while they proved to be less dependable at lower or higher mortality levels. Although the models published in 1955 rested—as we have seen—on much sounder foundations, it would seem that the higher the mortality, the greater the difference between models and the actual facts might be. This should serve as a warning that these models ought to be used for historical research with at least as much caution as historical sources.

CHAPTER II

METHODS OF PALAEODEMOGRAPHIC STUDIES

A SURVEY OF PALAEODEMOGRAPHIC LITERATURE

When studying mortality and length of life and, generally speaking, demographical processes over longer periods of time, no written historical sources are available as a rule. Nor are there records from the past of primitive people, often not even from their present, as has been indicated in the first Chapter. It is unfortunate that prior to the development of modern demography and statistical services hardly any written records have come down to us (apart from some merely mythical or legendary memories and sporadic records of some ancient states) to supply information on the size and reproduction of populations, their biological and social structure, fertility and mortality conditions, in short, their demographic patterns.

For this reason the historical demographic study of past epochs is divided into two parts, not so much by the temporal differences between periods but on the basis of utilizable sources. The first, historical demography proper is concerned with the reappraisal of written sources that had not been prepared for demographic purposes (such as the notes of historians, tax rolls, documents, etc.), while the second, palaeodemography, studying practically the entire period of the history of mankind, is based on the analysis of available material remains. The materials of palaeodemography may consist of a variety of archaeological documents and observations. From implements, refuse pits, traces of settlements, etc. conclusions can be drawn on the size and density of populations. Palaeodemographic analysis relies for the most part on the anthropological material of one-time populations, i.e. on skeletal finds. This fact assigns a most important role to anthropology in palaeodemographic research, especially in the field of historical investigations into length of life and mortality. It should be noted that in historical demography a special group of source material is represented by inscriptions in stone, which on account of their written character may be regarded as belonging to historical demography proper, and on account of their antiquity and material character to palaeodemography.

Anthropology and demography, these two separate disciplines, are linked by their scope of subjects over a wide field of contact. Substantially in both branches research is aimed at acquiring knowledge about mankind in general and specifically about its various groups, although their fields of research and methods are rather distinctly separated. The connections between anthropology and demography are generally known, but the opportunities arising in the course of the historical investigation of skeletal finds whenever a cemetery is excavated are less known, and certainly less exploited.

The rich source of historico-demographic knowledge that may result from the analysis of cemetery excavations usually evades the horizon of demographic scholars. For the most part, historical demography relies on the assistance of historians and tries to revive the past of population trends on the basis of written records, rather than calling on anthropologists and archaeologists to analyse material remains for this purpose. Material remains are difficult to get at for demographers and, for lack of expert knowledge, they appear to be less suitable for analytical purposes than written sources are. Maybe this is why so few demographers have been engaged in palaeodemography based on material finds. On the other hand, anthropologists and archaeologists when examining their material have often tried to find answers to the demographic problems continually turning up as a matter of course, and have thereby made many a valuable contribution to our historical knowledge of the trends in the length of human life and certain questions of mortality. Yet these experts, as they are not demographers, conducted their investigations with a rather limited setting of objectives—often because the material was scanty—or possibly with deficient methods, and for this reason, despite some attempts at synthesis, no comprehensive picture has resulted in this field.

In support of the above statements, we give a brief survey, without aiming at completeness, of the more important literature on palaeodemography available to us, including the literature on investigations into the history of mortality based mainly on the source material of epitaphs.

If the source material of epitaphs is included here, the first palaeodemographic analyses were supplied by the archaeologists of antiquity. Beloch's standard work on ancient population history, published in 1886, contains a special chapter in which the material of 1831 epitaphs from the Ist, IInd and Xth Italian regions is analysed on the basis of the *Corpus Inscriptionum Latinarum* in connection with the sex and age structure of the population. Beloch tabulated the ages at death for both sexes, the survivals, and determined on this basis the probable lengths of life at given ages, comparing these with the data in Ulpianus' table of that time. Research into population history was not limited to the antique; in 1891 Motta studied the mortality in Milano at the end of the Middle Ages. However, the material of the *Corpus Inscriptionum Latinarum* (*C.I.L.*) provides ample opportunity for further studies into the questions involved in the length of life and mortality. A comprehensive study by Harkness, analysing the material relating to age at marriage and death in volumes II–III, V–VII and XIV of *C.I.L.* was published ten years after Beloch.

The initiatives of Beloch and Harkness inspired a number of followers who were specifically studying the problems of the history of mortality. Their work shows the influence of Pearson's study which was published in 1901. Pearson, a distinguished representative of statistical research, did not collect sporadic epitaphs for studying mortality but, on the basis of Spiegelberg's data, used the description by sex and age of a homogeneous series of finds consisting of Egyptian mummies from the Roman era, and computed with adequate demographic methods the expectations of life at various ages, and analysed mortality on this basis. Although he did not treat this subject as the establishment of a new scientific field but considered it a by-product of his versatile statistical and biometrical activities, the methods he employed and the exemplary standards of his analyses have rendered his work one of the most often quoted sources of palaeodemography.

In Pearson's short study the manner in which he considers the value of the examined material as a sample (i.e. whether the series comes from a single population; whether all members of the population had an equal chance of becoming mummies; estimation of the material missing; smoothing of data) is highly instructive. MacDonnel followed his example and published his study of a similar character in the journal *Biometrika* in 1913. His work, which had been based on the data of *C.I.L.*, reported on the expectation of life according to sex and age in ancient Rome, the provinces of Hispania, Lusitania and Africa. De Marchi had analysed the data of *C.I.L.* in 1903.

During and after World War I palaeodemographic research was discontinued for some time and this pioneering work found no followers for a long time. It was not until 1927, when Todd published his investigations, that palaeodemographic research gained new momentum. His researches into the physiological and morphological changes on skeletal finds on which the determination of age at death can be based has become a standard work on mortality studies based on historical anthropological material. As a result of Todd's activities, palaeodemographic research based on opportunities found in archaeological and anthropological discoveries developed in two directions during the 1930's. Through interaction new fields of research were created.

Studies of antique populations were resumed in 1932 by Gomme who investigated the Athens of the 5th and 4th centuries B.C., then by Richardson who in the following years published his conclusions drawn from epitaphs on the expectation of life in ancient Greece. In 1938 Valaoras published an article on the expectation of life in Greece at about 400 B.C., based on the analysis of epitaphs. The problem of length of life in the Roman Empire was summarized from the demographer's point of view, by Willcox in the same year. The study of the expectation of life on the basis of epitaphs continued to be the subject of archaeologists studying antiquity. In 1945 Hombert and Préaux published their remarks on the length of life of the populations in Greco-Roman Egypt. Etienne in 1955 analysed the data of grave-stones erected in Bordeaux in the first three centuries, and in Hungary, Szilágyi made an analysis of Pannonian epitaphs in 1959, comparing them with other materials of the Roman era. The results of these epitaph analyses were then adopted by historians, and Russel, for instance, relied on them in addition to documentary material, particularly in his comprehensive work published in 1958 on the populations and population growth of the late antiquity and the Middle Ages.

The analysis of ancient epitaphs is founded on the assumption firstly that the data provided were true samples; secondly that there had been no abrupt changes in the size and structure of the studied population and thirdly that no great migration had taken place. But these requirements were not always taken into account by the investigators and even Beloch's computations were criticized severely at the time. Such criticism was justified also later on: in 1953, Burn wrote about the preconditions of analysing epitaphs. Again Russel used the data with critical reservations in his work. From the demographic point of view, Henry in 1957 and Acsádi in 1960—in connection with Étienne's and Szilágyi's work—considered it necessary to warn archaeologists that distortions arising from the special character of this material involves risks when demographic requirements are neglected.

Following the publication of Todd's studies palaeodemographic research was extended to include anthropological material in addition to archaeological finds. In 1930 Hooton published a monograph on Pecos Pueblo, which contains a study of demographic character somewhat different from the subject matter of length of life and mortality. Hooton wrote that by anthropologists, who are privileged to examine skeletal finds at excavations, the opportunity to make estimates of the size and trends of population is taken as a matter of course. Accordingly, he tried to reconstruct the development of the population—relying partly on historical records and partly on anthropological and archaeological material—being well aware of the importance of the completeness of the material and the chronology of burials. The somewhat cumbersome method he employed for solving the problem is based on death rates estimated from ages at death.

Under the influence of Hooton in America the palaeodemographic analysis of Indian cemeteries from the anthropological approach together with the investigation of populations in the preliterate stage in general were started. In 1932 Aberle wrote about the child mortality of pueblo Indians and in 1934 Kryzwicki published a book about primitive societies and their population trends. Wissler discussed the death particularities of Amerindians in 1936 and, late in the 1940's, Cook studied the problems of survival of the aboriginal populations, followed by Snow (1948) who published data on the skeletal finds of Ohio Indians. Ten years later Schwartz (1956) studied the demographic character of Cohinina's early periods; Churcher and Kenyon (1960) that of the Iroquois, and Kidder (1958) made archaeological comments on Pecos. Willey's work discussing the settlement conditions of Mayan ancient history, published in 1956, had its antecedents too. Among the investigators studying the problems of the size and development of populations with an approach similar to Hooton's, we should like to mention Nougier (1950) who tried to give an outline of the development of prehistoric populations. He relied mainly on archaeological data in the beginning but, increasingly, on the achievements of anthropologists later on. Nougier's study of the prehistoric population of France, published in 1954, is essentially based on the frequency of occurrence of archaeological finds and on the palaeodemographic data supplied by Vallois, Naef, Schenk, Sauter and Giot. His study was commented on by Henry. Along similar lines Birdsell (1958) discusses certain population problems of Pleistocene man and the structure of hunting and gathering populations. The problems of estimating population size on the basis of archaeological and skeletal finds has been summed up recently by Howells in 1960, and the subject has been dealt with in Braidwoord's (1960) accounts of the beginnings of civilization and urbanization.

The above two tendencies in subject treatment developing after Hooton emerged in a certain sense as side branches of palaeodemography. But the historico-anthropological analysis of material, which began with Todd and is still regarded as the main tendency to date, has actually gained momentum from two important studies published in 1936–1937, one by Franz and Winkler, and the other by Vallois. True, there were comparable investigations in Europe, in addition to the examination of skeletal finds of Amerindians. An attempt was made in 1935 by Skoutil to determine the sociological characteristics of the Hallstatt cemetery on a statistical basis and Euler and Werner studied the length of life of Palaeolithic man. These studies prove that the palaeodemographic approach was spreading while the work of Franz and Winkler and of Vallois are concrete models of analysis and methodology on which numbers of researchers have relied ever since.

The paper of Franz and Winkler was published in 1936 and was the result of the cooperation between anthropologist and demographer-statistician. It was based on anthropological finds from the Bronze Age in Lower Austria and many practical and theoretical problems of palaeodemography were raised in it. Although their series were rather deficient, and their age determinations were not well founded, from the distribution of the finds according to age at death they drew interesting conclusions on the trend of mortality by sex and age, and on the average age at death, etc. The question of the age structure of the studied population was also mentioned, but no solution was given, only comparative material was submitted for surmounting the difficulties.

Soon after the publication of Franz's and Winkler's work, in 1937, Vallois presented the criteria of determining the probable age at death of Palaeolithic and Mesolithic skeletons on the basis of which he outlined the distribution of deaths by age among fossil men. His paper studies this highly important material with an express palaeodemographic approach and represents an important landmark in the history of research. Under the influence of Franz and Winkler, and especially Vallois, palaeodemography became quasi naturalized in anthropology; although subsequent investigations did not bring much that was new, nor were their standards any higher, their number increased considerably from the second half of the 1940's and today the palaeodemographic approach is increasingly applied in historico-anthropological research.

In 1939, Weidenreich was the first after Vallois to write about the length of life of the fossil man. His studies included material from China. He was followed by Riquet in 1943 and, beginning from 1951, by Giot, Gerhardt, Fusté, Bröste and Jörgensen, Cunha, Gejvall, Ferembach and others who analysed palaeodemographic data rather as a by-product of anthropological research (distribution of deaths by age, length of life, and pathology). The papers by Ivaniček and Kurth are of a similar character, but Ivaniček (1951) made additional computations on the number of people and expected the hygienic characterization of periods from palaeodemographic studies, while Kurth (1955), who undertook the summarization of palaeodemographic materials later on, discussed the palaeodemographic aspects on a somewhat theoretical basis in his report on the excavations of Jericho.

Angel's palaeodemographic work published in a large number of archaeological papers written after 1947 deserves special mention. He discusses palaeodemographic aspects not only on the basis of the age structure of the buried, but also computes the expectation of life using life-table methods, and even gives brief however correct remarks about these methods.

Many of the researchers listed above saw that the determination of the distribution by sex and age at death of these series was not the only possibility inherent in anthropological material. Many others, however, did not merely touch on palaeodemographic problems, but devoted special studies to the description of their conclusions reached in the investigation of the historical problems of mortality using similar methods. Among these the work of Bartucz, published in 1950, should be mentioned first. Bartucz, who had discussed some palaeodemographic aspects of anthropological materials before, wrote in this paper about the ethnic and demographic significance of the Avarians of Hungary. Parallel with Angel's work, Senyürek in 1947 published his study on the expectation of life of the aboriginal population of Anatolia. In 1949 Sauter contributed data to the mortality of the neolithic population of Switzerland. Starting in 1952, Acsádi and Nemeskéri published a series of ten studies in which materials from purely palaeodemographic excavations were used for the first time. From anthropological material, complete enough to meet strict palaeodemographic requirements, they were able to outline the mortality features and demographic situation of populations living in Hungary during the early Middle Ages. Using life-table computations they were also able to reconstruct the size and structure of these populations. In 1952 Skerlj published the palaeodemographic data of adjacent Jugoslav regions from the same period, and Stloukal in 1962 published those of Czechoslovakia. A somewhat more comprehensive paper was published by Goldstein in 1953, which discussed some demographic features disclosed on the basis of skeletal finds. In the following year Gheorghiu and associates published the results of their work with Rumanian materials. Although the methods and materials they used to illustrate the historical development of life spans were not adequate, they were supported by investigations concerning the determination of age and sex. Research activities of a distinct palaeodemographic character grew during the second half of the nineteen-fifties; Ferembach's studies (1959, 1960, 1961) of the North African populations and the development of isolates, as well as Schaefer's, Grimm's and Schwidetzky's studies ought to be mentioned in this respect.

Naturally, the increasing number of practical results in palaeodemographic research resulted in the shaping of theories and methods in this branch of science. Many among the listed studies are thought-provoking, showing a breadth of view and many of them contain valuable methods, useful analyses and dependable results. Spengler's and Schwidetzky's articles, published in 1950, are theoretical; the former gives a theoretical survey of the state of historical demography touching on palaeodemographic studies as well, the latter surveys historical research based on anthropological materials. In several papers Acsádi and Nemeskéri give an outline of the subject and methods of palaeodemography. They show that complete series and a knowledge of chronology are required and they emphasize that the principal aim of any investigation is the determination of the developmental trends in human life spans and mortality, together with the size, structure and reproduction features of populations. In their papers published in 1957 and 1959 they show that by palaeodemographic reconstruction it is possible to revive the size and demographic functions of ancient populations that have passed without leaving written records mainly from the lifeless material of cemeteries. These discoveries can enrich anthropological research with novel possibilities.

The publications enumerated here show that palaeodemographic progress has gone a long way during the past seven decades. It is unfortunate that the results of investigations are usually limited to single periods and specific territories, as a comprehensive analysis of the trends in length of life and mortality is impeded by the deficiencies of the materials studied or the methods employed. Often these make comparisons next to impossible. Irrespective of these facts, many authors endeavour to survey complete historical periods or larger territories, and certain summaries, even if not adequately founded, are included in works of general character. For instance, in the 1949 edition of the demographic monograph by Dublin, Lotka and Spiegelmann, discussing length of life and mortality, nearly a complete chapter is devoted to the presentation of development, and Montagu's anthropological handbook of 1951 contains a similar summary. Nougier (1959) published his prehistoric anthropogeography, and Genovés (1962), in the first chapter of his book on the determination of age and sex, makes an attempt at surveying the palaeodemographic material; a new summary was given by Vallois in 1960.

We do not think it necessary to continue our survey to show that there are adequate basic points available for attempting investigations of a synthetic character. Yet the comprehensive analysis of length of life and mortality has not yet been accomplished. We can, however, attempt only an incomplete synthesis in this book because successful palaeodemographic research work is subject to methodological conditions seldom met in the past and may not be invariably fulfilled in the future either.

THE PRECONDITIONS OF INVESTIGATION

Practically every author mentioned in the literary survey has experienced the difficulties connected with the source material used, but they have referred only sporadically to the basic methodological conditions of palaeodemographic research. Yet the use of palaeodemographic source material is subject to particular aspects of criticism, just as is the case with any other historical source. A brief description will therefore be given of these preconditions, as follows:

(1) Completeness of the series studied, or else if they are incomplete, the extent thereof should be taken into account.

(2) Accurate knowledge, or estimation of adequate accuracy, of the sex and age at death of the members of the series studied.

(3) Information of approximate accuracy on the historical (archaeological) data relating to the series, such as the chronology of burials, origin of the series (circumstances of burials), etc.

(4) Fulfilment of demographic requirements in the series (unchanging 'natural' population with no migrations, the representative character of the series).

(5) Adoptation of suitable demographic methods depending on the set aim.

(6) Carrying out analytical work, from the excavation of the series to its evaluation, as far as possible from a uniform approach based on the cooperation of archaeologists, anthropologists and demographers.

The requirement of a complete series is exacting and not always possible to meet. We only know of few series that could be termed as complete, and the amount of material from which the size of the multitude of which the series forms a part and the manner in which the latter was sampled can be ascertained, is not too high either. Therefore, series consisting of epitaphs or skeletal finds are seldom suitable for demographic analyses. For it is obvious that there has been no period in which inscribed gravestones should have been erected for every dead person, and the material of cemetery excavations does not usually fulfil the above conditions.

It is an extremely difficult task to meet the requirements of completeness. Limited means or other circumstances are insurmountable barriers in the majority of cases. It is not only the epitaphs that may be fragmentary and incomplete, but many cemeteries of archaeological age are of a partial character only, as they had been tampered with earlier (despoiled or destroyed) or the graves have vanished as a consequence of geological surface changes, or perhaps foundation work. But even so, partial uncoverings may be useful for the reconstruction of the length of life and mortality trends, especially if the selection of the material has not been tendentious in any way (e.g. not only the adult skeletons were preserved at excavation). Consequently in the case of partial series, knowing the relevant historical data and the circumstances of excavation, it should always be debated whether the partial series can be treated as a sample of the population of the cemetery and whether it roughly meets the requirements of a sample and permits conclusions on the mortality of the entire population.

It should be noted that if we are to make generalizations on the basis of given cemeteries or partial excavations, on the mortality of the entire population or period, theoretically we ought to apply the rules of cluster sampling. Practice shows, however, that the cemeteries of historical populations, forming part of the same people and having been under identical social, economic and cultural conditions, usually correspond to one another in respect of essential demographic characteristics. There may be certain minor local features which differ and these can be explained by the low number of elements in the sample, and so the computed results can be generalized even if only a few series are taken into account.

The problem of completeness arises also in connection with the other requirements. For we must consider not only whether the archaeological or anthropological source material is complete or not, but also whether every member of the one-time population is represented in the series to be analysed, or can be included in the partial sample at all. Could there not have been, for instance, such a migratory movement (as accepting employment abroad, dragging into servitude, transfer for work, emigration of part of the population, etc.) or other event (military expedition, battle, etc.) as a result of which certain members or groups of the population were buried somewhere else? And, *vice versa*, could such factors not have been instrumental in the discovery that members of other populations are to be found in the cemetery of the population or series to be analysed? Was the population a 'natural' one characterized mostly by biological relations and made up of family and clanship elements, or had the number of people buried at the same place been brought together by purely social factors? Such a non-spontaneous population could be evolved by some special event, e.g. the cemetery of a monastery, convent, military camp, social class, royal tombs, or people buried in battlefields, victims of cannibalism, etc. Perhaps special customs prevailed by which certain persons were not buried with the other dead or their corpses were annihilated as in the practice of exposure, suicides, unbaptized children, cremation, etc. There may have been symbolic burials in that cemetery. In the case of series made up of epitaphs or mummies, it has to be decided whether the custom was applied only to people of a certain age, sex, family status or social standing.

It is to be noted that series consisting of epitaphs hardly ever comply with the requirement of completeness. The distribution of such series by sex and age is determined by two factors in combination, i.e. mortality and the habits governing the erection of graves. Consequently, if we knew the mortality, we could draw conclusions regarding the habits of grave erection, and if we knew these habits, we could conclude on the mortality. However, even in full knowledge of the first or second factor we should take into consideration that the probability for different tombs to survive is not equal.

It is equally important, as we have mentioned above, to determine whether the cemetery has been left undisturbed, i. e. the finds and remains needed for the computations have not been destroyed prior to the excavation. It is also important to make sure that the excavation and the work of collection is complete, whether observations are of a uniform system and unequivocal, and that chronologically or regionally different elements should not get mixed up in the material to be analysed.

It is also necessary to know the chronology of burials. First, one should determine the epoch in which the burials took place, i.e. the one from which the finds serving as the basis of computation originate. For certain purposes, e.g. estimates on the size of a population, the length of period during which the cemetery was in use must also be known. In addition to the chronological data on the beginning and end of use, the succession of burials is of great importance. The latter represents the chronological order of the cemetery itself on the basis of which the stages of demographic development can be determined. In order to establish this internal chronology, the circumstances of burials must be carefully considered, i.e. whether burials took place in groups of graves connected with the dwelling-place, or in caves, dwelling-pits, mounds, or in graves arranged concentrically, in rows or in strata, or in single graves. With ancient graves or later ones without coin finds we are usually to work with relative or estimated chronologies.

In connection with historical requirements we must emphasize how important it is to know the archaeological type of the cemetery, with the clearly discernible social and ethnic differences. Such knowledge plays an important part in the full demographic reconstruction of a population and in the understanding of social, economic, historical and biological processes involved. The quality, number, type, location and material of the various finds buried with the dead are characteristic data of social and cultural stratification and are of valuable assistance also in the study of mortality structure. The type of cemetery supplies information also on whether the investigated series comes from a population of natural origin, or from a social formation composed 'non-spontaneously' as a result of special circumstances. In such non-spontaneous samples, palaeodemographic analysis reveals the dissimilarities of distribution by sex and age and serves as a warning to the investigator to take into account particular problems in the course of his work.

The matters of detail of the six preconditions of investigation summarized above are so many and so far-reaching for every period and population that the following practice should always be used: each cemetery and each series of data must be considered separately to decide whether the data are suitable for analysis and which method should be used. In each case the real value of the results obtained by analysis must be calculated, with corrections where necessary, owing to the scantiness or deficiencies of the material available. When partial series are being investigated it is very important to decide exactly how far the data meet the requirements of statistical sampling. Mention should also be made of the accuracy requirements of age and sex determination, the anthropological and biological possibilities of which will be discussed in the next Chapter (we have already pointed out that data taken from epitaphs also require a critical approach as regards accuracy: there may arise difficulties in determining the sex from name inscriptions, in relying on the accuracy of age-recording and in connection with age-accumulation). We must conclude, therefore, that a correct appraisal of palaeodemographic investigations can only be accomplished by an expert, or a group of experts, well versed in demographic, anthropological and historical (archaeological) aspects.

LIFE TABLE CONSTRUCTION FROM ARCHAEOLOGICAL MATERIALS

If the material which is to be investigated meets all the necessary requirements mentioned above we will be able to make a full analysis, irrespective of whether it is anthropologically appraisable skeletal finds or epitaphs. We shall be able to determine the distribution by sex and age of the dead, the characteristic values of the length of life, and the respective life table functions and values. We may even be able to obtain essential facts about the size, structure and population trends of a given population.

What methods can we employ to answer the questions arising in connection with mortality, length of life and demography in general? It is obvious that life table methods combining the correlations between age and mortality into models according to sex can be used. We have chosen as a fundamental starting point of the methodology of analysis the system of life table computations and have disregarded archaeological data which are suitable only for the determination of population density, social structure and cultural standards, although they are also of interest to the demographer.

The basic idea of the computation of life tables is that if the number D_x of people who died between age x and $x + 1$ is related to the total number of people who died during the entire period of burials, the proportion d_x of the dead, i.e. the first function of the life table relating to the entire period of burials, will result. Therefore:

$$d_x = \frac{D_x}{\sum\limits_{x=0}^{\omega} D_x}$$

The method of life tables computed on this basis corresponds to the method of Graunt, the founder of demography, who used it for the first time in the 17th century for studying mortality in London; later on it was used by Petty, Halley and it is also called Halley's method. Large numbers of statisticians, mathematicians and demographers applied and improved it according to their purposes. This method has been replaced with others more suitable for eliminating distortions due to migrations and other factors, since data are being made available by population statistics showing the conditions of survival more directly.

The method of life table computation applied in palaeodemography resembles the methods of generation life tables in a certain respect. With Halley's tables the mortality conditions of the entire period of burials are summed up, including possible changes: generation tables, too, (opposed to current life tables constructed on the basis of the mortality of short periods) contain the changes of mortality taking place meanwhile, which affect the survivorship pattern of the various cohorts. At the same time, current life tables regard the momentary mortality of living generations as if it were a mortality characteristic throughout the life of a single, hypothetical generation during one century.

The results of life tables may be distorted considerably by migrations. Therefore, it is a basic requirement in preparing life tables that the investigated population and its mortality have not been affected by migrations, or if there has been migration, its effect should be eliminated. But this is very difficult, often almost impossible, when considering historical or generation life tables. Indeed the effect of migrations can only be taken into account without difficulty in current life tables. For instance, the immigration of adults increases the values of life expectancy in historical tables, while emigration diminishes them. Migration has a similar effect on mortality values in the opposite direction.

If, however, the migration in a given population is negligible, or its effect can be eliminated from the life table and mortality does not change during the investigated period, all three computation methods will produce the same results. With Halley's method, for instance, we may regard the dead as if they had been born at the same time and their mortality represented that of one cohort, as with constant conditions the mortality of various cohorts will be the same, whatever the date of birth. So there is no difference whatever between the Halley table and the generation table in this case. Nor is there any difference in the results of tables computed with modern methods where the life table of the hypothetical generation is drawn up on the basis of the probability of survival of various generations measured for short time intervals.

Thus the tables computed with Halley's method express reality, as fertility and mortality in historic periods have probably changed very little, during the time a cemetery was used. They can be used for comparison with most historical series and, taking into account the differences of principle, can be compared with current tables as well.

Technically the computation of the d_x values of the life table should begin by computing the age distribution of deaths and establishing the various D_x values. D_x is a set value if arising from the analysis of epitaphs. When anthropological finds are examined the age of the dead can be given only with approximate accuracy. Usually, dead adults' age is indicated between limits of five, possibly ten or even more years, while the age of children is given as 1–3 years or as infant I or infant II. In order to reach a correct figure for the age distribution when ages are given between limits, the number of the dead must be distributed among the ages within these limits. For example, if three people who died at the age of 18–20 figure in the series, one dead person each must be taken as aged 18, 19 and 20. If on the other hand there is only one person in the series who died in the age interval from 50 to 59, we must reckon with 0·1 dead for the various ages (with 0·2 dead with age groups of five years, etc.). When age is defined within very wide limits, such as 'adult age' or 'old age' (i. e. 23–x resp. 60–x years) the number of cases must be distributed between the lowest and highest age limits. When the frequency values of the various ranges of age are calculated, it is advisable to work to two or three places of decimals. The values of d_x, which serve as the starting point for all further computations, can be derived from the absolute values calculated for the various years of age as indicated above. The d_x series, expressing the percentage distribution of the deaths, is given to two places of decimals:

$$\sum_{x=0}^{\omega} d_x = 100{\cdot}00$$

The d_x series serves not only as the basic value of the life table, but offers in itself valuable information as regards the length of life and mortality. The location of the mode, the appearance and interrelationship of various lateral modes are all characteristic data.

When investigating small series, or if it is not necessary for the data to be broken down to individual age, i. e. if results of approximate accuracy will do, further computations of the life table can be made with an abridged method, working with groups of 5 years. Even so the data of the various 5-year groups required for drawing up the abridged life table are taken from the distributed data of the deaths.

If the d_x column is established, we can compute the number of survivors (l_x). The radix of the life table is

$$l_0 = \sum_{x=0}^{\omega} d_x = 100{\cdot}00$$

The values of survivorship for every one year—for every five years in case of an abridged table—are as follows (the formulae shown in the left-side column give the values computed for single years of age, the ones on the right side show the values obtained with the abridged method):

$$l_1 = l_0 - d_0 \qquad\qquad l_5 = l_0 - d_{0-4}$$

$$l_2 = l_1 - d_1 \qquad\qquad l_{10} = l_5 - d_{5-9}$$

etc. etc.

Probability of death (q_x) can then be computed on the basis of the distribution of deaths and the number of survivors:

$$q_0 = \frac{d_0}{l_0} \qquad\qquad q_{0-4} = \frac{d_{0-4}}{l_0}$$

$$q_1 = \frac{d_1}{l_1} \qquad\qquad q_{5-9} = \frac{d_{5-9}}{l_5}$$

etc. etc.

The computation must be made up to four places of decimals.

The values of expectation of life at birth and at various ages can be computed with the help of two further functions. The first of these is the number of years (L_x) lived by survivors at age x, i. e. between ages x and $x + 1$, and between ages x and $x + 5$ using the abridged tables. Where there is a uniform frequency of deaths, the number of years lived in the first year of life may be taken as equal to the total of the number of children attaining the age of one year and the half number of the dead (assuming that the latter lived half a year on the average).

$$L_0 = l_1 + \frac{d_0}{2} \qquad\qquad L_{0-4} = 5\,l_5 + 5\,\frac{d_{0-4}}{2}$$

Further values are computed as follows:

$$L_1 = l_2 + \frac{d_1}{2} \qquad L_{5-9} = 5l_{10} + 5\,\frac{d_{5-9}}{2}$$

$$L_2 = l_3 + \frac{d_2}{2} \qquad L_{10-14} = 5\,l_{15} + 5\,\frac{d_{10-14}}{2}$$

etc. etc.

Considering the fact that the frequency of deaths is not distributed evenly in the first year of life but is massively concentrated on the first month as a result of which those dying at the age of 0 do not live half a month on the average but a shorter period only, the value of L_0 is sometimes computed with the approximating formula of Reed and Merril as follows

$$L_0 = 0{\cdot}2\ l_0 + 0{\cdot}8\ l_1$$

and for the subsequent four years:

$$L_{1-4} = 0{\cdot}34\ l_0 + 1{\cdot}184\ l_1 + 2{\cdot}782\ l_5$$

The parameters of the formula depend on the level of age-specific infant and child mortality, so the given approximation is not correct in every case.

The use of the above approximating formula can usually be omitted in the analysis of anthropological series. Namely the length of life determined from skeletal finds is given within such wide limits that modifications resulting from such refinement remain within the probable errors of the results anyway. The condition of the even distribution of deaths approximates to reality well at the other ages, and is applied even in current life tables.

The number of years lived by survivors at given ages can also be computed on the basis of the pattern of survivorship:

$$L_0 = \frac{l_0 + l_1}{2} \qquad L_{0-4} = \frac{5(l_0 + l_5)}{2}$$

$$L_1 = \frac{l_1 + l_2}{2} \qquad L_{5-9} = \frac{5(l_5 + l_{10})}{2}$$

etc. etc.

The computation should be made up to three places of decimals.

The other set of values needed for expectation computations shows the total number of years (T_x) that can be lived to the highest age attainable by survivors aged x until all have died. It is computed from the L_x values as follows

$$T_x = L_x + L_{x+1} + \ldots + L_{\omega-1} = \sum_{x}^{\omega-1} L_x$$

The total number of years that can be lived after birth by the entire populations of the life table is

$$T_0 = \sum_{x=0}^{\omega-1} L_x$$

Further values are calculated as follows

$$T_1 = T_0 - L_0 \qquad T_5 = T_0 - L_{0-4}$$

$$T_2 = T_1 - L_1 \qquad T_{10} = T_5 - L_{5-9}$$

$$\text{etc.} \qquad \text{etc.}$$

The computation of T_x is only of technical importance. The values L_x, however, are necessary not only for determining the expectation of life but may also be used directly, for studying the age structure of the stationary population. The values l_x and L_x are very similar both as regards their theoretical significance and actual value. However, the number of those attaining a given age is always higher than the number of years lived by the survivors at the same age ($l_x > L_x$). L_x corresponds to the mid-year population of a cohort aged x.

The expectation of life at birth or at a given age (e_x^0) is computed—to two places of decimals—as follows

$$e_0^0 = \frac{T_0}{l_0}, \qquad e_1^0 = \frac{T_1}{l_1} \text{ etc.}$$

In addition to these most important functions of the life tables, the values of further fuctions can also be derived, e.g. probability of survival or probable length of life (cf. Chapter I).

In order to show sex differences, the computations are made for males and females separately and also for both sexes combined. When anthropological series are analysed, it is seldom possible to draw up life tables for males and females separately as the determination of the sex of children is difficult. But even in such cases it is advisable to establish the values of the life table separately from the age of 20 upwards where sex can be determined dependably.

FURTHER PROBLEMS OF ANALYSIS

By using the data of life tables, other population characteristics can be determined. The size of the population, for instance, can be estimated on the basis of the total number of the buried and the length of the burial period. For this purpose we have developed the following simple formula

$$P = k + \frac{De_0^0}{t}$$

where P = the average size of population,
D = the total number of the dead,
e_0^0 = the expectation of life at birth in the life table,
t = the period during which the cemetery was in use,
k = a correction factor, approximately 10 per cent of t

Table 9 shows the relationship between the population, number of the dead, length of life and the period of burials, providing a basis for making rough estimates. The age and sex structure of a population can also be estimated, in addition to its size. As has been mentioned, age distribution can be determined as a stationary age distribution on the basis of the values of L_x, but the l_x values can be used for this purpose as well; these are referred to some power of ten and can therefore be handled more conveniently. The age structure can be determined for men and women separately, but before doing so the ratio of the sexes must be estimated.

As the conclusions to be drawn from the sex ratio are very important in respect of the structure and reproduction of a population, we must not be content with regarding the ratio of men's and women's graves as the sex ratio. For the ratio of men's and women's graves or epitaphs, or the ratio of skeletal finds whose sex has been diagnosed are not identical with the actual sex ratio of the one-time population. Determination of the sex ratio is necessarily inaccurate because of the difficulties involved in determining the sex of children's skeletons, and its validity covers only the members of juvenile or older age groups, but not the whole population. When epitaphs are analysed it must also be taken into account that the sex ratio of the dead reflects only the conditions to be found in the cemetery among the dead. These are not necessarily in agreement with the conditions of the population that had used the cemetery. If, for example, the sex ratio in a given cemetery is 1 : 1, but the age at death of males is higher, then it is obvious that more men than women were living at the same time in the community using the cemetery.

The number of people of either sex must be estimated separately (by means of the formula used for determining the size of the living population) and the sex ratio can be determined on the basis of the number of men per 1,000 women (masculinity ratio). When skeletal finds are analysed and no attempts are made to approximate the sex ratio of children (assuming a higher number of male births and a higher mortality of boys) we often must content ourselves with estimating the sex ratio of the population over the age of 20.

Factors of the social structure, such as monogamy or polygamy, i.e. the family pattern, are sometimes inferred from the sex ratio. Such conclusions are unfounded as a rule. However, the number and average size of small biological family units can be estimated by means of the sex and age structure fairly well. The reproduction of a population and the demographic limits of the trends in genetic variants are mainly determined by the population in the reproductive age and by the number of basic family units that maintain reproduction. The number of bio logica family units can be approximated from the stationary size of the female population aged 15–49.

The death rate of the population of the life table can be derived—as the reciprocal of expectation of life at birth—and will be the same as the general death rate, given stationary conditions. By using the vital index, from the death rate we can get

TABLE 9

Population size estimated on the basis of the number of buried, expectation of life and the period of burials

No. of dead (D)	Life expectancy at birth (e_0^0)					Period during which the cemetery was used (t, in years)
	20	25	30	35	40	
2,000	880	1,100	1,320	1,540	1,760	50
	440	550	660	770	880	100
	293	367	440	513	587	150
	220	275	330	385	440	200
	146	183	220	257	293	300
1,000	440	550	660	770	880	50
	220	275	330	385	440	100
	146	183	220	257	293	150
	110	138	165	193	220	200
	73	92	110	128	147	300
500	220	275	330	385	440	50
	110	138	165	193	220	100
	73	92	110	128	147	150
	55	69	83	96	110	200
	37	46	55	64	73	300
300	132	165	198	231	264	50
	66	83	99	116	132	100
	44	55	66	77	88	150
	33	41	50	58	66	200
	22	28	33	39	44	300
200	88	110	132	154	166	50
	44	55	66	77	88	100
	29	37	44	51	59	150
	22	28	33	39	44	200
	15	18	22	26	29	300
100	44	55	66	77	88	50
	22	28	33	39	44	100
	15	18	22	26	29	150
	11	14	17	19	22	200
	7	9	11	13	15	300
50	22	28	33	39	44	50
	11	14	17	19	22	100
	7	9	11	13	15	150
	6	7	8	10	11	200
	4	5	6	6	7	300

information regarding population growth. The rate of natural growth (e) is the difference of the birth (n) and death rates (m):

$$e = n - m$$

The vital index (v) is the quotient of these two rates:

$$v = \frac{n}{m}$$

and shows the mortality conditions, i.e. the frequency of childbirths by women in the propagative age, at which a given growth takes place. If, on the basis of other data, it is possible to forecast a correct hypothesis on population growth, the birth rate can be estimated in the indicated manner, and even the outlines of female fertility can be given.

In conclusion, the role played by migrations ought to be mentioned. As migrations affect the life table, their extent can be traced by comparing the distortions in the life table of a specific population with a table showing a population living under comparable mortality conditions undisturbed by migrations.

In connection with life table computations we should like to refer to the question of smoothing and completion. Smoothing may usually become necessary because the number of cases in the series to be analysed is not high, as a consequence of which the data in the table might show undue fluctuations. If such fluctuations are not too intense, and do not interfere with the interpretation, smoothing may not be necessary. If, however, the amplitude of fluctuations is considerable, or the frequency is periodic, or signs of age accumulation appear, the table must be smoothed. Adjustment of the table must be carried out with the absolute values D_x of the dead, or with their distribution values d_x. But before smoothing is effected, completions must be made if necessary (e.g. including the missing data of infant deaths).

The phenomenon of age accumulation has been referred to in Chapter I in connection with the accuracy of data on old age. But this phenomenon also plays an important part in epitaph material. It is not easy to secure the accuracy of age data even now. There are still people who would like to be held younger or older than they are and others are fond of rounding off the number of their years. The risk of rounding off was still worse in bygone ages when, in the absence of registration, the accurate recording of the chronological age was not considered important. Consequently the number of persons at certain ages at death was considerably accumulated.

The major accumulation tendencies are the following:

(1) Bringing up or exaggerating the age of very young children (e.g. a child of 10 months is reckoned as being 1 year old).

(2) Ages are brought up to the age of majority before coming to age, and brought down to it afterwards.

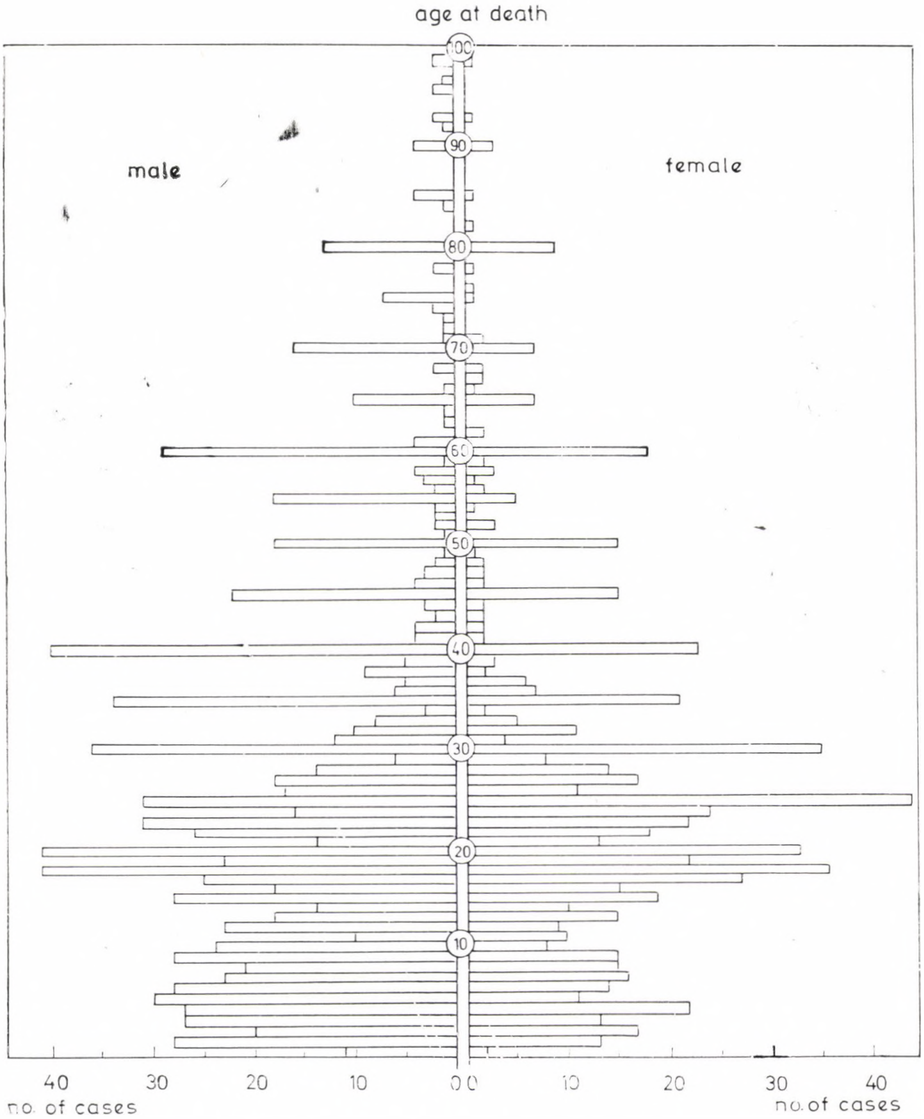


Fig. 11. Age accumulation on grave-stones erected in ancient Italy.

(3) Accumulation at ages that amount to the multiple of five, especially if ending in 0. This type is frequent with people using the decimal system; other numerical systems may lead to accumulation at the multiples of other numbers (e.g. twelve).

(4) Rounding up the age of old people, especially in case of very old people (the age of 100 has the greatest appeal here).

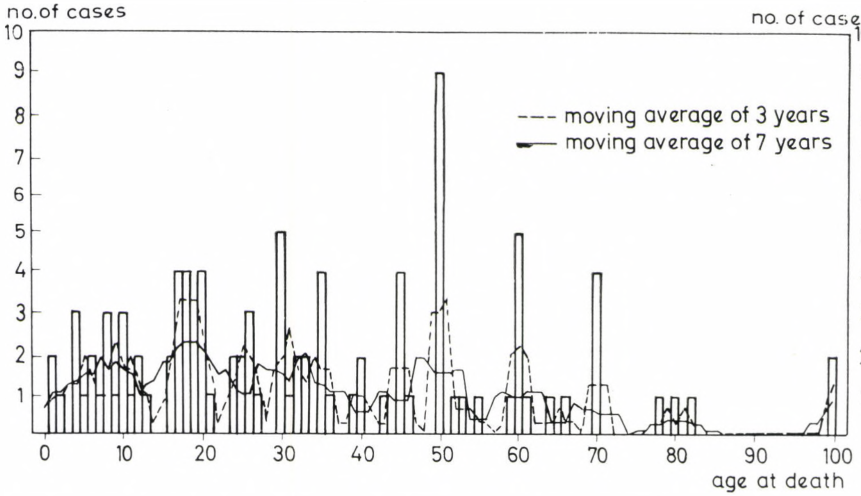


Fig. 12. Age data on Roman epitaphs of Intercisa, smoothed by means of moving averages.

Of the types of accumulation shown above, the first one did not occur in ancient epitaphs, mainly because it was not usual to erect gravestones for dead infants. This circumstance must be taken into account whenever a series is to be completed. The effect of the second type of accumulation is felt, e.g. in materials of the Roman era, when the time of coming to age was strictly kept in evidence as important legal consequences were attached to it. This, naturally, does not exclude the effect of such tendencies altogether. The series of the Roman era are mainly affected by accumulation at the multiples of five, but the tendency to bring up figures at old age is also present.

As an example let us mention Beloch's data. Figure 11 shows the age at death of people whose sex could be determined on the basis of epitaphs found in regions I, II and X of Italy and included in *C.I.L.* The age distribution of the dead of both sexes shows that the Romans, who used the decimal system, did not consider it necessary to remember their age and often rounded it off.

Old-age accumulation is also evident from Fig. 11. It appears from the epitaphs that not a single man or woman died at the age of 69, 79 and 89, while the number of deaths at 70, 80 or 90 is considerable. As has been mentioned, the appeal of hundred years, or round figures above it, is very strong as appears also from Pliny's or Phlegon's records (see also Fig. 12).

A number of methods are available for eliminating such distortions. These are based for the most part on the smoothing of accumulated data. Their application is justified not only with the above-discussed types of accumulation, but also for smoothing other discrepancies of data—e.g. the consequences of inaccuracies in determining age on the basis of skeletal finds—provided, however, that smoothing is aimed solely at eliminating distortions and not at levelling off actual differences.

The smoothing method requiring the greatest skill and consideration is the graphical method. This means that some regularly changing curve is applied to data illustrated graphically. The other methods of smoothing are of a mechanical or analytical character. The simplest and usually adequate mechanical method is that of the moving averages. In this case the original values are replaced with the means of successive data. The values to be averaged are taken from both sides of the age in question (including the value to be smoothed). The two extreme members of the series to be averaged are successively changing as the series 'moves' along with the age values to be smoothed. For example, the smoothed values of a three-member moving average series at the age of 18–20 years is as follows

$$D_{18} = \frac{D_{17} + D_{18} + D_{19}}{3}$$

$$D_{19} = \frac{D_{18} + D_{19} + D_{20}}{3}$$

$$D_{20} = \frac{D_{19} + D_{20} + D_{21}}{3}$$

etc.

Smoothing by means of moving averages is illustrated in Fig. 12, which shows the age distribution of a series made up of 100 Pannonian epitaphs (the gravestones come from Intercisa, eleven out of the hundred were probably brought there from Aquincum at the close of the Roman era). Distribution of deaths was smoothed here first with a three-member, then with a seven-member series of moving averages.

A similar method, involving more computation work, is analytical smoothing based on the method of least squares. This consists in assuming that the given series of data is changing regularly in accordance with some second-degree or third-degree curve, and replacing the actual data with those obtained from the equation of the curve.

The smoothing methods listed above consist, essentially, in a redistribution of accumulated sums in a manner that is chosen arbitrarily. As opposed to these, more dependable results are obtained in certain cases by a method where successive age data are so grouped that the totals within the groups should correspond to the total of real data which serve as the basis but are actually unknown to us. Such groupings usually include five-year age groups (e.g. 3–7, 8–12 etc. years of age). The limits of the groups should be set in a manner that the grouping cause the smallest distortion possible. In certain cases the criterion of grouping with minimum errors is that the pertaining curve is showing the least fluctuation.

We should like to add a few critical remarks to the palaeodemographic methods outlined so far and these should be taken into account when working with their results.

(1) Although based on careful research, the data forming the basis of the computations are not the result of present-day statistical sampling; thus an absolute absence of distortion (completion and the accuracy of the chronological age) can hardly be expected.

(2) The results of life table computation depend on the extent to which the sources used fulfil the criteria of the palaeodemographic method employed. Data determined on the basis of the life tables in respect of the size, structure and reproduction of a population apply to the stationary type of population and, although giving a fairly good approximation to real conditions in certain cases, are therefore likely to differ from reality to a certain extent.

(3) From the statistical point of view, the analysis of length of life, mortality and population characteristics in general, if based on a single series, is actually a monograph and consequently its results cannot be generalized for longer periods or larger regions without reservations. It should be added, however, that taken on a historical scale there are no substantial differences between the various series even if they come from periods or regions far remote from one another. The differences, if any, are not so considerable as in our era, therefore the drawing of conclusions of a generalizing nature cannot be regarded as unfounded even if the number of available series is relatively low.

(4) Historical investigations in the field of both the biological and social sciences must often rely on demographic information. The necessity of palaeodemographic research is justified by the lack of any other source supplying such information.

CHAPTER III.

DETERMINATION OF SEX AND AGE FROM SKELETAL FINDS

From the biological point of view, the individual and social position of man is determined primarily and the most comprehensively by his sex and age. These two characteristic features are the basic subject of historical anthropology and palaeodemography, and should be estimated invariably when individual skeletal finds as well as series are evaluated. Owing to the lack of written sources, excavated skeletal remains provide the only suitable means of studying the historical development in the life span of ancient populations. This can be done by determining the sex and age at death. These two factors, in addition to being utilized by the biologist and demographer, also help to solve anthropological problems and to make historical reconstructions. Extreme care and circumspection must be taken relating to these fundamental data. A detailed description of the methodological problems of sex and age determination, and of the technique of analyses will be given in the following.

THE POSSIBILITIES OF SEX DETERMINATION

Sex identification is a highly important task when considering the differences manifest in the length of life and the mortality pattern of the sexes. This is rather difficult when working with skeletal finds, since the secondary sex characters that can be discovered on the skeleton are not so marked as on the living. The complexity of the problem is aggravated by the fact that individual manifestations of secondary sex traits of the skull and the various skeletal bones may vary considerably both in measurement and morphologically; it is even possible to distinguish masculine, hypermasculine and femino-masculine males, as well as feminine, hyperfeminine and masculo-feminine females. Secondary sex traits may also be present in a form showing an apparently indifferent individual. In these marginal cases sexing becomes especially problematical. In cases where only the skull or some other less characteristic parts of the skeleton are available sexing presents considerable difficulties (Harsányi, Nemeskéri and Földes, 1963). Unfortunately, the majority of ancient finds are but fragmentary skeletal remains (Harsányi and Nemeskéri, 1964).

A further factor to be considered are the variations in the morphological sex traits according to regions and historical periods due to differences in living conditions, hard physical work, and functional wear of the bones. Obviously a clear-cut identification of sex and the degree of sexualization is very difficult under such conditions. Sexing of individuals is difficult when studying both Mesolithic populations living under adverse conditions and civilized peoples. In the former the secondary sex characters are predominantly masculine and in the latter they are manifest in a weakened, more feminine form owing to different living conditions.

The various bones of the skeleton, and their morphological and metric features cannot be equally used for the purpose of sex determination. For instance, first class sex indicators are the pelvis as a whole as well as the individual pelvic bones or the head of the femur. The skull may be of primary importance in certain cases, while the long, short and flat bones of the skeleton are of secondary importance.

The robust quality of the bones is another possibility in sex determination; marked robustness or its absence may serve as indicators of the male or female sex, respectively. It ought to be remarked, however, that the absence of robustness is no absolute indication of the female sex, as the sex traits of the skeletal bones are greatly affected by constitutional factors. In this respect the thickness of the bone, the appearance of muscle markings, lines and spines should be considered. The value of these features is obvious if populations are considered as a whole, but is rather limited when dealing with individual determinations. In addition to the thickness of bones, their weight might also be of some help, although in historic or prehistoric skeletal finds it is bound to be influenced by decomposition processes depending on soil conditions and the time elapsing between burial and uncovering.

Sex determination also depends on the individual's age. The chances of an accurate determination are the greatest in adults (young adult–middle adult–old adult age) showing definitely marked secondary sex characters. Theoretically the sexing of children is also possible, based on the measurements and morphological traits of the skeletal bones, but in practice sex can at best be only presumed.

The presumed age at death should always be considered, as at young (juvenile) and early adult age the sex characters of men are often feminine, while they show alterations towards masculinity in women following the menopause. Taxonomic points of view are just as important as age. Secondary sex characters observed on skeletal bones are usually described in literature concerning *Homo sapiens* in a rather uniform manner, but in fact substantial metric and morphological differences may occur between the great races, such as described by Genovés (1959, 1962) and Krogman (1962).

Sex determination is made in three steps. First the secondary sex characters of the skeleton are established followed by investigation into the degree of sexualization, and finally the actual sexing is made. In addition to the degree of sexualization established on the basis of sex characters manifest in the skeletal bones, also factors connected with microevolution, gracilization, age, living conditions, functional wear, i.e. work, are taken into account when determining the sex of a skeletal find (Nemeskéri, 1962).

In the final analysis, the accuracy of sexing depends on the completeness of the characters observed. The authors of anthropological, anatomical and medicolegal works take a fairly uniform stand on this question. Krogman (1962), for example, concludes that if a complete human skeleton is available, accuracy of sexing is 98–100 per cent in the most favourable cases. Based on the pelvis only, accuracy is 95 per cent, based on the complete skull (jawbone and cranium) it is 92 per cent, and if the complete skull and the pelvis are examined together, accuracy is 98 per cent. The long bones of the extremities in themselves afford an accuracy of 80–85 per cent, and the long bones plus pelvis, an accuracy of 98 per cent. The complete skull and the long bones of the extremities taken together afford the same accuracy as the pelvis. Trevor (1950) agrees with Krogman (1962), but Hrdlička (1920, 1952) says that accuracy in sex determination is only 80 per cent if based on the skull without the jawbone, and that this accuracy may be increased to 90–92 per cent if either the mandible or the skeletal bones are available. Hrdlička (1952) believes that accuracy of determination is no more than 96–98 per cent even if the complete skeleton is available. He observes that if 100 skeletons are analysed, determination may be doubtful in 2–4 cases even if made by highly skilled experts. Hooton (1946), and later also Krogman (1962), reached the conclusion that the accuracy of sexing is relative even in cases of large series, and is affected by a number of factors; so they suggest a 5–10 per cent lowering of the above probabilities. B. Mueller (1953) emphasizes that sex determination requires much circumspection as the result might often be doubtful. For a reliable determination an adequate choice of method, critical approach and much practical experience are required.

SEX DETERMINATION ON THE BASIS OF THE SECONDARY SEX CHARACTERS OF THE SKELETON

In anthropological literature the sex characters found on the skeleton are often described in general terms only. Following from their biological nature, these characters may appear in a most varied form and show considerable deviation if referred to a given norm. It also happens that various sex characters are examined separately, and are not classified according to their importance (Walcher, 1934). Such findings may contain contradictions, which may render the results of sexing doubtful. Therefore, we intend to discuss the sex differences in the skull, pelvis (Strauss, 1929) and other skeletal bones, showing the biological content of sex dimorphism and the practical requirements of sex determination (Heyns, 1947; Imrie and Wyburn, 1958; Stewart, 1954; Iordanidis, 1961–62).

As regards the skull, the most conspicuous feature is perhaps that in the male skull there are more anatomical details than there are in the female skull. The former shows more muscle markings and lines. The female skull is more rounded, the features are more gracile, the muscle markings also tend to be smoother and the lines are less prominent (Woo, Joo Kang, 1949; Keen, 1950). The male skull is heavier, with a capacity of 150 cm^3 more on the average than that of the female skull. The male facial skeleton is more massive—especially in the malar region—broader, and more rugged. The female facial skeleton is smaller, narrower, the orbit is large and the circular form, characteristic of children, is common. The male mandible is heavier, broader, and higher; the ramus is also higher, and broader. Male teeth are accordingly larger, broader, and more robust (Gustafson and Simpson, 1953; Brothwell, 1963). The general sex characters of the male and the female skull have been summed up in Table 10 on the basis of data bv Martin-Saller (1957), and Krogman (1962).

In addition to general sex characters given for the skull as a whole, there are a number of anatomical features to be considered for sex determination. In the following we shall discuss such features as described by Lander (1917–19), Hrdlička (1920, 1952), Hooton (1946), and Krogman (1962).

TABLE 10

The general sex differences in the skull

Trait	Male	Female
General size	Larger, heavier	Smaller, lighter
Average weight, g	795	595
Average capacity of cranium, cm^3	1,450	1,300
Cranial bones in general	Thicker, with marked muscle markings	Thinner, with less marked muscle markings
Roof or vault contour	Less vaulted	Intensely vaulted
Foramen magnum	Larger	Smaller
Forehead	Higher, receding	Lower, rounded
Frontal eminences	Small	Large
Parietal eminences	Small	Large
Glabella and superciliary arch	Marked, rugged	Smooth, moderately marked
Orbits	Squared, subrectangular	Rounded
Supraorbital margin	Heavy, protruding, rounded	Thin, sharp
Mastoid processes	Larger, heavier	Smaller, more pointed
Facial skeleton	Larger, broader	Smaller, narrower
Mandible	Larger, higher, broader	Smaller, lower, narrower
Mandibular angle	Approximates rectangle,* masseteric tuberosity marked	Obtuse, rounded, surface corresponding to masseteric tuberosity smooth
Teeth		
Incisors	Broader	Narrower
Cuspids	Longer	Shorter
Molars	Larger	Smaller**

* Owing to loss of teeth and atrophy, the mandibular angle of males also becomes obtuse at old age.

** The number of cusps on the lower molars, expecially on *M* 3, is often less than usual.

Among the anatomical traits of the skull the appearance of the glabella and superciliary ridge are highly important in demonstrating sex differences; both are more marked in males than in females. The degree of development of the glabella (the eminence of the frontal bone above the root of the nose) is expressed by six degrees according to the classification by Broca (1879) (from 0 to 5); the various degrees range from the entirely flat variety that does not depart from the plane of the frontal bone to the massively protruding shape. Female skulls are usually characterized by degrees 0 to 2, male skulls by 3 to 5. The definitions used for characterizing the supraorbital ridge are the following: 'traces', 'indistinct', 'moderate', 'medium', 'marked', 'extraordinary'. The first three definitions are usually characteristic of females, the rest of males. The male sex may also be characterized by a complete transversal course of the supraorbital margin, which assumes the character of a torus supraorbitalis in such cases. It should be remarked that the 'traces' and 'moderate' types may occur in males, especially at early adult age, and *vice versa*, the 'marked' version may occur in females at young adult or, perhaps more often at middle adult age.

Size and shape of the mastoid processes are also characteristic; they are described with the following terms: 'low-narrow', 'moderate', 'medium', 'heavy-massive'. 'Medium' and 'heavy-massive' are characteristic of males; 'low-narrow' and 'moderate' degrees are frequent in female skulls. In addition, the process may be 'high-massive' or 'broad-stubby-low' which is characteristic of male skulls, while female skulls are characterized rather by 'low-narrow', or 'high-pointed' forms. Naturally, these traits cannot be regarded as unfallible indicators of sex.

Important information for sex determination can be derived from the appearance of the external occipital protuberance (the median prominence on the outer surface of the squamous part of the occipital bone). Based on Broca's classification, six degrees of this protuberance are distinguished (0 to 5), ranging from a smooth surface to the form protruding like a stud. The commonest degrees in female skulls are 0 to 3, in male skulls 3 to 5. The development of the nuchal lines and the external occipital crest may range from the 'trace' degree to 'extraordinary', the more marked forms indicating males. Marked temporal line and supramastoid line are characteristic of the male, their absence or indistinct appearance of the female.

The base of the skull of males contains more evident anatomical details and more marked sex traits. The base of the female skull is flatter. The pterygoid process of the sphenoid, the styloid process of the temporal bone, the mandibular fossa and the occipital condyles must be observed first of all.

One of the features most often used is cranial capacity. For its determination the three principal measurements (Pittard, 1947) of the cranium are established as a rule. In this connection it should be noted that the cranial capacity of males calculated in this way is 100–200 cm^3 less than it is in reality; the difference is smaller in case of females. This discrepancy is explained by the differences in the thickness of the cranial wall and in the amount of morphological details on the endocranial surface between the two sexes. The thickness of the male cranium measured at the squama occipitalis is 4–7 mm, or possibly 6–9 mm, that of the female cranium is 3–5 mm, or rarely 4–6 mm. Similar differences appear at the pars temporalis of the parietal bone. Owing to these factors, capacity calculations on the basis of the three principal measurements may produce misleading results in the determination of sex.

The sex characters of the facial bones are highly important factors in sexing. As has been indicated above, the orbit may be 'rounded', 'circular', 'square' or 'rectangular'. According to Whitnall's (1932) measurements and calculations, the opening of the female orbit is larger compared with the whole face than that of males; the average difference between the sexes is 1·5 mm in width and 0·5–0·7 mm in height. The supraorbital and infraorbital margins of females are thin and sharp, while in males they are much thicker and rounded. The heavy anterior nasal spine, the large size of the nasal bones in general, their protrusion from the plane of the face, the more marked malar region, the protrusion of the jugae alveolares corresponding to the dental sockets on the maxilla, and the sharp demarcation margins of the nasal aperture are clearly recognizable sex characters of the male facial skeleton. Along with the regression of the upper and lower dental arches the sex differences become less marked.

The appearance of the malar surface is a good criterion of sex determination. In males it is higher and thicker, with a marked tuber malare and marginal process. The marginal process of males often appears as a sharply delimited part forming a triangle. The malar surface of the female face is low, its surface is smaller, it is finely arched and its contours are blurred. The zygomatic arch may be described as 'thin', 'moderate', 'medium', 'heavy' and 'thick'. The latter two types are common in males, while the 'thin' and 'moderate' types occur more often in females. The alveolar process of the maxilla is usually higher in males than in females. The importance of this feature is equivalent to that of the malar region in sex determination.

The male palate is usually broad, long and vaulted, while female skulls are characterized by shorter, rounded, sometimes flatter palates. Teeth are secondary criteria in sex determination. The teeth of females are usually smaller, those of males larger and longer; but a sex diagnosis based on the teeth is rather uncertain. It is only from the size of the canines that male sex can be definitely inferred in certain cases.

The sex traits of the mandible have been studied most thoroughly, e.g. by Morant (1936), Martin and Saller (1957) and Cleaver (1937–38). They have found that the size and weight of this bone, the degree of development of the chin, its medial or bilateral shape, the height and width of the ramus, the degree of the mandibular angle, the amount of muscle markings at the gonion area, the size and degree of development of the condyles are all features supplying information regarding sex. A short, narrow, low, gracile mandible of relatively light weight, a low symphysis, a rounded mandibular angle, the even, smooth surface of the gonion area, a narrow ramus and a rounded chin are female characteristics, while the opposite is characteristic of males. Mandibular angles of more than 125° are indicative of female sex. We should like to emphasize that sexing can be based only on a simultaneous presence or absence of all these traits, as regressive processes accompanying the advance of age may affect the individual characters in many respects. The mandibular angle, for example, may assume values exceeding 125° in the late mature or senile age even in men as a result of losing the teeth, which also reduces the height of the alveolar arch (Schranz, 1961).

Krogman (1962) recommends taking into account the sex characteristics of the skull for sex determination in the following order of diagnostic value: general size and architecture of the skull, supraorbital ridges, mastoid processes, occipital region, zygomatic bones, orbits, mandible and palate (Augier, 1931).

In Krogman's (1962) opinion, the maxillary sinus and especially the frontal sinus should also be studied, as the size and capacity of the latter are considerably larger in males.

As has been shown in the foregoing, the cranial bones display considerable sex differences. Yet a skull is not always available for anthropological analysis; therefore postcranial bones, primarily the pelvis and the long bones, might also be important in sexing. Naturally, the most comprehensive analysis is the one based on both cranial and skeletal finds.

The secondary sex characters of the pelvis are functional, as determined by female reproduction (Bernard, 1951–52; Greulich and Thoms, 1938, 1939). The female pelvis is lower and wider, the iliac bones are more divergent laterally, and the pubic angle is rectangular or obtuse. The ilium of the male pelvis tends to the vertical, the pelvic inlet is narrow, heart-shaped and the pubic angle is acute (Young and Ince, 1940) (Fig. 13). The general sex differences in the pelvis are summed up in Table 11 according to the classification of Stewart (1956), Martin and Saller (1957) and Krogman (1962).

TABLE 11

Sex differences in the pelvis

Trait	Male	Female
Pelvis as a whole	Massive, with marked muscle sites Narrower, higher	Gracile, with less marked muscle sites Wider, lower
Ilium	Tends to the vertical	Laterally more divergent
Iliac crest	Tends to S-curvature	More arched
Pelvic inlet	Narrow, heart-shaped	Elliptical
Sacrum	More arched, narrower	Ventral curve less distinct, broader
Greater sciatic notch	Close, U-shaped	Wider, V-shaped
Obturator foramen	Oval, with longer vertical axis	Triangular, low, wide, with sharp edges
Acetabulum	Larger, broader, tends to be directed laterally	Smaller, position more antero-lateral
Pubic angle	Narrow, acute-angled	Wide, rounded, rectangular or obtuse

Of the entire skeleton the pelvis as a whole as well as its various parts show the most distinct manifestations of sex characters, and it is on this basis that sex can be determined most accurately (Thoms and Greulich, 1940; Muratori, 1951;

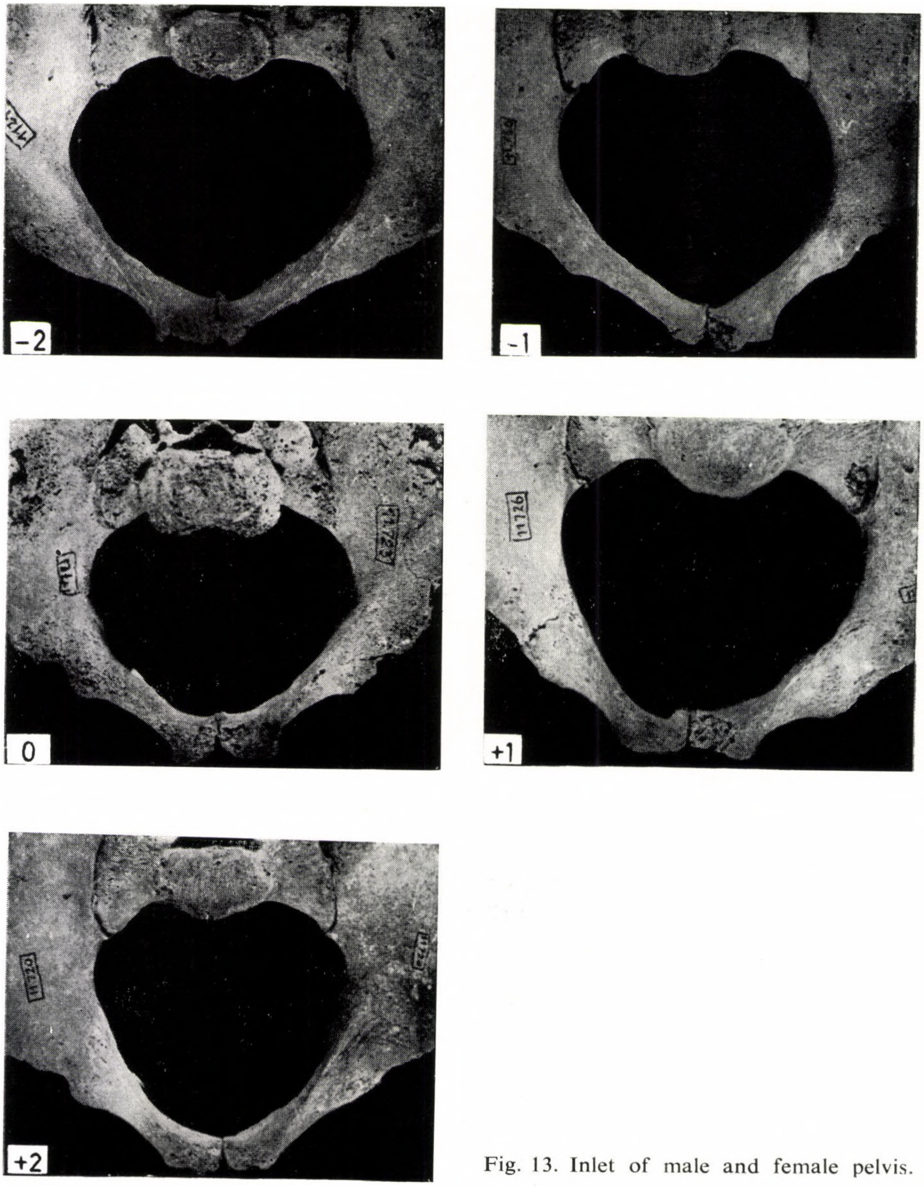


Fig. 13. Inlet of male and female pelvis.

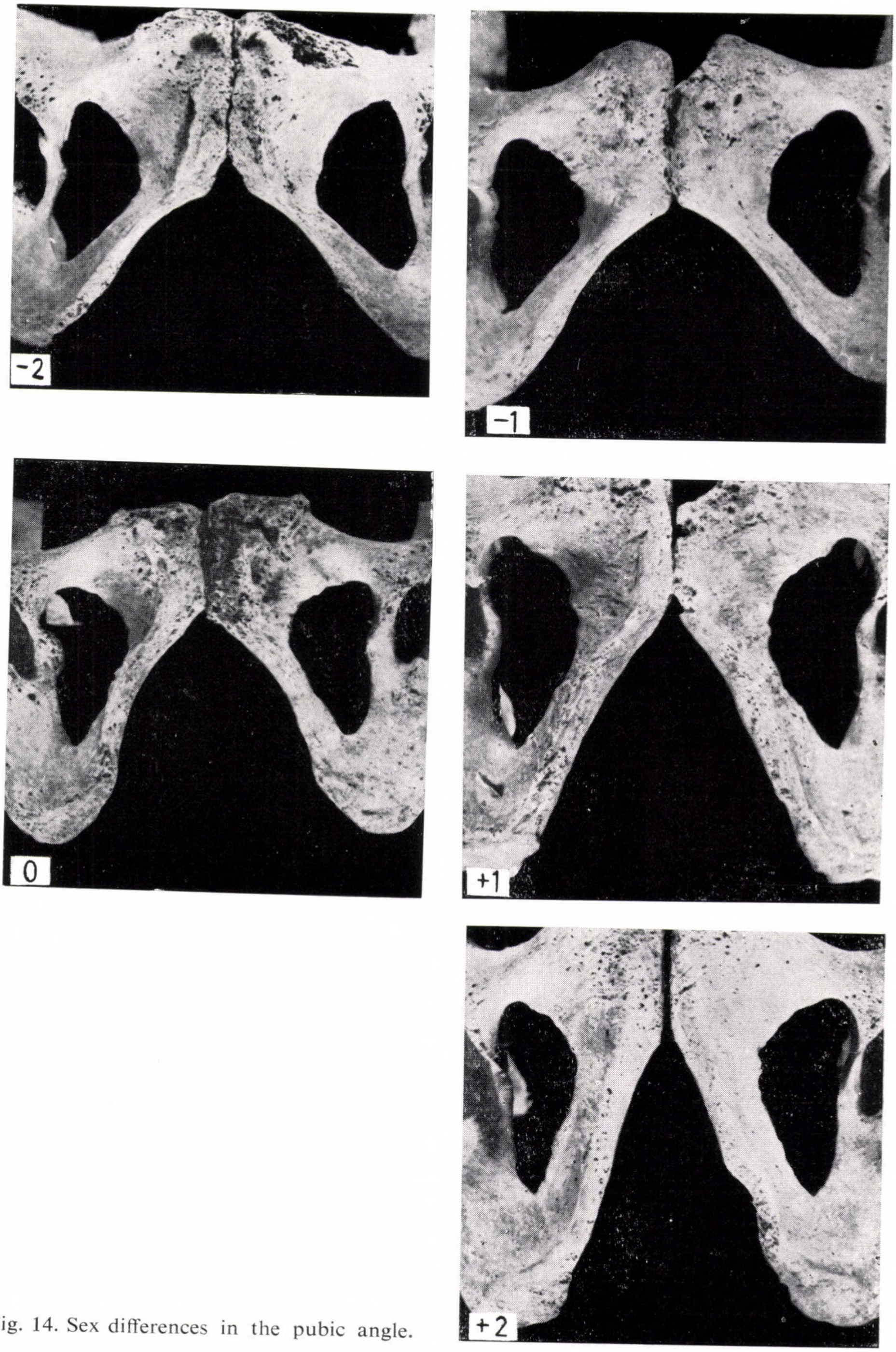


Fig. 14. Sex differences in the pubic angle.

TABLE 12

Most important pelvic measurements and indices

Measurements, indices	Means characteristic of	
	mal	female
Pubic angle, degree	70	110
Pelvic breadth, mm	270	250
Breadth-height index	79	74
Average length of pubis, mm	74	78
Minimum and maximum length of pubis, mm	65–83	69–95
Average ischium length, mm	88	78
Minimum and maximum ischium length, mm	75–98	69–93
Mean ischium-pubic index	84	100
Minimum and maximum of ischium-pubic index	73–94	91–115

Siracusa, 1955). The pelvis has been mentioned in the second place, after the skull, when assessing the value of various skeletal finds from this point of view only because fewer pelvic bones are collected during excavations than are skulls, and even of the pelvic bones saved few have remained intact and suitable for anthropoolgical analysis (Hanna and Washburn, 1953). The sex differences in the important measurements and indices of the pelvis are shown in Table 12.

Although the sex characteristics of the pelvis shown in Table 12 relate to adults, it is also possible to determine the sex on the basis of these values at juvenile age. Under favourable conditions estimation of the sex of skeletons at the early stages of development, i.e. in the infant age groups, may also be attempted (Boucher, 1955).

The diagnostic value of the traits shown in Table 12 is not the same. An order of importance might be suggested as follows: pubic angle, pubis and ischium (these two values are interdependent), and, finally, the greater sciatic notch.

Washburn (1948, 1949) has studied the pelvis of 300 individuals and found that the slim V-shape, an acute pubic angle in males is a result of measurement changes in the pubis taking place in late puberty. The angle becomes U-shaped, definitely obtuse and wide in females at the same time (Fig. 14). Yet measuring the values of the pubic angle is cumbersome, and Washburn (1948, 1949) therefore suggests that it is preferable to measure the length of the os pubis and os ischii, and to compute the ischio-pubic index derived from them. These measurements are useful but care should be taken to hold the sliding calipers parallel to the axis of the bone. In the male pelvis the foramen obturatum is rounded, oval, and the measurement proportions of the two bones are opposite. In the series of Washburn (1948, 1949)—consisting of 150 individuals of each sex—only five male ischio-pubic indices were found to fall within the range characteristic of females. From this fact he concluded that this index alone gives a 90 per cent accuracy in sexing, provided of course that all the skeletal finds examined belong to the same main race.

The reliability of the ischio-pubic index (Poulhés, 1948) is greatly enhanced if the greater sciatic notch is taken into account as the latter is not directly related to the characteristics of the pubis and ischium and, owing to its ontogenetic (Reynolds, 1947) and evolutional antecedents, is an important criterion (Moeschler, 1961–62). Derry (1923–24), then Verneau, Sauter and Privat (1954–55), Schultz (1949), Schleyer (1958) and Genovés (1959, 1959) studied the measurement of the sciatic notch and the evaluation of the computable indices. Derry (1923–24) was the first to find that the greater sciatic notch is shallower and wider in the female pelvis, while it is deeper and narrower in males (Fig. 15). This characteristic in itself gives a 75 per cent accuracy in sex determination; when combined with the ischio-pubic index, accuracy is practically 100 per cent. Taking these two criteria as a basis, Washburn (1949) has discriminated between the two sexes in a series containing 300 individuals beyond any doubt in every case.

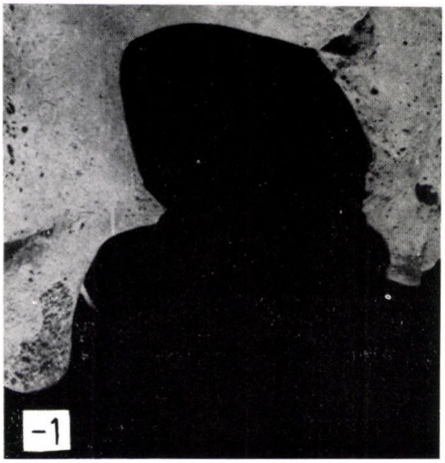
The importance of the pubic angle and the greater sciatic notch as indicators of sex in case of historico-anthropological materials is enhanced by the fact that an intact pelvis is seldom found, and these characters can be ascertained even in fragmentary, disintegrating pelvic bones.

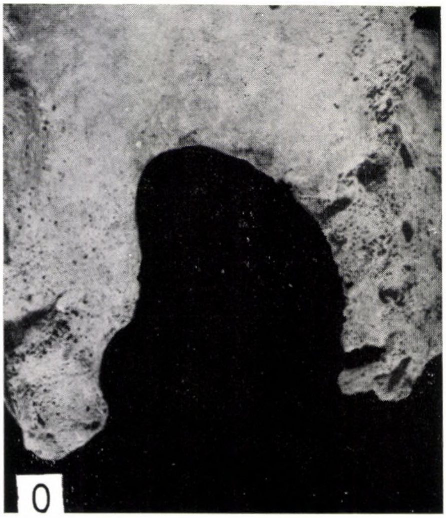
The vertebral column in the male is heavier in structure, the body of the dorsal and lumbar vertebrae is larger and the spinous processes are thicker and more protruding (Latarjet and Sourina, 1947). The lumbar lordosis of the female column is marked (Allbrook, 1955). It is advisable to exercise great care when considering the sex differences of the vertebral column, since individual variability is very high and constitutional features may be misleading in many respects (Boyd and Trevor, 1953).

The atlas is the most suitable for sex determination among the vertebrae; its dimensions are larger, and the structure is considerably heavier in males (Dubreuil-Chambardel, 1907). Clavelin and Dérobert (1946) have found that the transversal diameter of the male atlas is 11 mm longer on the average than the female (the mean in males is 83 mm, range: 74 to 90 mm; the female mean is 72 mm, range: 65 to 76 mm).

The sex differences of the sacrum (Piganiol and Olivier, 1958) ought to be discussed here, although certain features have been mentioned in connection with the pelvis. Whereas the female sacrum is broad and short, the male sacrum is narrow and elongated. The female sacrum is usually less arched (Fawcett, 1938). The facies auricularis extends to the second segment in females and to the third segment in males. Trotter (1926) has found that the sex differences between the male and female sacrum are of no specific importance, and that there is considerable overlapping in both measurement and morphology. Patterson and Derry (1911–12), on the other hand, emphasize that if the overlapping is kept in mind, the sex differences of the sacrum can be satisfactorily evaluated in series of identical origin.

Sex traits of the sternum may also be used in sexing. According to Dwight (1878) and Patterson, the ratio of the manubrium length to the body length of the sternum is different in the two sexes (49 : 100 in males and 52 : 100 in females). The





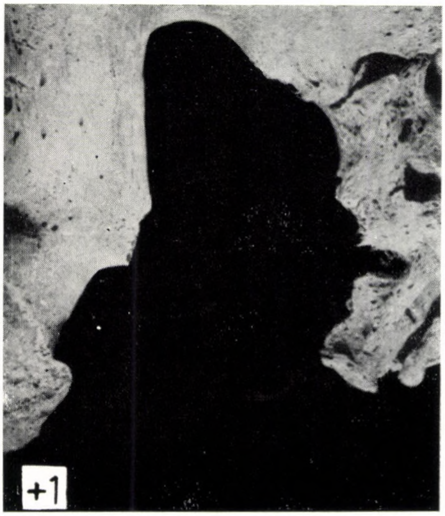


Fig. 15. Sex differences in the shape of the greater sciatic notch.

studies of Ashley (1956) and Dürwald (1960) deserve mention. Both devised methods for detecting sex differences on the basis of sternal length, and the width and thickness of the segments. According to Ashley (1956), in males the length of the sternum exceeds 149 mm (not including the xiphoid process, and referred to Europeans only); in females it is less than 149 mm. According to Dürwald's (1960) investigations, the sum of the length and width measurements of the sternum ought to be taken into account. He has found that the length of the sternum (without the xiphoid process), the width of the sternum in segment I (between costal notches II and III), the width of the sternum between costal notches III and IV), the minimum thickness of the manubrium along the medial line and the thickness of the corpus sterni (in segment I) also along the medial line give a total of between 226 and 262 mm in males, and between 192 and 223 mm in females. The sex traits of the sternum become important especially in cases where the pelvis is unfit for analysis due to its fragmentary condition.

The bones of the limbs are of varying importance in sexing. They are particularly important if no complete skeleton is available.

Olivier (1960) puts the average height of the female scapula at 144 mm, that of the male scapula at 157 mm; the width of the glenoid cavity is 26 mm in the female scapula, and 29 mm in the male, and he sees the greatest difference between the means of the lengths of the scapular spine, the female mean being 128 mm, the male 141 mm. Morphologically the importance of the traits can be ranked as follows: vertebral margin, lines, acromion, and coracoid process. The vertebral margin of males is especially thick, even showing occasional lipping, the muscular lines protrude like a ridge on the costal surface of the scapula in males of marked masculinity (Bainbridge and Lebrun, 1911).

Like the scapula, also the clavicle shows certain sex differences. The female clavicle is shorter (mean 138 mm), the circumference is smaller (mean 32 mm); it is gracile, slightly arched, and the anatomical details on its surface are less distinct. The male clavicle is longer (mean 150 mm), heavier, thicker, it has a larger circumference (mean 36 mm); the S-curvature is more marked, the anatomical features are clearly defined, and the muscle sites are more evident. Female and male characteristics partially overlap of course, so, in Olivier's opinion, the clavicle alone is not a reliable basis of sex determination, and can be appraised only in combination with other features (Olivier, 1951, 1952, 1953, 1954, 1955, 1956, 1960).

The long bones of the upper and lower extremities are usually longer, more massive (Olivier and Pineau, 1958) and also heavier in males than in females (Bello y Rodriguez, 1909). The male long bones are richer in anatomical detail, showing more marked muscle sites, lines andpits (Godycki, 1957). The female long bones have a smooth, rounded surface and are gracile. The sex differences are especially conspicuous in the size of the proximal and distal ends of the long bones: these are usually larger in males than in females (Dwight, 1904, 1905). For instance, a 44·5 mm or longer vertical diameter of the head of the femur is characteristic of the male and diameters below 43·5 mm of the female. The means of the principal dimensions of the upper and lower long bones are shown according to sex in Table 13 on the basis of Olivier's 1960 data.

Other skeletal bones for sex determination are the ribs, the patella (Pyle and Hoerr, 1955), the talus, the calcaneus, and the proximal phalanx of the big toe. The ribs of males are higher, more massive, and richer in morphological details; whereas the female ribs are short, low and less arched. Well defined lines on the anterior surface of the patella and a high eminence of the upper arch of the talus are characteristic of the male; the opposite, of the female. The calcaneus of the male is larger than that of the female. The length/width index varies between 45 and 60 in Europeans, and the female index is usually 2–3 units lower. The female calcaneus is shorter in the anterio-posterior, and broader in the transversal direction. The superior surface is sharply delimited on the calcaneus of the male (Pons, 1955).

TABLE 13

Sex differences in the principal measurements of the long bones

Measurement	Males mm	Females mm
Humerus		
maximum length	330	280
Radius		
maximum length	235	200
length in natural position	250	215
Ulna		
maximum length	265	230
length in natural position	240	205
Femur		
length in natural position sagittal diameter of head	44·5	43·5

Further descriptive features as well as the anatomical variations should also be studied, for example the third condyle on the skull, the insertion line of m. teres major in the scapula, the supracondyle of the humerus, the third trochanter of the femur (gluteal tuberosity), etc. as these occur more often in males.

All other osteometric data relating not only to the skeleton as a whole but also to its parts, and the indices derived from these data are usually taken into account, together with the enumerated traits. The variability of these measurements is so high, however, that it is barely possible to draw a distinct line between the sexes on this basis (Neto, 1956).

In conclusion, we should like to point out that the characteristics discussed above are valid primarily for the Europoid main race. This should be remembered especially when considering certain parts of the facial skeleton, and parts of the pelvis showing finer details. Although standard works treat these conclusions in a generalized manner, temporal and regional differences must not be disregarded. It was for this reason that we studied the degree of sexualization, in addition to sex characters; for if discriminant features are taken as a basis, it is possible to define (within the known limits of reliability) the sexes in all the main races (Olivier, 1949). Determination of the degree of sexualization may also serve as a basis for getting acquainted with the process of gracilization continuing since the Mesolithic.

A METHOD FOR DETERMINING SEX AND SEXUALIZATION

From among the many characters indicative of secondary sex traits discussed above we have chosen 22 for the determination of sex in our series. Each of these features were ranked into five grades. Based on Washburn's (1949) experience, we have taken into consideration an additional eight characters (22 + 8) when formulating our conclusions. The grades of the various characters and the concomitant scores are as follows: 'hypermasculine' = +2; 'masculine' = +1; 'indifferent' = 0; 'feminine' = —1; 'hyperfeminine' = —2. The features chosen and their grades are shown in Table 14 and in Fig. 16.

Depending on the state of preservation of the skeletal finds, the degree of sexualization should be determined as the first step of sex determination in as many of the selected features as possible. If the features indicate a male or a female unmistakably, sex may be regarded as determined on this basis, and the degree of sexualization can then be determined as the second step of the procedure. The degree of sexualization not only gives a reliable indication of the masculinity or femininity of the subject but if the sex characters themselves are indistinct, it will give a lead to sex determination.

The degree of sexualization is determined by computing weighted means from the scores of the various grades of the individual features, taking into account, naturally, also their signs. For weighting the scores of the grades, we have divided the 22 features into two groups, partly on the basis of their importance (discriminating value), partly for using only one of several correlated features with increased weight at a time. The first group of the features is considered to have double weight. The formula of the weighted mean used in determining the degree of sexualization and, indirectly, in sexing is as follows:

$$M = \frac{\sum w x}{\sum w}$$

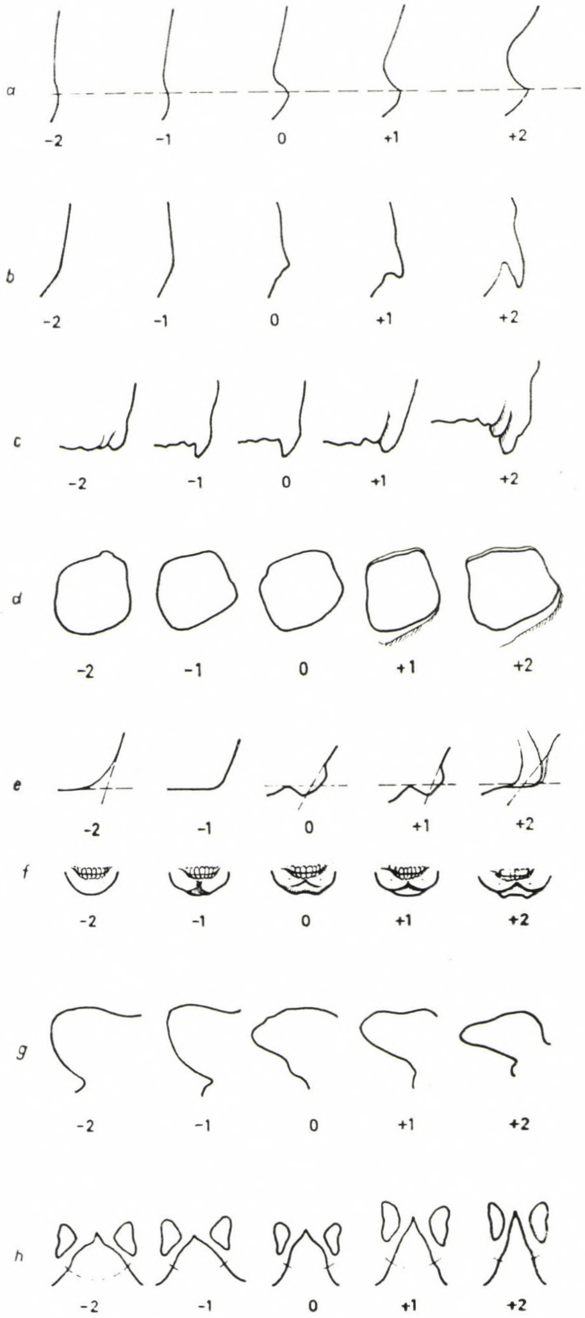


Fig. 16. Degrees of sexualization of some important secondary sex characters. (*a*) Glabella; (*b*) external occipital protuberance; (*c*) mastoid process; (*d*) orbit; (*e*) mandibular angle; (*f*) mentum; (*g*) greater sciatic notch; (*h*) pubic angle.

where M = the mean value showing the degree of sexualization (and sex),

x = the scores corresponding to the grades of the individual features (in accordance with their signs),

w = the weight applied to the particular feature (2 in the first group of features, and 1 in the second).

The distribution by weight of the 22 features is as follows:

Group $w = 2$ of the features includes the following features of the skull: glabella and superciliary arch, mastoid process, external occipital protuberance, supraorbital margin and the shape of orbit, trigonum mentale; of the skeletal bones: pubic angle, greater sciatic notch, the ischium-pubic index, the 'cotylo-ischiatic' index, and the diameter of the head of the femur. Cranial capacity may be included here in certain cases.

Group $w = 1$ includes the following features of the skull: frontal and parietal eminences, squama occipitalis, zygomatic arch, malar surface, body of the mandible, mandibular angle, head of the mandible; on the skeleton: greater pelvis, true pelvis, obturator foramen, sacrum, linea aspera, as well as the thickness of the cranial wall, clavicle, scapula, sternum and computed body height in given cases.

The means computed from the scores may result in values ranging from $+2$ to -2. Results with positive signs indicate masculinity, results with negative signs indicate femininity. If the result is 0, or approximating zero (e.g. $\pm 0{\cdot}4$), sex determination must be regarded as uncertain, just as in cases where means are computed from a few features. The order of magnitude of the means obtained reflects the degree of masculinity or femininity.

In our opinion, this method has the advantage that it reflects the appearance of the various secondary sex characters numerically, and that where determination is uncertain the numerical data serve as evidence to show the factors which make determination questionable.

As an example we show the results of sex and sexualization determination in the skeletal finds excavated from graves 152, 195 and 229 of the 11th-century cemetery of Fiad-Kérpuszta; the finds are itemized 5,386, 5,415 and 5,442 in the Collection of the Anthropological Department of the Museum of Natural History, Hungarian National Museum (Table 15).

TABLE 14

Traits chosen for sex determination and their classification

Trait	Hyperfeminine (−2)	Feminine (−1)	Indifferent (0)	Masculine (+1)	Hypermasculine (+2)
(1) Frontal and parietal eminences	Marked	Medium	Moderate	Indistinct	Missing
(2) Glabella; superciliary arch	Smooth (0); showing a line occasionally	Slightly delimited (1)	Delimited (2)	Marked, arched (3)	Massive, prominen (4–5)
(3) Mastoid process	Very small	Small	Medium	Large	Very large
(4) External occipital protuberance	Smooth (0)	Hardly visible (1)	Poor (2)	Marked (3)	Massive (4–5)
(5) Squamous part of the occipital bone	Smooth	Slightly arched traces of nuchal lines	Nuchal lines and occipital crest evident	Nuchal lines and occipital crest marked	Nuchal lines and occipital crest with rough surface
(6) Supraorbital margin and orbital aperture	Very sharp edge; circular	Sharp edge; circular	Intermediate	Slightly rounded edge, slightly squared	Rounded edge, squared
(7) Zygomatic arch	Very thin	Thin	Medium	Thick	Very thick
(8) Malar surface	Very low, smooth	Low, smooth	Medium high, contoured	High, well-contoured	Very high, marked contours
(9) Body of the mandible (at height of *M* 2)	Very narrow	Narrow	Medium	Thick	Very thick
(10) Trigonum mentale	Rounded, smooth	Medial, slightly delimited	Medial, delimited	Inverted T-shaped, protruding	Bilateral protuberance
(11) Mandibular angle	Smooth	Incipient eminences	Moderate eminences	Marked eminences	Strongly marked eminences, laterally directed angle
(12) Head of the mandible	Very small	Small	Medium	Large	Very large
(13) Greater pelvis	Very low, broad	Low, broad	Medium high, intermediate	High, abrupt	Very high, abrupt
(14) True pelvis	Very broad, oval	Broad, oval	Circular, medium broad	Narrow, heart-shaped	Very narrow, heart-shaped
(15) Pubic angle	Up to 100°	Up to 90°	Up to 75°	Up to 60°	Up to 45°

TABLE 14 (cont'd)

Trait	Hyperfeminine (−2)	Feminine (−1)	Indifferent (0)	Masculine (+1)	Hypermasculine (+2)
(16) Obturator foramen	Triangular, sharp rim	Triangular	Intermediate	Oval, rounded rim	Oval, rounded rim
(17) Sciatic notch	Very wide, shallow	Wide, shallow	V-shaped, medium deep	More closed, tends to U-shape	Closed, deep
(18) Ischium-pubic index	115–106	105–96	95–90	89–80	79–70
(19) 'Cotylo-ischiatic' index	*x*–99	100–121	122–129	130–149	150+
(20) Sacrum	Very broad, low	Broad, low	Narrow, medium high	Narrow, high	Very narrow, very high
(21) Head of femur	*x*–40	41–43	43·5–44·5	45–47	48+
(22) Linea aspera (pilaster)	Missing	Poor, delimited only laterally	Medium, delimited bilaterally	Narrow, high	Very narrow, very high

Also to be taken into consideration:
(23) Cranial capacity
(24) Thickness of cranial wall
(25) General character of skull
(26) Clavicle
(27) Scapula
(28) Sternum
(29) General character of skeletal bones
(30) Body height

DIFFERENCES IN SEXUALIZATION (HISTORICAL AND RACIAL ASPECTS)

The method of sex determination described above can be applied to the historical populations belonging to the Europoid main race. This does not mean, however, that this method cannot be employed for analysing other populations as well. The masculinity or femininity and the degree of sexual dimorphism in the population must be taken into account in such cases.

From the Upper Palaeolithic on a certain gracilization of the bony structure has taken place (pointed out by Debets among others). In Table 16 we show the results of analyses made of nearly 800 individuals from 13 series ranging from the

TABLE 15

Examples of sex determination on the basis of skeletal finds

Serial no.	Sex traits	Weights (w)	Scores of grades (x)			Weighted scores (wx)		
			Grave 152	Grave 195	Grave 229	Grave 152	Grave 195	Grave 229
	On skull							
(1)	Frontal and parietal eminences	1	+1	—2	+1	+1	—2	+1
(2)	Glabella; superciliary arch	2	+1	—2	+1	+2	—4	+2
(3)	Mastoid processes	2	0	0	+1	0	0	+2
(4)	External occipital protuberance	2	0	—2	+2	0	—4	+4
(5)	Squama occipitalis	1	0	—1	+2	0	—1	+2
(6)	Supraorbital margin and orbit	2	+2	—1	+2	+4	—2	+4
(7)	Zygomatic arch	1	+2	—2	+2	+2	—2	+2
(8)	Malar surface	1	+1	—1	+1	+1	—1	+1
(9)	Body of mandible	1	+1	—1	+2	+1	—1	+2
(10)	Trigonum mentale	2	+1	—1	+2	+2	—2	+4
(11)	Mandibular angle	1	+1	—1	+1	+1	—1	+1
(12)	Head of mandible	1	+1	—1	+1	+1	—1	+1
	On skeleton							
(13)	Greater pelvis	1	+1	—2	+1	+1	—2	+1
(14)	True pelvis	1	+1	—2	+1	+1	—2	+1
(15)	Pubic angle	2	+2	—2	+1	+4	—4	+2
(16)	Obturator foramen	1	0	0	0	0	0	0
(17)	Greater sciatic notch	2	+1	—1	+2	+2	—2	+4
(18)	Ischium-pubic index	2	+1	—1	+1	+2	—2	+2
(19)	'Cotylo-ischiatic' index	2	+1	—1	+1	+2	—2	+2
(20)	Sacrum	1	+1	—1	+2	+1	—1	+2
(21)	Sagittal diameter of femoral head	2	+2	—2	+2	+4	—4	+4
(22)	Linea aspera	1	+2	—1	+2	+2	—1	+2
	$\sum w$	32	—	—	—	—	—	—
	$\sum x$		+23	—28	+31	—	—	—
	$\sum wx$					+34	—41	+46
	$\frac{\sum wx}{\sum w}$					$\frac{34}{32}=$ +1·06	$\frac{-41}{32}=$ —1·28	$\frac{46}{32}=$ +1·44
	Sex					male	female	male

Mesolithic to the Middle Ages. The average degree of sexualization in males and females, the mean of both sexes as well as the difference are given. The difference between the numbers standing for the degree of sexualization indicate the sex dimorphism within the population.

It can be seen from the values of the Vassilievka and Volni series, just as in other Palaeolithic or Mesolithic series (e.g. the Epipalaeolithic series of Taforalt) that the average degree of sexualization of the males is masculine-hypermasculine, even ultrahypermasculine (it might be classified as high as +3 or +4) in individual

TABLE 16

Sexualization and sex dimorphism of various populations, from the Mesolithic to the Middle Ages

Site, period	Males		Females		Degree of sexualization for both sexes	
	No. of cases	degree of sexualization (mean)	No. of cases	degree of sexualization (mean)	mean	difference
Vassilievka III (USSR), Mesolithic	11	+1·3	11	—0·1	+0·60	1·4
Volni (USSR), Neolithic	12	+1·0	14	—0·1	+0·45	1·1
Tiszapolgár-Basatanya (Hung.), Copper Age	45	+1·0	42	—0·7	+0·15	1·7
Mezőcsát (Hung.), Late Bronze Age	10	+0·4	8	—0·4	0·00	0·8
Mezőcsát (Hung.), Early Iron Age	9	+0·6	19	—0·8	—0·10	1·4
Keszthely-Dobogó (Hung.), Roman, 4th–5th centuries	48	+0·8	26	—0·6	+0·10	1·4
Mözs (Hung.), 5th century	6	+0·7	6	—0·8	—0·05	1·5
Hegykő (Hung.), Lombard, 6th century	23	+0·7	18	—0·8	—0·05	1·5
Zwölfaxing (Austria), Avarian, 8th century	75	+0·8	39	—0·8	0·00	1·6
Sopronkőhida (Hung.), Frankish-Avarian, 9th century	31	+0·8	37	—0·5	+0·15	1·3
Sarkel (USSR), Khazar, 9th century	67	+0·7	38	—0·7	0·00	1·4
Tiszanána (Hung.), time of Hungarian Conquest, 9th–10th centuries	6	+1·0	5	+0·1	+0·55	0·9
Fiad-Kérpuszta (Hung.), Magyar, 10th–11th centuries	97	+0·5	91	—0·5	0·00	1·0

cases, while that of the females is indifferent, or even masculo-feminine, classified with positive values only in individual cases. But sex can be determined even in such populations that might be termed ‘robust’ as the difference between the means characterizing males and females, i.e. sex dimorphism, is just as great as in ‘gracile’ populations. The sexualization and sex dimorphism in certain populations is shown in Fig. 17.

In ‘robust’ populations the quantitative and qualitative features may be found to include such a massiveness and robustness that the scale of sex diagnosis must be extended in the positive direction. Similar problems may also be found in ‘gracile’ populations, if, for instance, considerable taxonomic differences between the individuals of the two sexes can be seen. As an extraordinary example we should like to mention the population of the Tiszanána cemetery dating from the time of the Hungarian Conquest, where the sexualization index of the males is +1·0 and that of the females is +0·1, i.e. the latter are of a masculo-feminine character.

If the degree of sexualization in a population is taken into account in anthropological analysis, taxonomic evaluation becomes more reliable. It is also useful

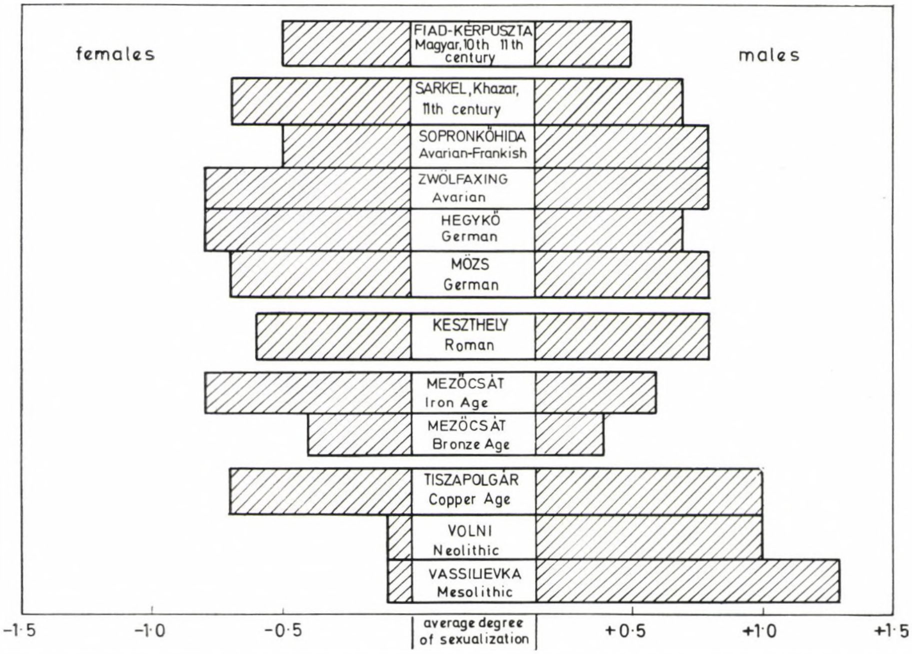


Fig. 17. Differences in the degree of sexualization and sex dimorphism in certain historical populations.

in the clarification of the living conditions of various populations. In populations where the division of labour obliges women to do hard physical work, the secondary sex characters are shifted into the masculine direction, because of muscle sites becoming more marked, wall thicknesses increased, etc.

In the opinion of Stewart (1957) and others, metrical data often lead to erroneous conclusions in sexing individuals, as they are only characteristic of the population studied and are less valuable than morphological descriptions. In contrast, Thieme and Schull (1957) assert that the measurements and indices of the skull and skeletal bones offer sufficient information for sex determination.

We, in our own studies, have preferred to use both the descriptive and metrical characters. Since our intention is to express the degree of sexualization numerically constituting thereby an exact basis for sex determination, we regard thorough and reliable establishment of the most important characters and measures as a basic requirement. The number and order of the characters chosen for the determination of sexualization and sex (considering also the possibilities provided by the material unearthed) are such as can be applied to all races of *Homo sapiens*. The five grades (sometimes depending on the series studied, it is necessary to put up 7 grades ranging from +3 to —3) make it also possible to express exactly the differences the secondary sex characters of the main races.

In connection with our method of sexing the objection might be raised that as it has been based on Europoid materials, it is less fit for use with Negroid and Mongoloid races. In order to rule out this objection and to check our own findings we performed a complementary study with the material of the Terry Collection of the Department of Anatomy of Washington University School of Medicine, in 1966. Professor R. J. Terry (1871–1966) compiled 1,500 recent skeletons, a collection of great value from both the anthropological and anatomical points of view. A complete documentation is available for each skeleton (sex, age, race, sometimes the populations, certificate of death, post-mortem report, laboratory tests, case history, X-rays, data of previous anatomical and anthropological examinations).

We determined the sex, age and degree of sexualization of 150 skeletons, representing 10 per cent of the collection. Every tenth box containing skeletal material was systematically selected. Out of the 150 skeletons 124 were suitable for evaluation as the age of several subjects (victims of accidents, individuals without personal records) was unknown at the time of their death. Out of these 124 skeletons 88 were males (40 Europoids and 48 Negroids) and 36 females (10 Europoids and 26 Negroids). Their age ranged from 18 to 80 years.

The degree of sexualization was determined on the basis of 21 secondary sex characters. Besides, also the endocranial suture closure coefficient and the stages of the symphysial face were determined. We could not determine the structural changes in the spongy substance of the humerus and femur since due to the brevity of time the bones could not be sawn up or X-rayed. After the examination had been completed with the assistance of Prof. M. Trotter, our findings were compared with the actual race, sex and age data. The results were as follows:

In 120 cases (96·8 per cent) our sex determination was correct; in 4 cases (3·2 per cent) it was false (3 Negro females were taken for males and 1 Negro male for female).

The weighted averages of the 21 secondary sex characters were determined separately for both sexes of the Europoid and Negroid populations (Table 17). The sex characters in the skull of the Europoid males were less pronounced than in the Negroid males. The pelvis and the skeletal bones of the Europoid males, however, were of a masculine character, while those of the Negroids were closer to the indifferent or feminine character. As regards the sexualization of the Negroid and Europoid females, on the basis of the relatively few cases, it seems that Negroid females scored indifferent in a higher number of indices than did the Europoid females, while the mastoid process showed a masculine character in both cases. Among Negroid females the facial bones, especially the cheek bones and the zygomatic arch were, in general, more of a masculine character.

The above-mentioned differences are interesting because the coefficients of sexualization determined for groups are identical for Europoid and Negroid males, thus the differences observed in the sexualization of the skull, pelvis and skeletal bones are balanced in the value of the index of sexualization.

TABLE 17

Differences between the sex dimorphism of Europoid and Negroid skeletons (on the basis of the Terry Collection)

Average values of 21 sex characters

Character no.	Europoid			Negroid			Difference between Europoid and Negroid	
	Males	Females	Difference	Males	Females	Difference	Males	Females
1	+0·38	—0·32	0·70	+0·58	—0·24	0·82	+0·20	+0·08
2	+1·18	—0·52	1·70	+0·78	—0·48	1·26	—0·40	+0·04
3	+0·90	+0·01	0·89	+0·98	+0·15	0·83	+0·08	+0·14
4	+0·55	—0·40	0·95	+0·66	—0·35	1·01	+0·11	+0·05
5	+0·48	—0·65	1·13	+0·61	—0·23	0·84	+0·13	+0·42
6	+1·16	—0·77	1·93	+0·43	—0·55	0·98	—0·73	+0·22
7	+0·38	—0·37	0·75	+0·71	+0·38	0·33	+0·33	+0·75
8	+1·06	—0·80	1·86	+1·03	—0·24	1·27	—0·03	+0·56
9	+0·40	—0·75	1·15	+0·63	—0·24	0·87	+0·23	+0·51
10	+0·84	—0·42	1·26	+0·93	—0·68	1·61	+0·09	—0·26
11	+0·42	—0·55	0·97	+0·63	—0·55	1·18	+0·21	0·00
12	+0·48	—0·82	1·30	+0·68	—0·37	1·05	+0·20	+0·45
13	+0·92	—2·00	2·92	+0·93	—1·48	2·41	+0·01	+0·52
14	+1·08	—1·42	2·50	+0·76	—1·47	2·23	—0·32	—0·05
15	+1·10	—1·92	3·02	+1·01	—1·58	2·59	—0·09	+0·34
16	+1·64	—1·05	2·69	+0·85	—0·78	1·63	—0·79	+0·27
17	+1·25	—1·64	2·89	+0·93	—0·78	1·71	—0·32	+0·86
18	+0·80	—1·50	2·30	+0·63	—0·88	1·51	—0·17	+0·62
19	+1·60	—0·75	2·35	+1·30	—0·70	2·00	—0·30	+0·05
20	+1·00	—0·65	1·65	+0·96	—0·22	1·18	—0·04	+0·43
21	+0·94	—0·85	1·79	+0·93	—0·45	1·38	—0·01	+0·40
Together	+0·84	—0·88	1·72	+0·84	—0·56	1·40	0·00	+0·32

In Table 18 the distribution of Europoid and Negroid males and females according to the degree of sexualization ranging between +2·00 and —2·00 is detailed. A slight difference in the sex dimorphism between the two main races is evident: the indices of sexualization of the Negroids is shifted in the positive direction as compared with the Europoids (Thieme, 1957). These differences in sexualization warn that the sex differences in certain characters should be judged with some reservation in the case of Negroids and, presumably, also of Mongoloids.

The changes or the sex characters in the course of life was studied separately. The data of Table 19 indicate that in the case of Europoids sexualization shifts in the negative (feminine) direction with advancing age while with Negroids this is not the case. In view of the possible connection between the degree of sexualization and age, in sexing also age should be taken into consideration and the same applies to studies on the differences in sexualization between the main races.

TABLE 18

Distribution of Europoid and Negroid skeletons according to degree of sexualization

Degree of sexualization	Males			Females		
	Europoid	Negroid	Total	Europoid	Negroid	Total
+2·00						
+1·99 to +1·75		1	1			
+1·74 to +1·50	4	5	9		1	1
+1·49 to +1·25	3	5	8			
+1·24 to +1·00	9	16	25			
+0·99 to +0·75	11	3	14		1	1
+0·74 to +0·50	4	5	9			
+0·49 to +0·25	5	4	9			
+0·24 to 0·00	1	7	8	1		1
—0·01 to —0·24	1		1	1	1	2
—0·25 to —0·49	1		1		2	2
—0·50 to —0·74	1	2	3	1	8	9
—0·75 to —0·99				2	4	6
—1·00 to —1·24				4	7	11
—1·25 to —1·49						
—1·50 to —1·74				1	1	2
—1·75 to —1·99					1	1
—2·00						
Total	40	48	88	10	26	36

No significant differences could be observed in the endocranial suture closure coefficient and the stages of symphyseal face between the Negroid and Europoid series.

TABLE 19

Per cent distribution of Europoid and Negroid skeletons according to degree of sexualization, sex and age

Degree of sexualization	Europoid				Negroid			
	Males		Females		Males		Females	
	←50 years	50 years→	←50 years	50 years→	←50 years	50 years→	←50 years	50 years→
+2·00 to +1·75					3·23			
+1·74 to +1·50	7·14	15·38			3·23	23·53	10·00	
+1·49 to +1·00	42·86	19·23			45·15	41·18		
+0·99 to +0·50	35·71	42·31			22·58	11·76		
+0·49 to 0·00	14·29	19·23		11·11	22·58	23·53		
0·00 to —0·49		3·85		11·11			15·00	
—0·50 to —0·99			100·00	22·22	3·23		40·00	66·67
—1·00 to —1·49				44·45			30·00	33·33
—1·50 to —1·74				11·11			5·00	
—1·76 to —2·00								
Total	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00

It has been shown by recent studies based on the results of Putschar (1931) and Stewart (1957) that female fertility can be estimated from the micro-anatomical changes of the female pelvis due to full-term pregnancies. These possibilities have opened up new vistas in palaeodemographic research. The above authors made this observations on recent European and Eskimo series and described all morphological changes on the female pelvis and primarily on the os pubis which could be attributed to full-term pregnancies. These were as follows:

(1) On the surface and margins of the pubis the sites of insertion of the m. rectus abdominis and m. externus abdominis and those of the inguinal ligaments become marked as a result of several subsequent pregnancies.

(2) The interpubic ligaments produce transversal impressions on the surface of the bone.

(3) On the inner surface of the pubis along the birth canal haemorrhagic pits of various depths can be discerned.

(4) On the medial margin of the pubis exostoses appear which are first isolated and pearl-like and form a thick rim.

Putschar and later Stewart distinguished several grades of the micromorphological changes observed — having compared them with an adequate control material — according to the number of full-term pregnancies. Making use of these grades a reliable estimation of female fertility becomes feasible.

Following 1 to 2 pregnancies thick muscle markings separated by deep pits appear in a spiral on the outer surface of the pubis.

After 3 to 4 full-term pregnancies there are isolated pearl-like exostoses to be observed along the spiral muscle markings. The transversal impressions on the inner pubic surface are marked and there are several haemorrhagic pits.

After 5 to 6 full-term pregnancies the muscle markings on the outer and inner surfaces of the pubis become thicker and labiated, and the pits among them become deeper. The haemorrhagic pits may merge and form cysts.

As a result of 7 to 9 pregnancies the muscle markings thicken to several times their original size and appear as labiated protuberances.

On the inner surface of the pubis haemorrhagic cavities with uneven contours develop, which are of irregular shape and size, and are partly merged.

Over 9 full-term pregnancies the pubic bone is so much destructed and so rough that further classification is impossible.

The rate of female fertility of a series can be determined from the well distinguishable changes of the pelvic bones of women who had died at or after the reproductive age. A joint analysis of theoretical calculations and practical results will facilitate a realistic assessment of female fertility in various prehistoric and historic ages. Naturally these investigations are still at an initial stage and post-mortem studies of large material are needed to obtain a sufficient number of controls for diagnosing changes caused by pregnancy. These observations are important not only from the point of view of sex determination but also from that of age diagnosis, because changes to be observed on the pubic symphysis may be equally due to pregnancies and age. This factor may be responsible for an unrealistically high survival rate established in historic or prehistoric series.

CHEMICAL POSSIBILITIES OF SEX DETERMINATION

As we have seen, the skeletal structure shows such definite features of the individual's sexual character that anthropologists, employing adequate morphological methods, are able to determine sex, and the degree of sexualization, with an accuracy of 85–95 per cent. Although, according to Stevenson (1924) and Todd (1925–28), these sex traits are genetically determined (Moore, 1962) in their morphological foundations, they assume their final character at the time when the sex hormones are produced. Of the morphological elements constituting bony tissue, it is the osteoblasts and the osteoclasts that shape the sex characters of the skeletal structure under the hormonal regulation of the organism. The question arises, however, whether sex dimorphism has roots that go deeper, down to the chemical structure of bony tissue. And indeed, chemical examination of the bony tissue has revealed phenomena that can be brought into connection with sex. Pucher and his co-workers as well as Dickens (1941), Gross and Schmitt (1948), have found that the citrate content of human bone in decreased and dried bones is approximately 1 g per cent. Thunberg (1947) analysed recent and fossil bones for citrate content and found average values of 0·71 and 1·11 g per cent in the vertebral bodies of males and females, respectively. Starting from these investigations, Lengyel and Nemeskéri (1963), making systematic analyses of series showed that differences according to sex appear in the citrate level of bones, both in material coming from the dissection room, and in skeletal finds originating in historical periods. This difference provides yet another indirect method of sex determination. The citrate content of bones (Dixon and Perkins, 1952) depends on the oestrogenic-androgenic hormonal effects within the organism. Therefore the hormonal status of the organism should be determined first of all, as this is connected with sexualization. Between the ages of 0 and 15, differences have not been found in citrate contents to provide a basis for indirect sex determination. Between the ages of 16 and 60, i.e. from the beginning of juvenile age, when the sex characters develop fully, up to old adult age, the differences between the sexes are so distinct that sex can be determined with an accuracy of 65–70 per cent. Individual variability between the age limits mentioned is not high enough to interfere with evaluation of the results. The reason for the relative inaccuracy in sex determination on this basis is that the citrate content shows indistinct values in females after the menopausal change in hormonal state. This loss of sexual character appears also in the morphological features. The process is somewhat slower in males, and sets in later, but becomes manifest at old adult age (60 and above) to such an extent that the extreme variations in citrate content overlap in the sexes. The citrate content of recent bones averages 0·94 g per cent between the ages of 0 and 14. The content in the bones of juvenile females is 1·0 g per cent or higher, while it is below 1·0 g per cent in males. The difference is even more marked in the young adult and middle adult age groups; female bones have citrate contents over 1·0 (1·04 g per cent on the average), whereas the average of males is 0·95. At late middle adult and at old adult age, the citrate values of females overlap those of males and the average falls below 1·0 g per cent.

If the citrate content in historical skeletal finds is to be used for sexing, the degree of decomposition due to soil and climatic conditions should first be established. The reduction percentage in citrate content must be taken into account when appraising sex differences. In skeletal finds from archaeological periods the reduction in the citrate content is usually 50–60 per cent and is proportionate to the time elapsed since burial.

This method is still in its early stages and its potentialities have not been fully exploited. But the fact that the hormonal conditions, and arising indirectly from this, the sex can be diagnosed from infinitesimal fragments of bone, is of paramount importance. A diagnosis can be attempted even where the fragmentary state of the skeletal finds excludes morphological analysis (Eastoe and Eastoe, 1954).

THE IMPORTANCE OF AGE DETERMINATION

The determination of age at death in palaeodemography is even more important than sex recognition. Whereas sexing provides an opportunity for the comprehensive reconstruction of populations, the determination of age at death is of primary importance when investigating the problems of length of life and mortality.

The age at death of the individual must be determined from skeletal remains with the greatest possible accuracy. This is a fundamental anthropological and biological prerequisite for palaeodemographic research based on anthropological material.

Because age and the accuracy requirements of age estimation methods based on skeletal finds are so exacting, we must discuss the methods of age determination in rather more detail than we did in the case of sex determination.

Sex and age are two fundamental biological characteristics of man; the former receives considerable attention when anthropological features are being evaluated. Yet the literature of historical anthropology shows that the majority of anthropologists are not so particular about age determination. There are not many investigators who—like Brothwell (1963), Gejvall (1960), Genovés (1962), Hooton (1946), Howells (1960), Senyürek (1947), or Vallois (1960), for instance—would treat age determination with a thoroughness that can withstand scientific criticism. The methods of age determination generally employed in historical anthropology include the order of tooth eruption in childhood; the closure of the spheno-occipital synchondrosis; the union between epiphysis and diaphysis of the extremital long bones at adolescence; the closure of cranial sutures, abrasion of teeth, and regressive signs in the external morphology of skeletal bones at young adult, middle adult and old adult ages. Rather liberal use of the classifications of Martin and Saller (1957), Hrdlička (1920, 1952), Hooton (1946), and of Lyon and Todd (1924, 1925, 1928) are generally made. Yet these methods are no longer adequate for meeting current requirements. If we consider the investigations conducted by Lyon and Todd (1924, 1925, 1928), then by Eränkö and Kihlberg (1955), Singer (1953), Gheorghiu (1954), Brooks (1955) and the practitioners of forensic medicine in general, justifiable doubts may arise on the accuracy of age determination based on the closure of cranial sutures and on the so-called classical anthropological methods in general. Age can only be determined if several age indicators are studied in a systematic and co-ordinated manner, and only data thus determined can be accepted as the basis of historico-demographic or anthropological appraisal.

When comparing age determination methods used by anthropologists with those used in forensic medicine it should be remembered that the non-detailed methods of the former result from the fact that in historical anthropology usually only the basic distinction between child, juvenile or adult is made. Age data even in conventional grouping of infant I and II, juvenile, young adult (adultus), middle adult (maturus) and old adult (senilis) are treated as collaterals. In forensic medicine, on the other hand, age determination is vital in establishing identity.

Even distinguished anthropologists such as Angel, Cunha, Debets, Ginzburg, Hooton (1946), Howells (1960) and Senyürek (1951, 1955), who have all contributed considerably to the knowledge of historical populations and have enriched historical anthropology with important ideas in theory and methodology, although presenting the age structure of their series, confine themselves to studying only sex differences when treating the metrical, morphological and taxonomical features and refer to age only in descriptions of individual cases.

And yet the skeleton, the basis of metrical and morphological analysis, is changing throughout the course of life. It is no mere mechanical framework of the organism permanently in the same morphological state. The skeleton participates in the overall metabolism of the organism, in progressive and regressive processes. It responds to exogenous and endogenous impacts (advance of age, change in environmental conditions, nutrition, working conditions, diseases, etc.) with morphological changes. Grimm (1959) and Stewart (1957) say that the plasticity of the bony structure is much higher than is generally assumed.

The changes in the skeletal system determined by age are important not only in demographic, but also in anthropologic studies where they may be a source of error. This will occur if metrical and morphological traits are treated on the basis of an 'ageless', abstract picture and the taxonomic character of a population is reconstructed from such data. Unless the racial elements are described according to age, the possibility exists that the taxonomical evaluation of a population and the ethnogenetic conclusions drawn on this basis will contain errors.

CHRONOLOGICAL AND BIOLOGICAL AGE

Today two kinds of age are distinguished in respect of living beings. In addition to the absolute, i.e. chronological, age, gerontologists emphasize that getting old depends on the actual condition of the organism rather than on the number of years lived. A new concept has been introduced into this field based on Nouy's initiative, which is known as the biological age.

Owing to the complexity of determining biological age, these two aspects of age have only recently begun to gain ground in scientific thinking. Yet the problem has been known for a long time; for instance, the saying 'an aged man is no old man' is to be found among the proverbs of many different peoples. Physicians give it a popular definition saying that everybody is as old as his arteries. Such a formulation of this view is untenable, of course. The condition of the central and peripheral nervous system, the muscles, the endocrine glands, etc. are as important in senescence as the heart and the circulatory system. But the saying points correctly to the fact that age is characterized not so much by the number of years that have passed since birth, but rather by the condition of the organism.

These two concepts of age are usually distinguished in literature as chronological and biological age. Chronological age—or calendar, registration, or civil age—is the term in general use. If anybody is asked about his age, he will give his chronological age. So chronological age means the number of years lived from birth. Biological age, on the other hand, cannot be measured by the number of years lived; it is measured by the senescence of the organism. Biological, real, or physiological age is a complex term. According to Laugier (1955), it may be defined as the aggregation of the senescence of physiological, chemical, sensory and psychological functions. Thus the determination of biological age is not at all easy.

There is a correlation between biological and chronological age, as the senescence of the organism advances with age. The relationship between these two ages is not very close however and they do not always coincide. Biological senescence is connected with factors other than the passing of time, and these factors are not evenly distributed along the course of life. They may even be more or less independent of time and this fact influences the positive relationship between biological and chronological age.

In childhood and in youth it is relatively easy to ascertain whether the individual is more or less developed than the normal physiological state at that given age, and the absolute difference between the two ages is not great. But in adults biological age is more difficult to establish and may differ from the state corresponding to the given chronological age. The older the individual, the greater the absolute difference between the number of years lived and the actual biological state of his organism may be. So biological ages show dispersion if compared to chronological ages.

The explanation of this phenomenon is that man's chronological age is a condition independent of any social and natural factors, since the number of years inevitably increases from birth to death with the progress of time. Biological age, on the other hand, may differ from chronological age under the effect of these factors. The effect of living conditions is of high importance in this respect and need not be proved here.

The importance of the above factors may be proved by statistical and historical studies, which show that the length of life of women is reduced if they do hard physical work. Their biological ageing is probably accelerated. The chronological age when biological senility may be expected to take place varies greatly and is of considerable interest. There are several instances in mediaeval literature showing that living conditions of that time caused biological senility to set in earlier than at the lower limit of old age defined chronologically today. Eustache Deschamps, who sees in old age nothing but pitiable bodily and mental decline, wrote at the beginning of the 15th century that one soon becomes old. He said that women are already old at the age of thirty, men at fifty, and that life usually ends at the age of sixty. Olivier de la Marche writes in a similar manner of a woman bewailing her youth: 'Even if you live as long as nature would allow—and sixty years is very much indeed—your beauty will decay into ugliness, your health be impaired by hideous diseases—and you will be nothing more than a clog, an horror to everybody'. The quoted descriptions are pretty far from that idealism with which Dante looks at the noble dignity of old age in *Convivio*. But even if these statements are tendentious—as they were inspired by literary fashion rather than by exact observation—the real foundations of the messages are apparent.

In the field of anthropology, we may cite an example from Bartucz, who at the disinterment of Apaffy, Prince of Transylvania, observed unmistakable signs of advanced ageing on the skeleton of the Prince. This Prince had died relatively young according to literary data, but had led a loose life. Similar results were obtained during the examination of larger anthropological series. A number of scientific analyses have proved the obvious fact that the way of living, diseases, social, economic and natural conditions in general (working conditions, housing, nutrition, climate, etc.) affect man's biological age.

Studies relating to modern man usually work with chronological age, as it is difficult to establish biological age in living persons. In palaeodemographic analyses, on the other hand, the examination of skeletal remains establishes biological age first of all, and chronological age cannot be determined with absolute accuracy. Studies of records, grave inscriptions and the like showing chronological age only can be excepted. The validity of any age-determination method rests, first of all, on the age-indicating features selected. The principal requirement is that the results must be as close to the chronological age as possible.

Age-indicating features used in anthropology are divided into three major groups according to the periods in man's life. First, childhood, where the age indicators are the eruption of deciduous and permanent teeth. Secondly, at the juvenile age, the union of epiphysis and diaphysis in the long tubular bones of the limbs, the closure of the synchondrosis in the base of the skull, i.e. formation of the os basilare must be noted at young adult age. Thirdly, at middle and old adult ages, the closure of the cranial sutures, the changes on the surface of the symphysial face of the pubic bone, as well as the structural changes in the spongy substance of the proximal epiphyses of the humerus and femur, and the expansion of the medullary canal should be observed. The degree of tooth abrasion is also important. If, however, the age indicators listed above are considered separately, there will be room for considerable error in age determination. The abrasion of teeth at adult age, for example, depends primarily on living conditions; nutrition for example influences this factor decisively. Stomatologists have shown that the degree of abrasion is more often indicative of the individual's way of eating than of the period of time during which the teeth have been used. In view of data to be discussed later we may assume that, although the closure of the principal cranial sutures proceeds parallel with the advance of chronological age, various factors that are less dependent on age may cause differences in this process. As a result, the closure of cranial sutures actually indicates the degree of biological senescence.

But other age indicators – such as the internal structural changes of the proximal epiphyses of the humerus and femur, the changes on the surface and rimming of the symphysial face of the pubic bone—show a much closer relation with chronological age. It follows therefore that the best way to bridge the differences between biological and chronological age is to base our opinion in age determination not on one, but on several age indicators. In the final analysis, the success of palaeodemographic investigations depends on how closely we are able to approximate chronological age. If all available age indicators are considered in their entirety, and the number of years actually lived is determined on this basis, a chronological age with adequate approximation suitable for demographic purposes can be given (Schott, 1959).

In the following some methodological problems of age determination, and practical methods based on morphological and physiological factors will be discussed, in the order of the special requirements appearing in the three major age groups.

DETERMINING CHILDREN'S AGE AT DEATH

The eruption of the deciduous and permanent teeth is the most important feature from which conclusions can be drawn from skeletal finds of children (age groups infant I and II) (Schour and Massler, 1940, 1941; Gustafson, 1950; Leslie, 1951; Kronfeld, 1954; Gleiser and Hunt, 1955; Hunt and Gleiser, 1955; Garn, Koski and Lewis, 1957; Garn, 1958; Koski and Garn, 1957; Olivier and Pineau, 1958; Seifert, 1959; Legoux, 1962–63; Miles, 1963). In addition, the length of the skeleton measured in the grave might be of some help, but this should only be used if the teeth have disintegrated (Demisch and Wartmann, 1956). Age determination on this basis is uncertain and liable to error.

According to Balogh (1964), stomatologists distinguish six successive phases in the development of deciduous and permanent teeth. These are as follows: (1) the foetal phase, (2) the toothless phase of infancy, (3) teething phase, i.e. the eruption of deciduous teeth, (4) phase of deciduous teeth, (5) phase of the eruption of the permanent teeth, or mixed denture, (6) phase of the development of permanent teeth. In practice, the teething phase and that of the eruption of the permanent teeth are the most evident age indicators. In historico-anthropological studies it is usually sufficient to classify the individuals into age groups infant I or II, or to give the age in a two to three years' range. In demography, however, we must pay special attention to the toothless phase of infancy and to the phase of deciduous teeth. For an analysis of perinatal or infant mortality can only be made if the age of the toothless infant is determined, directly or indirectly (X-ray examination), in months. In the deciduous phase, the presence of dental germs, the development of the crown and the absorption of the root are essential indicators, on the basis of which the accurate age in years can be diagnosed. If these characteristics are disregarded, age data tend to accumulate at certain years within groups infant I and II, while other years are missing. When considering permanent teeth, the development of the crowns and the delimitation of the cusps should be observed in addition to the sequence and chronology of eruption. It should also be ascertained whether the formation of roots has been completed.

Tables of age determination constructed using the above method will be submitted below. They show the succession and chronology of the eruption of deciduous and permanent teeth and also contain the chronology of the development of other characteristic features. In the tables the symbols introduced by stomatologists and accepted also by anthropologists for describing the denture will be used.

Both deciduous and permanent teeth form two (the upper and the lower) arches. The deciduous set consists of 20, the permanent set of 32 (28) teeth. Deciduous teeth include the incisors (*i*), the canines (*c*) and the molars (*m*). The denture is represented by the following scheme showing the upper and lower teeth, as well as the right and the left side separately. Using the letter symbols, the scheme of the deciduous teeth is:

$$\begin{array}{c} \text{Upper row} \\ \text{Right side}\quad \begin{array}{r|l} m\,m\,c\,i\,i & i\,i\,c\,m\,m \\ \hline m\,m\,c\,i\,i & i\,i\,c\,m\,m \end{array} \quad\text{Left side} \\ \text{Lower row} \end{array}$$

Using Roman numerals

$$\begin{array}{r|l} \mathrm{V\ IV\ III\ II\ I} & \mathrm{I\ II\ III\ IV\ V} \\ \hline \mathrm{V\ IV\ III\ II\ I} & \mathrm{I\ II\ III\ IV\ V} \end{array}$$

The permanent set is made up of the following teeth: the incisors (*I*), the canines (*C*), the premolars (*P* or *PM*) and the molars (*M*). In the case of permanent teeth, Arabic numerals are used to distinguish them from deciduous teeth. The two types of symbols (letters and numerals) are used combined for defining the individual tooth, i.e. the first, second or third tooth of a given type. The position of the numeral used as an index (or that of the comma with canines) indicates the tooth being placed in the upper or the lower row.

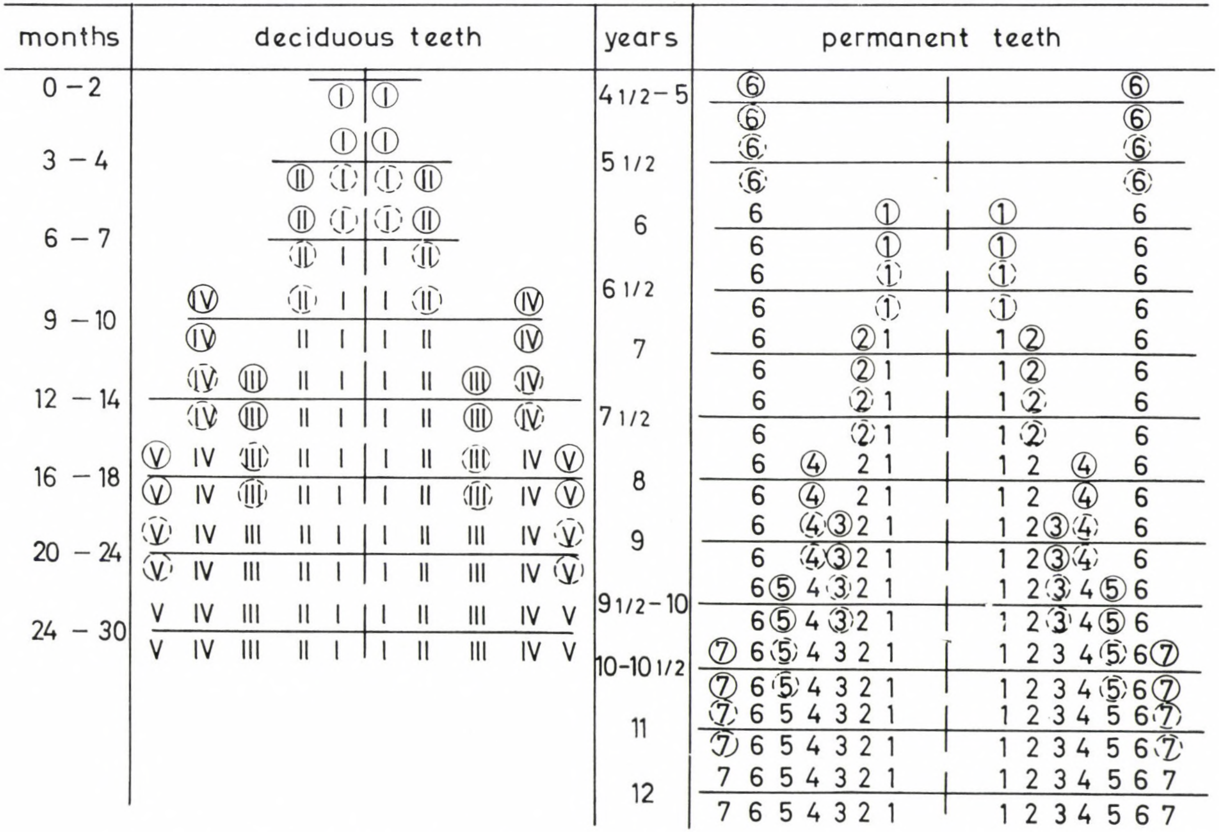


Fig. 18. Eruption order of deciduous and permanent teeth (after Schranz, 1959).

The scheme of permanent teeth using letter symbols is:

$$\begin{array}{c}
 & \text{Upper row} & \\
\text{Right side} & \dfrac{M\ M\ M\ PM\ PM\ C\ I\ I}{M\ M\ M\ PM\ PM\ C\ I\ I}\left|\dfrac{I\ I\ C\ PM\ PM\ M\ M\ M}{I\ I\ C\ PM\ PM\ M\ M\ M}\right. & \text{Left side} \\
 & \text{Lower row} &
\end{array}$$

Using numerals

$$\dfrac{8\ 7\ 6\ 5\ 4\ 3\ 2\ 1}{8\ 7\ 6\ 5\ 4\ 3\ 2\ 1}\left|\dfrac{1\ 2\ 3\ 4\ 5\ 6\ 7\ 8}{1\ 2\ 3\ 4\ 5\ 6\ 7\ 8}\right.$$

TABLE 20

Age at tooth eruption (after Vallois, 1960)

Deciduous dentition			Permanent dentition	
Tooth	Average age (months)	Normal range (months)	Tooth	Normal range (years)
		Upper row (maxilla)		
i I	7	8–11	I 1	7–8
i II	9	8–11	I 2	8–10
c	18	16–24	C	11–12
m I	14	9–21	P 1	10–11
m II	24	20–36	P 2	10–12
			M 1	6–7
			M 2	12–13
			M 3	17–30
		Lower row (mandible)		
i I	6	4–8	I 1	6–7
i II	8	7–12	I 2	7–10
c	18	16–25	C	9–10
m I	12	9–21	P 1	10–12
m II	22	20–36	P 2	11–12
			M 1	6–7
			M 2	11–13
			M 3	16–30

Olivier (1960) gives the order of eruption of the deciduous and permanent teeth as follows. Deciduous teeth: i_{I}–i^{I}–i^{II}–i_{II}–m^{I}_{I}–c;–m^{II}_{II}; permanent teeth: M^1_1–I^1_1–I^2_2–PM^1_1–C;–PM^2_2–M^2_2–M^3_3. This order of eruption is generally valid, but departures from the normal are often noted. There is no difference between the sexes in the order of deciduous and permanent eruption, only in the time of the eruption. Deciduous teeth begin to appear earlier in boys, while permanent teeth, in girls.

Schranz's chart (1959) (Fig. 18) supplies information on the dental status in the various phases of dentition, as well as of the corresponding age of life. In this chart the complete development of all deciduous and permanent teeth are registered up to the age of 12. Up to 2 years, age is given in months, between 2 and six years in half years, between 7 and 12 years in years. Circled numerals indicate teeth which have not yet erupted, i.e. they are in the state of impaction preceding dentition; same with broken line means that the tooth is erupting, i.e. it is in the state of dentition.

Table 20 compiled by Vallois, (1960) shows the eruption of deciduous and permanent teeth both for the upper and lower dentures. It also gives the normal variations of eruption.

The development of deciduous teeth is clearly shown in Table 21 compiled by Kronfeld (1954). It contains the chronology of tooth development, considering the appearance of the dental germ, the eruption and full development of the deciduous teeth. These three criteria constitute a firmer basis for age diagnosis.

TABLE 21

Chronology of the development of deciduous teeth (after Kronfeld, 1954)

Teeth	Appearance of dental germ	Eruption (months)	Full development (years)
$\frac{\mathrm{I}\,\vert\,\mathrm{I}}{\mathrm{I}\,\vert\,\mathrm{I}}$	16th foetal week	6–8	1·5–2
$\frac{\mathrm{II}\,\vert\,\mathrm{II}}{\mathrm{II}\,\vert\,\mathrm{II}}$	20th foetal week	8–10	1·5–2
$\frac{\mathrm{III}\,\vert\,\mathrm{III}}{\mathrm{III}\,\vert\,\mathrm{III}}$	9th month after birth	16–20	2·5–3
$\frac{\mathrm{IV}\,\vert\,\mathrm{IV}}{\mathrm{IV}\,\vert\,\mathrm{IV}}$	6th month after birth	14–14	1·5
$\frac{\mathrm{V}\,\vert\,\mathrm{V}}{\mathrm{V}\,\vert\,\mathrm{V}}$	1st month after birth	20–23	3

Table 22 shows Olivier's (1960) data taking into account several features of dental development. It contains the chronology of the development of deciduous and permanent teeth; this differs somewhat from Kronfeld's (1954) earlier information. Olivier's (1960) table also shows the development and formation of the germ, the crown and the root of deciduous teeth, the time of root absorption, and the approximate time of the sheding of deciduous teeth.

Data published by R. E. Moyers in 1959 give the chronology of development of permanent teeth, both for the upper and lower row, taking into account the eruption and the development of the crown and the root (Table 23).

TABLE 22

Chronology of deciduous and permanent dentition (after Olivier, 1960)

(*A*) Deciduous teeth

Tooth	Age at appearance of dental germ (foetal months)	Development of crown at birth (per cent)	Age at full development of crown (months)	Age at full development of root (years)	Age at absorption of root (years)	Age at dentition (years)
i I	4–4·5	Upper: 83 Lower: 60	Upper: 1·5 Lower: 2·5	1·5	4–5	6–7
i II	4·5	Upper: 66 Lower: 60	Upper: 2·5 Lower: 3	1·5–2	4–5	7–8
c	5	33	9	3·25	6–7	10–12
m I	5	cusps still continuous	5·5–6	2·5	4–5	9–11
m II	6	cusps still distinct	10–11	3	4–5	10–12

(*B*) Permanent teeth

Tooth	Age at appearance of germ	Age at full development of crown (year)	Age at full development of root (year)
M 1	At birth	2·5–3	9–10
I 1	3–5 months	4–5	9–10
I 2	Upper 10–12 months Lower 3–4 months	4–5	10–11
C	4–5 months	6–7	12–15
P 1	1·5–2 years	5–6	12–13
P 2	2–2·5 years	6–7	12–14
M 2	2·5–3 years	7–8	14–16
M 3	7–10 years	12–16	18–25

It should be noted that the data as determined by the various authors differ to a certain extent. This may be the result of different types of observation or the observations being limited to the lower or upper row, to boys or girls; in other cases again combined, general determinations have been given. Generalizing data give fairly approximate information of age for incomplete dentures, but if a complete set of teeth is available and the sex is known, a more accurate age determination can be made. For this purpose we show Moyers's (1959) detailed table, which gives the time of deciduous and permanent tooth eruption for boys and girls, taking into account the upper or lower position of the teeth (Table 24).

TABLE 23

Development of permanent teeth (after Moyers, 1959)

Tooth	Age at full development of crown (years)		Age at eruption (years)		Age at full development of root (years)	
	Maxilla	Mandible	Maxilla	Mandible	Maxilla	Mandible
1	4·5	3·5	7–7·5	6–6·5	10–11	8·5–10
2	5·5	4–4·5	8–8·5	7·5–7·8	10–12	9·5–10·5
3	5·5–6·5	5·5–6	11–11·7	9·8–10·3	12·5–15	12–13·5
4	6·5–7·5	6·5–7	10–10·5	10–10·8	12·5–12·7	12·5–14
5	7–8·5	7–8	10·8–11·3	10·8–11·5	14–15·5	14·5–15
6	4–4·5	3·5–4	6–6·5	6–6·3	9·5–11·5	10–11·5
7	7·5–8	7–8	12·3–12·8	11·8–12	15–16·5	15·5–16·5
8	12–16	12–16	20·5	20–20·3	18–25	18–25

Determination of age at death on the basis of teeth is feasible primarily in the Europoid race. There may be minor differences in the order and chronology of tooth eruption in the various main races. Genovés (1962) refers to the fact that the investigations made by a number of authors, e.g. Steggerda and Hill (1942), Dahlberg (1949), Bálint and Hegedűs (1955), Cattell, Ainsworth (1925), Leslie (1952), in American Negroes, Zulus, Mayas, English, New Caledonian and other populations revealed that there are differences in the chronology of dental development. Also Pedersen (1949) mentions this fact in his studies of Eskimos; but the differences are not significant enough to influence age determination to any great extent.

In conclusion there is another point we should like to mention. It may be assumed that, due to general acceleration, the time of dentition has changed, it takes place earlier compared with historical times. But this potential source of error does not affect the age determination on the basis of children's skeletons to any extent.

DETERMINING THE AGE OF JUVENILES

The second molar usually erupts at the age of 12 years. Juvenile age, however, is counted from the 15th year of life, and if the long bones are not available, the intervening years of life are a gap in age determination. This lack does not disturb anthropological analyses as the find in question is then classified as belonging either to infant II or to the juvenile age group. Yet from the demographic angle a decision in such marginal cases is most important, and we therefore give a detailed description of the significant age indicators of the juvenile age group.

Age indicators generally mentioned for the juvenile age are the formation, eruption and full development of the third molar. Here we share Vallois's opinion that this is of limited value in age determination, as the above process—allowing for normal variations—may last from the 17th to the 30th year of age.

A much more important feature than the third molar is the spheno-occipital synchondrosis at the base of the skull. The cartilaginous joint between the sphenoid and the occipital bone begins to close at the age of 17, and full closure is attained by the age of 22 years. This age indicator, therefore, can supply primary information on the juvenile age group.

More accurate information, referring even to the accurate age, is supplied by the fusion of the epiphysis and diaphysis of the long bones of the extremities. It would be possible, of course, to take into account the developmental stages of the

TABLE 24

Eruption chronology of teeth in the upper and lower jaw, according to sex (after Moyers, 1959)

Upper row	Tooth	Lower row
	(*A*) Deciduous	
	Boys	
8 m 14 d ± 2 m	*i I*	7 m 6 d ± 2 m
10 m 6 d ± 2 m	*i II*	11 m 9 d ± 3 m
17 m 18 d ± 3 m	*c*	18 m 0 d ± 3 m
14 m 24 d ± 2 m	*m I*	15 m 3 d ± 2 m
24 m 7 d ± 6 m	*m II*	23 m 28 d ± 3 m
	Girls	
9 m 0 d ± 2 m	*i I*	7 m 9 d ± 2 m
10 m 23 d ± 2 m	*i II*	11 m 19 d ± 2 m
18 m 5 d ± 2 m	*c*	18 m 6 d ± 3 m
14 m 23 d ± 2 m	*m I*	14 m 27 d ± 2 m
24 m 24 d ± 6 m	*m II*	24 m 18 d ± 3 m
	(*B*) Permanent	
	Boys	
7 y 2 m 13 d ± 0 y 11 m	*I* 1	6 y 3 m 23 d ± 0 y 8 m
8 y 4 m 12 d ± 1 y 0 m	*I* 2	7 y 4 m 20 d ± 0 y 9 m
11 y 1 m 23 d ± 1 y 2 m	*C*	10 y 8 m 28 d ± 1 y 2 m
10 y 7 m 6 d ± 1 y 4 m	*P* 1	11 y 6 m 8 d ± 1 y 3 m
11 y 4 m 12 d ± 1 y 4 m	*C*	11 y 6 m 8 d ± 1 y 3 m
6 y 4 m 1 d ± 0 y 10 m	*M* 1	6 y 3 m 26 d ± 0 y 9 m
12 y 6 m 1 d ± 1 y 3 m	*M* 2	12 y 0 m 7 d ± 1 y 3 m
	Girls	
7 y 0 m 0 d ± 0 y 9 m	*I* 1	6 y 1 m 23 d ± 0 y 8 m
7 y 11 m 14 d ± 0 y 11 m	*I* 2	7 y 1 m 8 d ± 0 y 9 m
10 y 6 m 1 d ± 1 y 1 m	*C*	9 y 8 m 10 d ± 1 y 2 m
10 y 1 m 8 d ± 1 y 3 m	*P* 1	10 y 0 m 3 d ± 1 y 4 m
10 y 8 m 7 d ± 1 y 5 m	*P* 2	10 y 11 m 27 d ± 1 y 4 m
6 y 3 m 15 d ± 0 y 10 m	*M* 1	6 y 2 m 22 d ± 0 y 11 m
11 y 11 m 26 d ± 1 y 2 m	*M* 2	11 y 6 m 10 d ± 1 y 4 m

m=month, d=day, y=year

TABLE 25

Evolution of the secondary points of ossification of the long bones in recent Europeans (after Vallois, 1960)

Long bones		Age at appearance of ossification centres (years)	Age at completion of union (years)
Clavicula	Epiphysis sternalis	16–20	21–25
Humerus	Epiphysis proximalis	1	18–22
	Epiphysis distalis	1–2	14–15
Radius	Epiphysis proximalis	4–7	14–18
	Epiphysis distalis	1–2	21–23
Ulna	Epiphysis proximalis (olecranon)	10–12	15–17
	Epiphysis distalis	4–6	18–20
Femur	Epiphysis proximalis	1	17–20
	Epiphysis distalis	0	17–19
	Trochanter maior	—	17–20
	Trochanter minor	—	16–
Patella	—	3–5	—
Tibia	Epiphysis proximalis	—	17–20
	Epiphysis distalis	2	16–19
Fibula	Epiphysis proximalis	3–5	17–20
	Epiphysis distalis	2	16–19

vertebrae and ribs as well, but these parts are usually found in a most fragmentary and poor condition unfit for analysis. According to Pyle and Hoerr (1955), the developmental features of the atlas are also excellent age indicators.

Table 25 shows the chronology of the fusion between the proximal and distal epiphyses with the diaphysis of long bones (after Vallois). This table can be used to practical advantage for age determination, but it ought to be mentioned that the completion of union is usually shown over a range of 2–5 years. Others, e.g. Stevenson (1924), Borovansky and Hnevkovsky (1924), Flecker (1942), Greulich and Pyle (1959), McKern and Stewart (1957), and F. E. Johnston (1961), have determined the time of union more accurately, taking into consideration sex differences as well. When using Vallois's table, it is advisable to proceed as follows. The stage of fusion should be determined first. If the metaphysis between epiphysis and diaphysis is still cartilaginous, i.e. open, in the case of skeletal finds = stage 0; stage 1 = ossification is found to extend over ¼ of the circumference; stage 2 = ossification has advanced over ½ of the circumference of the epiphysis-diaphysis border; stage 3 = union over ¾ of the circumference; stage 4 = the metaphyseal line appears only in traces. According to Schranz (1933, 1959) the stage marked 0 corresponds to the first value in the column headed 'completion of union', whereas the stage marked 4 to the other value of the range. On the basis of intermediate stages, age can be determined within the given range.

As has been mentioned, the time of osseous fusion between epiphysis and diaphysis in long bones differs according to sex. Table 26 contains data compiled by

Todd (1920–28, 1930), Flecker (1942), and Johnston (1961) showing respective sex differences.

TABLE 26

Sex differences in the time of union between epiphysis and diaphysis of long and pelvic bones (after Todd, Flecker and Johnston).

Age of union in years

Bones	Males			Females		
	Todd (1930)	Flecker (1942)	Johnston (1961)	Todd (1930)	Flecker (1942)	Johnston (1961)
Acetabulum	14	14	14	13	12	11·5
Humerus — dist. e.	14	16	14	13	13–14	11·5
Ulna — prox. e.	15	16	14	13	14	11·5
Radius — prox. e.	15	16	17·5	13	14	14
Head of femur	17	17	17	17	14	14·5
Femur — greater trochanter	17	18	17	17	14	13·5
Tibia — dist. e.	16	17	17	15	14	15
Humerus — medial epicondyle	15	16	17	14	14	15
Ischial tuberosity	—	—	18·5	—	—	15·5
Fibula — dist. e.	16	17	17	15	15	15
Fibula — prox. e.	—	18	18	18	17	16
Humerus — prox. e.	—	20	18·5	19–20	17	16
Radius — dist. e.	—	19	18·5	—	18	16
Femur — dist. e.	18	19	18·5	18	17	17
Tibia — prox. e.	—	18	18	18	14	16
Ulna — dist. e.	18	19	18·5	18	17	18

If the tarsal and metacarpal bones are also available for age determination, a diagnosis can be established also on this basis. According to Flecker (1942) and Johnston (1961), union of the calcaneus takes place at the age of 14–16½, while the time of the first metacarpal union is put by Flecker (1942) and Greulich and Pyle (1959) at 16–18 years in males, and 14–15 years in females. The data given for the time of fusion in long bones apply to modern Europoids and Mongoloids [Johnston's (1961) data for Indians], so this fact should be taken into account when historical populations are being reconstructed. Nor can the fact of acceleration be neglected. The best method for age determination in the juvenile age group is to determine the various age indicators separately, and then approximate the most likely chronological age by comparing the partial results.

AGE DETERMINATION AT ADULT AGE

Adult age begins at the time when the spheno-occipital synchondrosis at the base of the skull becomes ossified, union of epiphysis and diaphysis in the skeletal long bones has been completed, and the sacrum has developed into a unified bone. In theory, regressive processes commence along with the age-changes. Nevertheless regressive processes in the early stage do not disturb the biological balance. The first period of adult age is characterized by an apparent stability. But the length of this period and the characteristics of this stability are highly individual as they are affected by a number of exogenous and endogenous factors. Irreversible regressive processes may be accelerated or slowed down. As a result of all this the age determination of adults requires great circumspection. We may be satisfied that we have approximated actual chronological age correctly only if age determination has been made on the basis of as many age indicators as possible. For some fifty years this requirement has been the concern of anatomists, pathologists, anthropologists and experts of forensic medicine, and as a result a reliable basis is now available for determining the age of adults (Manouvrier, 1894; Frédéric, 1906–09; Zanolli, 1908; Todd and Lyon, 1924, 1925; Todd and d'Errico, 1928; Stewart, 1934; Kappers, 1935; Asley, Montagu, 1938; Keen, 1950; Vandervael, 1952; Weinmann and Sicher, 1955). Some time ago the closure of cranial sutures and the condition and wear of the denture were taken as the primary basis of age determination, and only recently has attention been paid to other age characteristics of the human skeleton. As early as 1930 Topp called attention to the circumstance that the process of changes with age can be appraised directly and dependably on the two opposite surfaces of the pubic bone (symphysial face), (McKern, 1956; 1957). Methods for studying the internal structural changes in the long bones of the extremities, i.e. in the cancellous substance of the epiphyses as well as cavitation that takes place later, have only been developed during the past thirty years. The methods developed so far for studying the changes in the humerus and the femur show that further progress can be made in this direction, as the age indicators found in these bones can also be applied to the bones of the forearm and the leg, to the vertebrae forming the spinal column, as well as to the carpal and tarsal bones, allowing, of course, for the given structural architecture and functional use.

The range of morphological age indicators used for analysis is widening. A great step forward has been made not only in the knowledge of changes with age, but in methodology as well. Gustafson (1950), whose achievements will be discussed later on, has based his age determination method on several criteria of the macroscopic and microscopic appearance of the teeth. We have followed the same principle in the age determination of adults, and have developed our complex method—to be discussed below—considering several elements of the human skeleton, which are of dissimilar structure and function. This was necessary because the changes in features that reflect man's biological state depend on different factors and therefore show certain differences themselves. The effects of accelerated or slowed processes are thus compensated for and a realistic basis for estimating chronological age is provided.

The accuracy of the age determination method for the adult age is conditional, first of all, on selecting the features in such a manner that the conclusions to be drawn from them will be as close to the chronological age as possible. For instance, the abrasion of teeth—one of the features used for ageing in anthropology – is determined mainly by living conditions (diet). The wear on the teeth often indicates the individual's eating habits rather than the period of time during which the teeth had been used. Also, though the closure of the main cranial sutures proceeds in parallel with the advance of chronological age, other factors may produce differences in the process. As a result, closure of cranial sutures becomes more indicative of the degree of biological senescence. Other age indicators such as internal structural changes in the proximal epiphyses of the humerus and femur (Balthazard and Lebrun, 1911), the morphological changes on the symphysial face of the pubic bone, etc., are in a much closer correlation with chronological age. Consequently, chronological age data required for palaeodemographic studies can be given an adequate approximation on the basis of skeletal finds.

In the following we give a summary of the most important criteria of age in adult skeletons, together with their changes, based partially on research work of our own. This will be followed by a description of the ageing method developed by us, and a description of recently developed chemical-analytical methods.

CLOSURE OF CRANIAL SUTURES

Taking into account the papers in the literature revising the role of cranial suture closure in ageing, as well as our own experience, we have investigated the correlation between cranial sutures and chronological age. In 1955 and 1956 we examined the calottes of 402 dissected corpses at the Institute of Forensic Medicine of Semmelweis University School of Medicine, Budapest. On the ectocranial and on the endocranial surfaces we ascertained the degree of ossification in certain parts of the three main sutures of the cranium (3 parts in the coronal suture on each side: C_1,C_2,C_3; 4 parts the sagittal suture S_1, S_2, S_3, S_4; and 3 parts each in the lambdoid: L_1, L_2, L_3). We used Martin's scale (suture open = 0, incipient closure = 1, closure in process = 2, advanced closure = 3, and closed suture = 4). The scores of the various subdivisions were averaged for each suture. The mean overall degree of suture closure was determined from the averages of the individual sutures, based on both ectocranial and endocranial observations.

TABLE 27

Sex and age distribution of the material examined for suture closure

Age group (years)	Males	Females	Total
15–19	3	2	5
20–24	4	3	7
25–29	8	9	17
30–34	8	6	14
35–39	7	7	14
40–44	14	8	22
45–49	17	6	23
50–54	29	13	42
55–59	18	13	31
60–64	32	17	49
65–69	28	15	43
70–74	19	19	38
75–79	13	11	24
80–84	4	10	14
85–89	4	5	9
Total	208	114	352

Our examinations included other questions connected with suture closure (wall thickness, causes of death, case histories, social status, etc.). Nevertheless, here we shall limit ourselves to the description of our research directly connected with age determination. We also looked for—both ectocranially and endocranially—sex differences in suture closure, but no significant differences were found. Taxonomical differences were disregarded, but attention was paid to pathological changes, in order to eliminate the pathological cases from the series. As far as possible we intended to obtain data in 'normal' individuals. After eliminating pathological cases, the number of examined crania was reduced to 352 of which 208 were males and 144 were females. Asymmetrically ossified crania were subjected to special examination; their suture closure showed no substantial departure from the normal.

The material (352 cases) was divided into age groups of 5 years each. Except for the three extreme age groups, 14 to 49 cases constituted the various age groups (Table 27).

In the majority of the examined calottes we have found that the ectocranial sutures range between stages 0 and 3 on the average, while the endocranial sutures were graded, usually 3–4. In agreement with other authors, we have concluded from this fact that the ossification of sutures begins inwardly and spreads outwardly.

From Table 28 the following chronology of suture closure can be derived: endocranially, coronal, sagittal and lambdoid suture (the coronal was completely closed in 76·4 per cent); ectocranially, the sagittal suture is that first to close, but always about one grade behind the grade found endocranially. The sequence of closure found on the ectocranial surface is exactly the opposite of that seen endocranially: higher grades appear in the sagittal and lambdoid sutures, lower ones in the coronal suture, thus the closure of the coronal suture, proceeding from the inside to the outside, is slow.

Owing to this circumstance, a distinction must be made between endo- and ectocranial data. In the following the degree of endocranial suture closure will be used unless mentioned otherwise.

TABLE 28

Distribution of the skulls according to stages of suture closure

Suture	Stages of suture closure					Total
	0–0·9	1–1·9	2–2·9	3–3·9	4·0	
			Ectocranial			
Coronal	29	114	94	76	39	352
Sagittal	28	64	111	115	34	352
Lambdoid	20	89	120	99	24	352
All three	25	97	132	88	10	352
			Endocranial			
Coronal	6	23	15	39	269	352
Sagittal	5	25	29	135	158	352
Lambdoid	16	50	58	129	99	352

The details of our comprehensive analysis of suture closure will be omitted here and only the conclusions drawn will be discussed.

(*a*) Coronal Suture

Closure commences at the age of 15–19, but does not reach stage 2 until the age of 24 as a rule. The process seems to the be quickest between the 25th and 29th years of age, as all stages are represented in this period and the suture was found completely closed in half of the cases of this age. At the age of 30 the suture was virtually completely closed in 80·5 per cent of the cases, and cases below stage 3 were found only sporadically (8·4 per cent). Means lower than 1 were found in only two instances over the age of 30, both being younger than 60.

On the ectocranial surface it was observed that stages below 2 were found at every age; stages above this, only in cases older than 25. Stages 3 and 4 occurred in relatively few cases, in about one third of the individuals examined. The ratio is not much higher in old adults either, as only 42·7 per cent of individuals over the age of 60 scored higher than 3.

The closure of the various parts of the coronal suture, observed ectocranially, shows no substantial age differences, but it might be noted that scores lower than stage 2 were found—though occasionally—in section C_1 rather than in C_3.

(*b*) Sagittal Suture

Closure onset is earlier here than in the coronal suture, scores ranging from 1 to 2·9 were found in individuals younger than 19, stages 3 and even 4, between 20 and 24 years. Although closure commences early (a fact which cannot be proved beyond doubt owing to the small number of juvenile cases available), the process itself is protracted. It passes stage 3 in the fourth decade, and stops here until the beginning of old adult age in a sizable proportion of the cases. Scores lower than 3 occurred after the age of 40 in 10·8 per cent of the cases, and in 5·9 per cent after the age of 70. The sagittal suture was completely closed in 67·1 per cent of the skulls older than 70.

Observed ectocranially, under the age of 20 most skulls scored less than 1. Ossification sets in at the age of 20–24 (reaching stage 3) and proceeds slowly. Completely closed sutures were found only after the age of 40. The sagittal suture does not close completely even at old age, showing stages 2 to 3·9 over the age of 60 in the majority of cases.

No appraisable differences were found in the closure of the various parts of this suture.

(*c*) Lambdoid Suture

Closure of this suture seems to be the slowest endocranially, but it should be mentioned here that it is this suture that produced the highest variability of data. Stages below 1 occur anywhere up to the age of 70, and the ratio of completely closed sutures is the same at the age of 25–29 as in some senile age groups. Stages 2, 3 and 4 all occur at senile age.

Observed ectocranially, the process shows a similar character, although it seems to be even slower here. Of the various parts L_1 is closed earliest, the others are open even at higher ages in many cases (stages 1–2·9).

(*d*) Completely Closed Sutures

Sutures completely closed both inside and outside were found in only 6 cases older than 55 years.

AGE DETERMINATION BASED ON THE DEGREE OF CLOSURE OF THE CRANIAL VAULT SUTURES

We have studied the relationship of suture closure and age by examining the above material of 285 crania with symmetrically closing sutures. In order to make an attempt at developing a practical method of age determination, we did not draw conclusions from the data of the individual sutures or their subdivisions, but calculated the endocranial closure index of the three main sutures jointly in all cases. The number of cases in the examined series was sufficient to establish the relevant trends, but not to draw detailed conclusions from the material broken down to five-year age groups.

Cross tabulations of suture closure and age have shown that the former is in a correlation with the advance of chronological age. The five-year age groups and the material ranged according to the stages broken down to two decimals appear in Table 29; in younger age groups lower, in older ones higher values are scored as a rule. A similar picture is conveyed by the means: the mean values of closure increase with age, and average age advances parallel with the increase in closure stages.

The means of stages are below 1 until the age of 20, below 2 until the age of 24, and below 3 until the age of 34; from the age of 35, however, they rise above 3 and keep increasing with age. Stages up to 1·5 are linked with average ages under 40, stages above 3·0 with average ages over 60.

The means of the suture closure stages found in the various five-year age groups are shown combined in Table 30. It appears from this table that the main cranial sutures of individuals belonging to the older age groups usually show rising means. It should be noted here that the dispersion about the means is very high even in age groups with a large number of cases.

On the basis of Table 30 the correlation between suture closure and chronological age can be expressed analytically. The regression curve (Fig. 19) can be plotted from the second-degree equation:

$$y = 1{\cdot}1627 + 0{\cdot}4212x - 0{\cdot}0171\,x^2$$

where y = the mean of closure stage,

x = the chronological age, i.e. the serial number corresponding to the age group as given in Table 30.

TABLE 29

Distribution of our material according to the stages of closure of the three cranial vault sutures and to chronological age

Stages of suture closure	Chronological age (years)															Total	Average
	15–19	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69	70–74	75–79	80–84	85–89		
0·4–0·5	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	2	22
0·6–0·7	1	1	—	—	—	—	—	—	1	—	—	—	—	—	—	3	32
0·8–0·9	1	—	—	—	—	—	—	1	—	—	—	—	—	—	—	2	35
1·0–1·1	1	—	2	—	—	—	—	—	—	—	—	—	—	—	—	3	24
1·2–1·3	1	1	—	1	—	—	—	—	—	—	—	—	—	—	—	3	35
1·4–1·5	—	1	—	1	—	—	—	1	—	—	—	—	—	—	—	3	35
1·6–1·7	—	—	1	—	—	—	2	1	—	—	—	—	—	—	—	4	43
1·8–1·9	—	—	1	1	—	2	3	—	—	—	—	1	—	—	—	8	45
2·0–2·1	—	1	1	—	1	—	—	1	—	—	—	—	—	—	—	4	35
2·2–2·3	—	—	3	—	1	—	—	—	1	—	1	—	—	—	—	6	40
2·4–2·5	—	—	1	—	1	—	—	3	—	1	—	—	1	—	—	7	51
2·6–2·7	—	—	—	3	1	—	—	2	—	—	—	1	—	1	—	8	49
2·8–2·9	—	—	1	—	—	3	2	1	—	1	—	—	—	1	—	9	49
3·0–3·1	—	—	—	1	—	2	—	—	—	1	5	1	1	1	—	12	62
3·2–3·3	—	—	—	—	1	1	1	1	4	4	4	1	1	—	—	18	60
3·4–3·5	—	—	—	1	—	1	2	6	2	1	4	3	—	2	1	23	60
3·6–3·7	—	—	1	1	2	3	1	4	2	5	4	1	3	1	—	28	57
3·8–3·9	—	1	—	1	3	6	4	11	6	14	12	15	3	3	2	81	61
4·0	—	—	2	—	1	2	3	6	4	9	5	9	14	2	4	61	65
Total	5	5	14	10	11	20	18	38	20	36	35	32	23	11	7	285	
Mean closure stage	0·9	1·9	2·8	2·6	3·2	3·4	3·1	3·3	3·5	3·7	3·6	3·7	3·8	3·5	3·9		

TABLE 30

Closure of the three main cranial sutures

Order	Age group (years)	Mean closure stage (M)	S. D.	Range ($M \pm 1$ S.D.)	No. of cases (N)
1	15–19	0·86	0·30	0·56–1·16	5
2	20–24	1·86	1·11	0·75–2·97	5
3	25–29	2·79	1·03	1·76–3·82	14
4	30–34	2·63	0·94	1·69–3·57	10
5	35–39	3·23	0·69	2·54–3·92	11
6	40–44	3·36	0·67	2·69–4·00	20
7	45–49	3·12	0·88	2·24–4·00	18
8	50–54	3·32	0·25	3·07–3·57	38
9	55–59	3·47	0·77	2·70–4·00	20
10	60–64	3·69	1·17	2·52–4·00	36
11	65–69	3·57	0·40	3·17–3·97	35
12	70–74	3·71	0·46	3·25–4·00	32
13	75–79	3·78	0·39	3·39–4·00	23
14	80–84	3·52	0·44	3·08–3·96	11
15	85–89	3·87	0·21	3·66–4·00	7
Total	85–89	—	—	—	285

The regression line appears to fit the dispersion of the means of suture closure to various ages well. This means that the trend of the ossification process is uniform, first rapid, then slowing down. It should be kept in mind, however, that individual data show a wide dispersion about the regression curve, i.e. the means of the various age groups (see Table 29). Thus the determination of the individual's age is uncertain or only possible between wide limits. This circumstance does not, however, prevent the use of the closure of cranial sutures as an indicator of age, especially if other age indicators are considered at the same time.

To determine age from endocranial sutures we studied the degree of closure relative to age in our control sample (Table 31). It appears that age increases parallel the stages. This parallelism is very

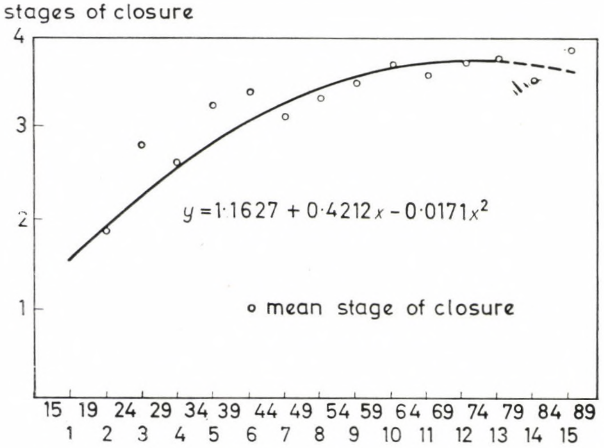


Fig. 19. Relation between chronological age and suture closure.

significant after stages 1·5, 2·5, 2·9 and 3·9 that further subdivision of these groups was possible. This was necessary because of the wide dispersion of the data about the means (Table 32).

In conclusion, age can be determined on the basis of the closure of cranial sutures within wide age limits. When combined with other age indicators, it is an important factor in age determination.

TABLE 31

Average ages belonging to the various closure stages

Mean closure stage	Average age (years)	No. of cases
0·4–0·9	29·9	7
1·0–1·5	27·6	9
1·6–1·9	44·1	12
2·0–2·5	43·5	17
2·6–2·9	49·1	17
3·0–3·3	60·5	30
3·4–3·5	60·5	23
3·6–3·7	56·8	28
3·8	61·4	36
3·9	60·2	45
4·0	65·4	61
Total	—	285

TABLE 32

Determination of age based on suture closure

Mean closure stage	Average age	Mean deviation	No. of cases	Range
0·4–1·5	28·6	13·08	16	15–40 juvenile–young adult
1·6–2·5	43·7	14·46	29	30–60 young adult–middle adult
2·6–2·9	49·1	16·40	17	35–65 young adult–middle adult
3·0–3·9	60·0	13·23	162	45–75 middle adult–old adult
4·0	65·4	14·05	61	50–80 middle adult–old adult

CHANGES WITH AGE IN TEETH OF ADULTS

On the basis of Gustafson's (1950, 1953) investigations, we deal briefly with the characteristic age-changes of teeth. Gustafson and Simpson (1950, 1953) recommend the observation of six phenomena:

(1) Abrasion. No abrasion resulting from mastication appears on the occlusal plane = A_0; abrasion on enamel = A_1; abrasion reaches the dentin = A_2; pulp cavity has opened = A_3.

(2) Periodontosis. Following eruption the tooth is closely surrounded by the periodontium = P_0; incipient stage of periodontosis = P_1; the tooth becomes increasingly exposed and periodontosis, which first extends to ⅓ of the root = P_2; periodontosis extends to ⅔ of the root = P_3.

(3) Secondary dentin formation within the pulp cavity. This phenomenon may be the result of ageing and/or pathological conditions produced by caries and periodontosis. No secondary dentin present = S_0; secondary dentin at the upper end of the pulp = S_1; the pulp cavity is filled half = S_2; the pulp cavity is almost completely filled with secondary dentin = S_3. Microscopic examination is needed for determination.

(4) Cement deposition round the root, which can be determined with microscopic examination. Normal cement layer = C_0; minimum accretion of cement beginning round the root = C_1; cement deposit extending increasingly in width and in root height = C_2; bulky cement deposit round the root = C_3.

(5) Root atrophy. This proceeds parallel with cement and dentin deposition. No root atrophy = R_0; isolated root atrophy = R_1; root atrophy manifest in increasing loss of substance = R_2; root covered with cement and secondary dentin over a large area = R_3.

(6) Transparency, i.e. thinning of the root, develops with the advance of age and is less affected by pathological conditions. Root not yet transparent = T_0; transparency discernible = T_1; one-third of root definitely transparent = T_2; complete transparency = T_3; to be detected with the microscope, usually in teeth prepared for such examination.

The sum of the scores represented by the above-described stages of decay (x) is the index which serves for the determination of chronological age (y). Age can be computed directly from the equation of the following regression:

$$y = 11{\cdot}43 + 4{\cdot}56\ x$$

If the sum of the scores is 0, this corresponds to the age of about 11 years, if the sum is 5, it represents the limit between young adult and middle adult ages; 8 corresponds to 53 years of age, and 10–12 to 60–70 years of age. S.D. is ± 3·6 years.

THE COMPLEX METHOD OF DETERMINING THE AGE OF ADULTS

Cranial age criteria can be used for determining the age of adults between wide limits only. Realization of this fact has led to an increasing number of investigations directed in past decades to other parts of the human skeleton which can be expected to provide a sufficient basis for age determination. The problem has been studied by anatomists, anthropologists and experts of forensic medicine alike (Bartha and Schranz, 1962). Research work was stimulated by the fact that in medico-legal practice it is often necessary to reconstruct the identity of dead persons of unknown sex and age in an authentic manner (Grüner, 1952). Proof requires as many reliable arguments and facts as possible, keeping to the principle that adequate safety in the conclusion can be provided only if these agree. The investigators of the above branches studied chiefly the long bones of the extremities to determine additional age indicators in them (Lasker, 1953).

Structural changes in the spongiosa of the humeral epiphysis were studied first. Wachholz (1894) was the first to describe these changes. Schranz (1933) developed a method, based on the examination of 650 humeri, which is employed mainly in medico-legal practice. Berndt (1947) made roentgenological studies of the humerus and developed a system of age determination based on the radial, ogival, columniform, loosening and rarefactive stages. Hansen (1953–54) examined 250 humeri and described the changes in the bone structure by decades, adding morphological age criteria to be determined externally.

On the basis of age-changes noted in the spongiosa of the proximal epiphysis of the humerus, Hansen (1953–54) studied the same in the femur and has developed an informative age-determination scheme on this basis. Prior to Hansen (1953–54), the anatomical features and structural changes in the spongiosa of the proximal epiphysis and the extension of the medullary cavity of the femur had been studied by anatomists and anthropologists only in general outlines. In 1867 Meyer described the trabeculae of the proximal epiphysis of the femur, and in their standard anatomical work Testut and Laterjet (1948) made reference to age-changes occurring in the trabecular system.

Anatomists and anthropologists studied the symphysial face of the pubis. Todd and d'Errico (1928) were the first to study this age indicator systematically and developed an age-determination method based on changes on its surface and the development of the rim delimiting it. Todd and d'Errico established ten phases of which nine cover the ages from 18 to 50 years, the tenth, ages over 50. The age-changes of the symphysial face have recently been studied by Stewart (1957) and Brooks (1955). Refining the above method they established the age limits by distinguishing five developmental stages in the changes of the dorsal margin, the development of the ventral rampart, and the formation and breaking down of the symphysial rim. In the Anglo-Saxon anthropological literature (Lansing, Krogman, 1962; Trevor, 1950; Howells and others) the use of the symphysial face as an age criterion is much more common than in continental literature.

Graves (1922) determined morphognostical age-changes in the scapula. Stewart (1954) and Merkel (1927) established age criteria on the basis of changes in the spinal vertebrae. The upper and lower lipping on the body of the lumbar vertebrae are the most significant in adults. Stewart (1934, 1954), then Ashley (1956) and Dürwald (1960) established age characteristics of the sternum, but the results of these studies are not yet adequate for use in analysis.

To test the age-determination methods based on age-changes in the humerus, pubis and femur as well as the cranial sutures, we have examined 105 skeletons of known sex and age (Nemeskéri, Harsányi and Acsádi, 1960). It appeared that if any of the above methods were employed independently, the results would differ from one another and from true chronological age considerably. However, our studies have shown that actual chronological age can be approximated fairly well if a complex, combined method is used. In such a complex age determination the age ranges established belong to morphological states which results in determination of a physiological age closest to the chronological age. When developing our complex method we did not look for, or determine the morphological status corresponding to the various age groups (decades), but preferred to determine the age, or range of age, characteristic of the various clearly separable morphological states.

Relying on the data of previous authors and our own examinations, we have defined the following phases of age-changes in the humerus, symphysial face and femur.

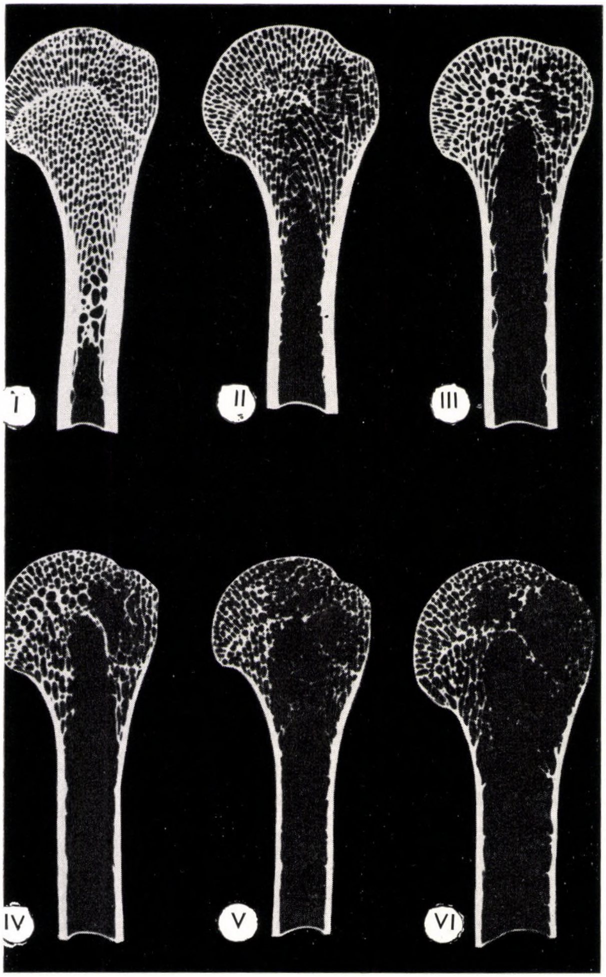


Fig. 20. Phases of structural changes in the spongy substance of the proximal epiphysis of the humerus.

Six characteristic phases can be distinguished in the proximal epiphysis of the humerus from the beginning of adult age. These are shown in the height of the apex of the medullary cavity measured in the proximal direction; the structure of the spongy substance, its transformation and rarefaction; cavity formation in the major tubercle; and in the thinning of the cortex.

Phase I. The apex of the medullary cavity well below surgical neck; trabeculae exhibit radial systems (ogival arrangement appears in smaller portions).

Phase II. Medullary cavity extending proximally, apex at height of surgical neck or above, to 1/4 of the distance to the epiphyseal line. Trabecular system more fragile and in part exhibits ogival structure.

Phase III. Apex of the medullary cavity may reach the epiphyseal line; trabecular system is ogival. Columnar structure appearing along the cortex at the border of diaphysis and epiphysis, while individual trabeculae become thicker.

Phase IV. Apex of medullary cavity reaches the epiphyseal line or higher; trabecular system shows gaps in the major tubercle and the columnar structure along both sides of the medullary cavity is occasionally breached.

Phase V. 2–5 mm lacunae develop in the major tubercle. Apex of the medullary cavity ranges above the epiphyseal line. Only discontinuous remains of the columnar structure appear on both sides of the medullary cavity.

Phase VI. Diameter of the cavity formed in the major tubercle exceeds 5 mm and may reach the cortex. Trabecular system in the head is intensely rarefied, the trabeculae become cobweb-like and torn. Apex of the medullary cavity extends upward and merges with the cavity formed in the major tubercle; there are only remains of the spongiosa. The cortex becomes thin and transparent. The anatomical features on the face of the proximal epiphysis are atrophied and the cortical substance becomes fragile (Fig. 20).

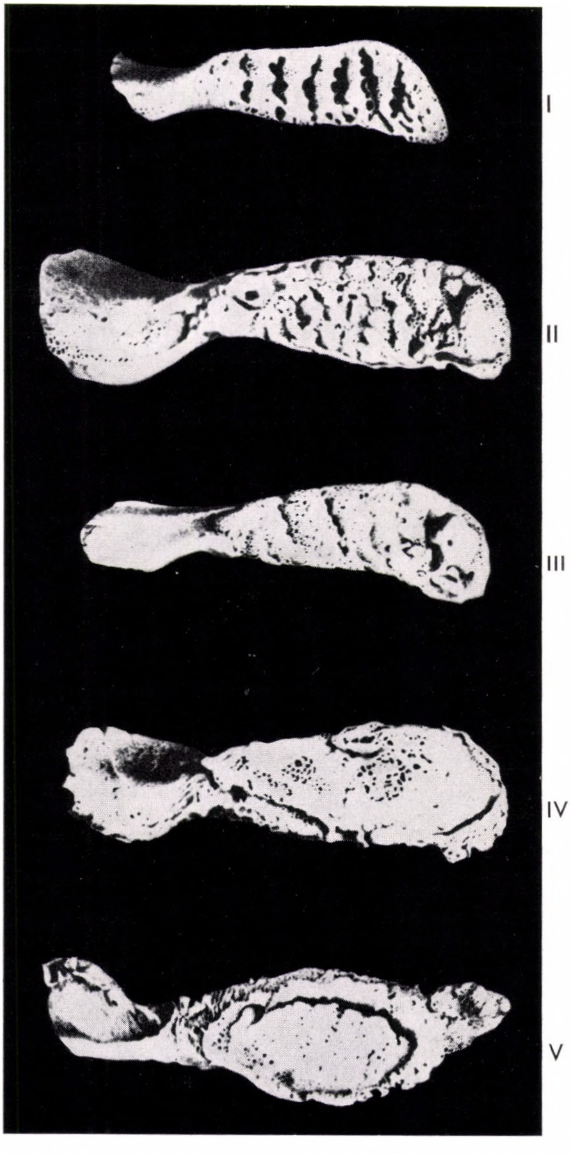


Fig. 21. Phases of superficial changes of the symphysial face (I–V).

Analysing the age indicators of 105 humeri on the basis of actual chronological age data, the following conclusions could be drawn. The various phases represent age limits with varying ranges and group intervals. They do not correspond to decades or any other classification with identical group intervals. The mean ages belonging to the various phases indicate that humeral age-changes proceed slowly in the beginning. After this the process is accelerated and the phases follow one another at short time intervals. Accordingly, the difference between the mean values of phases I and II is 11 years, between phases II and III 7 years, between phases III and IV only 3 years and no substantial difference appears between phases V and VI. The calculated range belonging to the means ($M \pm 3$ S.D.) shows the phase characteristics still better. The age ranges belon-

TABLE 33

Age determination for the phases established in the proximal epiphysis of the humerus

Morphological phases	Mean age ± S.D.	Mean deviation	Actual range	Calculated range (M ± 3 S.D.)
I	41·1 ± 6·60	19·8	18–68	21·3 –60·9
II	52·3 ± 2·51	13·3	24–76	44·8–59·8
III	59·8 ± 3·59	13·2	37–86	49·0–70·5
IV	56·0 ± 1·84	15·1	19–79	50·5–61·6
V	61·0 ± 2·05	11·3	40–84	54·9–67·2
VI	61·1 ± 3·39	13·9	38–84	50·9–71·2

ging to the various phases overlap partially or completely. Owing to their biological character, the age-changes cannot be confined within rigid limits and individual factors must always be considered. It should be noted that the values of phase I require further checking because of the relatively low number of such cases (Table 33).

Age-changes in the symphysial face appear on its surface, ventral and dorsal margins, and rim formation in the region of the rami. Making use of the observations of Todd and d'Errico (1928, 1954) the following five phases have been determined (Fig. 21):

Phase I. The surface is convex, traversed by horizontal ridges and furrows; curved transition in the region of the rami.

Phase II. The original structure of the surface begins to disappear with ridges becoming flatter and grooves shallower. Ventral and dorsal margins show rim formation; also bordering in the region of the rami.

Phase III. The original structure is present on the surface in granular remnants only; a continuous rim is forming on the ventral and dorsal margins; a well-defined border appears in the region of the rami.

Phase IV. The symphysial face has become completely smooth; a sharp rim has developed along the ventral and dorsal margins; the inferior end of the face terminates in a ridge forming an acute angle.

Phase V. The completely smooth surface is partly concave, sunken inwards, porous and shrivelled. The fully developed ventral and dorsal rim rises above the surface like a crest, and surrounds it together with the sharp lower extremity.

TABLE 34

Phases and age correspondences in the symphysial face

Morphological phases	Mean age ± S.D.	Mean deviation	Actual range	Calculated range (M ± 3 S.D.)
I	26·3		18–45	
II	46·5 ± 1·76	11·5	23–69	41·2–51·7
III	51·1 ± 1·62	10·9	25–76	45·8–56·3
IV	58·1 ± 2·16	11·5	24–81	51·7–64·6
V	68·5 ± 2·53	11·9	41–86	61·0–76·1

Secondary ossification of arthritic character is noted along the rim in phases IV and V in some cases. Age-changes are slow until the first third of middle adult age; then phases III, IV and V follow one another at intervals of 5–10 years. Age changes in the symphysial face of the pubis allow to decide whether the age at death of a skeletal find was considerably below 50 years, about 50 years, or over that age (Table 34).

We have also established phases of age-changes taking place in the spongiosa of the proximal epiphysis of the femur. Taking into account Hansen's (1953–54) conclusions, these are based on the position of the apex of the medullary cavity, the structure, structural changes and rarefaction of the trabecular system forming the spongiosa, cavitation, and the atrophy on the outer surface of the head. As in the humerus, six phases have been established (Fig. 22).

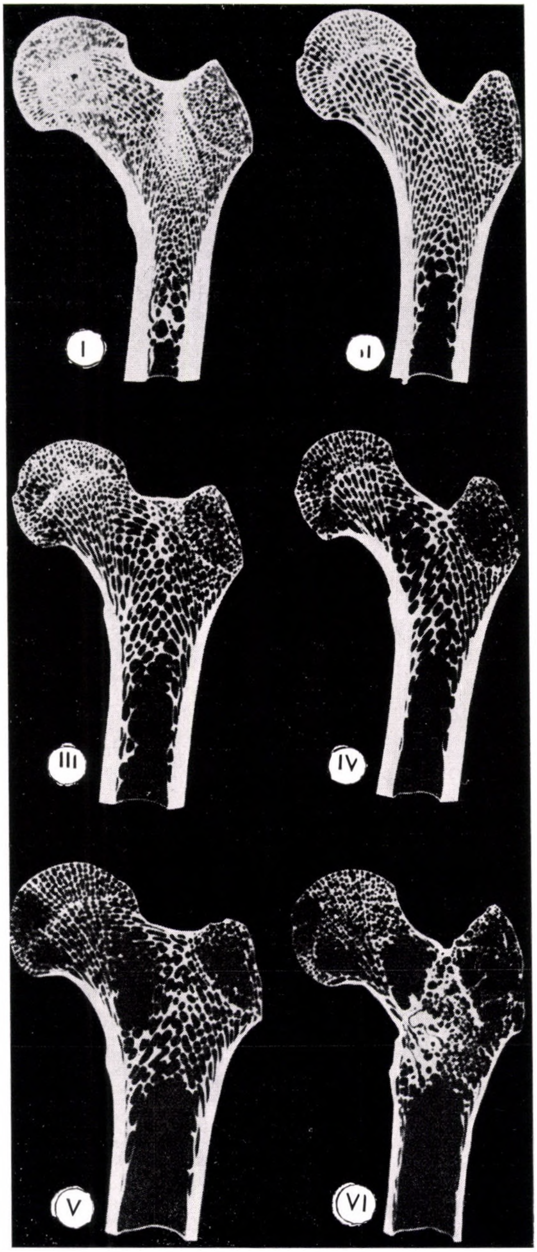


Fig. 22. Phases of structural changes in the spongy substance of the proximal epiphysis of the femur

Phase I. Apex of the medullary cavity well below the lesser trochanter; truss texture of trabeculae is thick; individual features hardly distinguishable.

Phase II. Apex of the medullary cavity reaches or surpasses the lower limit of the lesser trochanter; at the border of diaphysis and epiphysis, and in the neck trabecular pattern of fasciculus trochantericus and fasciculus arciformis begins to rarefy. Incipient rarefaction is most marked in the medial part of the neck.

Phase III. Apex of the medullary cavity reaches the upper limit of lesser trochanter. Rarefaction of the trabecular pattern in the medial part of the neck is marked, individual trabeculae become thinner and are breaking down. The bony structure becomes loose also in the greater trochanter.

Phase IV. Apex of the medullary cavity extends above the upper limit of the lesser trochanter. A delimited cavity of 5–10 mm diam. appears in the medial part of the neck. Distinct rarefaction at the border of diaphysis and epiphysis, in the greater trochanter and in the head below fovea capitis.

Phase V. Only cellular remnants of the original trabecular system appear in the neck. A delimited cavity of about 3–5 mm diam. is formed in the greater trochanter. Formation of cavities in the head beneath fovea capitis and at the medial and lateral borders. Apex of the medullary cavity extends beyond the upper limit of the lesser trochanter.

Phase VI. Cavities formed in the neck and greater trochanter have enlarged (more than 10 and 5 mm diam., respectively). Cavity in the medial part of the neck merges with the medullary cavity as the result of a further loosening of the bony structure, and only fractions of the original trabecular structure remain along the cortex. Cortex becomes thin and transparent, relief of outer surface of bone atrophies.

Age-changes in the proximal epiphysis of the femur begin in the second half of young adult age, when the process is still slow. The average age of individuals showing characteristics of phase I is 31·4 years, the difference between the averages of phases I and II is 13 years. Afterwards the difference between the averages of the individual phases decreases and the process shows a steady course similar to that observed in the humerus. The chronological age limits corresponding to the phases have ranges of 12–15 years (Table 35).

TABLE 35

Age correspondences of the phases in the proximal epiphysis of the femur

Morphological phases	Mean age ± S.D.	Mean deviation	Actual range	Calculated range ($M \pm 3$ S.D.)
I	31·4		18–52	
II	44·0 ± 2·60	10·4	19–61	36·2–51·8
III	52·6 ± 1·86	12·5	23–72	47·0–58·2
IV	56·0 ± 2·32	13·0	32–86	49·0–63·0
V	63·3 ± 2·17	12·2	38–84	56·8–69·9
VI	67·8 ± 3·64	15·3	25–85	56·9–78·7

The aim of our follow-up examinations has been to establish correlations between the four investigated age indicators and the actual ages at death, which were known. These correlations were expressed by linear regression; we calculated with

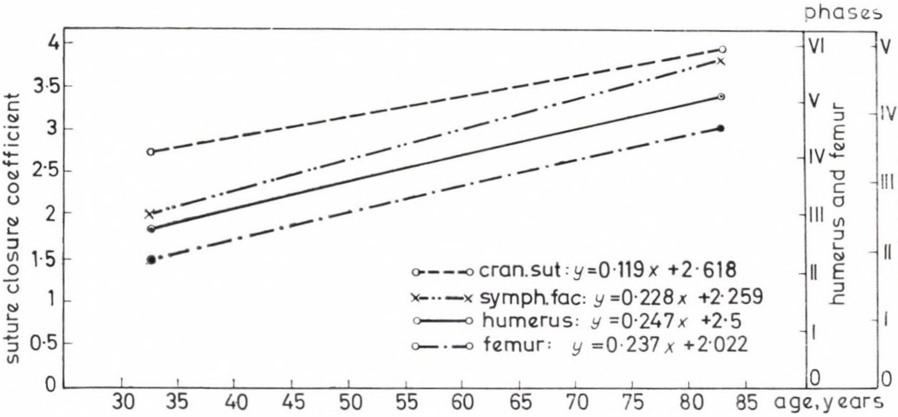


Fig. 23. Regression between the phases of age changes of various morphological features and age at death.

the means of the phase scores observed in five-year groups. As the material of our studies was relatively small, the results cannot be considered final; but it is at least clear that a positive relationship exists between the advance of age and the scores of the phases.

To make the processes comparable, in Fig. 23 the six phases each of the humerus and femur, the five phases each of the symphysial face and endocranial suture closure have been plotted as identical values. From the graph constructed in this way it appears that at the age of 30–35 the closure of cranial sutures is the most advanced change, followed by the symphysial face, humerus and femur. This succession does not change as age advances, although the trend of the symphysial face approximates that of the relatively early closing cranial sutures. The trend lines of the humerus and femur may be regarded as practically parallel. The age-changes in the structure of these two bones are similar, the only difference being that in time (some 11 years).

It is important to decide whether age or the phases should be regarded as independent variables. Our principle of computation was that the phases are variables depending on chronological age; although it might also be stated that biological age is dependent upon on the morphological status.

The changes studied can better be approximated with second-degree curves than with first-degree curves. The trend lines determined with quadratic equations are shown in Fig. 24.

The four curves shown follow one another in the sequence already mentioned although they put the processes in a somewhat different light. The most substantial differences appear between the closure of the cranial sutures on the one hand and the other three age indicators on the other. While the endocranial closure of the cranial sutures sets in early and progresses rapidly in the beginning followed by a slowing down at older ages, the changes of the other age indicators begin slowly,

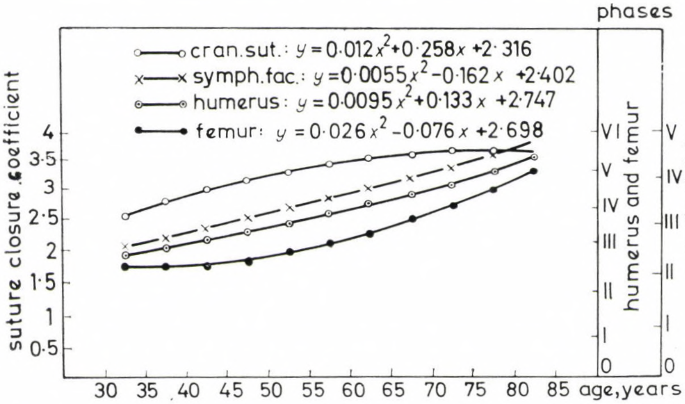


Fig. 24. Age changes of various morphological features.

but accelerate as age advances. This difference in tendencies is most conspicuous between the two extreme curves, those of the sutures and the femur.

If the phases of given age indicators are known morphologically, and a comparative analysis is made of the pertinent age ranges, a complex age determination can be carried out. Figure 25 shows the means of chronological ages corresponding to the phases of the four age indicators as well as the calculated ranges ($M \pm 3$ S.D.). The data shown in the figure are somewhat different from those of our material as graphic smoothing has been applied. On the vertical axis the scale of chronological age appears, from 20 to 78 years. On the horizontal axis the respective phases of the four age indicators have been plotted.

It appears that the age ranges belonging to the phases of the individual age indicators are not identical and frequently overlap. From this the advantages of the complex method we proposed are obvious.

The phases are usually more clearly delimited in the younger age groups than in the older ones where, as a consequence of physiological processes, the limits of the phases become narrower and increasingly overlap.

It appears from Fig. 25 that the highest mean ages are 62–67 years, and the upper values of the ranges are 70–76 years. This shows that regressive age-changes have run their full course by the time these ages are reached. Although no qualitative changes occur afterwards, certain quantitative changes may be observed, e.g. the compact substance of the bones may become still thinner, and the cavities larger, etc.

Table 36 has been compiled on the basis of the smoothed values of Fig. 25. The mean values and their ranges are given in integers.

When determining age, the first step to be taken is to establish the closure coefficient of the endocranial sutures. This is followed by the determination of the various phases of internal structural changes in the humerus and femur, and of the

TABLE 36

Age correspondences of the phases of the four morphological age indicators (years)

Phases	Lower limit of range				Mean				Upper limit of range			
	Suture	Symphysial face	Proximal epiphysis in		Suture	Symphysial face	Proximal epiphysis in		Suture	Symphysial face	Proximal epiphysis in	
			Femur	Humerus			Femur	Humerus			Femur	Humerus
I	23	23	23	23	30	32	33	41	39	40	43	57
II	35	37	35	41	44	44	44	51	52	49	53	61
III	45	46	44	48	53	52	52	57	60	58	59	65
IV	53	54	50	52	60	60	58	59	66	68	66	67
V	58	61	54	54	63	67	63	61	72	75	71	69
VI	—	—	58	55	—	—	67	62	—	—	76	70

superficial changes and rimming of the symphysial face. Scores of suture closure ranging from 0 to 1·5 correspond to morphological phase I, values ranging from 1·6 to 2·5 to phase II, 2·6 to 2·9 to phase III, 3·0 to 3·9 to phase IV, and 4·0 to phase V. The mean ages and limits relating to the phases of the age indicators can be read directly from Table 36.

The starting point in calculation should always be the symphysial face, from which it can be said whether the age at death of the individual studied had been under 50, about 50, or above 50 years. If it had been under 50 (phases I and II), the basis of estimation (averaging) should be the lower limit of the range for all the other age indicators. If the symphysial face indicates age about 50 (phase III), averaging is made on the basis of the mean values. Finally, if it indicates age considerably higher than 50 (phases IV–V), the upper limit of the range should be used for averaging.

In elaborating this method we have started from the variances, limit values and ranges of the material of our control examinations. These values may be regarded as a consistent estimation of the respective parameters of the multitude. Essentially this method is dual combination: first we determine the age index on the basis of which the age indicators can be used for calculation, and then eliminate, by means of averaging, the extreme values which might be due to an advanced or retarded morphological state.

In the following we give examples from the series we studied. It should be kept in mind that even when age is determined in this way, it may be accepted only as the 'most probable' age at death of the individual. The accuracy of this complex method is 80–85 per cent, with a margin of error of ±2·5 years in individual finds. (If the distribution according to age at death of a given multitude is estimated on this basis, the probable error is much lower, as distribution can be estimated with much higher accuracy than individual age. This is very important in palaeodemographic analyses.) Considering the mortality patterns of prehistoric man, it might be assumed that there have been no substantial differences in the rhythm of age-changes to render the age limits corresponding to the phases considerably dissimilar to those of modern man. Nevertheless age changes must have been more rapid in prehistoric man; this is a hypothesis open to debate.

In the examples below both the range and the mean are shown.

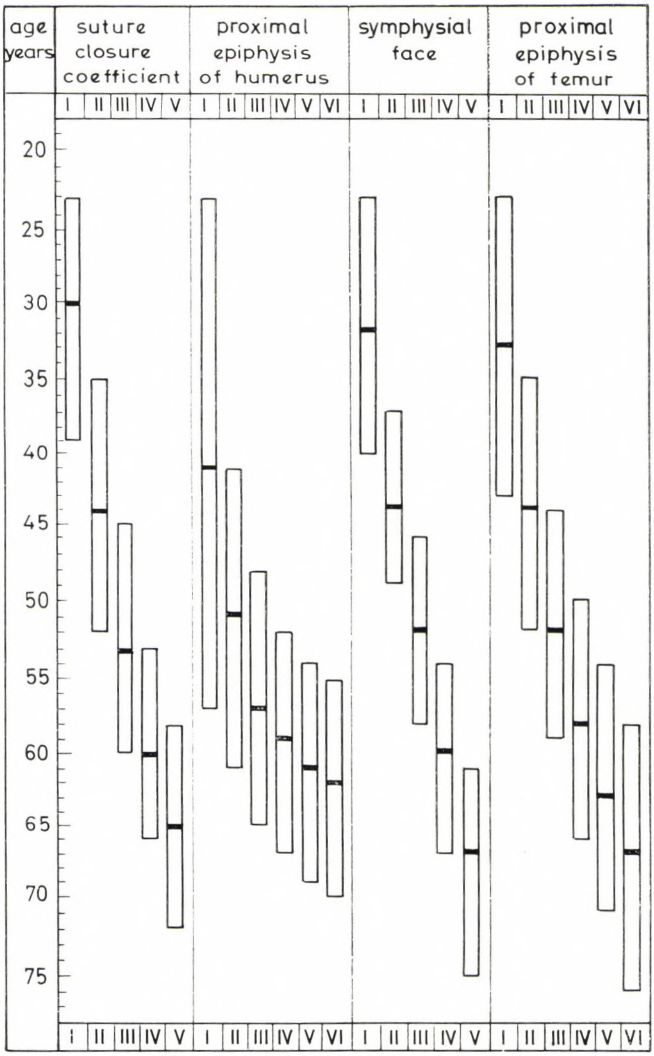


Fig. 25. Smoothed values of mean ages and age ranges pertaining to the various phases of age indicators.

(1) Young individual (No. 1416/1957); closure of cranial sutures indicated a somewhat advanced young adult age, but all the other age indicators pointed to younger age. The lower limits of the range were averaged in this case:

	Phase	*Range*	*Mean*
Endocranial suture closure	II	35–52	44 years
Humerus, proximal epiphysis	I	23–57	41 years
Symphysial face	I	23–40	32 years
Femur, proximal epiphysis	I	23–43	33 years
		104 : 4 =	26·0

Estimated age: 26·0 ± 2·5 years; the actual chronological age was 23 years.

(2) Middle adult (No. 960/1957); the state of the symphysial face—together with the other indicators—showed age to be about 50. In this case, age must be estimated by averaging the mean values.

	Phase	*Range*	*Mean*
Endocranial suture closure	IV	53–66	60 years
Humerus, proximal epiphysis	III	48–65	57 years
Symphysial face	III	46–58	52 years
Femur, proximal epiphysis	II	35–53	44 years
			213 : 4 = 53·3

Estimated age: 53·3 ± 2·5 years; the actual chronological age was 54 years.

(3) Old adult (No. 1537/1957); together with the other indicators the symphysial face pointed to age considerably over 50. In such cases upper limits of the ranges are averaged.

	Phase	*Range*	*Mean*
Endocranial suture closure	V	58–72	63 years
Humerus, proximal epiphysis	V	54–69	61 years
Symphysial face	V	61–75	67 years
Femur, proximal epiphysis	V	54–71	63 years
		287 : 4 =	71·8

Estimated age: 71·8 ± 2·5 years; the actual age was 75 years.

(4) The fourth case (No. 1422/1957) serves as an example of how the symphysial face as well as the rest of the age indicators (with the exception of the cranial sutures in this instance) can indicate an age much lower than the chronological age. Such cases are due to the actual biological processes showing highly individual variations, and thus limiting the possibilities of age determination. In this case the subject had died suddenly at work; he was an able-bodied man of biologically youngish appearance.

	Phase	*Range*	*Mean*
Endocranial suture closure	V	58–72	63 years
Humerus, proximal epiphysis	III	48–65	57 years
Symphysial face	II	37–49	44 years
Femur, proximal epiphysis	II	35–53	44 years
			208 : 4 = 52·0

As against the actual chronological age of 72 years, the estimated age was no more than 52, even if the mean values were taken as a basis because of the contradictory character of the phases.

(5) This case (No. 983/1957) shows that as a result of pathological changes the age indicators can indicate ages higher than the actual age, due to more advanced morphological changes. Extensive arthrotic secondary bone formation was found along the rim of the symphysial face and at the limit of the femoral head. In such cases age determination is biassed by the fact that the morphological state has been influenced by pathological processes.

	Phase	*Range*	*Mean*
Endocranial suture closure	V	58–72	63 years
Humerus, proximal epiphysis	V	54–69	61 years
Symphysial face	IV	54–68	60 years
Femur, proximal epiphysis	IV	50–66	58 years
		275	: 4 = 68·8

Estimated age: 69, much higher than the actual age, which was 45. When, owing to the pathological phenomena, the lower values were averaged, the estimated age (54) was somewhat closer to the actual age.

We have shown examples where the state of all the four age indicators could be determined from the skeleton. In historical materials, however, skeletal bones are often in a poor condition, or missing altogether, as a result of which only three, two, or even as few as one age indicator can be appraised. Reliability of age-determination is considerably reduced in such cases, so we must calculate with greater margin of error resulting in greater group intervals. Considering the fact that the age indicators are not of equal value we have to apply some weighting. In the following we describe methods to be employed when three or less age indicators are available.

With three age indicators and if the state of the symphysial face is known, determination is carried out in the same manner as with four indicators, only the mean is computed on the basis of three values. If the symphysial face is not available, the femur is taken as the basis. If the femoral phase is

I or II, the lower limits
III, the mean values } must be averaged
IV, V, VI, the upper limits

and a margin of error of ±3 years considered; thus the estimated age will have a seven-year group interval.

With two age indicators, if these are the symphysial face and the femur, the mean values are averaged, a ±4-year margin of error is used, resulting in a nine-year group interval. If one of the two features available is either the symphysial face or the femur, and the other is either suture closure or the humerus, the values to be averaged should be selected either according to the symphysial face or the femur; margins of error of −4 and +5 should be added, yielding a ten-year group interval. If one of the age indicators is the femur and its phase differs extremely from the phase of the other feature, the range of estimated age must be calculated by averaging the lower and upper limits of the respective phases separately.

The same technique should be applied if suture closure and the humerus are available.

In the case of only one age indicator the following ages should be established:

Suture closure		*Symphysis*		*Femur*		*Humerus*	
Phase	*Age range (years)*	*Phase*	*Age range (years)*	*Phase*	*Age range (years)*	*Phase*	*Age range (years)*
I	23–40	I	23–40	I	23–40	I	23–60
II–III	30–60	II	35–55	II	35–55	II	30–60
IV–V	40–80	III	40–60	III	40–60	III–IV	40–70
		IV	50–70	IV	50–70	V–VI	50–80
		V	60–80	V	50–75		
				VI	50–80		

Finally, it should be noted that when making determination in the old adult age group where ages of life are determined with seven-year ranges or less, the results of averaging should be given as follows: If the estimated age is between 60 and 64 years, the upper limit must be extended to the age of 70; between 65 and 69 years, to the age of 75; over 70 years, to the age of 80.

The final age diagnosis should be established in a most circumspect manner, considering all available factors. When dealing with biological phenomena, an over-simplified, mechanistic employment of the methods must be avoided by all means.

CHEMICAL POSSIBILITIES OF AGE DETERMINATION

Our knowledge of age determination must be completed by outlining the recent achievements in the study of changes in the chemical constitution of bones. It has been known for a long time in medicine that the chemical constitution of bones changes with age, but the application of analyses in anthropology, and especially in age determination, is relatively recent. This is due to the fact that the chemical changes taking place since the time of burial, the action of soil, climate and humidity must also be taken into accouut when analysing historical material. The age values and differences determined in recent, dissected material are not the same as in skeletal finds of historical periods, so the data derived from the latter cannot be interpreted in the same way as in the case of recent bones. The principle of analysis and the most important information relating to practical determination are summed up below on the basis of Lengyel's (1963, 1968) work.

It is generally known from the studies of Kramer and Shear (1928), as well as other researchers, that (*i*) the phosphate content of bones decreases with the advance of age, while the carbonate content increases; (*ii*) the absolute level of calcium decreases parallel with the atrophy of bony tissue, so the ratio remains more or less unchanged (Fourman 1955, 1960; Hansard, Comar and Davis, 1954); (*iii*) the volume of microcrystals impregnating the matrix grows as age advances, and the layer thickness of their hydratation shell diminishes (Robinson 1923, 1952; Watson and Pearce, 1949; Neuman and Neuman, 1953); (*iv*) the collagen content of the bones decreases in old age (Rogers, Weidman and Parkinson, 1952; Gersch and Cathpole, 1950).

Knowing these relationships, the analysis of bones for carbonate, phosphate, calcium and collagen levels may serve as a basis for age determination (Davies, Kronberg and Wilson, 1952). The practice of analysing chemical age indicators is as follows:

(1) Carbonate (CO_3). The carbonate level bound to inorganic substances must be determined directly from the ground bone powder. Carbon dioxide released through acidic treatment is absorbed by potash lye in Haldane's apparatus. The quantity of absorbed gas is inferred from the reduction of volume, the original amount of carbonate, from that of the absorbed gas.

The carbonate content of recent human bones shows a rising tendency from childhood to old age. The mean values of age groups are the following: infant I–II: 2·66; juvenile: 3·05; young adult: 3·25; middle adult: 3·25; old adult: 3·84. In skeletal finds from historical periods the decrease of carbonate content resulting from decomposition is about 40 per cent. It seems that it is more likely to depend on soil conditions than on the time that had passed since interment.

(2) Phosphate (PO_4). The level of phosphorus in inorganic bonds is determined from bone after incineration. Bone ash is acidified with sulphuric acid, ammonium molybdate is added, whereby phosphomolybdic acid is formed. Molybdenum blue is separated out from the latter under the effect of reductive agents in a colloidal solution. The colour-intensivity of molybdenum blue is proportionate to the phosphate content. The gradual decrease in phosphate content is a good basis for age determination. In recent bones the mean values from early childhood to old age were as follows: infant I–II and juvenile: 10·55; young adult: 10·94; middle adult: 9·61; old adult: 8·15. If the phosphate content of recent bones is low, the decomposition factor in skeletal finds of historical age is 72–84 per cent.

(3) Calcium (Ca). The calcium content of bones can be determined from the ash of bone powder. In an intensely alkaline agent and in the presence of an ammonium

purpurate indicator the calcium ions can be titrated directly by means of a Komplexon III measuring solution. In the first phase of the process the calcium ions are linked to ammonium purpurate and this is indicated by a red colour reaction. The calcium ions are abstracted by Komplexon III in the course of titration, so the true violet colour of ammonium purpurate appears in the final phase of titration.

The age-changes of calcium values are more of an informative character in age determination. It appears from the analysis of recent bones that these changes are slight from early childhood to the mature age, and that decrease becomes considerable in the senium only. Calcium decrease in skeletal finds from historical periods is 14–37 per cent.

(4) Bone collagen (BC). The level of collagenous substances can be determined from the ground unit of bony tissue decalcified with acid. The decalcified powder is steeped in 0·1 per cent sodium hydroxide solution for 48 hours, then boiled for 12 hours. In this way collagen can be transformed into gelatine and dissolved from the bone. Dissolved gelatine is concentrated to constant weight and its amount is compared with the weight of the bone powder unit.

Decrease in the bone collagen level intensifies in old adult age. The decomposition of bone collagen in skeletal finds from historical periods is 24–36 per cent. It should be noted that under the effect of decomposition factors the collagen content of bones is not only reduced but undergoes certain chemical transformation as well. The fibrous structure breaks up and this explains why only empty lacunae appear in the place of bone cells while the original histological structure of the bones is preserved unchanged.

It may be asked under what conditions, and with what measure of reliability these four chemical age indicators can be taken into account in analysing series from historical periods. It should be kept in mind first of all that, similarly to the morphological age indicators, these should also be regarded as a part of a complex system; also wide individual variations should be counted with. Even more important are the changes resulting from decomposition under various soil conditions for various periods of interment. No general formula can therefore be given for using chemical age indicators. Actually, this method cannot be used to determine the age of individuals if the decomposition changes are not known. It is possible, however, to make relative evaluation within a given population, i.e. in cases where the skeletal remains have been preserved under identical conditions.

But even so the chemical age indicators only serve as a complementary method, i.e. as controls to be used in addition to morphological age indicators. They are most important if only fragments of bone are available, as age estimation based on chemical indicators is the sole possibility in such cases.

CHAPTER IV

THE ARCHETYPE OF MORTALITY FROM THE PALAEOLITHIC TO THE MESOLITHIC

THE LIFE SPAN OF *ARCHANTHROPUS*

How long was ancient man's life? How long did he live on the average, and what could have been the maximum length of his life in favourable circumstances? For a considerable time science has not been able to answer these questions as the existence of ancient man itself was nothing more than a scientific hypothesis. It is not easy to find an accurate answer even on the basis of our present knowledge, and the old prejudices so often found in public opinion are still haunting scientific thinking.

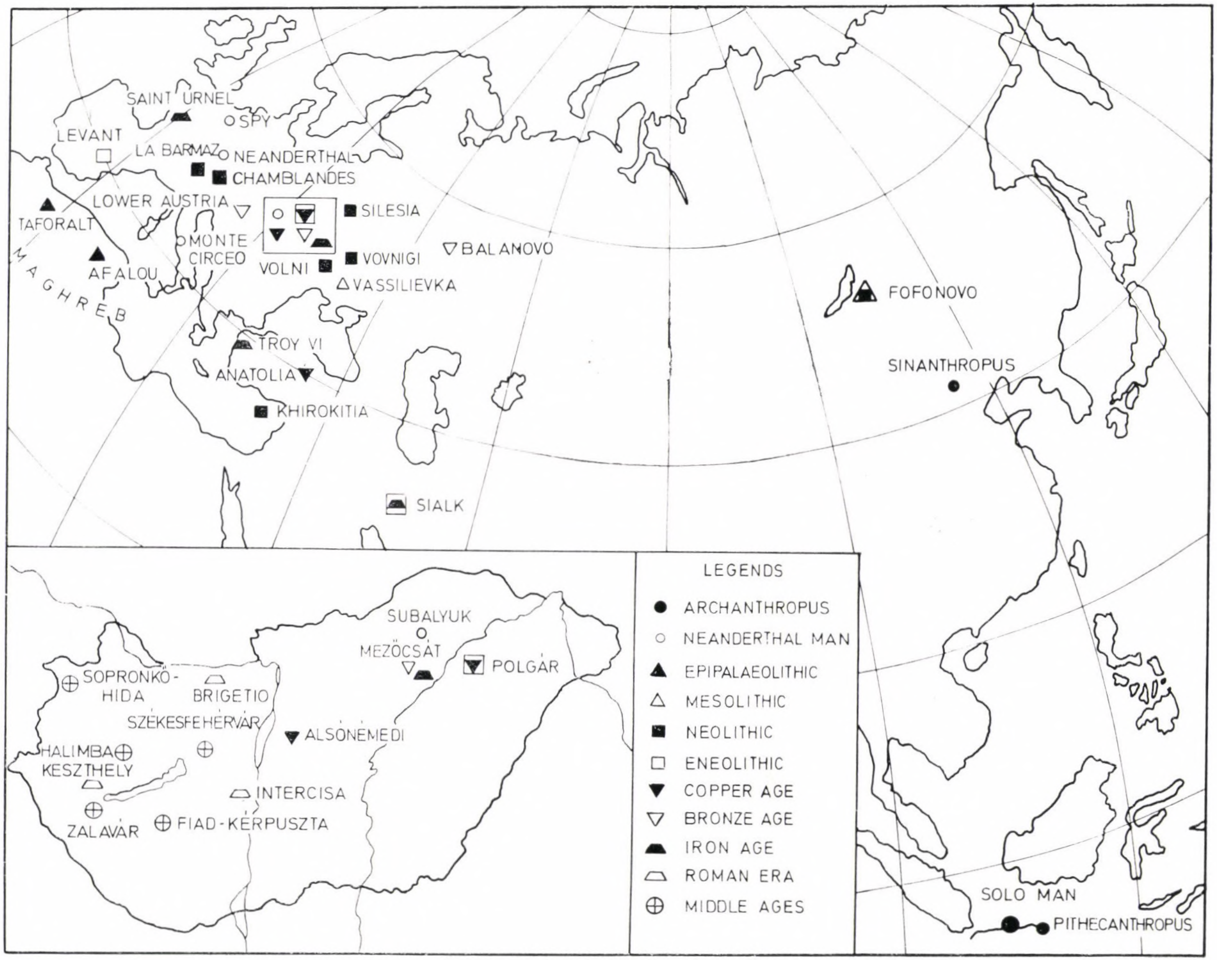
Two diametrically opposed ideas have been accepted by general opinion when considering ancient times. The one extreme starts from 'paradisiac' conditions, a happy 'golden age', where good health and attaining the age of Methuselah were matters of course. The other extreme is a mechanistic and distorted projection of the theory of evolution and believes that the farther one goes back the poorer the conditions of human life must have been, that people grew old and died soon and that ever higher mortalities and shorter lives must be assumed as one looks back at bygone ages. It is obvious that these ideas are not only contradictory but are pretty far from reality.

The earliest human finds that are the exclusive, direct evidence of ages attained are the skeletal remains of *Archanthropus* who lived several hundred thousand—up to half a million—years ago. Unfortunately, the number of these finds is very low. We know of two smaller series which serve as a basis not only for determining the life span of the individuals involved but also for assessing the characteristic length of life of *Archanthropus*. The data of these series—*Sinanthropus* and Solo man—are submitted after Weidenreich.

TABLE 37

Age at death of *Sinanthropus* and Solo man (after Weidenreich)

Age	*Sinanthropus*		Age group	Solo man	
	No.	Per cent		No.	Per cent
0–14	15	68·2	Child	1	9·1
15–30	3	13·6	Adolescent	3	27·3
			Relatively young	1	9·1
30–50	3	13·6	Adult, relatively young	2	18·2
50–60	1	4·6	Adult, advanced age	4	36·3
Total	22	100·0	Total	11	100·0



Sites of series used for the reconstruction of the history of life span and mortality.

It appears from Table 37 that the oldest member of the *Sinanthropus* series lived to the lower limit of old age. The age data of the second series are not given in years, but in groups of 'child', 'adolescent', 'relatively young', 'adult, relatively young' ('adult but young'), and 'adult, advanced age'. Comparing these designations with the grouping generally used in Anglo-Saxon anthropological literature (e.g. by Hooton):

	Age (*years*)
adolescent	13–17
subadult	18–20
young adult	21–35
middle adult	36–55
old adult	56–75
very old	76+

it appears that the term 'adult' is not used to denote the population aged between 22 and 39 as in continental literature based on Latin age terminology ('adultus'). It also includes the 'maturus' (40–59 years) and 'senium' (60 + years) ages. Thus Weidenreich's definitions do not exclude the possibility that at least one, or possibly more, individuals of the Solo series might have been of advanced age.

We do not know, however, on what basis Weidenreich determined the age of death. Since the remains of *Archanthropus* consist mainly of the calotte, Weidenreich, like the other anthropologists analysing similar material, must have based the determination of age principally on the closure of cranial sutures, on the morphological features of the representative bones, the condition of the teeth, etc. Considering, however, that the ossification process in cranial sutures is rather complex (see Chapter III) and that actual life spans show considerable individual variation, the age data have been determined rather cautiously, i.e. between wide limits, or else have only been circumscribed. There is also the theory according to which biological observations derived from studying modern man (in this case the chronology of suture closure) are not valid for *Archanthropus* and *Palaeanthropus* in view of the rapidity of this process in anthropoid apes. A practically general view prevails rearding aging in Palaeolithic man that is based on phylogenetic arguments not yet proved correct, because the deciduous and permanent teeth of anthropoid apes erupt earlier, their cranial sutures close earlier, and postcranial maturation is earlier than in man, suture closure must have started and also completed at a chronologically younger age in Palaeolithic man. The consequence of this hypothesis is that when Palaeolithic skeletal finds are studied younger ages at death are diagnosed from the cranial sutures than with finds coming from the Mesolithic or Neolithic. Such views are to be found not only in Weidenreich's works, but also in those of several other authors, such as Vallois (1937), Schultz (1956), or Harms (1956). Chinese investigators, whose views are not free of conflicts, adopt a critical attitude towards Weidenreich. Woo Joo Kang (1962), for instance, thinks that even if in modern man the sutures of smaller skulls close sooner than those of larger ones, this difference is of no importance; nevertheless he holds that the cranial sutures of fossil man closed earlier than those of modern man. He believes that the rate of these processes was the same in the fossil remains of *Neanthropus* or the man of the late Palaeolithic and in modern man although showing differences in phase. Chin Hue Tseng (1962) discussing the age at death of the skull of Tže-Yang, writes that the process of suture closure must have been considerably quicker and set in earlier in Palaeolithic man as a consequence of which he does not accept estimations about the age of *Archanthropus* and *Palaeanthropus* for Palaeolithic man.

It is not impossible that the rate of vital functions in *Archanthropus* and *Palaeanthropus* was actually quicker than is found in man today. We should like to point out, however, that the sequence of changes determined by age, the rate of the various biological processes and the length of various life cycles show a substantial difference in man and in anthropoid apes. The gestation of *Hylobates* is 30 weeks, its period of growth is 9 years, and its life span is estimated at 33 years. On the other hand, gestation of *Pongo pygmaeus* is 39 weeks, full development takes 11 years, while the life span is only some 30 years. Full maturation also takes 11 years in the *Gorilla*; dependable data on its gestation and life span are not available. Similarly, bodily development of *Pantroglodytes* takes 11 years, while gestation is 34 weeks and the life span is 35 years.

In sharp contrast with all this stands *Homo sapiens*; although the length of gestation is similar—38 weeks on the average—full growth is completed only after 20–22 years. Closure of human cranial sutures sets in only then and the process is continued throughout the entire adult age; the three main sutures are usually completely closed as late as about 65 years of age, that is on the verge of old age. True, complete suture closure may be found at younger ages because of individual differences, while ossification may continue to the age of 75–80, the limit of the normal length of life in others; and the maximum life span of man is 110 years. These facts show that no chronological parallel can be established between the vital cycles of anthropoid apes and man, and that to make any extrapolation relating the vital processes of early man to *Pongidae*, whose vital cycles are highly dissimilar from those of man, is a risky enterprise.

The speedier suture closure in *Archanthropus* might be regarded as possible if cerebralization, i.e. the increase of the capacity of the human cranium, is taken as a basis. The capacity of the cranium of Neanderthal man (*Palaeanthropus*) is 1,400–1,500 cm^3 on the average, and it is nearly identical with that of modern man. This value is only 1,175–1,300 in Solo man who stands between the Neanderthal man and *Pithecanthropus* but can be classified among *Archanthropus*. This capacity is usually only 900 cm^3 in *Archanthropus*, 915–1,225 cm^3 in *Sinanthropus*, 775–1,000 in *Pithecanthropus*, and about 500 cm^3 in anthropoid apes. The sequence seems to be gradual and the suture closure of *Archanthropus*, provided that it is closely connected with the capacity of the cranium, which has not yet been proved, ought to be placed somewhere along this continuum between modern man and the apes.

As shown in Chapter III, the course and rate of the closure of the various sutures differ considerably in the same cranium and between individuals. Even if we do not exclude the possibility of there being some correlation between cranial capacity and the rate of closure, such a correlation cannot possibly be too high. (The considerable individual differences noted by us were not only the results of differences in capacity.) Similarly it is obvious that the differences found ectocranially and endocranially as well as between the various sutures are dependent on other factors.

Bunak's results, published in 1955, are most remarkable in this respect. In his view, the development of the cranium is determined primarily by two factors: pressure from the growing brain, and tensions present in the cranial bones as a result of the work done by the jaws, the pull force of the muscles and the equilibrium conditions of the skull. The role of other factors must not be neglected either, although there is abundant material to show that the effect of other factors is only secondary. Bunak mentions that in monkeys the development of the crista sagittalis is so closely correlated with the relative size of the temporal muscle and the intensity of its function that the problem of the morphological role of hormonal and other factors need not even be raised. This does not mean, however, that there should be a direct correlation between the development of the crista sagittals and the dimensions of the jawbones in various species.

In connection with suture closure Bunak emphasizes the fact, established by others before and corroborated by the results of our investigations, that the various stages of suture closure follow one another in the same order as that in which their final fusion takes place. This order (sagittal, coronal, lambdoid) is fairly constant individually. It is a characteristic fact that the lambdoid suture is always less closed than the coronal, and that the indices derived from the closure values of these two sutures do not depend on whether the cranium is long or short. Consequently no correlation can be shown to exist between the intensity of suture closure and the form of the cranium. The order of obliteration of the various sections of ectocranial sutures is to a certain extent connected with the thickness of the bones. On the other hand, both phenomena depend on some common factors, first of all on the intensity and stabilization of tensions present in the bones. For a considerable time sutures bordering the temporal bone are exposed to changing tensions produced by the action of the jawbones and transmitted by the zygomatic process and articular fissure. Strong muscles keep the head balanced and produce changing tensions in the asterion zone which are diminished by the time they reach the dome. Along the central line of the cranium tensions become stabilized sooner than in other regions. The connective tissue layer of the cranial sutures responds to the stabilization of tension with gradual atrophy and deposition of bone tissue. This process sets in first in the sagittal suture and lasts longest in the facial bones.

Suture closure does not take place at the same time endocranially and ectocranially, which means – according to Bunak – that the external tensions do not reach the inner layers of the bone. Endocranial suture closure is independent of the stabilization of external tensions, and is connected with pressure conditions in the endocranial space.

In anthropoid apes, as well as in most mammals, the closure of sutures commences immediately after the brain has ceased to grow and the molars have erupted. In man, however, closure of the endocranial sutures does not usually set in before the age of 25 and continues spreading in an outward direction even after that age, irrespective of the fact that weight and mass of the brain reach their maximum values by the age of 18–20 and the third molars have generally erupted. The reason for the delay is that the weight and mass of the brain and arachnoid decrease gradually from the age of 20, while the capacity of the intermediate space filled with the cerebrospinal fluid increases with age. Owing to the considerable space between the brain and the cranial wall, pulsations resulting from respiratory movements are relatively greater in man than in animals and produce appropriate fluctuations in intracranial pressure.

The considerable periodic changes in intracranial pressure resulting from respiratory movements slow down the fusion of sutures. As Krompecher had already pointed out in 1948, it is with these particularities that the appearance of pacchionian granulations and the arachnoidea is connected; the processes of the latter intrude into the cranial wall, and render the fixation of the brain possible, thereby reducing its movement with respiration, and promoting the stabilization of intracranial pressure. Pacchionian granulations are located at the most prominent portion of the dome where the respiratory excursion of the brain has the greatest momentum. Closure of the sagittal suture starts at this point and spreads gradually to the other sections of the suture. Pacchionian granulations are either absent or rudimentary in animals. In man this process is of considerable importance, beginning at the age of 25–30. Obliteration of the sutures commences at the same time.

The process of suture closure has been discussed at some length here because we wanted to show that no parallel can be drawn between the life cycles and the cranial capacity of *Archanthropus* and anthropoid apes, and that such a comparison cannot serve as a basis for assumptions on suture closure. On the other hand, this digression makes possible the appropriate evaluation of morphological observations made on *Archanthropus.*

In October 1963 in Utrecht assisted by Professor G. H. R. v. Koenigswald we had the opportunity to study the finds of Solo man. The results of our study in relation to the age at death will be discussed later on; here we should only like to point out two important facts. It appears from the study of the finds of *Homo soloensis* (called also *Javanthropus soloensis* or, as usually mentioned by Weidenreich, Solo man) that:

(1) Pacchionian granulation can be detected on the internal surface of the cranial dome of Solo man, indicating that the process of ossification must have been similar to that in *Homo sapiens* rather than in the anthropoid apes of today.

(2) The order of suture closure in Solo man was the same as in modern man, as we shall see later on.

(3) The differences between the external and internal surfaces of the cranium in the phases of suture closure were the same in Solo man as in modern man.

All this points to the same conclusion which can be drawn anyway on the basis of morphological comparisons and historical proofs, i.e. that although the bones of *Archanthropus* and *Palaeanthropus* show a number of archaic features, there is no reason to suppose on the basis of their skulls that the closure of cranial sutures should have begun substantially earlier and completed in a much shorter time than today. There is no one who would argue — and could not possibly do so considering the cranial capacity of Neanderthal man—that the rate of suture closure in *Palaeanthropus* was different from that in modern man. And if the complexity of the morphological features is taken as a basis, the difference between *Palaeanthropus* and *Homo sapiens* is much greater than between any stages of evolution of *Palaeanthropus* and *Archanthropus*. Consequently—on the basis of morphological considerations at least — it is not likely that we should have to reckon with considerable differences between the suture closure of *Archanthropus* and modern man. Nor is this probable on the basis of palaeoarchaeological finds. The various forms of *Palaeanthropus* and *Archanthropus* were not so distant from one another in respect of social development as were the first makers and users of utensils from the anthropoid apes of today, or from any group of the *Dryopithecus* genus that lived at the turn of the Miocene and Pliocene.

The difference of some hundred cubic centrimetres separating the cranial capacity of *Archanthropus* on the phylum of evolution not only from the ape but his own predecessors is not simply a quantitative difference but one that involves an abrupt qualitative change that cannot be expressed by cubic centimetres. If we therefore speak of considerable differences in certain biological processes in man, e.g. in suture closure, we ought to look for an explanation in some earlier mutative change prior to the emergence of *Homo*, rather than in the various stages of human evolution.

Although Weidenreich assumed in two of his earlier papers that the sutures of ancient hominids closed earlier, he founded his estimation of the age at death of Solo man on the hypothesis that the cranial sutures of ancient man close at the same age as those of modern man. At the same time this means that the data shown in Table 37 are acceptable practically, and that the conclusions that *Archanthropus* may have attained what is called today old age is established. In our opinion the suture closure of *Archanthropus* is not likely to have set in much earlier than that of modern man. It may be assumed, however, that this process slowed down somewhat in the course of evolution—in connection with the thinning of the cranial wall—and so it is possible that the closure of certain sutures of *Archanthropus* was completed earlier than it is today.

THE AGE AT DEATH OF SOLO MAN AND THE LIFE SPAN OF *ARCHANTHROPUS*

In his monograph on the finds at Ngadong, Weidenreich only gave relative ages at death for all the 11 Solo men. He also published his observations on suture closure but from his brief comments the ages at death in years cannot be derived. We therefore give a summary of our investigations concerning these finds:

Solo man I. Female. The closure coefficient on the ectocranial surface is 2·7, on the endocranial surface, 3·5. On the endocranial surface the coronal and sagittal sutures are completely closed, the lambdoid suture only in part. Chronological age may be estimated within rather wide limits, i.e. 45 and 75 years; death is likely to have occurred at the turn of mature and old adult ages (Weidenreich: the sutures are completely closed, but they can be recognized occasionally; adult of advanced age).

Solo man II. Child. The morphological features are rather marked. The anterior fontanel is smaller compared with children of our time. The sutures are completely open. Judging by the size of the calotte and by the fontanel, the upper limit of age is 1·5–2 years (Weidenreich: the sutures are open throughout; child).

Solo man III. Male. Badly fragmentary calotte with many completions. It is very difficult to observe sutures on it. The closure coefficient of suture sections that can be determined on the ectocranial surface is 4·0; obliteration of sutures is even more marked endocranially, the coefficient being —4·0. The age at death may be estimated within wide limits, i.e. 50 to 80 years. Was probably older than 60 (Weidenreich: sutures are completely closed, but can be recognized at some points; adult of advanced age).

Solo man IV. Female. Must have died young, which is shown by the completely open sutures on the ectocranial surface, the closure coefficient being 0·9. Traces of incipient closure appear in the pars pterica of the coronal suture. Endocranial closure advanced along the coronal and sagittal sutures (mean closure coefficient is 3·5), while the lambdoid suture is open (0·0). Endocranial closure coefficient 2·5. Within wide limits the age is 30–50, probably adult (Weidenreich: the sutures are open throughout, which applies evidently to the external surface; adolescent. If he regarded this individual as adolescent, it is not easy to understand why he described nos I, IX, and X as adults of advanced age, and no. XI as an adult of young age.) Traces of a healed incised wound appear on the calotte.

Solo man V. Probably male (according to Weidenreich presumably male). The sutures are closed throughout, to a lesser extent at some points; relatively young adult. Age at death, 23–39 within wide limits.

Solo man VI. Probably male. Most of the sutures are closed on the ectocranial surface; the closure coefficient is 3·7. On the endocranial surface the sagittal and coronal sutures are ossified for the most part, the lambdoid suture is still in the incipient stage; the ossification coefficient is 2·9. Age at death, between 35 and 65 years. (Weidenreich: the sutures are closed but still identifiable; relatively young female).

Solo man VII. Female. Skull fragment. On the basis of the sagittal suture and the partly free edge of the coronal suture the closure coefficient is 0·0. This should, however, be accepted with reserve, as it is a common phenomenon that incipient ossification opens up subsequently. (Weidenreich: completely open sutures, indicating adolescent age—this statement is acceptable nevertheless.) The age at the upper limit of juvenile age, or a few years more.

Solo man VIII. Probably male. This find consists of a detached parietal bone on which the free edges of the three sutures are clearly discernible. Sutures markedly denticulated. On this basis the coefficient is 0·0. Age at death, 18–25 years, the end of juvenile age or the beginning of young adult age (Weidenreich: the sutures are open throughout; adolescent, probably male).

Solo man IX. Female. Ectocranial suture closure coefficient, 2·9. Beginning from the pars verticis of the sagittal suture, closure is only partial. To determine the endocranial coefficient is difficult because of glueing and completion, but even so its value can be set about 3·0. Ossification appears also along the lambdoid suture. Within wide limits the age may be 35–75, died probably at the beginning of mature adult age (Weidenreich: the sutures are closed completely; adult of advanced age).

Solo man X. Female. On the ectocranial surface the coronal suture is closed completely, closure of the sagittal suture is under way, the lambdoid suture is closed asymmetrically. Coefficient, 2·0. Endocranial coefficient is 3·3. The coronal and sagittal sutures are closed completely; closure of the lambdoid suture was under way on the left side, on the right side closure is completed in its pars asterica, while the two sections above it are only in the incipient stage (stage 2). Within wide limits the age is 45–75, within narrower limits, at the end of middle adult age (Weidenreich: the sutures are fused but can be recognized in part; adult of age).

Solo man XI. Probably male. Closure of the coronal suture on the ectocranial surface cannot be determined for certain; the sagittal suture is closed in its pars obelica, the other sections being in an advanced stage of closure. Coefficient, 1·3. Endocranially the sutures are closed almost completely, although they are difficult to observe along the sagittal suture of the right side. The coefficient is 3·5. Within wide limits the age is 45–75, within narrower limits death probably occurred in the first half of middle adult age (Weidenreich: the sutures are fused, but all of them can clearly be recognized; adult but young).

Comparing Weidenreich's conclusions with the above results the data of the Solo series are shown in Table 38 (question marks appear in the 'sex' column only where determination was actually uncertain).

It ought to be noted in connection with Table 38 that the 'probable' age values appearing in the last column are, of course, too uncertain individually to permit the application of such relatively narrow ranges. However, there is less distortion in

TABLE 38

Sex and age at death of the *Homo soloensis* series

No.	Sex	Age at death		
		According to Weidenreich	Between wider limits	Probable age
I	Female	Adult of advanced age	45–75	54–63
II	Female?	Child	0–2	0·5–1·5
III	Male	Adult of advanced age	50–80	58–67
IV	Female	Adolescent	30–50	30–39
V	Male?	Relatively young adult	23–39	23–39
VI	Male?	Relatively young	35–65	35–65
VII	Female	Adolescent	20–25	20–25
VIII	Male?	Adolescent	18–25	18–25
IX	Female	Adult of advanced age	35–75	40–49
X	Female	Adult of advanced age	45–75	50–59
XI	Male?	Adult but young	45–75	45–54

the distribution by probable ages at death, and this can be used for mortality computations more conveniently. The distribution of the summarized results shown in Table 38 is the same as in Table 37. The data are compared in Table 39, based on Vallois's classification.

TABLE 39

Percentage distribution according to age at death of *Sinanthropus* and Solo man (excluding children)

Age at death	*Sinanthropus* according to Weidenreich	Solo man	
		according to Weidenreich	on the basis of probable age
15–30 (adolescent)	42·7	40	25
30–50 (adult)	42·7	20	35
50+ (old adult)	14·6	40	40
Total	100·0	100	100

We have already mentioned that there is nothing to disprove that the life span of *Archanthropus* reached 60–70 years. We may now add that besides the individual of the *Sinanthropus* series that lived to the oldest age, individuals I and III of the Solo series, one male and one female, may also have attained this age. In view of the available possibilities of age determination these three data are no conclusive proofs that *Archanthropus* actually lived to old age. However, two facts render it probable that he did. The first is that the remains of the three *Archanthropus*, who died in all probability on the verge of old age, come from a series of as few as 33 finds. Since the values of biological criteria (such as life span) show a considerable dispersion, we may also conclude on a statistical basis that from larger series, say several thousand or ten thousand finds, it would even be possible to identify individuals who died at an older age. The other fact is that while the method of age determination discussed above is usually suitable for deciding the probable age at death, in the case of old individuals it is more likely to establish the age before which such an individual could not presumably have died. For instance, from a calotte with completely closed sutures we can only draw the conclusion that it belonged almost certainly to an individual who died after the age of 55, and all we can attempt to render probable is that the age pertaining to a closure coefficient of 4·0 is 65 years on the average. At the same time even in individuals older than 85 the closure coefficient may be 3·5, not to mention the fact that in old age no further discrimination can be made on the basis of sutures beyond stage 4·0.

We may adduce another proof to the relatively long life span of *Archanthropus*. In the Geological Institute of Utrecht—again with Professor Koenigswald's assistance—we had the opportunity to examine the Sangiran find II belonging to the *Pithecanthropus* group. All the three vault sutures of *Pithecanthropus erectus* II were almost completely closed endocranially. The coefficient was 3·8 which, taken within wide limits, corresponds to 40–80 years, the mature adult–old adult age; within narrower limits it corresponds to 56–65 years, which is the lower limit o old adult age. So *Pithecanthropus* II, probably a female, is the fourth *Archanthropus* individual of whom we have good reason to assume that had attained old age.

PALAEANTHROPUS AND LIFE EXPECTANCY IN THE PALAEOLITHIC

The life span of *Palaeanthropus*, much nearer to us in time and belonging to the Neanderthal group, was similar to that of *Archanthropus*. Similar is the case of Eurasian Upper Palaeolithic man, separated from us by some ten thousands of years only, or the man of the Mesolithic, who lived at the dawn of history. To illustrate this, in Table 40 we show the results of age determinations made by Vallois (1960) in 39 Neanderthal finds, including the pre-Neanderthal and Palestinian Neanderthaloid finds, in 76 finds of the Upper Palaeolithic and 71 finds of the Mesolithic.

When he published his data in 1960, Vallois did not indicate the finds to which they belonged. However, in an earlier work published in 1937, containing less ageing material, he also gave the localities and historical periods of the remains. The twenty Neanderthal man remains came from the following localities: Neanderthal, Spy, Bañolas, Ehringsdorf, Engis, Gibraltar, La Ferrassie, La Quina, Pech de l'Azé, Sipka, La Naulette, Le Moustier, Malarnaud, Galilee, Saccopastore, La Chapelle aux Saints.

Vallois estimated the age at death of the male remains coming from the Neanderthal site to be 41–50 years. On the other hand, Schwalbe (1901), the first analyser of this find, considered it to be probably 40–70, or, within narrower limits, 40–65 years. Schaefer in 1957 accepted Vallois's estimate (40–50 years). In 1962 Nemeskéri and Harsányi studied the endocranial suture closure of the find. They also examined the radiographs of the proximal parts of the humerus and femur and calculated a closure coefficient of 3·2 (taking into account the two missing sections

TABLE 40

Distribution by age at death of the Neanderthal, Upper Palaeolithic and Mesolithic men (after Vallois)

Age	Number			Per cent		
	Neanderthal	Eurasian Upper Palaeolithic	Mesolithic	Neanderthal	Eurasian Upper Palaeolithic*	Mesolithic
0–11	15	29	21	38·5	38·2	29·5
12–20	4	12	6	10·3	15·8	8·5
21–30	6	15	35	15·4	19·7	49·3
31–40	10	11	6	25·6	14·5	8·5
41–50	3	7	1	7·7	9·2	1·4
51–60	1	2	2	2·5	2·6	2·8
Total	39	76	71	100·0	100·0	100·0

* Data computed on the basis of absolute figures and hence somewhat different from the percentages given by Vallois.

of the lambdoid suture; the coefficient was 3·1). The humerus was found to be in stage III and the femur in stage IV (Fig. 26). In their opinion the age at death of this Neanderthal man was therefore 57–61 years. This is a good example of how the 'middle' adult age, determined for the fossil finds, may also include individuals who died at old age. It may easily happen that among the middle adults of the Upper Palaeolithic and Mesolithic there are also individuals of advanced age.

It appears from the foregoing that individuals belonging to the Neanderthal group, and *Palaeanthropus* in general, may have lived to what is known as old age today, or to its lower limit at least.

The life spans as shown in Table 40, apart from the fact that old individuals might have been classified as middle adult, correspond probably fairly well to reality. This has been confirmed by our analysis of the Spy finds where our results agreed with those of Vallois.

Fraipont and Lohest (1887), who studied Spy I for the first time, believed that it was a female. But Virchow (1887) was of the opposite opinion and beginning from that time, the experts studying this find—Schaafhauser (1887), Sollas (1907), Keith (1911), Morant (1927), Vallois (1937), Trevor (1949), Howell (1951)—have shared his views. Only Hrdlička (1930) found its sex doubtful. According to our analysis, the sexualization index was +0·8 (on the basis of 11 sex traits somewhat modified for *Palaeanthropus* and including 6 double-weighted traits) which indicated in this case a male of moderately masculine character. His age was estimated at about 35 by earlier studies, while Vallois put him into the 31–40 year group. Closure coefficient was 1·0 ectocranially, and 1·9 endocranially. The trabecular system in the spongiosa of the proximal epiphysis of the femur is continuous, and a very slight opening up only appears in the neck (phase I). On the basis of these two age indicators the estimated age is 30–39 years (Fig. 27). According to

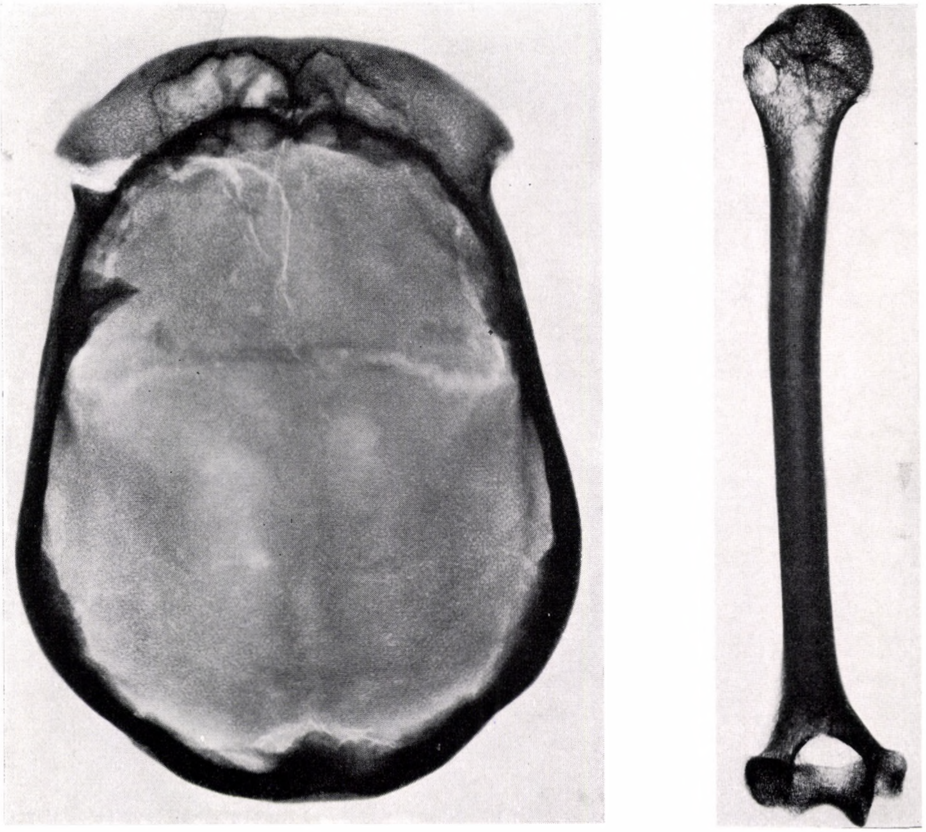


Fig. 26. Radiographs of the endocranial sutures (*a*) the proximal epiphyses of the humerus (*b*) and of the femur (*c*) of the Neanderthal find.

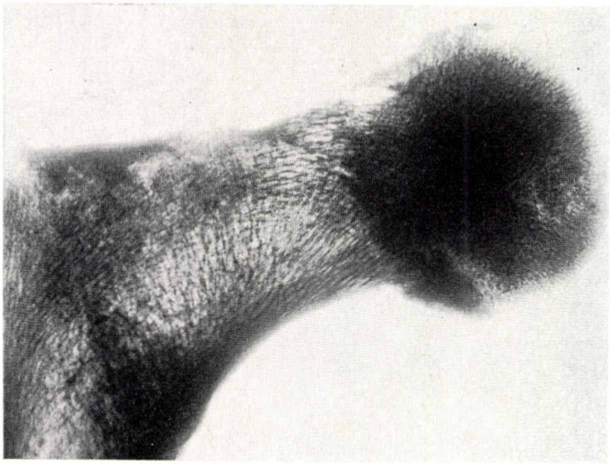


Fig. 27. Endocranial radiograph (*a*) and proximal epiphysis of the femur (*b*) of Spy I.

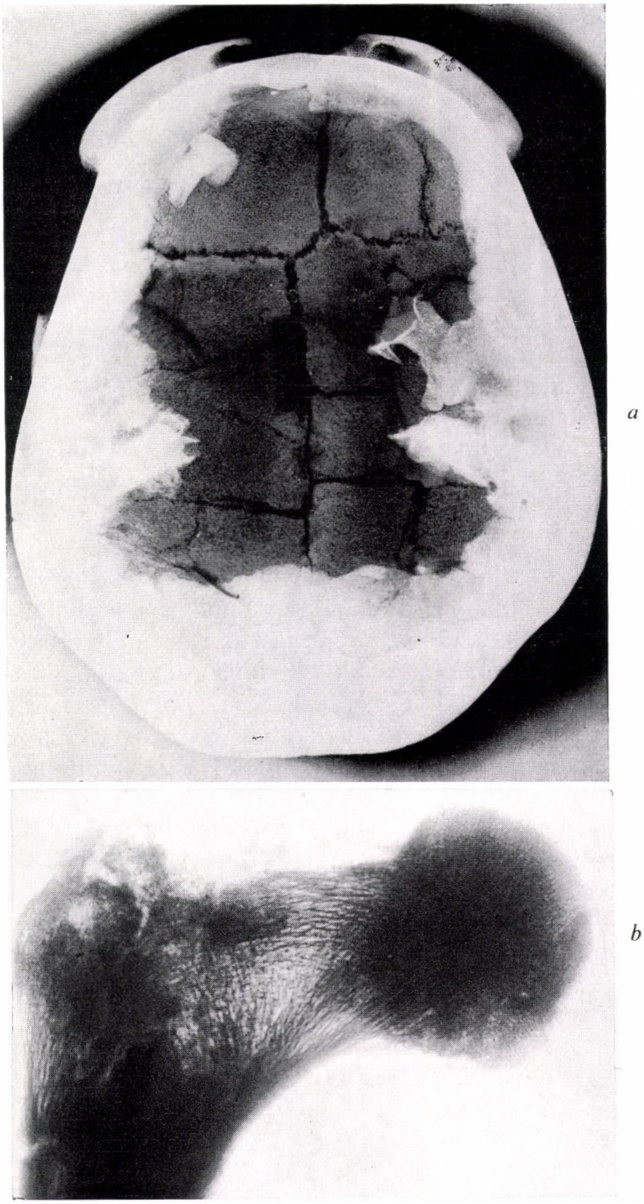


Fig. 28. Endocranial radiograph (*a*) and proximal epiphysis of the femur (*b*) of Spy II.

Fraipont and Lohest, the sex of Spy II is male and it had long been regarded so (Virchow, Schaafhauser, Sollas, Keith, Hrdlička, Vallois, Trevor). Howell was the first to identify it as a female in 1951. Our studies would seem to support Howell's opinion rather than that of the others, as the sexualization index was found to be –0·25 (calculated from 8 characters of which 4 were double weighted). Although this value is rather indifferent in respect of sex, it indicates a female of masculo-feminine character. Earlier estimates had set the age at 25 years. Closure coefficient is 1·0 ectocranially and 0·3 endocranially. In the proximal epiphysis of the femur some of the trabeculae are thinned, showing rarification in a small section of the neck (phase II). On the basis of these two age indicators the age at death may be estimated at 25–34 years (Fig. 28).

In connection with Vallois's data on the Neanderthal finds we should like to mention the similar finds in Hungary. The remains found in the Subalyuk (Cserépfalu) cave were analysed for the first time by Bartucz (1937). He concluded that Subalyuk I was a female and that, on the basis of tooth abrasion, the age at death was 40–45 years (the find consisted of mandible, vertebrae, sacrum, and the metatarsal bones). Find II (skull) is the remains of a child, aged 6–7 according to Bartucz, and 3–4 according to Thoma.

Data on the remains of *Archanthropus* and *Palaeanthropus* are unequivocal in that these men may have, and probably have, attained chronological old age as it is understood today; but they seem to be just as different in respect of characteristic life spans. Life expectancy at birth—by rather rough computation—was 14–15 years in the *Sinanthropus* series, 39 years in Solo man, while it was 22 years for the Neanderthal man according to Vallois's estimate, and 20 years for the men of the Eurasian Palaeolithic and the Mesolithic alike. The differences are explained only partially by the difficulties, or possible inadequacies of age determination. They, in fact, result from the absence in most series of remains of infants or children (such remains are more likely to decay and are less conspicuous). For this reason, e.g. the Solo series cannot be taken into account in this respect (Weidenreich believes that it was not a natural burial place, but may show the impacts of cannibalism). It seems probable that the 14–15 years' life expectancy of *Sinanthropus* can be taken as characteristic also for *Archanthropus* and that the life expectancy of *Palaeanthropus* was only a few years more if it was longer at all.

If infantile mortality is disregarded, i.e. if the expectation of life at the age of 20 is studied, the apparent differences in life expectancy vanish almost completely. Rough estimates are the following: *Sinanthropus* 14–15, Neanderthal man 15–16, Eurasian Palaeolithic man 14 years. In Solo man this estimate is higher (23 years), but this may be due to the fact that in determining the probable age at death we did not reduce the values to such an extent as others. However, the much lower mean of 7–8 years computed as the expectation of life at the age of 20 from the data of the Mesolithic is a departure in the opposite direction. From Vallois's study of 1937 it appears that this improbably low value results mainly from the unrealistic age distribution of the Hoëdic, Ofnet and Téviec series. Apart from the 21 individuals younger than twenty and 8 individuals older than thirty, the author has diagnosed 21–30 years of age at death in 27 members of these series.

It would seem from the data given above that expectation of life at birth of *Archanthropus* and *Palaeanthropus* was about 14–15 (rather 15–18) years, and expectation at the age of 20 was 14–16 years (possibly 15–25). Nevertheless, since the number of cases contained in these series is small, the series themselves are incomplete, and the available age determinations are confined to generalities, more complete series and more accurate age determinations would be required. Such series have been unearthed in the Epipalaeolithic cave cemeteries of Taforalt (Morocco) and Afalou (Algeria).

THE MAGHREB-TYPE MORTALITY

The Taforalt cave on the Maghreb peninsula was opened up by Roche between 1951 and 1955, and its anthropological data were published by Ferembach in 1962. The cave, 55 kilometres of Oujda (Morocco), contains the remains of 186 (or at least 183) individuals. This population, having earlier connections also in the Middle East, can be classified as belonging to the Epipalaeolithic period with an Ibéro-Maurusian culture. Anthropologically it is related to the populations of other Epipalaeolithic burial places in Maghreb, and above all to those of Afalou.

Considering the anomalies of the sacrum and the variations of the vertebral spinous processes, Ferembach thinks that this population must have been an isolate of distinct endogamous character. She states that mortality must have been very high, and was partially connected with the 'lethal genes' following from the isolate as such, but that this was not the sole cause. Hygienic conditions were extremely poor and the prevalence of factors affecting children must also be assumed, she writes. Indeed, infant mortality was especially high in this group and many of them died at a young age.

Few animal bones were found in the Taforalt cave. On this basis it is assumed that this population probably did not engage in animal husbandry or hunting, and that they were probably not meat-eaters. Among the bones found there, which have been studied from the pathological angle by Dastugue, there were relatively few fractured ones, so it is presumed also that this population could not have been of a martial nature or that the individuals buried in the cave had not lost their lives in the course of fights. The population here was fairly settled and their life must have not been characterized by migrations. According to Roche, the cave was inhabited for some 1,500 years and no signs of any technical progress were found during this period.

Although we do not agree with these statements in every respect, they serve as an assurance that this Taforalt cave is a completely opened-up burial place of a 'natural' population whose migration is practically negligible. It is therefore justified to consider this large series of nearly 200 members in determining the life span and mortality of ancient man.

TABLE 41

Distribution by sex and age at death of the Taforalt population (after Ferembach)

Sex and age at death	No.	Per cent*
0–1	44–45	24·2
1–2	23–24	12·9
2–5	14	7·5
5–16	16–17	9·1
Adolescent	6	3·2
Adult male	39	21·0
Adult female	31	16·7
Adult of indeterminable sex	10	5·4
Total*	186	100·0

* Computed on the basis of higher limits of the range.

Based on the skeletal finds from the Taforalt cave, Ferembach determined the probable ages at death and the distribution is shown in Table 41. It appears from the Table that there were many young among the dead, especially children under 5. The ratio of infants among the dead is also high, but not so high as to call it extraordinary. It is remarkable that the ratio of the population who died at the age of 0–16 (54 per cent) comes close to the corresponding value in the *Sinanthropus* series (68 per cent).

In her monograph, Ferembach gives the ages at death of children with higher accuracy (showing years of age for most individuals, or else limits of 2–3 years), and gives the age at death determined more closely—usually within 10-year limits—for 26 adults (16 males and 10 females). Distribution by age at death of the Taforalt population is shown in Fig. 29. To facilitate the comparison between the population who died as children and who died as adults, the data of all the 80 adults are included in the figure, those of unknown age being distributed according to the proportion of ages determined by Ferembach. For individuals under the age of 20, the figure shows a characteristic distribution. The distribution curve—indicating infant mortality of about 240 per thousand—starts high, then drops rapidly to assume minimum values at the age of 7–17. Apart from the somewhat low number of those aged 3, or possibly 4, and apart from the minor peak at the age of 5, and a

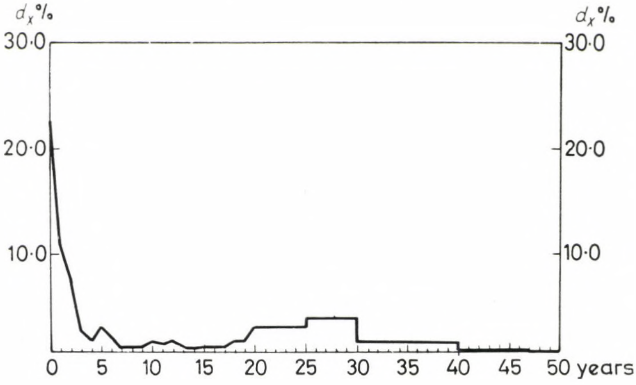


Fig. 29. Age distribution at death of the Taforalt population (after Ferembach).

few insignificant fluctuations in the series of values which can be ascribed equally to the not too large number of cases in the series or to the difficulties of age determination, it may be stated that the curve follows general principles. This mortality pattern, even if departing from that of today—or, more exactly, from the mortality types of populations of developed countries—is not inconsistent with our knowledge of the nature of mortality, and can be reconciled with the living conditions of ancient man.

With the distribution of those who died above the age of 20 the case is different. Following the high mortality value at 20–25, the curve culminates at the age group of 25–30, then decrease gradually to end at the age of 47. The data already discussed would render a normal age of 25–30 at death and a maximum life span of 47 years improbable. Although this section of the curve does not reflect reality—as we shall see later on—we have computed the life table of the Taforalt population on the basis of the data of Fig. 29, as this makes instructive comparisons possible (Table 42).

TABLE 42

The abridged life table of the Taforalt population; both sexes (after Ferembach)

Age (x)	Distribution of deaths		Survivors (l_x)	Probability of death (q_x)	Total no. of years lived between ages x and $x + 5$ (L_x)	Total after lifetime (T_x)	Life expectancy (e_x^0)
	No. (D_x)	Per cent (d_x)					
0–4	82·834	44·54	100·0	0·445	388·650	1,472·600	14·7
5–9	10·606	5·70	55·5	0·103	263·050	1,083·950	19·5
10–14	6·560	3·53	49·8	0·071	239·975	820·900	16·5
15–19	6·335	3·41	46·2	0·074	222·625	580·925	12·6
20–24	23·835	12·81	42·8	0·299	182·075	385·300	8·4
25–29	32·830	17·65	30·0	0·588	105·925	176·225	5·9
30–34	10·590	5·69	12·4	0·460	47·575	70·300	5·7
35–39	10·590	5·69	6·7	0·853	19·125	22·725	3·4
40–44	1·386	0·75	1·0	0·765	3·025	3·600	3·7
45–49	0·434	0·23	0·2	1·000	0·575	0·575	2·5
Total	186·000	100·00	—	—	1,472·600	—	—

The most characteristic value of the table is the expectation of life at birth, 14·7 years, which agrees with the comparable value of the *Sinanthropus* series. The number of survivors decreases rapidly, but justifiably, until the age of 5, then slowly until about 20. However, starting at the age of 20, or rather 25, the number of survivors decreases with dramatic rapidity up to complete extinction between 40 and 50 years of age. In column d_x the value of two age groups falling between 20 and 29 years shows a conspicuous peak. The causes of these phenomena will be discussed later on.

It is stated in Ferembach's monograph that for adults the determination of age at death was based only on the closure of cranial sutures, and on the state of denture, and that it was not possible to employ the methods we have outlined in Chapter III. It is her intention, however, to carry out a complex age determination of the finds, and this might modify the results, especially if the proximal epiphyses of the humerus and femur are examined radiographically. Thanks to the kindness of Professors Vallois and Ferembach, the radiographs of the bones of the similar Afalou series have been made available to us for a more accurate age determination. The distribution obtained from these differs from that of the Taforalt series and does not confirm the validity of the age determinations of Taforalt adults made on the basis of the cranial sutures. Also, with the help of Professor Ferembach we had an opportunity to study several essential age indicators of the Taforalt series, using the original material, putting Taforalt adult mortality in a different light. Before drawing conclusions from these determinations, we give a short description of the Afalou series.

Along the Algerian coast, in the Kabyl mountains surrounding the bay of Bougie, there are several caves and clefts. Some of these have been studied by archaeologists, some of them have still to be opened up. The cavernous cleft of Afalou-Bou-Rhummel is located along the road leading from Traziboun to La Falaise. This region was first visited by Boule and Vaufrey in 1927 and excavations were started in the next year. Seven complete skeletons and 50 skulls were secured from the 10 m deep and 20 m wide cavernous cleft. These finds are just as old as the Taforalt ones and belong to the North African Epipalaeolithic. These most important finds of the Maghreb peninsula were analysed anthropologically by Vallois in 1934, in his monograph on the Palaeolithic caves of Beni Segoual.

The skeletal material secured in the course of excavations is not suited for a detailed demographic analysis since the skeletons of children are usually missing from the series. Using the bone material made available to us by Professor Vallois, as well as the radiographs we received from Professor Olivier and Dr. Aaron, we were able to determine the age at death of 43 skeletons, taking into account 5 age indicators. Four of these were children (infant I), one was about 15–16 years old, the determination being based on the state of the teeth. The age of two other individuals was determined as about 20 by the state of teeth and also by the degree of obliteration. In the others the phases of the humerus or the femur (mostly both) were established; in one case also the pubic symphysis was studied, in addition to the cranial sutures. The distribution by age at death derived from the results is shown in Fig. 30. It appears clearly from the distribution that, on account of the

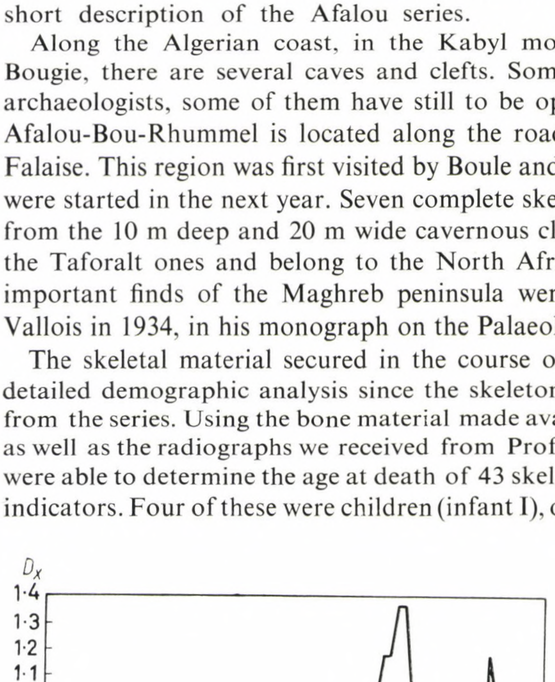


Fig. 30. Age distribution at death of the Afalou population.

absence of children, it is of no use to draw up a complete life table from this series. Starting, however, of the age of 20—apart from the data of a few ages, and some minor fluctuations—the distribution is fairly even (values between 0·7 and 1·4 as a rule). It therefore seems possible to compute a life table based on the data of 37 adults starting at the age of 20. (The data are shown in Table 102.)

In the life table of the Afalou population, expectation of life at the age of 20 is 21·9 years, which substantially exceeds the 8·4 years computed on the basis of Ferembach's determination, but approximates the 23 years of the Solo series, as well as the 14–16 years of *Sinanthropus*, Neanderthal man and the Eurasian Palaeolithic man. The substantial difference between the Afalou and the Taforalt data presented so far comes from the fact that while according to Ferembach's determinations about half of those aged 20 died in the course of 8 years, i.e. the curve of the survivorship pattern shows an abrupt drop here, the survivorship curve of the Afalou population descends—without unwarranted breaks—to the age of 60–65 and conforms approximately to the survivorship trend of the Taforalt curve after infant II.

As has been mentioned, we had opportunity to study the Taforalt finds. The age determination of children was made by Ferembach with such accuracy that we can accept it in full. Concerning the finds of adults, no radiographs of the proximal epiphyses of the humerus and femur remains were available. On the other hand, we could study the degree of endocranial suture closure, and, very important in respect of dependable age determination, we had opportunity to study the articular surfaces of the pubic bones in most cases, in addition to the abrasion of teeth and other age indicators. We determined the age at death of 28 individuals in this way, exceeding by two those presented in the monograph on Taforalt. We should like to mention that the age at death of three individuals among those analysed by Ferembach could not be determined because the endocranial surface of the skulls was covered with glue to such an extent that the degree of obliteration could not even be estimated. So the Taforalt adults whose age we determined are not exactly the same as the ones whose age at death was determined by Ferembach on the basis of suture closure. But the fact that the members of the two series are not completely identical is but a partial explanation of the substantial differences between the results of the two methods of determination. These differences arise to a large extent from the fact that the age-determination methods described in Chapter III yield more accurate results than did the method originally employed when studying the ages of the Taforalt adults. It follows therefore that the method of studying the obliteration of cranial sutures alone, and only ectocranially in many cases, may lead to an underestimation of the age at death of adults of other series too. Based on Ferembach's determinations for children, and on our determinations for adults, the abridged life table of the Taforalt population is shown in Table 43. According to the data in Table 43, the expectation of life at the age of 20 for the Taforalt population is 23·9 years, which approximates the 21·9 years of the Afalou population, and does not fall below the comparable values of *Archanthropus* and *Palaeanthropus*, but actually exceeds them. Expectation of life at birth is higher, too, 21·4 years rather than 14·7. The substantial change in these values does not mean that the mortality values of children had changed, it is only a consequence of the fact that the number of years lived at adult age has increased. (A detailed life table computed for early age—0 to 20 years—is shown in Table 103.)

TABLE 43

The abridged life table of the Taforalt population (both sexes)

Age (x)	Distribution of deaths: No. (D_x)	Distribution of deaths: Per cent (d_x)	Survivors (l_x)	Probability of death (q_x)	Total no. of years lived between ages x and $x + 5$ (L_x)	Total after lifetime (T_x)	Life expectancy (e_x^0)
0–4	82·834	44·54	100·00	0·445	388·650	2,137·400	21·4
5–9	10·606	5·70	55·46	0·103	263·050	1,748·750	31·5
10–14	6·560	3·53	49·76	0·071	239·975	1,485·700	29·9
15–19	6·335	3·41	46·23	0·074	222·625	1,245·725	26·9
20–24	5·115	2·75	42·82	0·064	207·225	1,023·100	23·9
25–29	16·508	8·87	40·07	0·221	178·175	815·875	20·4
30–34	14·384	7·73	31·20	0·248	136·675	637·700	20·4
35–39	3·832	2·06	23·47	0·088	112·200	501·025	21·3
40–44	4·130	2·22	21·41	0·104	101·500	388·825	18·2
45–49	4·985	2·68	19·19	0·140	89·250	287·325	15·0
50–54	6·250	3·36	16·51	0·204	74·150	198·075	12·0
55–59	6·250	3·36	13·15	0·256	57·350	123·925	9·4
60–64	6·678	3·59	9·79	0·367	39·975	66·575	6·8
65–69	7·831	4·21	6·20	0·679	20·475	26·600	4·3
70–74	3·274	1·76	1·99	0·884	5·550	6·125	3·1
75–79	0·428	0·23	0·23	1·000	0·575	0·575	2·5
Total	186·000	100·00	—	—	2,137·400	—	—

Knowing the expectation of life and the distribution of death in the adult age, we must revert to some statements of authors studying the Taforalt population as these touch indirectly upon the problem of mortality. One hardly credible conclusion is that this small population—186 people in all—should have lived for 1,500 years at this spot. Even if we assume that this isolate was a joint family of very few members, we must consider as a minimum one or two pairs of parents aged 15–45, one or two 'old' people over 45, i.e. with 4–6 adults on the average who must all have lived at the same time and with 6–8 children of various ages. This number would have been absolutely necessary for reproduction, taking into account infantile mortality which means a total of 10–14 persons at least. By means of the formula described in Chapter II, the maximum length of the period during which the cemetery was in use can be computed on the basis of the minimum population size as follows:

$$t = \frac{186 \times 21{\cdot}4}{13} = 306{\cdot}2 \text{ years, or } \frac{186 \times 21{\cdot}4}{10} = 398{\cdot}0 \text{ years}$$

But even if we reckon with a small family of the lowest possible membership (about 7 persons) given this mortality rate and the necessary fertility, this community could not have maintained life for more than 6 centuries.

A period of 600 years (or even 300) is practically inconceivable in the case of so small an isolate that has presumably been completely closed. For the relative high rate of extinction hides accidents, individual or group tragedies, as a consequence of which the reproduction of the family would cease if the losses were not compensated by exogamy. So we are of the opinion that even if the Taforalt population had lived at this spot for 300–400 years only, its isolation was only partial. We cannot even estimate what presumed infanticidal role the 'lethal genes' might have played in such a partial isolate, where the extent of endogamy cannot be ascertained on the basis of available data. It should be noted, however, that this hypothesis need not necessarily be accepted as an explanation of infant mortality, which is, in fact, not extraordinary. The suspected practice of exposure aimed at a restrictive demographic policy need not be raised, as this would have been improbable anyway at the given rate of child mortality, high even in comparison with that of infants.

We should like to point out, too, that survival conditions before the age of 20 seem to be somewhat better—if not to a great extent—than after. The acceleration of extinction at the age of 25–34, appearing in the series analysed by Ferembach, as well as in the one analysed by us, is especially striking. We do not wish to challenge the peaceful nature of the one-time Taforalt population, but it would seem that despite the fact that they were not hunters, the possibility of violent deaths not involving the fracture of bones, should not be excluded altogether. (It should be noted that the majority of persons dying at the age of 25–34 were men.)

The circumstance should serve as a warning that the mortality pattern appearing in the Taforalt series although containing a relative high number of cases cannot be regarded as a type suited for direct generalization. It was appropriate therefore that we should have partially smoothed the survivorship pattern of Taforalt, and have partially corrected it with the data of the Afalou series. In this way we have drawn up a standard life table that characterizes the mortality conditions of the Epipalaeolithic populations of North-West Africa fairly well. The model, which may be called the Maghreb-type mortality after the sites, was constructed on the basis of the survivorship pattern. The survivorship pattern of the Afalou and Taforalt series, as well as the Maghreb type derived from these, are compared in Fig. 31.

The survivorship pattern of the Maghreb type is identical with that of Taforalt at the ages of 0 and 1, and departs from it from the age of 2 to 20 only to such a degree as is necessary for a graphical smoothing of minimum extent. It is rather striking to see in Fig. 31 how the Taforalt population should have died out after the age of 20 without any transition, and in a very short time, according to the age determination in Ferembach's monograph. The temporary, more rapid descent of the curve between the ages of 25 and 34 appears also in the series studied by us; we have smoothed this away in the Maghreb-type mortality with the values of the

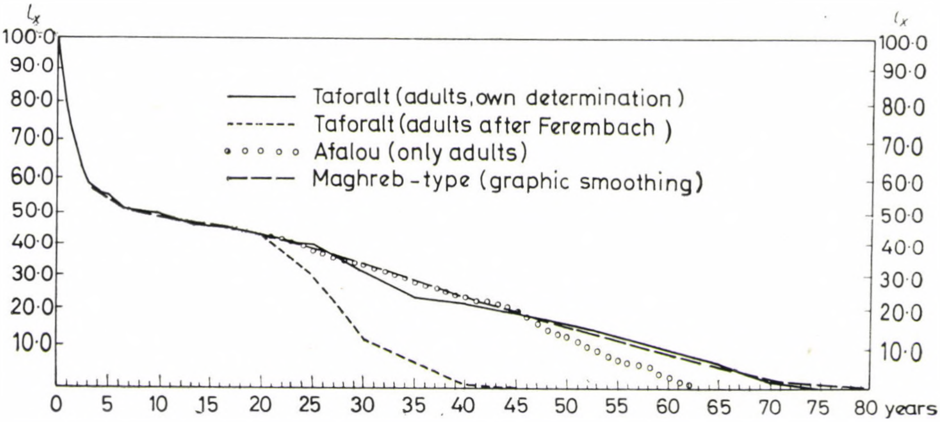


Fig. 31. Survivorship of Maghreb-type mortality, compared with the data of the Afalou and Taforalt populations.

Afalou survivorship pattern. For in this interval the Afalou curve fits well into the series of values of Taforalt childhood and mature age, and shows no inexplicable breaks. Yet beginning at the age of 45, we had to shift the Maghreb type from the Afalou survivorship pattern to that of Taforalt, since the Afalou curve, instead of becoming convex and approximating the horizontal age-axis in an asymptotic manner, crosses the Taforalt curve and, descending straight, ends at the age of 63. So we adjusted the Maghreb type at the middle adult–old adult age to the Taforalt curve which corresponded to the general pattern of mortality better, by making its course somewhat more convex, and more protracted toward old age.

The computed values of the Maghreb-type model life table are shown in Table 104. The probability of death in the Maghreb model results in the familiar U curve. From the 231 per thousand value of age 0, the curve descends, and becomes almost flat between the ages of 9 and 16. It reaches its minimum in childhood, at the age of 11. Beginning at the age of 17 the probability of death ascends, and, disregarding some minor fluctuations resulting from inadequate smoothing, this increase lasts up to the age of 73–74. The values are unreal from the age of 75 which indicates that there were no sufficient, dependable data to reconstruct the mortality of old people (see Fig. 34).

The Maghreb-type mortality does not contradict the rules of mortality observed today. This does not mean, however, that its level should be close to that of developed countries. For instance, infant mortality of the Maghreb type is about 4 to 5 times as high as infant mortality in Hungary today, the probability of death at the age of 1 is about 35 times as high, and that of two-year-old children 70 to 80 times as high. The difference in level then decreases with age: Maghreb-type mortality is 50 to 60 times higher at the age of 3, 25 times higher at the age of 11—the minimum of mortality—, 20 times higher at the age of 30, and 4 times higher at the age of 60 than today.

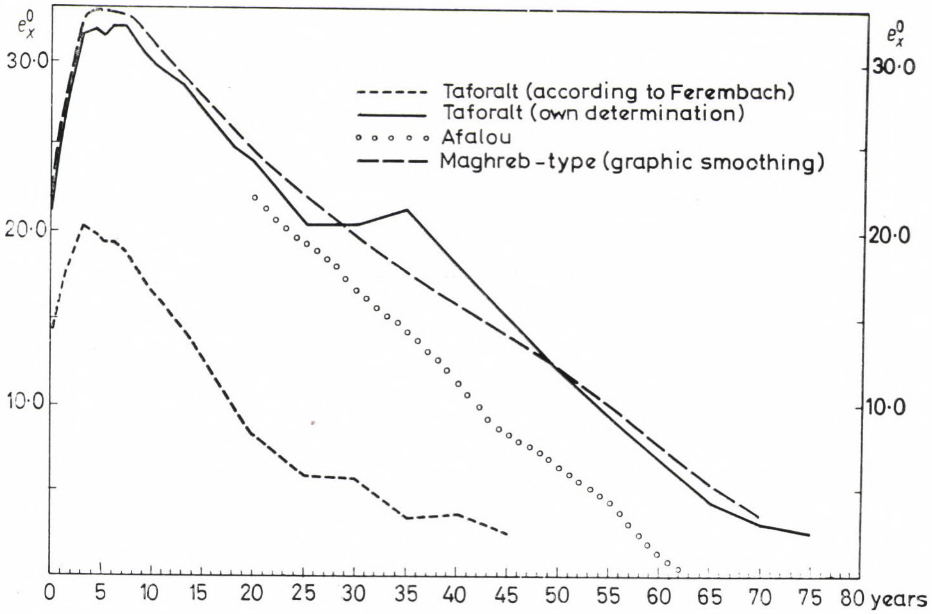


Fig. 32. Expectation of life in the Maghreb-type mortality compared with the data of the Afalou and Taforalt populations.

Expectation of life at birth is 21·1 years. Following the period of infant mortality the life expectancy increases considerably up to the age of 4–5. Expectation of life at the age of 5 increases to 32·8 years. But this value is only 24·5 years at the age of 20, which means that on the average people aged 20 had the chance to live to the age of 44·5.

The trends in the expectation of life in the Taforalt and Afalou population, compared with those of the Maghreb type is shown in Fig. 32. It appears that, on account of deaths occurring at the age of 25–34, the expectation of life up to the age of 25 is lower in the Taforalt population than in the Maghreb type; then the Taforalt curve rises abruptly resulting in a radical change in slope between 25 an 35 years. The Maghreb-type curve eliminates these irregularities. Because of the absence of aged people, the life expectancies of the Afalou population are lower than those of either the Taforalt or the Maghreb type, but run in parallel with Taforalt and, consequently, more steeply than the Maghreb.

The probable length of life can be given from the Maghreb-type table. Given such a type of mortality, half of the population must have died rather young, living hardly more than 8 years. This low value is a consequence of high infant and small-child mortality. Half of those attaining the age of 8 were likely to live another 31 years, i.e. one-fourth of the newborn may have lived to 39 years. One-tenth of the newborn had chances to attain the age of 58.

Data available on mortality in the Mesolithic give a very vague and unconvincing picture. If we study the data published by Vallois (1960), shown in Table 40, it appears that although the age structure of the dead changed considerably in the Mesolithic as compared with Neanderthal or the Eurasian Upper Palaeolithic, expectation of life at birth did not change at all. In fact, when compared with Neanderthal it even decreased. This is partially explained by the circumstance that the probability of finding skeletons of children and preserving them for scientific analysis is not the same as in case of adults, and varies at different excavations. For example, the ratio of children in the Neanderthal and Upper Palaeolithic finds is considerably lower than in the *Sinanthropus* or Taforalt series, and is still lower in the Mesolithic finds. If the higher child mortality of Taforalt and later ages could be disregarded, this phenomenon might serve as an indication of improvement in the general level; even so it would be in contradiction to the changes showing an opposite trend in the ratio of the dead at adolescent and adult age.

Referring to the well-known inadequacy of the child mortality pattern, Vallois tried to analyse mortality disregarding this. In a table he compared the distribution of individuals from age 12 onward of three series, the same as we have shown in Table 40. The only difference is that Vallois included in the Eurasian Palaeolithic also the North African finds (except for Taforalt).

TABLE 44

A comparison of distribution of death from the age of 12 (after Vallois)

	Total	Age group				
		12–20	21–30	31–40	41–50	51–60
				Number		
Neanderthal	24	4	6	10	3	1
Upper Palaeolithic	86	15	31	27	11	2
Mesolithic	50	6	35	6	1	2
				Per cent		
Neanderthal	100·1	16·7	25·0	41·7	12·5	4·2
Upper Palaeolithic	100·0	17·4	36·1	31·4	12·8	2·3
Mesolithic	100·0	12·0	70·0	12·0	2·0	4·0

It appears from Table 44 that while the ratio of those aged 12–20 and 51–60 shows hardly any considerable change in the course of time, that of those aged 21–30 increases in the Mesolithic; on the other hand, the ratio of people aged 31–40 decreases at the same time, and the ratio of those dying at the age of 41–50 is lowest in the Mesolithic. If the material is broken down to two large groups—people younger than 30 and older than 30—the following apparent trend of changes in the mortality structure emerges: (*i*) the ratio of those younger than 30 increases (this ratio is only 41·7 per cent in the Neanderthal series, 53·5 in the Upper Palaeolithic, and as much as 82·0 per cent in the Mesolithic); (*ii*) the ratio of people older than 31 decreases (58·4 per cent for Neanderthal, 46·5 for the Upper Palaeolithic, and 18·0 in the Mesolithic). This trend would indicate an extreme deterioration in mortality and a considerable decrease in the expectation of life, but there is no reason whatever to assume this. Consequently the data on the Mesolithic, appearing in Table 44, are either useless for estimating mortality due to shortcomings of the age-determination method, or represent an extreme distribution rendering them unfit for generalization.

It is obvious then that an attempt at reconstructing Mesolithic mortality could be made only on the basis of a fairly large series that had been unearthed more or less completely. The cemetery (no. III) opened up by Telegin in 1955 on the outskirts of Vassilievka in the immediate vicinity of Dniepropetrovsk seems to be a suitable series; the anthropological analysis is being conducted by Gochman.

With the assistance given by the Leningrad Ethnographical and Anthropological Institute of the Academy of Sciences of the USSR, we had the opportunity to study the anthropological finds of cemetery III of Vassilievka. Vassilievka III is a typical eastern example of the European Mesolithic, characterized by both microliths and macroliths. Anthropologically the finds belong to the Cromagnon group and are of extremely marked appearance. Two variations can be discerned within the population: one hypermassive and one gracile, from which the existence of two biological units can be inferred.

Forty-two graves were opened up at cemetery III of Vassilievka, and the unregistered skeletal remains of a grave opened up in 1953 are available for analysis in addition. Eleven of the finds were destroyed during excavation, so we could study the skeletal remains of only 32 individuals. We established the age diagnosis on basis of the following criteria: (*i*) the dental state in 2 cases; (*ii*) the fusion of the epiphysis and diaphysis of the humerus in 4 cases; (*iii*) endocranial suture closure in 19 cases, in addition the pubic symphysis, the humerus and the femur; (*iv*) in another 7 cases the diagnosis was established on the basis of other skeletal bones.

As the probability existed that three of the skeletal remains destroyed during the excavation belonged to individuals who had died at the adult age, we have shown the distribution by age at death of 35 individuals in Fig. 33. The most striking feature is the almost complete absence of children. There is only one child aged 6–7, and two children aged 13–16 in this series. From this we cannot, of course, draw conclusions on the absence or low ratio of child mortality. There certainly was infant and child mortality in Vassilievka, too, only persons dying at these ages were not included in the collection. It may be supposed, for instance, that of the 11 graves from which no anthropological material was collected and of which 3 belonged to adults, the other 8 contained children's skeletons. Including these, more than one-fourth of the Vassilievka graves are children's graves, but considering the fact that skeletal remains had been removed from the cemetery before, it is possible that a larger proportion of the children's graves had been destroyed than that of adults of a known age.

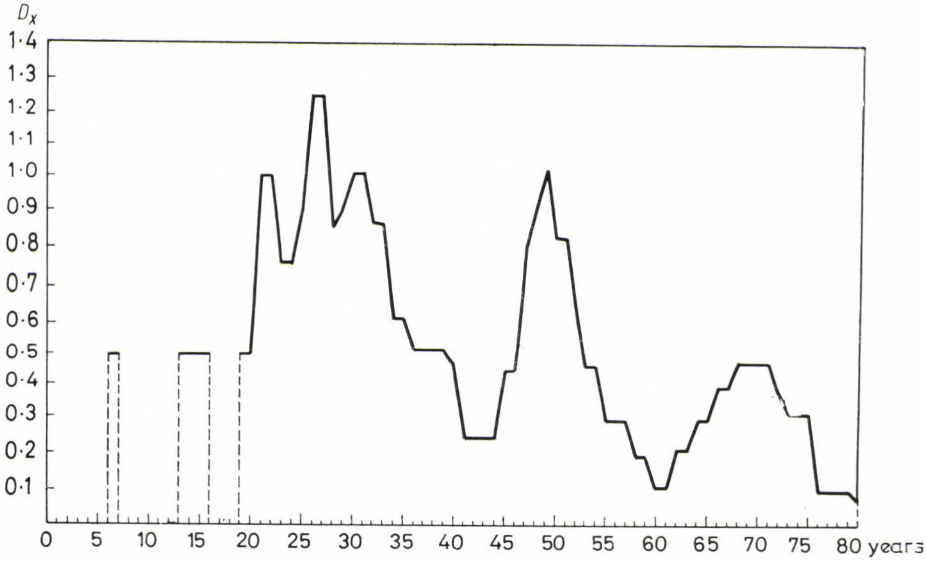


Fig. 33. Age distribution at death of the Mesolithic population of Vassilievka.

There is, unfortunately, no further foundation available on which to base a reasonably realistic estimate of the ratio of children's graves at Vassilievka. But even so, Vassilievka III is an important and valuable series for reconstructing human life spans and adult mortality in the Mesolithic period. The size of the Vassilievka series (32 adults) is comparable with the series of Afalou and Taforalt, but its distribution by age at death presents a peculiar picture. Figure 33 of the Vassilievka distribution calls attention to three modes of diminishing value, to which a parallel can hardly be found in the Afalou material of fairly even distribution. The distribution of Vassilievka III agrees much better with that of Taforalt. The peak at adult age starting at 20, or rather at 25, and going on to 34, appears here, and is almost as characteristic as at Taforalt. The old-age mode between 68 and 71 appears here too as it appears at Taforalt mortality between the ages of 65 and 69, although in Taforalt a milder form and a considerable asymmetry are characteristic. Only the mode pertaining to the age group of 45–50 departs from the Taforalt features (although it is from this age, too, that the ratio of the dead in Taforalt mortality begins to rise more abruptly towards the old-age mode). On the other hand, this feature converges with the distribution of the dead at Afalou, where the d_x values become modal just at the age of 44–47.

If the distribution of the Vassilievka III, Taforalt and Afalou series is compared with the distributions shown in Table 44, we obtain the picture given in Table 45 (to facilitate comparison, only those dying at the age of 20 or older have been included; in the series determined by us, the distribution was computed on the basis of the D_x values of the life tables).

TABLE 45

Comparison of percentage age distribution of Palaeolithic and Mesolithic series

Series	Total	Age group (years)*				
		20–29	30–39	40–49	50–59	60+
Neanderthal (Vallois)	100·0	30·0	50·0	15·0	5·0	—
Upper Palaeolithic (Vallois)	100·0	43·7	38·0	15·5	2·8	—
Afalou (Acsádi–Nemeskéri)	100·0	21·9	21·9	26·1	22·9	7·2
Taforalt (Acsádi–Nemeskéri)	100·0	27·3	23·0	11·5	15·8	22·4
Mesolithic (Vallois)	100·0	79·4	13·7	2·3	4·6	—
Vassilievka III (Acsádi–Nemeskéri)	100·0	29·2	22·2	16·2	14·3	18·1

* In Vallois's series the age group limits are one year higher than in our series.

Notwithstanding the afore-mentioned features, the distribution in the Vassilievka III series is very close to the distributions of Afalou and Taforalt, and all three series compare better with the distribution in the Neanderthal series (which is otherwise rather extreme) than with the increasing departures found in the Upper Palaeolithic and Mesolithic series. It is obvious from the comparison that we come nearer to the estimation of Mesolithic mortality if we take into account the adult dead in the Vassilievka series rather than the combined series of data referred to.

We have therefore computed the abridged life table of the Vassilievka III population on the basis of the distribution shown in Fig. 33; the results are shown in Table 46. Although we have based the calculations on the complete series, owing to the absence of children the table only gives acceptable results beginning from the age of about 15–20 years. Indeed, the value of life expectancy at birth is unduly high, nearly double that of Taforalt. Beginning from the age of ten, however, the expectations of life come very close to the values of the Taforalt table and are parallel from that point on.

Age-specific mortality —and the probability of survival at certain ages—shows certain fluctuations after the age of 10 in the Vassilievka series too. Mortality is temporarily lower, and the curve breaks and falls back, first between the ages of 35 and 44, then between 55 and 64. We ascribe these declines to the relatively small size of the population sampled, and to the deficiencies of age determination, rather than to any special characteristic, although the decline of mortality between the ages of 35 and 44 appears in the Taforalt table as well, and is even more marked there resulting in a temporary rise in the value of life expectancies.

Since Vassilievka III is the most complete and largest Mesolithic series we have known so far, we also computed the detailed life table beginning from the age of 20. The data are shown in Tables 105 and 106.

TABLE 46

The abridged life table of the Vassilievka III population (both sexes)

	Distribution of deaths						
Age (x)	No. (D_x)	Per cent (d_x)	Survivors (l_x)	Probability of death (q_x)	Total no. of years lived between ages x and $x + 5$ (L_x)	Total after lifetime (T_x)	Life expectancy (e_x^0)
0–4	—	—	100·00	—	500·000	3,987·510	39·88
5–9	1·000	2·86	100·00	0·0286	492·850	3,487·510	34·88
10–14	1·000	2·86	97·14	0·0294	478·550	2,994·660	30·83
15–19	1·500	4·29	94·28	0·0455	460·675	2,516·110	26·69
20–24	4·023	11·49	89·99	0·1277	421·225	2,055·435	22·84
25–29	5·169	14·77	78·50	0·1882	355·575	1,634·210	20·82
30–34	4·357	12·45	63·73	0·1954	287·525	1,278·635	20·06
35–39	2·675	7·64	51·28	0·1490	237·300	991·110	19·33
40–44	1·439	4·11	43·64	0·0942	207·925	753·810	17·27
45–49	3·632	10·38	39·53	0·2626	171·700	545·885	13·81
50–54	3·205	9·16	29·15	0·3142	122·850	374·185	12·84
55–59	1·272	3·63	19·99	0·1816	90·875	251·335	12·57
60–64	0·948	2·71	16·36	0·1656	75·025	160·460	9·81
65–69	2·034	5·80	13·65	0·4249	53·750	85·435	6·26
70–74	1·948	5·57	7·85	0·7096	25·325	31·685	4·04
75–79	0·722	2·06	2·28	0·9035	6·250	6·360	2·79
80–84	0·076	0·22	0·22	1·0000	0·110	0·110	0·50
Total	35·000	100·00	—	—	3,987·510	—	—

The mortality conditions reconstructed on the basis of the Vassilievka III series represent Mesolithic mortality fairly well, but are nevertheless close to the mortality in the Late Palaeolithic. This justifies taking Mesolithic mortality into account when the archetype of mortality is discussed. Yet with regard to mortality the Mesolithic finds known to us—apart from Vassilievka—are of so little palaeodemographic value that it is difficult to adduce more conclusive data. We nevertheless succeeded in studying a smaller series, which can be regarded at least in part as Mesolithic. This can be used in estimating Mesolithic mortality although its palaeodemographic authenticity is restricted. The series comes from the excavations at Fofonovo, in the Transbaikal region of Siberia. The excavations have been conducted by Gerasimov. The series consists of the remains of 3 children, 8 men and 9 women, and the material has not yet been published. According to Gerasimov's personal communication, part of the finds may be dated back to the end of the Mesolithic, part of them to the Early Neolithic. The chemical analysis of the bones seems to support this conclusion; it appears from Dr. Lengyel's verbal report that the values determined in this series are very different. An early and a substantially later phase might therefore be inferred. From the anthropological point of view, the Fofonovo series is the most interesting among the Mesolithic–Neolithic finds coming from North Asia. Three varieties of *Homo sapiens*—Protomongoloid-Baikal, Cromagnon and Protoaustraloid—can be observed in this series. Otherwise the appearance of these varieties at the same spot also supports the probability of differences in the archaeological age of the series.

Although it may be assumed that the Fofonovo series is Mesolithic only in part, and although children are practically absent from this series too, we have, for the sake of the interest of the matter, computed a detailed life table from the data (Tables 107 and 108). Table 47 below shows a life table computed with the abridged method from the age of 20.

TABLE 47

Abridged life table of the Fofonovo series

Age (x)	Distribution of deaths		Survivors (l_x)	Probability of death (q_x)	Total no. of years lived between ages x and $x+5$ (L_x)	Total after lifetime (T_x)	Life ex-pectancy (e_x^0)
	No. (D_x)	Per cent (d_x)					
20–24	2·240	13·18	100·00	0·13180	467·050	2,890·920	28·91
25–29	0·600	3·53	86·82	0·04066	425·275	2,423·870	27·92
30–34	0·560	3·29	83·29	0·03950	408·225	1,998·595	24·00
35–39	0·760	4·47	80·00	0·05588	388·825	1,590·370	19·88
40–44	1·135	6·68	75·53	0·08844	360·950	1,201·545	15·91
45–49	2·000	11·76	68·85	0·17081	314·850	840·595	12·21
50–54	3·677	21·63	57·09	0·37888	231·375	525·745	9·21
55–59	2·583	15·19	35·46	0·42837	139·325	294·370	8·30
60–64	1·398	8·22	20·27	0·40553	80·800	155·045	7·65
65–69	0·885	5·21	12·05	0·43237	47·225	74·245	6·16
70–74	0·845	4·97	6·84	0·72661	21·775	27·020	3·95
75–79	0·285	1·68	1·87	0·89840	5·150	5·245	2·80
80–84	0·032	0·19	0·19	1·00000	0·095	0·095	0·50
Total	17·000	100·00	0	—	2,890·920	0	—

As the series is incomplete, the expectation of life values in the Fofonovo table are improbably high. As a result of an almost complete absence of children, expectation of life at birth is more than 44 years, but expectation is equally very high at the age of 20. This latter circumstance is explained by the fact that a considerable proportion of the dead at Fofonovo are concentrated in the age group of 50–59, while there are hardly any dead in the 25–39 group. With this type of distribution the Fofonovo series is in clear contradistinction to the Mesolithic data published by Vallois.

The distribution of Fofonovo individuals who died when older than 20 is compared in Table 48 with the corresponding data of Vallois and the Vassilievka Mesolithic series. The distribution in the Fofonovo series bears a much greater resemblance to that of Vassilievka than to the distribution in the Mesolithic series made up of sporadic data. However, it differs from Vassilievka with its low proportion of individuals aged 30–39, and with its marked mode at the age of 50–59.

TABLE 48

Per cent distribution of deaths after the age of 20 in the Fofonovo, Vassilievka and Vallois's Mesolithic series

Serial no.	Series	Total	Age (years)				
			20–29	30–39	40–49	50–59	60–*x*
1	Vallois's series*	100·0	79·4	13·7	2·3	4·6	—
2	Fofonovo	100·0	16·7	7·8	18·4	36·8	20.3
3	Vassilievka	100·0	29·2	22·2	16·2	14·3	18.1
4	Mean of series 1 and 2**	100·0	48·0	10·8	10·4	20·7	10·1

* In Vallois's series all age group limits are one year higher.

** Unweighted averages.

While the average difference between the respective age groups of Vallois's series and Vassilievka III is 20·1, the same value for Fofonovo and Vassilievka III is 10·8, about half of the former. The average difference between the Fofonovo and Vallois's series is 27·4, which means that these two series differ from each other to a much greater extent than either of them from Vassilievka III. Yet if counting (nos 1 and 2 in Table 48) with unweighted averages, we obtain a much more balanced distribution (no. 4). This is somewhat, if not considerably, closer to the Vassilievka distribution than is the distribution of Fofonovo (the average difference is 10·1). The fact that the properties of the mean of the two extreme series which are unfit for generalization approach those of the Vassilievka series supports our hypothesis that Vassilievka III is a series standing close to the hypothetic Mesolithic type and is suited for a certain degree of generalization.

Despite all its incompleteness, the Fofonovo life table conveys a certain information on ancient mortality. From the probabilities of death by age of the detailed Fofonovo life table, we obtain the familiar U curve of mortality (Fig. 34). Although the curve shows considerable fluctuation, and the left side, the one representing childhood, is practically missing, the governing principles of mortality referred to age are clearly presented, beginning from the age of 20 at least. It appears from the figure that Fofonovo mortality, disregarding the peak values of the ages 21–23, is lower up to the age of about 45 than would be expected, while it rises abruptly

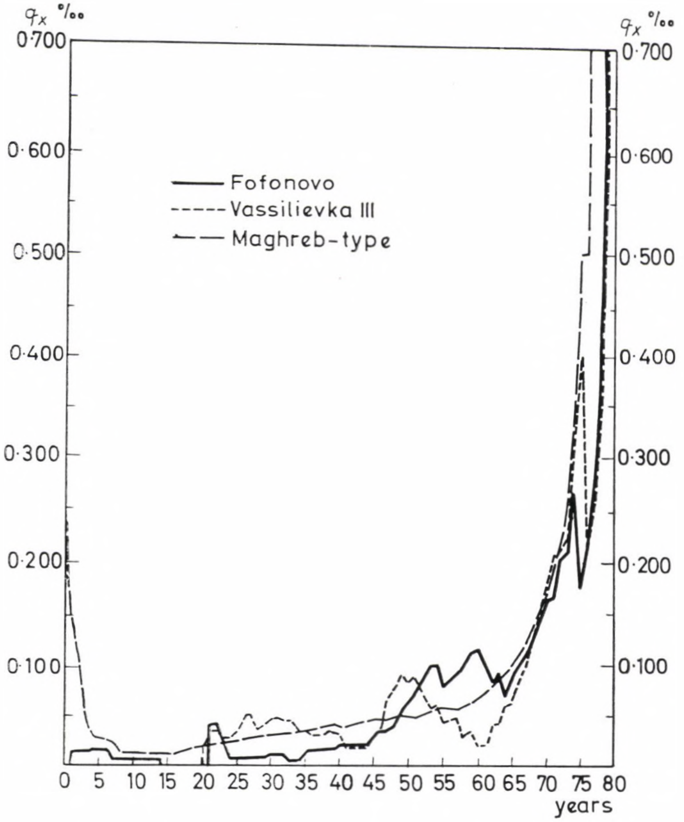


Fig. 34. Probability of death at various ages of ancient man (both sexes).

for a while between the ages of 50 and 60. Following a minor decline after the age of 60 the values of the curve rise fast, apart from some fluctuation at the ages 74–75, to reach 1,000 per thousand at the age of 80. However the mortality of the oldest people is rather hypothetical in value after the age of 70–75 and ends at 80, only because there is no possibility to diagnose death at older ages with the methods available to us.

In Fig. 34 we have shown the Vassilievka and the Maghreb-type mortality, in addition to Fofonovo mortality. Based on the Taforalt factual data, the Maghreb-type probabilities of death yield the left-hand side of the U curve, which is missing from the Mesolithic series. Together with the intensely fluctuating probabilities of death of Vassilievka III they outline that zone of ancient mortality within which the archetype of mortality may have varied. True, the differences between the various series are considerable, but the trends are obvious and marked enough to warrant the conclusion that Mesolithic mortality may have been identical with that of the Upper Palaeolithic.

THE FEATURES OF THE ARCHETYPE OF MORTALITY AND PALAEOLITHIC REPRODUCTION

It appears from Fig. 34 and from the entire material surveyed so far that by and large in the initial period of the history of mankind, embracing hundreds of thousands of years, there existed a certain 'archetype' of mortality. This naturally cannot be characterized by a single curve, it is rather a zone, delimited by series of values, within which the mortality of various ancient populations depends on a number of environmental factors. This 'mortality zone' differs from the mortality pattern of modern populations of developed countries considerably although they have a number of general features in common.

Let us first consider the survival zone of the archetype on the basis of the most authentic series. Before scrutinizing these data again, we should like to point out once more that in judging them we must not reckon with the mortality conditions of our days but rather with those particular to the natural and social environment of ancient man. It need not be assumed that human life of the remote past existed in completely austere and adverse circumstances, and that the length of human life was increasingly curtailed by the 'cruel' conditions as we go back in time. Adult men of ancient times had to overcome a number of difficulties, but they were exposed to fewer hazards than those confronting modern man living in advanced socio-economic circumstances. At a primitive stage of social evolution, owing to the everyday struggle for life and to biological selection, only viable, resistant individuals survived, who then were capable of attaining even older ages than is usually assumed.

On the basis of the series studied, we have constructed the zone of the archetype of survivorship in Fig. 35. We first took into account the data of the *Sinanthropus* series as determined by Weidenreich. The data within the class intervals of the distribution by age at death in the *Sinanthropus* series were determined by means of

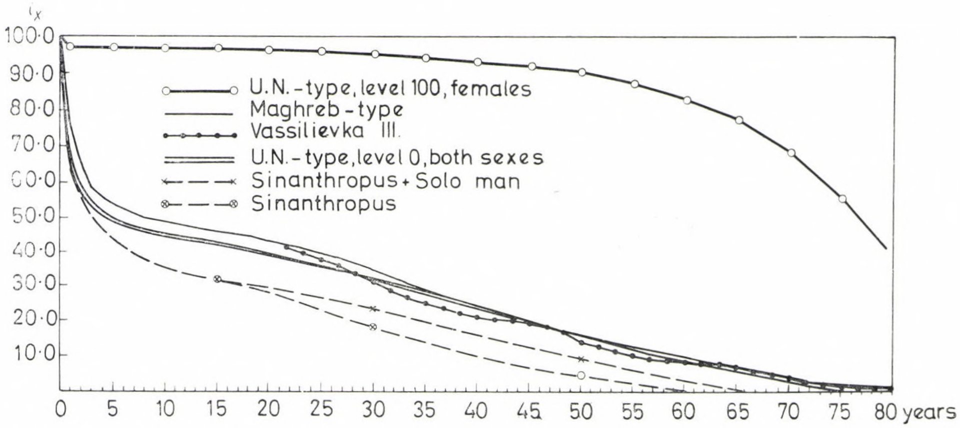


Fig. 35. Survivorship zone of ancient mortality.

graphic interpolation, taking into account the conclusions drawn from other distributions. In respect of adult survivorship we made use of the Solo series as well, drawing up a combined survivorship pattern from the means of the Solo and *Sinanthropus* series without weighting. The resulting survivorship of *Archanthropus* is somewhat more favourable than the one obtained from the *Sinanthropus* series alone.

The curve of the *Sinanthropus* series can be regarded as the lower limit of the zone of survivorship. This is not to say that during the long history of mankind certain populations could not have suffered natural catastrophes or social impacts that would have resulted in a still more rapid extinction. We are of the opinion only that mortality conditions in general could not have been so bad as to produce a curve of substantially lower values than appear in the *Sinanthropus* series.

This hypothesis can be supported by conclusions which may be drawn from the laws of population reproduction. The reproduction of a population, i.e. the process by which the population is renewed is characterized most conveniently in demography by the net reproduction rate, R_0.

$$R_0 = \sum_{x=\omega_1}^{\omega_2} l_x f_x n$$

where f_x = the age-specific fertility,
n = the ratio of females at birth,
ω_1 = the lower limit of reproductive age,
ω_2 = the upper limit of reproductive age.

The net reproduction rate expresses the number of females to be borne by one female generation during their lives. If the value of the rate is lower than 1, the size of the population will decrease during the lifetime of one generation—given unchanged mortality conditions; if the value is 1, the population will stagnate. To double a population in the next generation, the value of the rate must rise to 2. Thus the value of the net reproduction rate is determined by fertility and by the mortality level, if the ratio of females at birth is constant. But human fertility has a physiological limit, which determines the maximum of mortality, too, and the latter cannot exceed—generally and permanently—this limit without endangering the survival of the species.

Let us try to outline the physiological limit of fertility under the specific circumstances of *Archanthropus*. Lacking birth control and social impediments, only natural fertility as determined by the natural environment was effective. Considering, however, the long suckling time, which reduces the probability of conception, a very high level of fertility is probable. We estimate, using a rather rough approximation, the annual number of births per 1,000 women at the age of 15–24 to be 500 (which means childbirth every other year), and to be 400 at the age of 25–44. (At this point we took into consideration the highest fertility observed, published by Henry in a population group, the Hutterites. The age-specific fertility of 15–19-year-old females amounts to 0·300, that of the 20–24-year-old to 0·550, of the 25–29-year-old to 0·502, of the 30–34-year-old to 0·447, of the 35–39-year-old to 0·406, of the 40–44-year-old to 0·222 and finally that of the 45–49-year-old females to 0·061. The fertility of 15–19-year-old persons is a hypothetic value.)

With due regard to the lower fertility of women under 15 and over 44, to twin births, physiological and occasional sterility, and spontaneous abortions no survival probabilities higher than 1·1–1·2 can be postulated for the *Sinanthropus* even when calculating with the above extreme fertility rates. This means that a *Sinanthropus*-type mortality, combined with such a high fertility, may have in fact existed, resulting in a low rate of survival. Considerably higher mortality or lower probabilities of survival would have led to the extinction of mankind.

Next to the *Sinanthropus* and Solo series, we have plotted in Fig. 35 the Maghreb-type survivorship, representing the upper limit of the zone. It appears that the survivorship of the Mesolithic Vassilievka III series is close to the Maghreb type, although somewhat lower, i.e. it belongs to the zone delimited by the *Sinanthropus* and Maghreb types.

Figure 35 contains both the historic data and the data of two U.N. models computed on the basis of current mortality conditions. The models allow very interesting comparisons. The survivorship functions pertinent to the 'level 100' mortality, which is a modern, advanced type, shows how far apart ancient and modern mortality are. On the other hand, the survivorship of 'level 0' mortality, corresponding to the highest contemporary mortality rates, is well comparable to Palaeolithic survivorship, in spite of the immense difference in time. The Maghreb-type survivorship and that of Vassilievka III coincide almost completely with 'level 0' beginning from the age of 30–35, and, apart from some minor differences, run practically parallel between ages 0 and 25. Although the values of the *Sinanthropus*-type survivorship are much lower than those of the U.N. 'level 0' model tables, there is certain parallelism here, too (Table 49).

TABLE 49

Comparative data of ancient survivorship (l_x)

Age (x)	*Sinanthropus* (both sexes)	*Sinanthropus* and Solo man (both sexes)	Maghreb type (both sexes)	U.N. level 0 model (males)	U.N. level 100 model (females)
0	100	.	100	100	100
5	44	.	54	49	97
10	35	.	49	45	97
15	32	.	46	42	96
20	28	29	43	39	96
30	18	24	34	32	95
40	10	16	24	24	93
50	5	9	15	15	90
60	.	.	9	8	84
70	.	.	3	3	69
e_0^0	13	(15)	21	20	70

In Chapter I, where we have discussed model life table construction, we have pointed out that these models are built on the general characteristics of recent human mortality and, although not suitable for replacing historical data, are an excellent basis for comparisons, and for reconstructing missing pieces of information. Thus the conspicuous parallelism between theoretical values and historical observations is not surprising. The latter have in fact shown the correctness of the starting hypotheses of the U.N. demographers, who constructed the models, and again the models support our view that palaeodemographic studies, if meeting the requirements outlined in Chapter II, may lead to acceptable results.

Yet the conformity of facts and models suggests further-reaching conclusions. Although the difference between Palaeolithic and modern, advanced mortality conditions is fairly conspicuous in Fig. 35, it appears mainly in the level of mortality rather than in changes of biological factors. The relationship of ancient mortality with the 'level 0' model—which, after all, has been constructed by analysing the mortality of modern man—suggests that the biological rules of mortality of *Archanthropus* and *Palaeanthropus* were not basically different from those of modern man. Putting it in another way this would mean that the biological possibilities, realized in our days, were 'contained' in ancient man as well. The 'demographic revolution' of recent times has brought profound changes in the level of mortality and its age structure. As a result, it has changed characteristic life span values as well. Historically, this change has taken place rapidly enough even in populations of advanced socio-economic structure, and today it is going on before our very eyes in developing populations at a speed unthinkable before. All this shows that ancient man must also have been ready biologically to take this step. Today, however, it takes only a few decades for developing populations to go the long way that took hundreds of thousands of years for mankind to cover. *Archanthropus* is separated from *Homo sapiens* by a long time and considerable morphological differences. Yet it would seem, in respect of mortality and life span at least, that the difference between them may have been smaller than between generations of yesterday and today.

This train of thought would lead us a long way from drawing up the main features of ancient mortality, illustrated by the pattern of survivorship from one side only. In Table 49 we have given the values of life expectancy at birth, but this conveys only little information on prospective chances of life expectancy at higher ages. An attempt is made to answer this question in Table 50, where the data of the *Sinanthropus* and Maghreb types are compared once more, using values computed from the various series. The data which cannot be used at all (e.g. missing or badly incomplete data on children and old age) have been omitted from the outset. But even so, values appear that cannot be regarded as typical (Neanderthal, Fofonovo). In addition to the life expectancies from the age of 20, computed from the main values of the *Sinanthropus* and Solo series, we have computed the expectation of life at birth (shown in brackets) on the basis of the *Sinanthropus*-type child mortality. This value of 15 years is probably more characteristic of the expectation

TABLE 50

Ancient expectation of life (e_x^0)
(both sexes)*

Age (x)	*Sinanthropus* type	*Sinanthropus* and Solo man	Neanderthal	Afalou	Taforalt	Vassilievka	Fofonovo	Maghreb type
0	13·0	(14·6)	.	.	20·8	.	.	21·1
10	23·3	.	21	.	29·9	30·8	.	31·2
20	17·9	22·6	.	21·9	23·9	22·8	29·8	24·5
30	14·7	17·1	.	16·7	20·4	20·0	24·1	19·8
40	12·5	12·2	.	11·3	18·2	17·3	14·1	16·0
50	11·0	8·1	.	6·4	12·0	12·7	9·7	12·2
60	.	3·7	.	.	6·8	9·8	7·7	7·7
70	.	.	.	.	3·1	3·7	4·1	3·5

* The data have been taken from the detailed life tables.

of life at birth of *Archanthropus* than the 13 years computed on the basis of the *Sinanthropus* series alone.

Following infant and early childhood mortality, expectation of life grew considerably—by more than one-third—up to the age of 5–8 years. Then life expectancy starts diminishing, although it is still higher at the beginning of adult age than at birth; it becomes equivalent with the value at birth only at about the age of 30 (see also Fig. 32).

The Maghreb type is the best Palaeolithic mortality we know of, in respect of not only survival, but also of life expectancy—not counting the Fofonovo data—and seems to represent Mesolithic conditions (see Vassilievka) as well. But, as was the case with the *Sinanthropus* type, where the question arose whether there could have been such a high mortality of mankind at all, we may also ask whether the mortality of ancient man could have been relatively low. Namely a possible high rate of reproduction is contradicted by the fact that the multiplication of the human species was extremely low during the entire Palaeolithic, when the growth of the earth's population was near to stagnation.

If we apply the fertility conditions controlling the *Sinanthropus* type, we obtain a net reproduction rate of 1·9–2·1 for the Maghreb-type mortality. But reproduction at such a high rate is practically impossible to conceive for that period, be it only locally. Thus the question can be raised whether the Maghreb-type mortality is not unrealistically low. To decide this, we must first make a thorough study of the problem of fertility.

For the survival of a population with a high mortality rate, a high rate of fertility is required. Mankind could not have survived even the age of *Archanthropus* if there had not been a high rate of fertility. The question is, however, if fertility could have been so high at all in ancient times as we have assumed it to be by a very rough approximation. Namely our assumed fertility would mean childbirth every two, or two and a half years, i.e. an average of 13 childbirths per individual woman during the entire reproductive period. Thirteen children are reasonable in individual cases, but taken as an average for an entire female population it would be so incredibly high that there has been no precedent for it, not even in populations with no birth control.

Lorimer (1954), who made thorough studies of fertility levels observed in populations with no birth control, found values as low as 5–7 childbirths in various populations. For instance, the total of childbirths during the entire reproductive period (total maternity ratio, i.e. some of age-specific fertility) was 6·57 in Bulgaria between 1901 and 1905 (Kuczynski, 1928), 5·34 in Japan in 1925 (Taeuber and Notestein, 1947, adjusted data), 6·40 in China in the Yangtze region between 1931 and 1935 (Chiao, Thompson and Chen, 1938), 6·94 among the Chinese in Malaysia from 1946 to 1948 (Smith, 1952), 6·45 in Brasil in 1940 (Mortara, 1948), 5·25 in Mexico between 1929 and 1931 (Mortara, 1948), 5·48 to 6·78 in various regions of India (Chandrasekaran), etc. These values have been computed on the basis of age-specific fertility rates, but agree in that they are all considerably lower than the rates we used as a first approximation.

The natural, or physiological, fertility of a fecund woman is essentially determined by a temporary sterility following conception, pregnancy and delivery, and by the probability of conception outside this period. While the length of the former can be taken as roughly constant, the second factor, and consequently the natural fertility of women, is largely conditional on age. By means of functions that take into account these factors, natural fertility can be determined on the basis of vital statistics relating to populations with no birth control. Applying the pertinent data of six European countries Henry obtained the following relationship between natural fertility and age:

Age groups of women (years):	20–24	25–29	30–34	35–39
Natural fertility (per thousand):	494	483	443	389

He determined the relationship of sterility and age at the same time:

Age of women (years):	20	25	30	35	40
Ratio of sterile women (per cent):	3	6	10	16	31

No doubt, these conclusions are not constant regionally and historically, and they certainly cannot be applied to the whole of the female population. More recent representative vital statistics recording the frequency of births in populations of a high, practically unrestricted fertility are shown in Table 51, based on a U.N. Demographic Yearbook. For the sake of comparison we have included in the Table the legitimate fertility rates of some developed countries (European countries, U.S.A. and New Zealand). Although the marital fertility rate is relatively high in these countries, the effect of birth control becomes more and more sizable from the age of 25.

TABLE 51

Age-specific live birth rates in countries with registered highest fertility, around 1960

Country (region, date)	Age of mother (years)							
	10–49 Total	10–19	20–24	25–29	30–34	35–39	40–44	45–49
	Age-specific fertility*							
Africa								
Dahomey (1961)[1, 2, 3]	226·9	196·9	335·4	305·5	253·5	166·4	85·9	29·4
Guinea (1955)[2]	201·3	139·1	334·4	310·6	245·8	171·0	68·7	30·9
South Africa (coloured, 1960)[4]	162·0	53·9	324·5	311·1	241·5	181·3	84·8	23·7
America								
Chile (1960)	118·5	35·4	213·9	244·2	208·3	143·3	63·0	14·1
El Salvador (1961)	170·3	66·1	327·2	320·4	268·0	191·2	70·7	20·8
Guadeloupe (1961)	124·8	26·4	209·8	265·2	243·3	192·8	90·4	9·8
Venezuela (1961)[1]	163·6	60·5	335·9	321·6	242·4	189·1	65·2	17·4
Europe								
Albania (1955)	163·1	30·0	269·2	336·9	287·4	245·1	122·1	71·8
Ireland (1961)	81·0	4·2	108·2	216·9	209·5	152·2	57·7	4·2
Oceania								
American Samoa (1960)	150·2	17·8	282·9	347·8	317·7	201·2	135·5	35·8
	Age-specific marital fertility**							
Africa								
Dahomey (1961)[1, 2, 3, 5]	244·7	287·9	342·4	300·9	254·5	168·1	94·4	31·9
Guinea (1955)[2]	252·0	278·0	345·7	323·1	263·9	188·1	84·0	38·9
South Africa (coloured, 1960)[4]	265·8	529·7	482·4	370·2	275·7	203·6	98·2	28·0
America								
Chile (1960)	236·4	623·9	444·5	333·9	251·6	169·1	74·5	17·5
El Salvador (1962)	264·1	446·7	424·1	353·8	284·8	213·4	85·7	25·8
Guadeloupe (1961)	244·7	400·0	455·7	382·6	293·7	225·2	106·7	13·8
Venezuela (1961)[1]	272·4	472·5	463·4	371·0	254·0	193·7	71·0	15·2
Europe								
Ireland (1961)	195·5	612·6	478·0	392·3	298·6	202·4	77·1	5·8
Oceania								
American Samoa (1960)	300·4	325·8	528·6	388·2	350·0	215·8	150·6	43·5

* Rates are the number of live births to mothers of specified ages per 1,000 female population of the same ages.

** Rates are the number of legitimate live births to mothers of specified ages per 1,000 married female population of the same ages.

(1) Estimated data or data from civil registers which are incomplete or of unknown reliability.

(2) Rates are based on a sample survey.

(3) Rates of 10–49, 10–19 and 45–49 are computed on somewhat different age groups (i.e. 15–49, 15–54, 15–19, 45–54, etc.).

(4) Provisional data.

(5) Data are for women who were reported as married including those in *de facto* (consensual) unions.

General fertility is restricted to a certain extent even in primitive populations because of social factors connected with marriage, which probably played a minor role in ancient times. Natural fertility seems to be manifest more directly in legitimate fertility, but in connection with these data it should be kept in mind that married women represent a selected group of population in whose selection biological aspects play a role beyond purely socio-economic considerations. As a consequence, the number of pathologically or physiologically sterile women is much higher among unmarried than among married women. This explains the circumstance that when Lorimer constructed his hypothetical fertility rates on this basis he failed to take into account occasional extreme values of legitimate fertility.

TABLE 52

Hypothetical high fertilities (rounded data)

Age of mother	Unrealistic maximal hypothesis for ancient man	Lorimer's hyrothetical fertility	High legitimate fertility	Highest general fertility	Probable fertility of ancient man
15–19	500	180	400	170	200
20–24	500	340	450	350	350
25–29	400	340	400	350	350
30–34	400	290	300	300	300
35–39	400	210	250	250	250
40–44	400	100	130	130	150
Average no. of all births	13·00	7·30*	9·65	7·75	8·00

* Taking into account the fertility of women younger than 15 and older than 44, the value is 7·45. Lorimer's hypothetical fertility is the result of a selection of reported high age-specific rates. This value of the 'total maternity ratio' on the basis of his 'hypothetical fecundity model' is somewhat higher: 8·32.

Disregarding certain extreme values, we give an outline of the highest rate of female fertility on a similar basis. In Table 52 the most probable series of data representing the fertility of ancient man is the one which has been selected from the highest general fertility rates. The data in Table 52 do not comprise the entire reproductive period, i.e. births before the age of 15 and after the age of 44. According to Pearl's studies (1939), the average age at menarche in 142 examined series varied from 13·2 years to 17·0 years, and that of the menopause between 44 and 49·4 years (in 20 series). The average length of the menstruation period is 31·2 years, lasting from the age of 15·2 to 46·4. Although the fertile period is not identical with that of menstruation, we can reckon the reproductive period in women as about 31 years. This is longer by one year only than the 30 years reckoned within the table. According to the U.N. Demographic Yearbook, the fertility rate of women under the age of 15 is usually under 1 per thousand in populations of high fertility, and 10–30 per thousand at the age of 45–49. When we constructed the probable fertility data for ancient man (last column in Table 52) we took into account this circumstance for the age groups of 15–19 and 40–44, and it was for this reason that we put the values higher than Lorimer's hypothesis or the highest general fertility observed. In determining the values of the last three columns, we relied on the fertility type assumed by Lorimer.

The assumed different fertility levels yield different reproduction rates for the *Sinanthropus* and Maghreb-type mortalities (Table 53).

TABLE 53

Net reproduction rates on the basis of *Sinanthropus*- and Maghreb-type mortality and estimated fertility levels

Fertility type	Net reproduction rate (R_0)	
	Sinanthropus	Magherb
1. Unrealistic maximal hypothesis	1·23	2·25
2. Lorimer's hypothesis	0·71	1·23
3. High legitimate fertility	0·99	1·65
4. Highest general fertility	0·73	1·29
5. Probable fertility of ancient man	0·76	1·33

Of the net reproduction rates listed in Table 53, the last fertility hypothesis (no. 5) seems to be the most probable. The high reproduction rates (nos 1 and 3) are altogether improbable. The net reproduction rates based on hypotheses nos 2 and 4 are far more realistic, though they are of a rather limited value (for instance, mankind would have soon died out with *Sinanthropus*-type mortality, while it would have overmultiplied with the Maghreb type).

Doubtless, certain ancient populations may have had mortality of this or that type, and the possibility cannot be excluded that smaller or more isolated populations living under adverse conditions died out, and that other populations showed sudden, rapid multiplication and dispersion in proportion to ancient conditions. Yet it is obvious that the mortality of mankind as a whole was within these extremes in the Palaeolithic, as shown by the entire course of the population history of mankind. We should like to point out here that if (*i*) the Solo adult mortality is taken into account with the *Sinanthropus* type or (*ii*) child mortality, somewhat higher than that of Taforalt and corresponding better to adult mortality, is coordinated to the Maghreb type, the reproduction rates get considerably closer to 1. Some information on the evolutionary progress of mankind is supplied by Fig. 36.

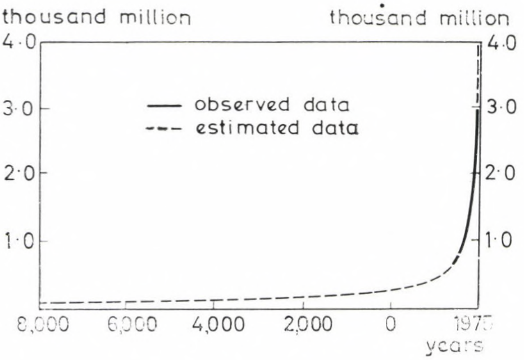


Fig. 36. World population growth up to 1960, and growth forecast till 1975.

World population has grown over three thousand million by now, and will in all probability reach the four thousand million mark by 1975. Historic sources and reliable estimates show that in 1650 only some 550 million people lived on this globe; and that the number was 210–250 million at the beginning of our era. Going back from that time, the curve shows hardly any slope despite the fact that during the period from the Neolithic to the highly developed empires of the antique world development must have been rapid, at least compared with the low rate of growth during the hundreds of thousands of years of the Palaeolithic. To illustrate the almost stagnating population conditions of the Palaeolithic with figures we say with Deevey (1960) that if mankind was one or two hundred thousand in the Lower Palaeolithic—perhaps one million years before—it could not have grown to more than a few millions by the end of the Upper Palaeolithic.

The very low rate of natural increase and the high, probably unrestricted, fertility of ancient times render a high rate of ancient mortality probable. It is obvious, too, that in such circumstances reproduction must have been most extensive. The women of *Archanthropus* and *Palaeanthropus* must have given birth to very many children to secure the survival of the population. Pregnancy, childbirth and infant care engrossed the women, and this explains the place they occupied in the primary division of labour of ancient times.

On the basis of the foregoing we may characterize the archetype of mortality by a range delimited by the probabilities of death in the *Sinanthropus* and Maghreb-type tables, respectively, where the mortalities at various levels show the features of the two investing curves. The zone of the mortality archetype is shown with graphically smoothed data in Fig. 37. Conclusions drawn from the age-specific mortality of ancient man substantiate the hypotheses based mainly on the observation of uncivilized, natural populations.

The mortality curve is far more U shaped in the case of the archetype than in modern populations. Though the peak value of the left side of the U curve is due to high infant mortality in ancient times, too, the shape of the curve, and with it the entire survivorship, is determined by the values of child mortality rather than by infant mortality. A possible explanation of this phenomenon is a long period of lactation, and the natural protection, and resistance of the newborn going along with it. Among the causes of infant death congenital malformations, violence, and certain neonatal diseases may have played the principal role.

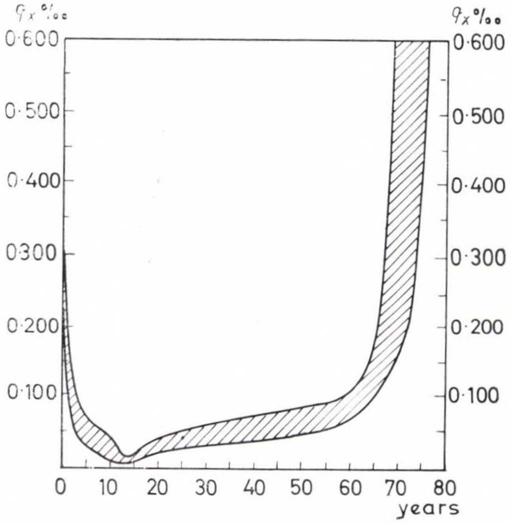


Fig. 37. Zone of the archetype of mortality (both sexes).

Following infant mortality, the probability of death decreases until the age of 10–15 years. But the descent of the curve is not so abrupt as today, mainly because of the high mortality rate of children aged 1–6 and belonging to the infant I age group. Following the minimum of mortality the curve ascends first rapidly, then, without falling back, somewhat slower up to the age of 50–60. Beginning from this point, the chances of survival deteriorate rapidly.

Following the end of the lactation period, when also intense care had ceased, the lot of the fairly independent children was determined by selecting environmental factors, under the effect of which their numbers were decimated every year in the beginning, and every two or three years later on. Given this high mortality rate of children and of the juvenile and young adult ages, it would be obvious by recent experience to consider the impact of communicable diseases. It is highly questionable, however, whether these deaths were caused by the same diseases as are known today.

In this connection fatal diseases, injuries, and poisonings can be divided into two groups: those which are as old as man himself, and others which have emerged in the course of hominidal evolution. Certain bone diseases, such as osteoarthritis, dental diseases, accompanying inflammatory processes and tumours have already been found in early vertebrate fossils. Hare (1954) has shown that microorganisms causing certain less dangerous communicable diseases, such as the staphylococci of the skin, streptococci of the throat or certain coliform organisms in the intestine that produce inflammation of the tissues when becoming numerous, are older than man.

But we know from laboratory examinations of strains of bacteria that their virulent nature had undergone considerable changes in the past. And it is improbable anyway that the bulk of pathogenic organisms should have preceded man. Hare believes that the virulence of these bacteria and the possibility of their settling in man depend on the size and concentration of the human population. Consequently, masses and intensivity of virulence of various genera and species that would suffice to produce diseases are conditional on population masses larger than could have lived in the ancient era. Judging from the burial places, the size of Palaeolithic populations was probably not larger than one joint family, and with their gathering, fishing-hunting way of life even small communities had to use such large areas for maintaining life that they must have been rather isolated, and communication between various populations was necessarily restricted.

It is hardly conceivable under such conditions that infections caused by bacteria should have spread and persisted. Even if there had been virulent strains of bacteria, and these had invaded some isolates occasionally and locally, the bacteria themselves must have been annihilated in given circumstances. This hypothesis is confirmed by recent observations of uncivilized populations. For epidemics introduced to populations living in natural circumstances and having no immunity, having taken heavy toll, the bacteria became completely ‘extinct’, there being no basis for their survival. The cultivation and spread of communicable diseases require larger populations with immunizing power, and more advanced societies where populations are more closely connected, making communication possible.

It follows from the foregoing that among the causes of death in the mortality pattern of *Archanthropus* and *Palaeanthropus*, communicable diseases, although these assumed a considerable role later on, were of less importance. The decisive importance lay in injuries due to accidents and violence and in diseases resulting from the factors of the natural environment or their changes. Atrophies or accumulating pathological conditions determined by regression with age also counted. The causes mentioned in the first place endangered mainly the lives of children, as was also pointed out by Wood Jones (1908) and Brothwell (1961). Consequently the child mortality rate was so high that only few of them could reach adolescent age. But those who attained it had probably sufficient resistance to environmental influences, and acquired all the knowledge that was needed to maintain life up to old age. Yet adult life was not devoid of the possibilities of injuries and disasters, and there were regressive and aggregative phenomena connected with ageing; all this prevented mortality rates from staying low, and increased the probability of death with every year lived, as appears from Fig. 37.

Among disasters we make special mention of the reduction or exhaustion of sources of nutrition, the resulting famines, the possibility of deficiency and nutritional diseases in general. Such circumstances must have had tragic consequences for smaller isolates where no reserves were available if they were unable to create better conditions in due time. In connection with the mortality rates of ancient man cannibalism is often mentioned along with the causative factors determined by the way of living. Indeed, the custom of anthropophagy can be shown to have existed in ancient communities, or rendered highly probable at least. In our opinion, however, its importance lies not in appearing as a factor of mortality or nutrition; it was rather a religious, ritual factor, a means for acquiring the defeated enemy's mental properties and abilities.

*

In 1965 László Vértes archaeologist detected a settlement of great interest of *Archanthropus [Homo erectus (seu sapiens) palaeohungaricus]* (in the site Vértesszőlős from the pebble/chopper culture, dated to the interstadial of the Mindel. Four fragments belonging to the deciduous denture and the occipital bone of a man aged not more than thirty were found here (Thoma. 1966, 1967). The remains of a child and that of the male—died at the beginning of the adult age—prove the features of the archetype of mortality to be valid also in the case of the Hungarian figures, because the evaluation of the finds had not been finished before we submitted our manuscript for publication.

CHAPTER V

DIFFERENTIATION OF MORTALITY IN PREHISTORIC POPULATIONS

PRIMARY DIFFERENTIATION OF MORTALITY. SEX DIFFERENCES

When outlining the archetype of mortality we noted characteristic age-specific differences; moreover traces of the differences specific to present-day mortality could be detected. However, we have not so far studied mortality trends in relation to man's other fundamental biological feature, which is at the same time an important social determinant, i.e. sex.

Today fairly distinct sex differences are manifest in mortality which, according to generally accepted views, are ascribed to physiological differences. Here we should like to refer, first of all, to the higher neo-natal mortality rate of males, as a consequence of which the surplus of male births soon falls away in the course of life. Considering the lower mortality rate of females at advanced ages, a considerable surplus of females results in old age in most of the modern populations.

In Table 54 the mortality differences of the sexes are illustrated by age-specific mortality rates in Hungary, the neighbouring countries, and some other European

TABLE 54

Sex-specific mortality and expectation of life at birth in the years around 1960

Country	Mortality rate (per thousand)			Expectation of life at birth (years)		
	Year	Males	Females	Year	Males	Females
Europe						
Austria	1961	13·1	11·1	1959/61	65·6	72·0
Bulgaria	1960	8·5	7·7	1960/62	67·8	71·4
Czechoslovakia	1960	9·9	8·5	1958	67·2	72·3
England and Wales	1960	12·2	10·9	1960	68·3	74·1
France	1960	12·0	10·9	1960	67·2	73·8
Hungary	1960	10·7	99·6	1959/60	65·2	69·6
Italy	1960	10·2	8·7	1960/62	67·2	72·3
Jugoslavia	1959	10·0	9·6	1960/61	62·2	65·3
Poland	1957	10·3	8·8	1958	62·8	68·9
Rumania	1956	10·4	9·6	1956	61·5	65·0
Soviet Union	.	.	.	1958/59	64·4	71·7
Sweden	1960	10·6	9·5	1959	71·7	75·2
Other						
Argentina	1960	10·0	7·3	1959/61	63·1	68·9
Australia	1960	9·6	7·6	1953/55	67·1	72·8
Canada	1960	9·1	6·9	1960/62	68·4	74·2
Japan	1960	8·2	6·9	1959/60	65·3	70·2
U.S.A.	1960	11.0	8.1	1963	66·6	73·4

and overseas countries. Considering, however, that the number of deaths per 1,000 males and females (the crude mortality rate) depends largely on the varying age distribution of the sexes, we have also shown the expectation of life at birth for both sexes. Life table factors are not subject to the disturbing effects of age structure, and therefore clearly reflect the differences in the mortality of the sexes.

It is not by chance that the mortality rates of females are in general lower than those of males. This phenomenon is not the result of some biased selection, but the practically unanimous evidence in various vital statistics. Constitutional differences between man and woman, promoting the lower rates of female mortality, are emphasized also by somewhat longer expectations of life at birth of females. Expectation of life at older ages also reflect the 'superiority' of females.

Unless we know the demographic conditions of populations of developing countries, or study recent materials of historical demography, the results obtained from the examination of the *Archanthropus* or *Palaeanthropus* series might take us by surprise. True, we are not in the position to determine accurately, on the basis of historical series, the differences in mortality and expectation of life at birth of males and females, as there is no adequate method available for sex determination from skeletal remains of persons dying before adolescence. But on the basis of finds in which the sex can be identified we can establish the expectation of life by sex at the beginning of adult age, from which we must infer higher mortality rates for females.

The series studied in the preceding chapter are not of equal value when considering expectation, nor are the sex determinations equally dependable. The reality of sex determination varies even within single series. The number of males and females whose age can be determined is so low in these series that, except for Vassilievka III, we have not computed sex-specific life tables. But even so, if we determine the expectations of life at the age of 20 according to sex, the series give a clear demonstration of the sex differentiation of ancient mortality.

Sex differences established by approximation in the series of the Palaeolithic and the Mesolithic are shown in Table 55. Needless to say, the expectations of life in the various series cannot be compared with one another, but the rates in the last column shown a surprisingly harmonious evidence to the longer life span of males.

In seven out of eight series shown in Table 55, life expectancy at the age of 20 is higher for males; the values are identical in one series only. The difference between the sexes ranges from 7 to 40 per cent. Considering various series as a whole (116 males and 88 females), we may conclude that expectation of life for males was longer by about 20 per cent. The longer life of males is rendered probable not only by the summarized values of the individual series, which in themselves are not sufficiently authentic and cannot be generalized, but also by the circumstance that the sex differences are uniformly manifested in all the series.

Shorter life spans of females add up to their higher mortality rate which appears in the Neolithic and later series as well. Concerning sex differences we have studied seven relatively complete series from the period between the Neolithic and the

TABLE 55
Sex differences in ancient expectations of life

Series	Estimated expectation of life at the age of 20 (years)		Expected age at death of males as a percentage of females
	Males	Females	
Solo man	23	23	100
Neanderthal (Vallois, 1937)	15	5	140
Upper Palaeolithic (Vallois, 1937)	15·5	9·8	119
Afalou	26·8	16·8	127
Taforalt	23·7	21·0	107
Vassilievka III	23·96	20·33	109
Mesolithic (Vallois, 1937)	8·6	6·0	110
Fofonovo	35·85	22·74	131
Together	19·1	12·7	120

Early Iron Age. The results will be discussed in this Chapter later on, but it deserves mention here that somewhat longer life spans for females were found in only one of the seven series, while the sex differences in mortality of the other six showed the marked advantage of males in this respect. The same results were obtained by other investigators as well, e.g. by Franz and Winkler (1936) in connection with the Bronze Age of Lower Austria, by Angel (1953) in connection with the Neolithic of Khirokitia, and also by Senyürek (1955), Nougier (1954), or, earlier, by Pearson (1901–02) and MacDonnel (1913). Thus the women lived under poorer mortality conditions not only in the Palaeolithic or Mesolithic, but also in the Neolithic and subsequent prehistoric ages.

The longer male expectation of life in various prehistoric periods appears as a general feature. The differences are so characteristic that this must doubtless be interpreted as a rule of mortality manifest under given socio-economic conditions.

To challenge the validity of a lower male mortality would be warranted only if the various investigators had underestimated the age at death of females by about six years. Following Vallois, who thinks such underestimation possible, several authors have regarded this phenomenon with scepticism. So did Henry (1954), who believes that the proofs adduced by Nougier (1954) are not convincing enough. Nevertheless, Henry himself finds the data on excess female mortality reported by Franz and Winkler or Pearson worth of attention. More recently, Ferembach (1962) expressed careful scepticism about her own data on Taforalt.

Regarding the underestimation of the age at death of females, we do not share the aforesaid scruples. In the course of our analyses, outlined in Chapter III, we have found no differences between the cranial suture closure of males and females, nor were any substantial differences revealed by other investigators, as far as our information goes. It is not very probable either that such differences should have existed in the course of history, or that differences existing several thousand years before should have been equalized in such a short time. There is still less reason to suppose that the further three age indicators of the complex age determination method we have employed should have distorted in the direction of underestimation. And in the series determined by us we have similarly obtained characteristically higher mean ages at death for males, as had the authors who based their age determinations mainly on suture closure. In any case the differences between the ages of males and females are too great to be explained by the aforementioned assumption.

On the other hand, proof is available to corroborate the sex difference in prehistoric mortality to the advantage of males with indisputable validity. This proof goes beyond the uniform evidence of finds available from a variety of sites and periods, and beyond the significance of demonstrable dissimilarities. Proof is provided by populations of our day—mainly by those in backward socio-economic circumstances—where shorter expectations of life for females can be shown to exist. An account of such populations is given in Table 56 where we have shown life expectancy at the age of 20, in addition to age 0. It ought to be added to these data that expectation at birth is equal in the Bolivian life table, but one year later expectation for males is 56·1, and for females 57·9 years, in contrast to the female superiority at 20. Again the males have better chances at the age of 40 (33·4 as against 32·9 years).

TABLE 56

Modern populations with higher male life expectancy

Country (population); period covered by life table	Expectation of life (years)			
	at birth		at 20	
	Males	Females	Males	Females
Bolivia, 1949/51	49·7	49·7	47·0	47·2
Cambodia, 1958/59	44·2	43·3	39·4	38·4
Ceylon, 1954	60·3	59·4	51·0	50·3
Guatemala, 1949/51	43·8	43·5	41·1	40·3
Guinea (rural population), 1954/55	30·5	26·0	31·3*	28·5*
India, 1941/50	32·5	31·7	33·0	32·9
India, 1951/60	41·9	40·6	37·0	35·6
Pakistan, 1962	53·7	48·8	47·8	42·9
South Africa (Asiatic population), 1950/52	55·8	54·8	43·2	42·4
Upper Volta, 1960/61	32·1	31·1	34·5	33·9

* Life expectancy at 25 years.

Considering modern populations, where life tables show longer expectations for males, we may draw the conclusion that the sex having a better chance of living at the age of 20, may have expected a longer life at birth in prehistoric times, too. So it is likely that not only adult male mortality but male mortality in general was lower than female mortality.

Present-day equivalents of this generally higher female mortality exist not only in countries shown in Table 56 (e.g. Ceylon or Cambodia), but also in others including also a European country. Although it is probable that the higher neo-natal mortality of males is a biological phenomenon, and higher male neo-natal mortality must therefore be assumed to have prevailed in the past, too, we cannot exclude the possibility that the female mortality rate was higher in prehistoric ages. Present-day data on excess female mortality are shown in Table 57.

TABLE 57

Modern populations with higher female mortality

Country, territory	Year	No. of deaths per 1,000		Difference (per thousand)
		Males	Females	
Albania	1955	14·6	15·3	0·7
Barbados	1960	8·3	9·2	0·9
Cambodia	1959	19·6	20·0	0·4
Ceylon	1955	10·6	11·1	0·5
Cook Islands	1957	15·4	17·8	2·4
Greenland	1955	13·2	15·1	1·9
Jordan	1961	7·0	7·5	0·5

The crude rates shown in Table 57 may be distorted by the difference in age structure of the sexes. But the expectancy factors of life tables, which are not affected by the age structure, show that the differences are real.

Summing up the results of our studies we emphasize that we do not wish to challenge the biological potentiality of the female sex that is now manifest in a longer life span. Indeed, certain series warrant the conclusion (indicated by Franz and Winkler) that female mortality at a greater age may have been somewhat higher in ancient times, too. Owing to the small number of cases, this might be purely accidental, of course, or else it may be connected with the more intense selection of women, or with the status of older women held in the system of matriarchy. In the final analysis the actual mortality depending on physiological sex features was determined by the historical division of labour between the sexes, and by the status in society of men and women. In view of the changes in the status of women, there is no contradiction between historical evidence and modern developing populations on the one hand, and present-day advanced populations on the other. In the course of history it was not the biological differences between the sexes that underwent modification, but rather the respective status of the sexes, and mortality conditions changed accordingly. In countries where adult women are practically engrossed with pregnancy, childbirth, suckling, and in addition have to do all the work that falls on them by ancestral division of labour, often more exacting and wearing than the men's work, female mortality continues to be higher even today.

For many hundred thousand, maybe half a million, years after its evolution into man, the mortality level of the tool-using, tool-making being that also availed itself of the primordial source of energy, of fire, may have fluctuated within the zone we have outlined in the previous chapter. This was a level where the survival of mankind was still warranted, there was even very slow growth needed for its dispersion that actually took place. But the rate of natural increase of ancient man must have been extremely slow. Although gathering, fishing-hunting men lived all over the African and Eurasian continents, the size of the individual communities, the density of population did not increase substantially.

This demographic situation began to change only some 20–30,000 years ago, after the last glacial period, when the immediate ancestors of modern man got into more favourable circumstances. At similarly high fertility, better conditions have probably led to reduction of mortality rates, which resulted in a somewhat higher rate of population growth. Nevertheless, the density of population must have been very low prior to the era of the tillage of land and animal husbandry. Estimates show that in an area of 100 square kilometres an average of at most 8–16 people were able to subsist on gathering and hunting alone.

In 1788, before European settlement, 250–300,000 natives inhabited Australia's 7·7 million square kilometres, only 3–4 persons for every 100 square kilometres. In certain provinces of Canada, where the climate is severe, density is still very low. In 1956, 12,000 people lived in the 3·4 million square kilometres of the Yukon, and 19,000 in the half million plus square kilometres of the North-West territories, an average of 0·4 to 4 inhabitants for every 100 square kilometres.

It is conceivable that the predominance of the proto-mortality pattern began to wear out at the Upper Palaeolithic or the Mesolithic. The Maghreb-type, or the comparable Taforalt, Afalou or Vassilievka patterns, used to define both the lowest level of proto-mortality and the highest level of the survivorship pattern, were therefore the first signs of something new in the progress of human mortality.

There is no doubt that the new type of mortality began to take shape under the economic revolution of neolithization in the Mesolithic. It was lower than in the Palaeolithic, i.e. corresponded to the lower zone of the archetype, and rendered a somewhat higher rate of growth possible.

First let us have a look at the Khirokitia series from the Neolithic, one of the largest from that age except for the pre-dynastic Egyptian Badar series. The cemetery in Khirokitia was opened up between 1936 and 1946. It is an adequate collection of the population of one of the first village settlements in Cyprus. Dikaios, who conducted the excavations with great care, secured the skeletal remains of 123 individuals from the cemetery of a population that had lived there 5–6,000 years ago. The series has been studied anthropologically and demographically by Angel (1953), who published the results of his analyses in Appendix II to his monograph *Khirokitia.*

According to Angel's determinations, the Khirokitia series consists of 34 infants, 11 children, 39 men, 37 women, and two adults of indefinable sex. On this basis, expectation of life at birth was determined by direct computation as 22·1 years, the average age at death of adult males as 35·2, of females as 33·6 years. Angel's life table functions are shown in Table 58.

TABLE 58

Life table of the Khirokitia population according to Angel (both sexes)*

Age (x)	Distribution of deaths		Survivors (l_x)	Life expectancy (e_x^0)
	No. (D_x)	Per cent (d_x)		
0	34	28·3	100·0	22·1
1–4	7	5·8	71·7	29·7
5–9	3	2·5	65·9	28·1
10–14	1	0·8	63·4	24·1
15–19	1	0·8	62·6	19·4
20–24	0	0·0	61·8	14·7
25–29	17	14·2	61·8	9·7
30–34	28	23·3	47·6	6·8
35–39	15	12·5	24·3	5·9
40–44	10	8·4	11·8	4·6
45–49	2	1·7	3·4	5·0
50–54	2	1·7	1·7	2·5
Total	120	100·0	—	—

* Life table functions (D_x) and (e_x^0) have been taken from Angel's report, while (d_x) and (l_x) were compiled for comparison with other series.

Regarding this table Angel noted that it has not been computed with present-day methods. Hence a relatively large number of dead appear in the age groups that had also been large in the living population. This view is now generally held in palaeodemographic literature, probably because of a correct conclusion by Franz and Winkler. These authors wrote that the age distribution of deaths is determined by two factors: the age structure of the living and age-specific mortality. On the other hand, Nougier (1954) gives priority to the age distribution of the population. According to him, the occurrence frequency of skeletal finds of individuals who died at various ages depends not only on the mortality rate at various ages, but also on the preservation chances of skeletons during thousands of years.

It must be clearly understood, however, that birth rates are unchanged in populations not practising birth control, and that the age structure of such populations is not shaped by trends in the birth rate but by age-specific mortality. In this case the number of deaths does not depend on the population structure, it is the population structure itself that is determined by the number of deaths. More precisely age-specific mortality determines not only the number of deaths at various ages but the age structure of the population as well. This is known as a 'stationary' age structure, or if the crude death rate is lower than the given birth rate we have to deal with a 'stable' age structure of an increasing population. Considering the very slow rate of population growth during those periods we may use the stationary model to simplify calculations. Where there is a growth trend we shall, of course, obtain somewhat higher mortalities and shorter expectancies.

It ought to be noted that several authors emphasize the isolated character of ancient populations. If, therefore, the analysed series come from the cemeteries of isolates, where it may be assumed that members of the population are not buried elsewhere, and that no members of other populations have been included in the life tables of various generations, we can actually compute average values for the entire burial period. Tables computed in this manner are highly informative, in certain respects better than current tables, and are, in theory, suitable for comparisons.

Concerning the evaluation of the data of Khirokitia, Angel notes that many of the children's skeletons may have disintegrated in the soil, or been destroyed in some other way, which probably compensates the influence mentioned above. The same fate may have happened to the skeletal remains of individuals who died at an older age. The average age determined from the skulls whose measurements can be taken is lower than the age computed from non-restorable ones. On this basis Angel thinks that factor D_x ought to be corrected with the higher ratio of small children, the elderly, and perhaps some middle-aged individuals. He suggests that in this case expectation of life ought to be 17 years at birth, 27 years at the ages of 2 or 3, and 16 years at the age of 20. Expectancies from the age of 20 must then have been somewhat higher throughout than appears in Table 58.

The remarks added to the Khirokitia life table and the logical correction of the crude data give proof of Angel's proficiency in questions of palaeodemography, and of his meticulously thoughtful analysis. It is not impossible, though, that his corrections were affected to a certain extent by his earlier investigations. In connection with the 22 years of expectation at birth he writes that this is almost certainly somewhat too high, and compares these data with those of prehistoric Greece. Yet it is obvious that the trends in the level of mortality depend on a population's natural environment and socio-economic conditions, and not on historic chronology, with which it is only indirectly and loosely connected through evolution. It is readily conceivable that the mortality of a later population living under poorer conditions could have been higher than that of an earlier population in better circumstances. For instance, though Angel makes no reference to this, the distribution of the Troy VI series, which agrees well with the data of the prehistoric Greeks, is not inconsistent with the Khirokitia distribution merely because of the fact that it shows a higher child mortality, 47 per cent, as a later series, while this rate is lower at Khirokitia (37 per cent).

We do not know any details of skeletons which may have been destroyed in the Khirokitia soil, or during excavations. We assume, nevertheless, that this series is a really good sample of individuals who lived there in the Neolithic Age. In this case we cannot consider the 283 per thousand infant mortality as low, we merely find the rate of child mortality too little. The lack of individuals dying at old age is uncommon, and individuals of the older middle adult age are represented rather poorly, but considering the extremely high proportion of the 25–39 age group, especially the 30–34 age group, we think it possible that the missing individuals of middle adult age are hidden among these, and that old adults could also be diagnosed by using more dependable age indicators.

In this connection we should like to refer to an experience of our own. For the sake of control we have made two analyses of a completely excavated cemetery of the 10th–11th centuries, the Kérpuszta series containing about 400 elements. On the first occasion we determined the ages at death with the usual, 'classical' methods. We studied the closure of cranial sutures, the state of epi- and diaphyses, condition of teeth, and some external morphological features, probably in the same way as Angel analysed the Khirokitia series. Following this, we made another analysis of the series, using the complex age-determination method described in Chapter III, and had to modify the age distribution drastically as a result. The sharply protruding mode of ages 30–34 vanished completely in the new age distribution, and was shifted to the middle adult age, where it was less conspicuous; an adequate number of individuals who died at old age was determined at the same time. Considering our second analysis of Kérpuszta it seems probable that excepting the children Khirokitia represents Neolithic mortality fairly well, and that the irregularities of distribution would vanish after a more thorough age determination.

Comparing the age distribution of Khirokitia with another Neolithic material, the 94-member Silesian series analysed by Euler and Werner (1936), we find certain conformities. This is not surprising as the age distribution in the Silesian series is also based on 'classical' methods of age determination. This material is known to us from Grimm's report (1956), in which the data are shown in an illustration. Unfortunately the distribution appearing there does not include the complete series, neither in absolute figures nor in percentages, and cannot be used for analysing mortality. It does appear from the figure, however, that the number of the dead is relatively low at the age of 0–5 (maybe about 10 per cent); then it decreases gradually to reach the minimum at the ages of 16–20; following an increase the maximum is reached at the turn on young adult–middle adult ages (36–40 years). Thus the essential features of the Silesian series conform to the Khirokitia distribution, but the position of the mode of the normal age at death indicates that in the Neolithic this characteristic value is already shifting from the young adult to the middle adult age, or at least to the end of young adult age.

No life table can be computed from the Silesian data, not even expectation of life can be determined. But the data justify a correction for the young adult age considered necessary by Angel. Considering that this is the Neolithic Age, we agree with this correction, especially if we recall the data of the Fofonovo series where the mode appears distinctly at the second half of old adult age.

It is instructive to compare Angel's data with those of two Neolithic necropolises from East Switzerland. The distributions in two series coming from sites in Chamblandes (Vand) excavated by Naef and Schenk, and from La Barmaz (Barmaz I and II) excavated by Sauter (1949), are compared with those of Khirokitia in Table 59.

TABLE 59

Distribution by age at death in the series of Khirokitia, Chamblandes and Barmaz

Age group*	No.			Per cent		
	Khiro- kitia	Cham- blandes	Barmaz	Khiro- kitia	Cham- blandes	Barmaz
Infant I (0-4 years)	41	4	7	34·1	15·4	18·4
Infant II (5–14 years)	4	1	9	3·3	3·8	23·7
Juvenile (15–24 years)	1	7	2	0·8	26·9	5·3
Young adult (25–39 years)	60	4	10	50·0	15·4	26·3
Middle adult (40–59 years)	14	8	10	11·8	30·9	26·3
Old adult (60 + years)	—	2	—	—	7·6	—
Total	120	26	38	100·0	100·0	100·0

* The Barmaz and Chamblandes series are shown in the usual anthropological age-grouping, the Khirokitia series by years of age.

The proportion of the infant I group is very low (17 per cent in total) in the Chamblandes and Barmaz series, but the high proportion of the infant II and juvenile groups is striking. The proportion of infant II is higher in the Barmaz series and that of juvenile in the Chamblandes series, than that of infant I, and the total of these two is close to infant I (16 and 14 per cent, respectively) although it slowly decreases with age. The Swiss series with relative low numbers of cases indicate that infant II and juvenile mortality were fairly considerable in the Neolithic and that the Khirokitia data cannot be generalized, or need completion, in this respect.

Some information on adult mortality is supplied by Table 59. The Chamblandes and Barmaz series agree in that the maximum of the deaths has shifted from young adult to middle adult age (in total, 22 per cent of the dead is in the young adult group, 28 per cent in the middle adult group), the proportion of middle adult deaths in the Chamblandes series is even fairly close to the Fofonovo distribution. If the rates at middle adult age in Fofonovo and Chamblandes are regarded as extreme values, Khirokitia, with half the deaths occurring at young adult age, where more than one-quarter were 30–40 years old, must also be extreme, or rather distorted, by the age-determination method. In the Chamblandes series the proportion of the old is remarkable and the total in the two Swiss series is 3 per cent.

The Vovnigi series is mentioned chiefly in connection with the problem of Eneolithic child mortality. At Vovnigi, near Dniepropetrovsk, Rudinsky opened up two cemeteries on both banks of the river Dnieper between 1949 and 1952. The cemeteries originated from the 4th millenium B.C. Excavation was completed on both banks, and gave 130 graves on the right bank and 31 graves on the left. The Vovnigi series is kept at the Anthropological Institute of Moscow University, where we analysed it in 1962 with the consent of Professor Yakimov. We were not in the position to use the complex method of age determinations, we only observed the degree of the endocranial suture closure, the fusion phases of the epi- and diaphyses, as well as the morphological state of the bones. On this basis we obtained the age distribution as shown in Table 60.

TABLE 60

Distribution by sex and age at death in the Neolithic series of Vovnigi

Age group	Males	Females	Unidentified sex	Total
Infant I–II (0–14 years)	.	.	(72)	(72)
Adult of unidentified age (14 + years)	.	.	(36)	(36)
Juvenile (15–22 years)	—	2	2	4
Young adult (23–39 years)	12	9	—	21
Young adult–middle adult (30–60 years)	9	3	—	12
Middle adult–old adult (40–80 years)	15	1	—	16
Total	36	15	110	161

The figures in brackets are estimated data. The skeletons were found in such a poor condition that only 32 were secured from the right-bank cemetery, representing one-quarter of the finds, and 21 from the left bank, i.e. two-thirds of the finds. So we were able to study the skeletal remains of 53 of the 161 buried individuals. According to Konduktorova (1960), who carried out the anthropological analysis of the series, the skeletons in poor condition were usually those of children and juveniles, and only one-third of the missing part of the series could have been adults. If so, the number of deaths in childhood in this series of 161 individuals might have been 72, i.e. 45 per cent of the series might have been children aged 0–14. This proportion agrees with 42 per cent at Barmaz, and is not too dissimilar from the 37 per cent of Khirokitia.

Owing to the absence of dead children, the life table of the Vovnigi population cannot be computed even by rough approximation. We have made a very crude estimation of expectation of life at the age of 20 on the basis of the adult skeletons of identified sex and wide age limits. The average age at death of male adults was 47 years and that of females considerably less, only 35 years. This estimation conforms roughly with the Afalou data. No further computations can be made from the relatively large Vovnigi series, although it might have been suitable for a generalization of mortality at that particular site. But the information gathered from the mortality pattern of adults of identified sex and age suffices to suggest the probability that the mortality rate of middle adult age was approximately the same as the young adult rate in the Neolithic.

There is no difficulty, however, in finding examples to prove the contrary, we need not even go very far, as in 1958 Gerasimov opened up a similar Neolithic cemetery at Volni in the Ukraine. The anthropological analysis has been conducted by Shurnina. Chronologically, the series may come from 3500–2500 B.C. The Volni population had been living in continuity since the Mesolithic and was attached by some links to the Mediterranean. It is possible that this population may have reached the lowest stage of tillage and animal husbandry, although the small series (45 elements in all) does not yield entirely dependable data; nevertheless it reflects relatively poor mortality conditions.

We had the opportunity to study the Volni series with respect to sex and age and the life table is shown in Tables 109 and 110, the age distribution in Fig. 38.

More than one-third of the Volni population (33·6 per cent) are children, two-thirds are juveniles or young adults with a roughly equal share of males and females. This distribution would seem to be fairly well-proportioned, but Fig. 38 reveals the lack of complete data, or rather features of a disadvantageous mortality pattern. The absence of infants and small children is striking and cannot be explained by natural reasons considering the high number of children who died after the age of 4. Children who died at 0–3 years of age are not

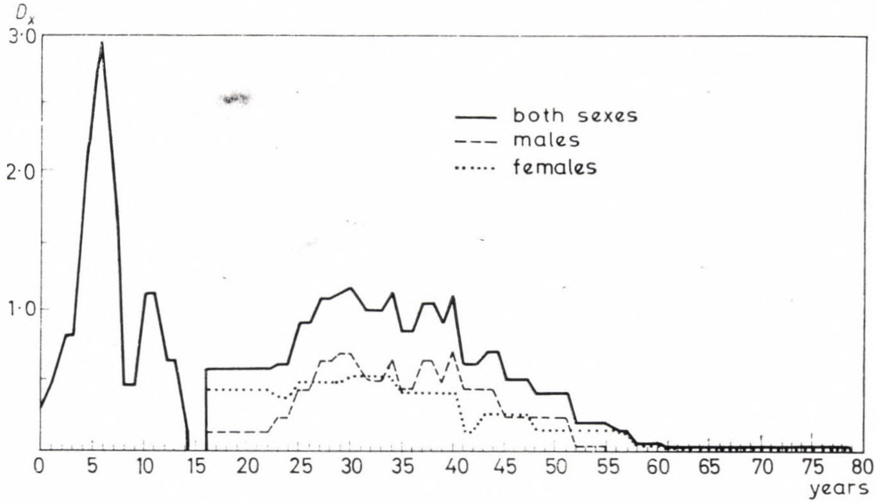


Fig. 38. Age distribution at death in the Volni population.

adequately represented in this series, so these had either not been buried here, or their remains had disintegrated, or they have not been excavated. The other fluctuations of the curve evidently reflect the small size of the series. But the fact that normal age at death was in the young adult age cannot be attributed to small size; this fact appears in both sexes and results in short expectations of life for both.

Expectancy for males at the age of 20 is only 35·8 years, that of females—despite a higher juvenile mortality rate—is somewhat more, 36·8 years. It should be noted that even in this small series the oldest individuals were females, and analysing both male and female deaths the difference between the number of females who died at young adult and at juvenile age is lower. (Expectation of life at birth of 24·9 years, computed from the Volni series, is relatively high on account of the absence of infantile and small-child mortality.)

The Fofonovo, Chamblandes, Barmaz and Vovnigi features show in a uniform manner that the mode of deaths has shifted from young adult to middle adult age in the Neolithic, but the Volni series is not unique with its young adult-age mode. If the Volni data are compared with Bröste's and Jörgensen's Neolithic data of Denmark (1956), as well as with Riquet's (1943) and Fusté's (1952) combined Neolithic–Eneolithic series of Aulnay-aux-Planches and Dolmen des Bretons, we see that the proportion of young adult deaths is very high in these series, too. The data are compared in Table 61 from the age of 12; no child mortality is considered, as these series contain no children. The series compared in this Table are rather dissimilar in size (the number of elements in Volni is 30, in Riquet's and Fusté's combined series 28, in Bröste's and Jörgensen's study 252), but their distributions are very similar. Yet even this considerable conformity is not too convincing, especially not in Denmark, where 63 per cent of the deaths is concentrated on the end of juvenile and the beginning of young adult age representing a mere 10–12 years. It would seem likely that the series compared with Volni are selected samples, statistically distorted in respect to age (this is also indicated by the absence of children), but it is equally possible that the distortion is due to inadequate age determination.

We do not regard the distribution in Table 61 as suitable for generalization, but the question may be raised all the same whether, at this period, a characteristic development of mortality could have taken place in parallel with its differentiation between various populations. In the following an attempt will be made to answer this question.

TABLE 61

Per cent distribution by age at death of the Volni, Aulnay-aux-Planches and Danish Neolithic series

Age group	Volni	Aulnay-aux-Planches*	Danish Neolithic**
12–19	11·7	7·1	5·6
20–39	61·1	64·3	63·1
40–59	25·5	25·0	23·4
60+	1·7	3·6	7·9
Total	100·0	100·0	100·0

* Age groups of 13–20, 21–40, 41–60, 61+ years.

** Age groups of 12/13–18/20, 18/22–30, 30–50/55, 55+ years.

SOCIAL AND ECONOMIC PROGRESS INITIATES REGIONAL AND TEMPORAL DIFFERENTIATION OF MORTALITY

Surveying the evidence of Neolithic mortality adduced so far, it doubtless shows new features that differ from the archetype of mortality. Exactly what this type of mortality may have been, we are not able to describe accurately on the basis of the defective and distorted series available. But the background of the changes seems clear enough, and, as we are dealing with the beginnings of history, it may also be inferred from other data such as the estimable values of population growth.

About 7–8 thousand years before our era, the changes in implements, introduction of farming and animal husbandry, and the appearance of the first villages and permanent settlements created a new economic basis for mankind. These changes did not take place simultaneously in the inhabited parts of the earth and mankind had by then spread over large regions and had begun to multiply from the Upper Palaeolithic and Mesolithic. To what extent this growing density promoted the 'economic-technical revolution' is open to debate. But it is indisputable that the new economic basis provided the possibilities for maintaining the more concentrated, permanent populations. Indeed, several considerable masses of population, relying on farming and animal husbandry, began to develop in this period: one in South Asia (in the territory of India), the other in South-West Asia and North Africa. Probably independent of these, and somewhat later, similar concentrations of population emerged in Central America.

About 4000 B.C. this outlined process was considerably accelerated by further changes in the economic basis. The spreading of water regulation (building of dams, canals, strip cultivation, etc.) mainly in Lower Mesopotamia, in the valley of the Lower Nile, in West India and in the region of the Indus had great effect. Similar development took place in the Yellow River valley, the centre of Chinese civilization, as well as in the Americas, in the region of the Northern Andes and in Lower Mexico.

An intense population density emerged in these regions which increased considerably in the surrounding regions as well. Depending on local dissimilarities, economic, social and political conditions, the great empires of antiquity reached the zenith of their progress at different times, but invariably a few centuries B.C. or A.D. Considering the fact that relatively smaller populations, at a lower stage of development, were living in 'peripheral' regions outside the civilized ones at that time, fairly accurate estimates can be made of the size of the human population. We mentioned before that it may have consisted of 210–250 million people at the beginning of our era.

So the beginnings of human history, as well as the preceding millenia, were characterized by rapid growth of population compared with more ancient times. Yet the rate of growth could not have increased unless there had been a change in one single factor, the reduction of the mortality rate.

Farming and animal husbandry meant subsistence for more people in a given area. However, the new economic system was more than a basis for the multiplication of mankind: it precipitated a population process which may well be called the 'demographic revolution of the Neolithic' on account of its striking similarities with the demographic revolution of our time. The development of agriculture, the emergence of villages, towns and the like have made man's livelihood more independent of the hazards of his natural environment, but affected his health conditions, and his mortality through nutrition and the settled way of life. The diminishing mortality promoted multiplication, which has led to more concentration of populations and to the aforementioned historic development.

The results of the palaeodemographic studies made of Neolithic series reflect these effects. Unfortunately, these series are not suitable for the analysis of features of a mortality type conforming the above development, not even if we assume that progress has brought differentiation not only in time but also between various populations. We shall therefore survey further series—from the Eneolithic, the Copper Age, the Bronze Age and the Iron Age—as data from finds nearer in time and richer in content are promising the clue to the problem. Let us first have a look at the series most often referred to in palaeodemographic literature. In Table 62, the series of Vallois (1940), Fusté (1954), and Senyürek (1951) are compared. They comprise finds coming from various regions and ranging from the Neo-Eneolithic to the historic times.

TABLE 62

Distribution by age at death from the Neo-Eneolithic to historic times

Series, period, author	No. of dead	Per cent distribution of deaths					
		0–12	13–20	21–40	41–60	60+	Total
Spanish Levant, Neo-Eneolithic							
Fusté (1954)	101	24·8	14·8	41·6	17·8	1·0	100·0
males	46	.	8·7	58·7	28·3	4·3	100·0
females	23	.	21·7	60·9	17·4	0·0	100·0
Sialk (Iran), from Eneolithic to Iron Age (4200–900 B.C.)							
Vallois (1940)	39	12·8	5·2	53·8*	28·2†	.	100·0
Jericho, Copper Age (300 B.C.)							
Kurth (1962)	226	34·9**	8·8††	47·9	8·4*†	.	100·0
Anatolia, Copper Age							
Senyürek (1951)	104	31·7	12·5	34·6	17·3	3·9	100·0
Anatolia, from Chalcolithic to Byzantine era (11th century)							
Senyürek (1951)	122	20·5	13·1	41·0	19·7	5·7	100·0

* 30·7 per cent are 31–40 years old.

† 15·4 per cent are 51+ years old.

** Aged 0–14; there are no infants in this series.

†† Aged 15–20.

*† Aged 41–50.

The series shown in Table 62 are contradictory. For instance, the proportion of children varies from 12·8 to 34·9 per cent, of persons aged 13–20 from 5·2 to 14·8 per cent, etc. The most acceptable of them is the Copper Age series of Anatolia, although the proportion of young adult deaths seems to be too high if compared with the children, or conversely, the proportion of the children is too low. The distributions shown here cannot be adjusted to the archetype of mortality even by applying corrections. On the other hand, they do not provide enough data to form an opinion of the mortality between the Neolithic and historic times. The largest amount of relevant information is provided by Fusté's Spanish data, which adduce further proof, broken down by sex, of the longer life expectancy of males. The survivorship has been computed from Senyürek's data on the Anatolian Copper Age. This is the most balanced series of the Table and can be used fairly well for generalization. The pattern is shown in Fig. 39 together with the more characteristic Neolithic series, discussed before, and the Maghreb type. The course of various survivorship patterns in the figure presents a confused picture. The Khirokitia curve, which is the lowest one at the age of 1 is the highest at the age of 25; it then approaches complete extinction abruptly, and intersects all curves at the age of 30–35. The other curves run without characteristic bends, practically transversally, from the outset along the horizontal axis towards ages 50–60, and intersect in turn the curve of the Maghreb type between ages 35 and 55.

But some remarks *in merito* can be made on this figure. The infant mortality rate of the Khirokitia series is rather high, though this may be a local trait. And yet the probable survivorship curve in childhood is best approached by the curve of the Khirokitia series, although on the basis of child mortality of Volni a more rapid decrease in the number of survivors ought to be assumed for that period. The various curves intersect one another about the ages of 15–17, where the ratio of survivors is 60–65 per cent, which seems to be an unrealistically high value. Before reaching the point of intersection, the survivorship curve turns concave from

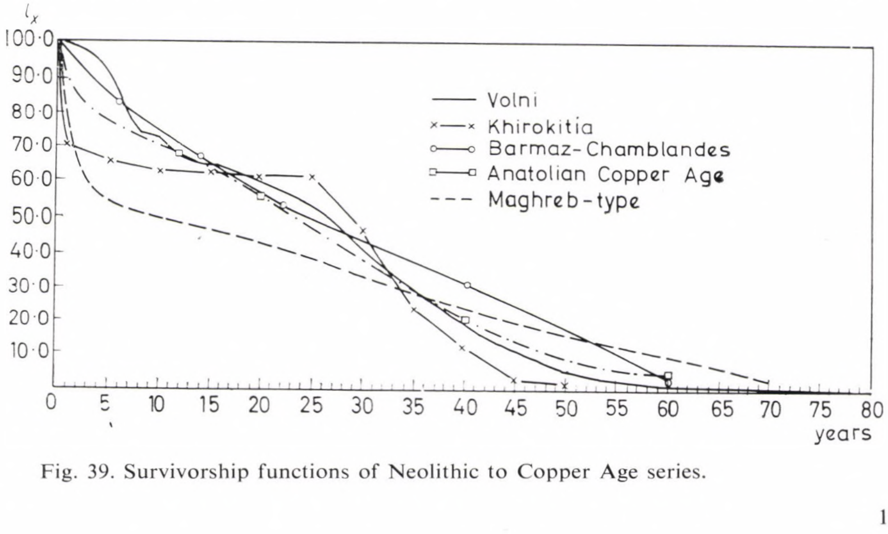


Fig. 39. Survivorship functions of Neolithic to Copper Age series.

convex in most series, to resume its convex character from the middle of young adult age. The methods employed for age determination cause the curves to take an extreme course at young adult age, and render them altogether unfit for generalization.

Regarding young adult age, we present the data of Riquet's (1953) and Angel's (1946) series. That of Riquet ranges from the Eneolithic to the Bronze Age, Angel's series provide data from the time between the Neolithic and the Roman-Byzantine era (Table 63).

TABLE 63

Age distribution of deaths from the Neolithic to historic periods (after Angel and Riquet)

Series, period and author	No. of dead	Per cent distribution				
		18–20	21–35	35–55	55+	Total
Greece; from the Neolithic, (3500–1150 B.C.) Angel (1946)	148	8·8	54·0	33·8	3·4	100·0
Greece; from Sub-Mycenaean to the end of classical era (1260–150 B.C.) Angel (1946)	163	5·5	39·3	50·9	4·3	100·0
Greece; Roman-Byzantine era (150 B.C.–1300 A.D.) Angel (1946)	73	2·7	53·5	41·1	2·7	100·0
Baye caves (Paris); from Eneolithic to Bronze Age (200–800 B.C.) Riquet (1953)	242	.	57·0*	24·8**	18·2†	100·0

* Aged 18–40. ** Aged 41–60. † Aged 61+.

Angel's Greek series show a certain progress. The proportion of ages 18–20 decreases throughout, and the proportion of individuals aged 35–55, as well as those of 55 + grows in the Copper Age. True, the mode of deaths shifts back to young adult age in the Roman-Byzantine era, but this can be explained by the low number of cases. Riquet's series, excavated in the Paris basin, does not fit Angel's data, yet the relatively high, but still acceptable, proportion of old individuals is remarkable. For if we assume on the basis of Fig. 39 that the age of 17 was attained by 50–60 per cent of the population, then the proportion of people attaining the age of 61 would be about 10 per cent according to the Baye series.

We have drawn all these conclusions on the basis of series that often show considerable dissimilarities and they can be rendered probable only with the help of series that meet the requirements outlined in Chapter II. If such cemeteries show conformity with conclusions reached so far, we consider them suitable for generalization. In the following we shall study Hungarian prehistoric series. We have taken part in their excavation and they meet the requirements of palaeodemographic analysis.

Archaeological excavations conducted at Tiszapolgár-Basatanya in 1950–54 have yielded one of the most valuable prehistoric series in Hungary. The series is suitable for demographic analysis, as it consists of 156 graves and, taking into consideration earlier excavations as well, it provides possibilities for a reconstruction of a population that lived in the early and middle Copper Age.

The first excavation of this cemetery was reported by Banner, who mentioned 7 graves. In the course of highway construction, Bender was informed about the graves and it was he who secured the first finds. In 1929, Tompa and Csalog conducted excavations with the help of Buxton, and supported by Louis C. G. Clark. Fifteen graves were opened up in the course of those excavations. The material of the 1929 excavation and of Bender's earlier finds is described by Bognár-Kutzián (1946/48). But her description contains no data that could be evaluated palaeodemographically.

When the Selypes canal was cut in 1928, several graves were destroyed. On the basis of the distribution of graves found at the excavation, Bognár-Kutzián (1963) estimates their number at 30. Accordingly, about 50–52 graves belong to the period of the earlier excavations.

We estimate that the number of the graves is 210–230 including the excavations of 1950–54. Patay (1956) puts the number at about 190–220, Bognár-Kutzián at 195–213. So it may be concluded that about one-fourth of the series had been destroyed, and only partial data of this part are known. Three-quarters therefore are known to us from careful, comprehensive excavations.

The origins of the population that had developed in the second half of the third millenium B.C. and lived here up to the turn of the 2nd millenium B.C. go back to the Neolithic. The genetic origin of the Tiszapolgár-Basatanya population can be traced back along the river Tisza, then down along the Danube, in a southeastern direction through the Carpathians, to the eastern basin of the Mediterranian. From here they must have entered the Carpathian basin through slow penetration. Essentially, this population consisted of a new element of the early Copper Age attached to a late Neolithic population. In the middle of the Copper Age it was amalgamated into a population forming an incoherent isolate, in which the original element and the associated element of the early Copper Age already formed a unit. This population was engaged in farming and most extensive animal husbandry, and the original and imported elements were balanced in its material civilization.

Its origin and genesis are substantiated also by the anthropological structure, insofar as the early phase is determined mainly by the protoeuropoid and partially by the protomediterranean components. The middle Copper Age is characterized by a uniformity of the population, which is marked by taxonomic indices determining the Mediterranean variety. As a result of isolation, the process of gracilization sets in at this time, characterizing principally the population that had lived in the middle Copper Age. The process of adaptation was probably not void of ob-

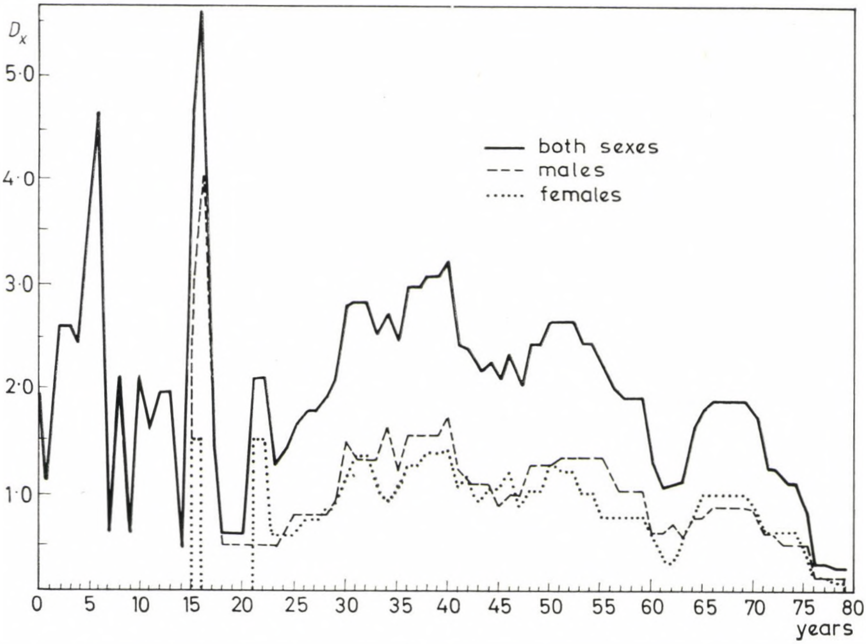


Fig. 40. Age distribution of the dead of the Copper Age population of Tiszapolgár-Basatanya.

stacles and is presumably expressed in the conditions of mortality and length of life.

The detailed life table of the Basatanya population is shown in Tables 111 to 113. The age distribution of the dead is shown in Fig. 40. The most conspicuous feature of the Basatanya series is the lack of deaths at the ages of 0 and 1 years. This phenomenon is not unique as we have seen it in other series too. The comprehensive excavation of the Basatanya cemetery, however, does not allow the supposition that the skeletons of infants might have mouldered. We have seen other comparable skeletons, and it cannot be assumed either that the excavators should have failed to mention such graves, since careful records have been made of any relevant details (cenotaphs, and the like) in the course of the systematic excavation. Knowing of the meticulous care shown in this work, it may be taken for certain that no more dead infants had been buried in this cemetery than are shown in Fig. 40.

Yet the two individuals who died at the age of 0 would indicate such a low rate of infant mortality that it would be sheer absurdity. So it is not impossible that we are concerned with the cruel, but demographically proved custom of exposure already mentioned by Bognár-Kutzián (1963) quoting Haberland. Exposure explains why the infants and small children are missing from the cemetery. If this is taken into account, the distribution in the Basatanya cemetery may be regarded as fairly characteristic and suited for generalization. To avoid misunderstandings we should like to emphasize that exposure can serve as an explanation for this absence only if it had been carried out on a selective basis. In this case, exposed children are naturally not taken to the cemetery, but non-exposed children do have a mortality pattern, which must be rather high if exposure is not selective. The presence and low number of individuals who died at the age of 0 and 1 in this series indicates that there was a selection of the newborn, i.e. a social practice of control based on biological considerations. If a cemetery contains no 1–2-year-old children at all, this is not an evidence to the practice of exposure; it only shows that such children were not buried, or buried in other places outside the cemetery.

Concerning the exposure and killing of children, we should like to make some remarks from the demographic point of view. Bognár-Kutzián quotes Haberland's opinion, according to which infanticide was customary in the early phases of development of every population. But it may be asked in what period, or, more exactly, under what social and economic—and we may add, demographic—conditions was this custom general. If exposure is to be defined solely as an act of 'population policy', this custom cannot be too ancient. For it is difficult to assume that at the given archetype of mortality, just making possible the survival or slow multiplication of population, man should have controlled his reproduction limited enough through natural selection. On the other hand, it is not inconceivable that this custom began to spread by the time mortality improved substantially and growth was greater occasionally and locally than could have been supported by a developing economy under prevailing natural and social conditions. Such a situation may well have arisen in the Neolithic or the Copper Age, maybe even earlier, and it is equally possible that such a custom survived because of 'eugenic' considerations, or just as a left-over, at times when it was no longer justified by economic conditions. If so, natural selection was probably replaced by social selection.

Despite all this, it cannot be shown conclusively that this custom was general in the Neolithic or the Copper Age. This appears from the Khirokitia series, or the cemetery of Alsónémedi, to be described later, where infant mortality is normal, i.e. close to the values to be expected. Infant mortality among the settlers of Khirokitia was so high, 283 per thousand, that they could hardly have exposed their children. If, on the other hand, this high infant mortality was the result of the practice of infanticide, we are faced with the unusual case (though indifferent in respect of mortality analysis) of burying killed infants in the cemetery.

The numerous instances of exposure known do not prove that this custom should invariably have accompanied the development of human society. It seems much more plausible that it appeared only where and when the balance of economic and social conditions and the mortality level was upset threatening with a relative over-population.

The proportion of dead children is rather high in the Basatanya series, especially in the age group of 5–6 years. The proportion of ages 15–16, males for the most part, is even more conspicuous. If these peaks are not accidental, we must assume

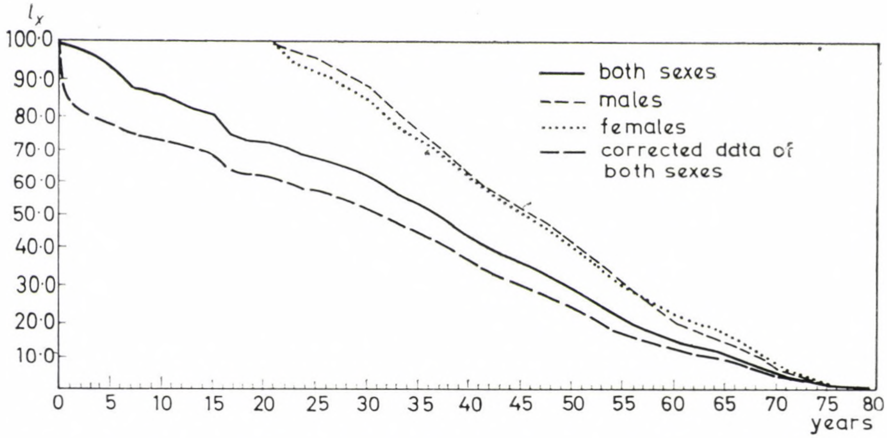


Fig. 41. Survivorship of the Copper Age population of Tiszapolgár-Basatanya.

certain social customs which have affected mortality (e.g. initiation ceremonies, immolation, etc.).

The mode of adult deaths in the Basatanya population appears in the second half of young adult age, and death rate in the first half of young adult age is low; a second mode, approaching that of young adult age, appears in middle adult age (culminating at the age of 50–52), and even an old-age mode, corresponding to the normal age at death of our days, is discernible between the ages of 65 and 70. Considering that all three modal values are to be found among males and females alike, it might be postulated that in this distribution the first traces of a social stratification of mortality are encountered.

The differences between male and female mortality, not readily comparable from the numerical distribution, shape the survivorship of adults in a characteristic manner. This is shown in Fig. 41.

The survivorship curve of males is higher up to the age of 55; then the number of female survivors exceeds that of the males and their curve keeps higher throughout. Expectation of life at the age of 20 is therefore higher for males (27·1 years) than for females (26·6). Later, as the survivorship of females is better in the older age groups, female life expectancy becomes somewhat longer. As appears from Fig. 42 the expectancy curves of the two sexes run very close.

The survivorship curve declines evenly, showing breaks only after the ages of 6 and 15, and some fluctuation round the three modal values at adult age. Based on an altogether crude estimation, we have plotted another curve in Fig. 41. It was constructed on the basis of an assumed infant mortality. This curve, which follows the actual data closely and differs from them only as regards its level, would seem to be more suitable for generalization, disregarding possible sudden rises and fluctuations.

The life expectancy curve of the Basatanya population is shown in Fig. 42. The values computed with an estimated infant mortality are shown with a dotted line.

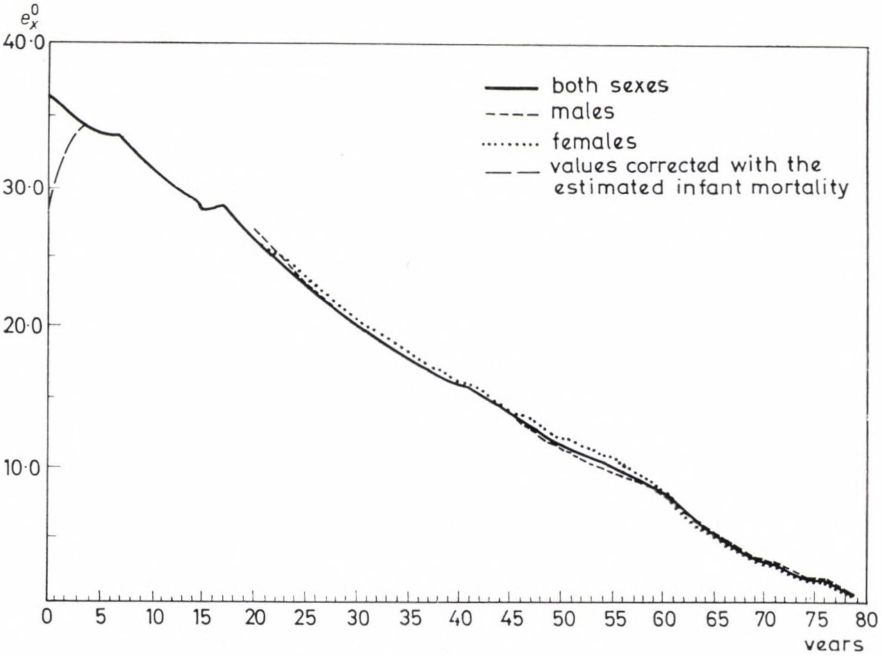


Fig. 42. Expectation of life of the Copper Age population of Tiszapolgár-Basatanya.

The values of the curves based on estimated infant mortality in Figs 41 and 42 have been chosen with view to generalization. It is not certain, however, that the mortality at Basatanya was actually of this type. If this population, which lived in favourable circumstances, had practised exposure out of population-political considerations, infant mortality ought to have been much higher. Our correction would have been realistic only if (*i*) there had been more dead infants in the destroyed part of the cemetery (among the approximately 30 graves, destroyed when the Selypes canal was cut), i.e. a certain area of the cemetery had been reserved for infants, a custom not encountered in other cemeteries either; or, (*ii*) only nonviable or seriously ill children had been exposed, i.e. not with the purpose of population control.

Finally we present from the life table of the Basatanya series the probabilities of death at various ages (Fig. 43). We have shown data for both sexes, in addition to their combined mortality pattern. Mortality of the sexes shows hardly any difference.

Basatanya mortality is relatively low in childhood. That of ages 5–6 and 15–16 is prominent here too. The values, although not striking in the figure, are considered exceptionally high at this age. Beginning from the age of 20, mortality grows slowly and steadily, apart from some fluctuation round the modes (which may be characteristic), and the curve rises rapidly at old age. The two breaks at old age

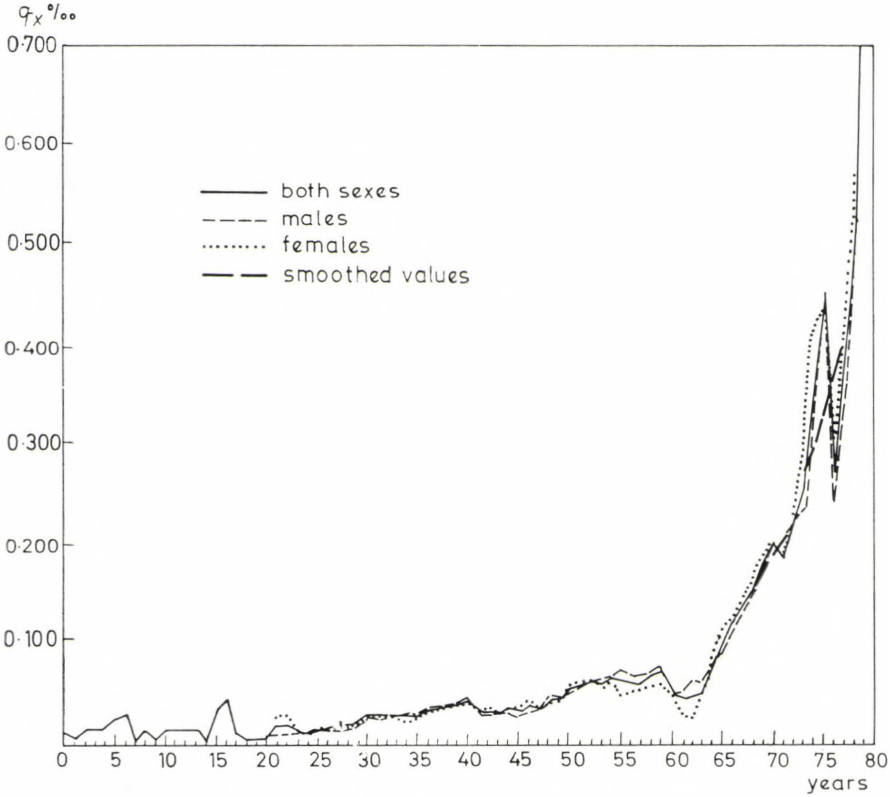


Fig. 43. Probability of death of the Copper Age population of Tiszapolgár-Basatanya.

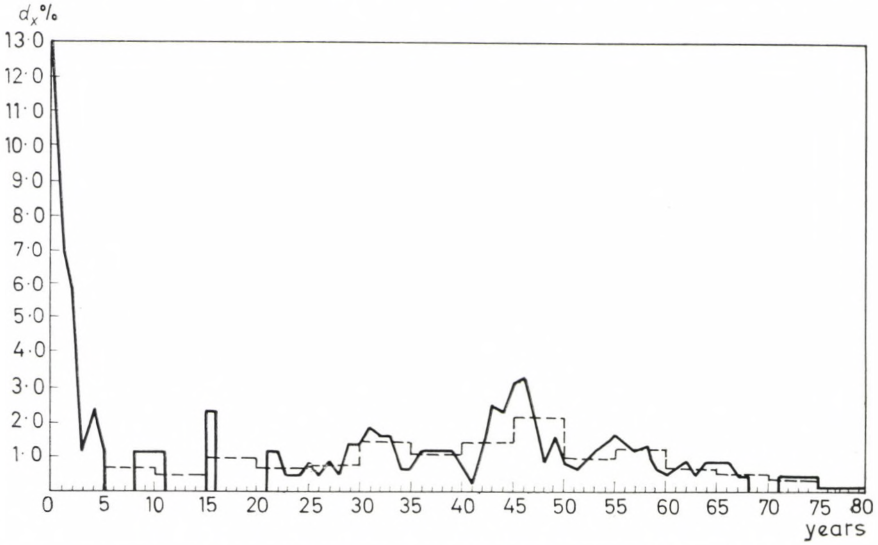


Fig. 44. Age distribution of the dead in the Copper Age population of Alsónémedi.

and the termination of mortality at the age of 80 in Fig. 43 reflect only a shortcoming of the age-determination method, resulting in an age accumulation at 70 and at 75 years and that we are not able to diagnose people older than 80.

The other series pointing to the emergence of a new type mortality in the Neolithic is the Copper Age series excavated at Alsónémedi. The number of graves in this cemetery is relatively low, but the mortality they reflect is perhaps better suited for generalization than that of Basatanya.

Fifty-eight graves have been opened up at Alsónémedi; nos 3 and 57 are double graves, so the number of people buried here is 60. Eighteen of the 60 had been buried in the Sarmatian period, 42 lived in the later Copper Age, at the end of the third or at the beginning of the second millenia (2100–1900 B.C.). Korek (1951) estimates the length of time during which the cemetery was in use to be 60–80 years. In the opinion of the excavators about 15 graves had decayed before the excavation was started; including these, the maximum number of these Copper Age graves may have been about 55–60. The sections excavated for checking the boundaries of the cemetery proved unproductive.

As to the origin of the population of Alsónémedi, a local aboriginal population and immigrants coming from south-east have been distinguished. Anthropologically the basic population were dolichocephalic Europoid, which can be identified

TABLE 64

Abridged life table of the Copper Age population of Alsónémedi (both sexes)

Age (x)	Distribution of deaths		Survivors (l_x)	Probability of death (q_x)	Total no. of years lived (L_x)	Total after lifetime (T_x)	Life expectancy (e_x^0)
	No. (D_x)	Per cent (d_x)					
0	5·5	13·1	100·0	0·1310	93·45	2,896·60	28·97
1	3·0	7·2	86·9	0·0829	83·3	2,803·15	32·26
2	2·5	6·0	79·7	0·0753	76·7	2,719·85	34·13
3	0·5	1·2	73·7	0·0163	73·1	2,643·15	35·86
4	1·0	2·4	72·5	0·0331	71·3	2,570·05	35·45
5–9	1·5	3·6	70·1	0·0514	341·5	2,498·75	35·65
10–14	1·0	2·4	66·5	0·0361	326·5	2,157·25	32·44
15–19	2·0	4·8	64·1	0·0749	308·5	1,830·75	28·56
20–24	1·4	3·4	59·3	0·0573	288·0	1,522·25	25·67
25–29	1·8	4·2	55·9	0·0751	269·0	1,234·25	22·08
30–34	3·1	7·4	51·7	0·1431	240·0	965·25	18·67
35–39	2·3	5·5	44·3	0·1242	207·75	725·25	16·37
40–44	3·1	7·3	38·8	0·1881	175·75	517·50	13·34
45–49	4·7	11·2	31·5	0·3556	129·5	341·75	10·85
50–54	2·2	5·1	20·3	0·2512	88·75	212·25	10·46
55–59	2·7	6·4	15·2	0·4211	60·0	123·50	8·13
60–64	1·5	3·5	8·8	0·3977	35·25	63·50	7·22
65–69	1·2	2·8	5·3	0·5283	19·5	28·25	5·33
70–74	0·8	2·0	2·5	0·8000	7·5	8·75	3·50
75–79	0·2	0·5	0·5	1·0000	1·25	1·25	2·50
Total	42·0	100·0	—	—	2,896·60	—	—

with Neolithic Tisza culture population. The immigrants were partly hyperdolichocephalic, gracile Mediterranean (Europoid), partly brachycranial Europoids. These two latter elements must have come to the Carpathian basin from south-east, may have been connected with the population of the Cucuteni culture of Rumania, and their traces go back as far as Anatolia.

From the demographic point of view the small series of Alsónémedi shows a characteristic distribution with minimal fluctuation (Fig. 44).

In addition to the distribution by age at death in years, we have shown a smoother distribution by age groups of five years. However, it appears from both distributions that (*i*) infant mortality is of acceptable height; (*ii*) the mortality of small children is decreasing but high; (*iii*) the lowest mortality rates appear between the ages of 11 and 20, with a mode of age 15–16; (*iv*) the number of the dead increases with age and culminates at 44–47, that is in the middle adult age; (*v*) the number of the dead decreases slowly until extinction.

We have drawn up a detailed life table of the Alsónémedi population (Tables 114 and 115) and also one with the abridged method (Table 64).

The survivorship of the Alsónémedi series also deserves attention. It declines rapidly at the age of 0–2, the curve becomes flat, to proceed with a slight, then somewhat more abrupt slope up to the age of 40. Then the death rate rises, and the number of survivors from the age of 50 proceeds in an asymptotic manner towards 0.

The mortality curve assumes a distinct U shape at the same time. It sets on with an infant mortality of 131 per thousand, and is followed by a small-child mortality of 75–83 per thousand. After passing its minimum, the mortality rate increases in a regular manner and, apart from some minor fluctuations (e.g. at the age of 15–16), is similar to the present-time curve. Expectation of life at birth is 29 years, like the corrected expectancy of Basatanya. At the age of 20 it is 26 years.

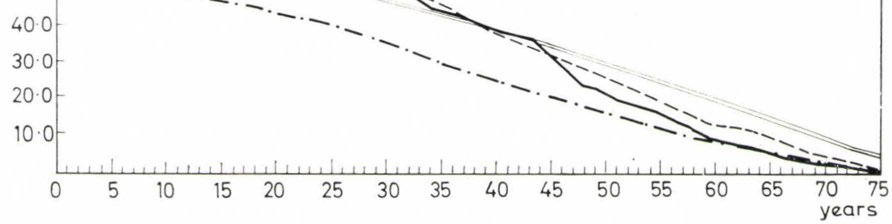


Fig. 45. Prehistoric survivorship.

The survivorship of the Alsónémedi series of relatively few elements and that of Basatanya are very close and tally with what we have found in the various Neolithic and later prehistoric series surveyed thus far. All this supports our assumption that in these two series a new-type, more favourable mortality emerges.

Prehistoric survivorship allowing for a higher rate of reproduction is outlined in Fig. 45. To give an idea of the progress made, we have also shown the Maghreb-type survivorship. The curve of the Alsónémedi-Basatanya mortality type is similar to the respective curve in the U.N. model life tables with the difference that there are more survivors in childhood and less in the middle adult age.

DISEASES AND PROBABLE CAUSES OF DEATH

Before discussing the finds of the Bronze and early Iron Ages yielding convincing data on the differentiation of mortality, let us deal with the palaeopathologic observations on the Basatanya and Alsónémedi series. These permit conclusions regarding the health conditions and, to a certain extent, the causes of death in these populations.

In 52 of the individuals belonging to the Basatanya series we have found clearly diagnosable pathological changes in the skeletal bones. The degree of these, and the sex- and age-distribution are shown in Table 65.

TABLE 65

Pathological changes in the Tiszapolgár-Basatanya population (Copper Age)

Degree of pathological changes	Inf. I–II	Males				Females				Total
		Juv.	Young ad.	Middle ad.	Old ad.	Juv.	Young ad.	Middle ad.	Old ad.	
Mild	1	1	3	6	1	1	7	8	1	29
Moderate	1	—	3	1	—	—	1	1	—	7
Serious	—	2	4	5	2	—	—	2	1	16
Together	2	3	10	12	3	1	8	11	2	52

According to Gáspárdy (1960), an immediate cause of death can be assumed in one case: the male individual aged 20–22 (inventory no. 7346) found in grave no. 80 must have died of the injury sustained on the skull. A 25 mm long and 15 mm wide split wound appears on the plate of the frontal bone which shows no callus formation.

Eleven characteristic pathological conditions could be detected in the finds of the Copper Age population of Tiszapolgár-Basatanya, of which spondylarthrosis, spondylosis and arthrosis stand first. Arthritic changes noted on the bones of the thoracic and pelvic girdles as well as of the extremities were mild. Distribution according to the various pathological conditions was as follows:

Arthrosis	28	Spondylolysis	2
Spondylarthrosis	21	Epiphysiolysis	1
Spondylosis	21	Osteomyelitis	2
Hernia interspongiosa	6	Vertebral osteochondrosis	1
Osteoporosis	4	Fractured bones (healed)	5
Baastrup's disease	2		

Among the signs of healed fractures one was a fractured femur, one that of the vertebral column, one a metacarpal bone, and two fractures of the skull.

The fact that in several individuals the above pathological conditions occurred combined supplies useful information on the general conditions of health and mortality. The frequency of common occurrence of the pathological conditions was as follows:

1 pathological condition in	30 cases
2 pathological conditions in	10 cases
3 pathological conditions in	7 cases
4 pathological conditions in	3 cases
5 pathological conditions in	2 cases
Total	52 cases

Of the 12 cases with 3 or more pathological conditions, 8 were males and 4 females. Most of these diseases occurred in the middle adult age group. Serious conditions were seen in the young adult age group, too.

Twenty-one pathological changes have been found in 10 members of the Alsónémedi series, constituting one-third of the adult population. There were six cases with one pathological change; and four cases each with 3 and 4 changes. Sex and age distribution is shown in Table 66.

TABLE 66

Pathological changes in the Alsónémedi population (Copper Age)

Diagnosis	Males			Females			Total
	Young ad.	Middle ad.	Old ad.	Young ad.	Middle ad.	Old ad.	
Cribra orbitalia	—	—	—	—	1	—	1
Spondylosis	—	1	1	—	2	1	5
Spondylarthrosis	—	1	1	—	1	1	4
Ligamentum ossific.	—	1	1	—	—	—	2
Arthrosis	—	—	1	—	—	1	2
Hernia interspongiosa	1	1	—	1	—	—	3
Costovertebral arthrosis	—	—	—	—	—	1	1
Osteochondrosis	—	—	—	—	—	1	1
Atrophia	—	1	—	—	—	—	1
Vertebral fracture	—	—	—	1	—	—	1
Together	1	5	4	2	4	5	21

Distribution by the degree of the changes was as follows:

Mild	4
Moderate	3
Serious	3
Total	10 cases

Death of the female buried in grave no. 55 may have been caused indirectly by the lumbar vertebral fracture.

The palaeopathological analysis of the Tiszapolgár and Alsónémedi series yields information on the health conditions of the population, in connection with which another highly important circumstance must be mentioned.

Animal husbandry and farming presuppose a certain density of population. By an improving mortality pattern they contribute at the same time to a growing rate of natural increase, further concentration of the population and, consequently, to social and economic progress. More advanced, less isolated, communicating, trading populations are no longer protected against the spread of communicable diseases and against the ravages of epidemics. Finds that can be analysed palaeopathologically indicate that some epidemic diseases such as tuberculosis and syphilis appeared already in the prehistoric age. A number of historical sources from the first centuries A.D. show that there occurred widespread epidemics resulting in high mortality (syphilis, plague, tuberculosis, malaria, etc.). Thus the improving mortality itself creates the obstacles to development. Prior to the era of the successful fight against epidemics, i.e. the recent 'demographic revolution' of the 19th and 20th centuries, they had been serious obstacles to development, and even affected mortality adversely in certain periods and regions.

In addition to the epidemics and restrictive population policies (e.g. exposure), a third factor should be mentioned which affected the differentiation between various populations: mortality due to homicide. Death by violence was no rarity in the Palaeolithic, but the many bone fractures found in sporadic and isolated populations must have been the result of fighting beasts and struggling with the forces of nature. Sauter and Nougier refer to a decrease in deaths by violence in the Neolithic, but other series contain large numbers of war victims (maybe even of cultic acts as we have seen in the Basatanya and Alsónémedi series). Giot (1951) believes that in his series, collected in France and ranging from the Neolithic to the early Iron Age and consisting of 78 adult skeletons, the mode appearing at the age of 20–30 is due to violence, accidents and battles. This is proved by the many weapons buried with the dead: daggers, swords, battle-axes, not designed for hunting, but for fighting men. It appears from Table 67 that the distribution of adult deaths in the Saint-Urnel series of the early Iron Age is very close to Giot's data from other periods.

Already Henry (1954) pointed out the anomalies in the Saint-Urnel series, saying that a length of life of about 11 years, which would follow from the distribution and would mean a mortality rate of nearly 90 per cent under stationary conditions, is improbable. Henry thinks that the Saint-Urnel series is not representative of the Iron Age and warns that only really characteristic samples should be used for generalization.

Although we agree with Henry's opinion, we should like to add that Giot's data are instructive. It may be that the distortion in his series is due to his sex- and age-determination method, but the 480 per thousand (!) infant mortality rate, the high child mortality and the very high juvenile mortality of Saint-Urnel—even if they cannot be generalized and were perhaps not really so high in this population—prove the differentiation of mortality between various populations, and show the significance and presence of such factors as death by violence and, perhaps, communicable diseases.

TABLE 67

Giot's collection showing the per cent distribution of violent deaths and the Saint-Urnel series from the early Iron Age

Age (years)	Giot's data, from the Eneolithic to the early Iron Age	Saint Urnel	
		Adults	Total
0*	.	.	48
1–6**	.	.	21
7–14†	.	.	3
15–20††	.	.	5
20–30	57	57	13
30–40	20	17	4
40–50	21	26	6
50–60	1	—	—
60–x	1	—	—
Total	100	100	100
No. of cases	78	24	104

*Small children, no deciduous teeth yet.
**Children aged 6–7.
†Older children.
††Adolescents.

FURTHER TEMPORAL, REGIONAL AND SEX DIFFERENTIATION OF MORTALITY

Series coming from other comprehensive excavations also show regional and temporal differences in mortality. Certain causes of death differ among the series in frequency and importance. Mortality in the Mezőcsát Bronze and early Iron Age series computations are shown in Tables 116 to 120.

The excavation of the Mezőcsát-Hörcsögös cemeteries was conducted by Patek with the help of Kalicz. They uncovered 37 graves from the late Bronze, 48 from the early Iron Age, a few graves from different ages (late Copper Age, Sarmatian period) not used in the analysis and six other graves where it was not possible to determine the origin. The cremation graves from the Iron Age were not analysed. It was found that about 20 graves had been opened up by the local inhabitants prior to the excavation. Including these 20 graves and relying on Patek's report an estimated 50–55 Bronze Age and 55–60 Iron Age people were buried here. The late Bronze Age cemetery may have originated between 1400 and 1200 B.C., and the early Iron Age one in the 8th century B.C. The Hörcsögös district at Mezőcsát covers an area of about 5 square kilometres. It rises above the plain like an island and may have provided suitable conditions for the settlement and maintenance of a population although it was probably surrounded by swampland and waters at that time. The population of the early Iron Age belonged to the Füzesabony-Mezőcsát group, who lived a nomadic life in the area that is now the southern part of the counties Heves and Borsod and demarcated by Füzesabony, Maklár and Ároktő (Pelypuszta and Dongóhalom). The most characteristic material of the archaeological find is the black, graphit-slipped pottery with turban-volute decoration and the iron material.

In the Mezőcsát cemeteries of the Bronze and early Iron Ages the number of dead infants is not adequately represented. The survivorship pattern or the values of the expectation of life at birth computed from these two cemeteries are not acceptable. The number of infant deaths does not affect the comparison of expectancies at various ages, so we have shown these in Fig. 46.

The curves of the Mezőcsát and the Alsónémedi series indicate two different levels. One level is represented by the Copper and Bronze Age series, which run together from the age group of 25–30. The other level is produced by the Iron Age series, which shows life expectancies usually higher by 4–6 years, up to old age, than those in the Alsónémedi series. There is, however, a substantial difference between the Bronze Age series of Mezőcsát and the Copper Age series of Alsónémedi, owing to the high child mortality rate in the former. The rate of deaths before the age of 20 in the Mezőcsát Bronze Age series is over 40 per cent, while infant mortality is not adequately represented.

The Mezőcsát and Alsónémedi series represent the differences in mortality between populations of different periods. But differences between populations belonging to the same period may be even greater than that seen in Fig. 46, e.g. the difference between the Mezőcsát-Hörcsögös and Saint-Urnel series.

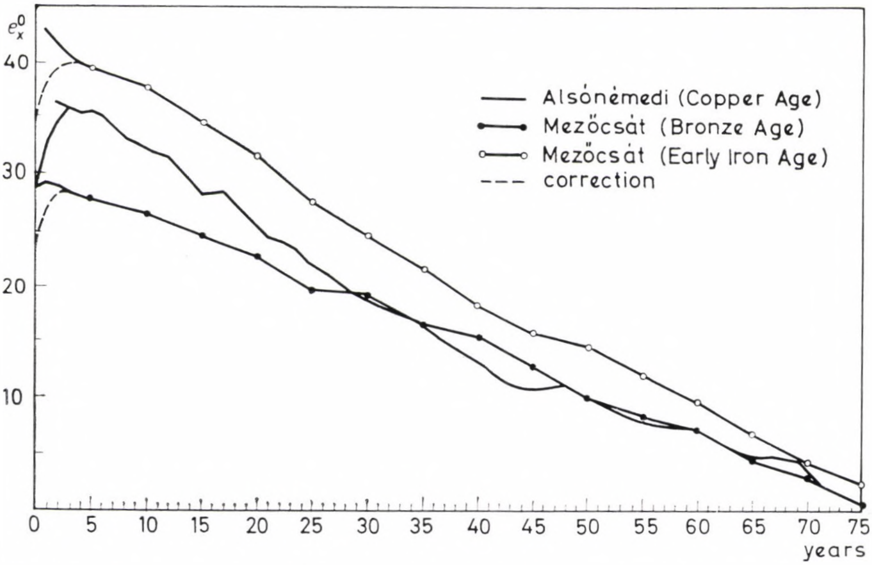


Fig. 46. Expectations of life in the Bronze and early Iron Age populations of Mezőcsát and Copper Age population of Alsónémedi.

In connection with the Bronze Age series we should like to present the series of Lower Austria analysed by Franz and Winkler (1936). The data of these series are shown in Table 68.

TABLE 68

Sex and age distribution of the deaths in the Bronze Age series of Lower Austria (after Franz and Winkler)

Sex	Child	Juvenile	Young adult	Middle adult	Old adult
Males	.	12	45	54	9
Females	.	28	57	14	9
Not identified	19	7	7	10	2
Total no.	19	47	109	78	20
Per cent	7·0	17·2	39·9	28·6	7·3

The 273 skeletal finds of the early Bronze Age in Lower Austria which we analysed come for the most part from the Hainburg a.d.D. series (111) and the Gemeinlebarn series (109) as well as from further 16 smaller series (consisting of 1–12 elements each). Except for the old adult age, the sex- and age-specific structures of the Hainburg and Gemeinlebarn series are identical (while there are more than 10 per cent old individuals in the Hainburg series, there are no such individuals in the Gemeinlebarn series). The abnormally low number of child skeletons found was not explained: it nevertheless showed that many more children ought to have been among the dead at that time. Owing to the uncertain data relating to the children, they studied the distribution of the dead disregarding the former. Based on the dead of identified sex, the percentage distribution showed in Table 69 was obtained, beginning from the adult age.

On the basis of the data shown in Table 69, the authors have raised the idea that the high proportion of female juvenile and adult deaths may be connected with childbearing. The ratio of females who died in very old age is similar to that of the males, somewhat higher in fact, indicating that the rate of female mortality was more favourable even in ancient times. At the same time, the authors supposed that the higher frequency of male deaths in the young adult and mature adult ages resulted from the hazards of fighting and hunting, although it cannot be decided whether the high mortality rate, differing from that of today, was caused by a high

TABLE 69

Per cent sex and age distribution of the adult dead in the Bronze Age series of Lower Austria (after Franz and Winkler)

Age (years)	Males	Females	Total
14–20	10·0	25·9	18·5
20–40	37·5	52·8	42·9
40–60	45·0	13·0	30·7
60+	7·5	8·3	7·9
Total	100·0	100·0	100·0

morbidity, epidemics, or by violent deaths, as fatal wounds can be inflicted without any injury to the skeleton.

In connection with this problem we compared the life expectancies of males and females in the series of Vovnigi, Volni, Levant, Tiszapolgár, Alsónémedi, Mezőcsát and Lower Austria. It should be noted that the Bronze Age data from Lower Austria, computed by Franz and Winkler, do not give the actual years of life to which they apply. The values computed from Fusté's data are the result of a crude estimation and only suggest the sex differences. The comparative data are shown in Table 70.

TABLE 70

Life expectancies of the two sexes from the age of 20, from Neolithic to Iron Age

Series, period (author)	Expectation of life from the age of 20		Expected age at death of males as a percentage of females
	Males	Females	
Vovnigi, Neolithic* (Acsádi and Nemeskéri)	21	14	121
Volni, Neolithic (Acsádi and Nemeskéri)	15·84	16·80	97
Spanish Levant, Neo-Eneolithic* (Fusté)	18	14	112
Tiszapolgár, Copper Age (Acsádi and Nemeskéri)	27·06	26·62	101
Alsónémedi, Copper Age (Acsádi and Nemeskéri)	28·69	20·89	119
Lower Austria, Bronze Age** (Franz and Winkler)	21·8	20·0	105
Mezőcsát, Bronze Age (Acsádi and Nemeskéri)	25·09	17·74	119
Mezőcsát, Iron Age (Acsádi and Nemeskéri)	31·97	31·36	101
Together	2·72	20·2	109

*Crude estimates.

**Data relating to ages of about 20.

With the exception of Volni, the differences mentioned by Franz and Winkler can be found in each series, although the sex differences in the expectations of life are far from uniform. Similar discrepancies have been found in other cemeteries, such as the Balanovo series of the Central Volga region. At Balanovo (Chuwash territory) the late Bronze Age cemetery (origin 2000 B.C. — classified as belonging to the Fatjanovo culture) was unearthed by Bader and Akimova.

We studied 42 elements of the Balanovo series, 16 children, 14 males and 12 females. Mean life expectancy at birth of this population was 26 years, approaching the Copper Age series of Alsónémedi. At the age of 20 it was 41 years for males, and 36 for females, with a difference similar to that in the Bronze Age

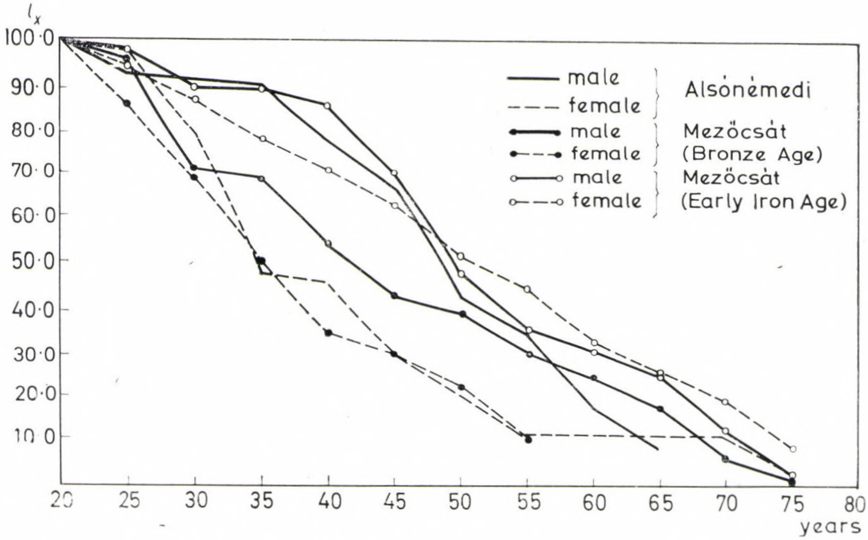


Fig. 47. Age-specific survivorship.

series of Mezőcsát. It is possible to examine the trends in sex differences at various ages after 20 compared with the Alsónémedi and Mezőcsát series.

Figure 47 shows that only in the Bronze Age series of Mezőcsát are the expectancies for males longer than for females at every age of life. The possibility of living longer is better at old age for females than for males in the Alsónémedi series, and better already from the age of 50 in the Mezőcsát Iron Age series.

In the following we give a distribution of deaths in the Sarata-Monteoru Bronze Age series (1800–1400 B.C.) reported by Maximilian and co-workers (Kurth, 1962) (the percentage has been computed by us on the basis of the absolute numbers, so they are somewhat different from the numbers in Kurth's publication). The Sarata-Monteoru series is characterized by a relatively low rate of infant and child mortality or the lack of deaths in these ages, as well as by a mode in the young adult age (Table 71).

Although much more recent, the data of Snow (1948), Kidder (1958), Goldstein (1953) and Faulhaber (published by Genovés in 1962) should be mentioned here; they relate to the Indian series of Indian Knoll, Kentucky (500 B.C.–500 A.D.), Pecos (1300–1700 A. D.), Texas (850–1700 A. D.) and Tlaltico (1100–600 B.C.). These series, though differing in time and certain other respects from those already discussed, confirm the impressions we have formed in studying the mortality patterns of regions in Europe, Asia and Africa.

TABLE 71

Distribution by age at death in the Bronze Age series of Sarata-Monteoru (after Maximilian and co-workers)

Age	Distribution of deaths	
	No.	Per cent
0–6	32	18·5
6–14	18	10·4
15–20	8	4·6
21–30	41	23·7
31–40	37	21·4
41–50	20	11·6
51–60	14	8·1
61–70	3	1·7
Total	173	100·0

CHAPTER VI

LIFE SPAN AND MORTALITY IN THE ROMAN EMPIRE

INTEGRATION OF MORTALITY IN ANCIENT EMPIRES

Evidence studied so far indicates that the new social and economic conditions which developed through the 'agricultural revolution' of the Neolithic Age created a new demographic situation. The fundamental factor in the changed demographic conditions was a considerable lowering in the mortality level, i.e. the lengthening of life spans. This change was not uniform, of course, and as it did not take place simultaneously in the various regions, a regional and temporal differentiation of mortality resulted. It is likely that in the age we have outlined—in settled, farming populations rather than in the nomadic stock-breeding ones—a tertiary, social-economic differentiation already began to take shape. The mortality pattern of the age discussed in the preceding chapter showed that the role of mortality differences between various populations was greater than the differences between social strata within a given population.

The lowering of mortality rates has accelerated population growth and, interacting with economic progress, has promoted the increase in population density. In this way preconditions for the emergence of the empires of antiquity were created. A new trend in the history of mortality appears in ancient empires: that of integration. This means that populations with more balanced mortality patterns were living under identical social and economic conditions in larger, contiguous regions.

There are insufficient data available on early empires to make the trend in mortality integration clearly recognizable. Nevertheless, we do not infer that the development of this process was a matter of necessity, using logic alone. The basis of our assumption is provided by the Roman era from which sufficient historical data—primarily from epitaphs—are available. The integration of mortality, which gives a more general validity to a given specific mortality pattern, was recognized by the Romans themselves. Ulpianus, the renowned Roman legal scientist and administrative expert, has drawn up a practical life table in connection with the capitalization of annuity payments. This table has come down to posterity in Justinianus's Digests. These data are shown in Table 72. Though Ulpianus's table is rather mechanistic, it reflects considerable progress. In the tables used previously, a further 30 years of probable life were uniformly attached to every year of age up to the age of 30; beginning from this, one year less was given for each age, so 60 years were taken into account invariably after 30 years. Ulpianus, on the other hand, accepted the further 30 years of life only up to the age of 20, and reduced the number of years still to be expected by 2–3 every five years after the age of 20.

TABLE 72

Ulpianus's 'life table'

Age	Expectation of life*	Age	Expectation of life*	Age	Expectation of life*
0–20	30	40–41	19	49–50	10
20–25	28	41–42	18	50–55	9
25–30	25	42–43	17	55–60	7
30–35	22	43–44	16	60+	5
35–40	20	45–46	15		
		46–47	14		
		47–48	12		
		48–49	11		

*It is doubtful whether these data should have applied to the unit value of the annuity.

The second column of the Table, in which the years of life to be expected between the ages of 40 and 50 grow less every year, is very interesting. Here Ulpianus retained the pattern of previous tables considering perhaps that expectation of life decreases most rapidly as the mode had shifted to the middle adult age. Ulpianus estimated that it was possible to attain the age of 57 once the age of 35 had been reached, and again it was possible to attain 60 after the age of 40 and so on. But from 40 to 50 he invariably puts the number of years to be expected at 60, and raises the limit only after 50. After the age of 50 the values of the table are lowered by 2 years in every 5 years. As a result, life expectancy increases to 64 at the age of 55, for instance.

Considering the practical purpose of the computations, the values in Ulpianus's table are evidently somewhat too low, and not too high. However, these data are real in certain respects. This also appears from Beloch's (1886) studies, the first of this kind, which provoked some debate. Based on epitaphs from the Italian districts of *C.I.L.* II, III and X, Beloch obtained the data shown in Table 73.

Ulpianus's table and Beloch's data supply information that differs from expectations of life computed in previous chapters, so it cannot be compared directly with the latter. But even so it is evident that Ulpianus's or Beloch's mortality characteristics do not differ substantially from those of the Eneolithic or Bronze Age. It would seem therefore that the increase in mortality rates slowed down at the beginning of historical times, then came to a halt to turn into stag-

TABLE 73

Beloch's mortality computations, (Italy)

Age	Males		Females	
	Survivors	Probable age	Survivors	Probable age
0	1,005	.	754	.
10	812	27–28	616	25–26
20	588	36–37	445	30–31
30	374	45–46	241	41–42
40	246	55–56	145	55–56
50	161	60–61	92	60–61
60	108	70–71	60	68

nation in ancient empires. This conclusion is supported by results of analyses made of the rich epitaph material of the Roman era. Stagnation of mortality was produced by a number of factors most of which had an effect not only on small populations but were rather widespread, and thus promoted the trend of integration.

Limitation to the decrease in mortality rates appeared even in prehistoric times and can be traced throughout the course of human history. The rate of population growth may have exceeded the rate of economic progress in certain periods resulting in a population surplus. This surplus may have led to 'social selection' replacing the ancient, natural one. The custom of exposure discussed in the previous chapter probably belonged to this category, and may have been aggravated by the abandonment of the helpless and the old. Induced abortion and birth control may also have been discovered once a certain level of animal husbandry had been attained.

Wars were also an important factor in this context. Even in the Palaeolithic age man killed man and at the dawn of history various implements and weapons (swords, shields, etc.) had been buried with the dead. Wars play an important role in the creation, expansion, maintenance and fall of empires, and have taken their heavy toll even in ancient times. The number of cultic victims must be taken into account as mortality factors in certain populations. The greatest obstacle to the decrease in mortality, however, must have been a natural factor, i.e. the spreading of communicable diseases under the new social, economic and demographic conditions. Ancient empires with high population density and highly developed trading systems were 'ideal' for the cultivation of such diseases and for the ravages of epidemics.

The studies of the mortality pattern of the Roman Empire are based, primarily, on the rich epitaph material. Pearson gave a fine example of evaluating these highly controversial data. In 1902 this renowned expert of mathematical statistics and biometrics made a demographic analysis of a 2000-year-old Egyptian mummy series of the Roman era, on the basis of W. Spiegelberg's publication a year before. In view of the criticism of Willcox (1938), Burn (1953), Henry (1957) and others on investigations of the Roman era, it would be instructive to have a look at Pearson's authentic data.

Pearson believed that a series of 141 individuals (82 males and 59 females) can form the basis of a reasoned analysis, allowing for certain inevitable conditions. For instance, it was probable that the elements of this series belonged to the wealthier classes and the small-child mortality figure was not representative as such mummies, if there had been any, had fallen to decay in a greater number than others. It must also be presumed that population conditions were stationary. Bearing the above in mind, Pearson determined life expectancy of various ages, starting from the supposition that after the age of 2 the mean value of data available in reasonably adequate numbers may be attached to various ages of life. The smoothed curve of Pearson's expectancies is given in Fig. 48.

The values determined by Pearson are marked with circles. These give a curve showing the signs of graphic smoothing, which he regarded as the general trend of

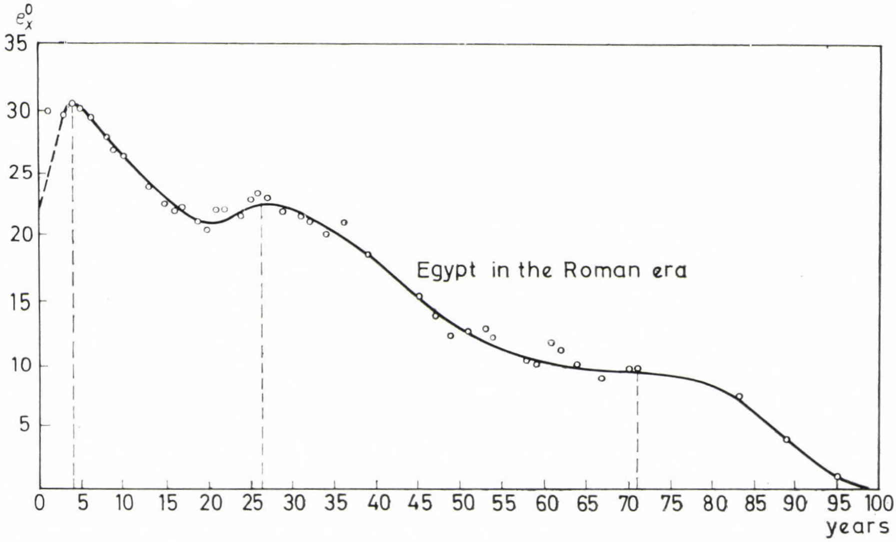


Fig. 48. Life expectancy in Egypt 2000 years ago (after Pearson).

mortality in Egypt of the Roman era, except for infant mortality and the extreme values of old age. In his opinion, the following conclusions can clearly be derived from this curve:

(1) Expectation of life is much longer today than it was 2000 years ago which proves that man has become better adapted for survival either by physique, or by developing mental power to organize his social and physical environment more effectively. Social, economic and sanitary development has taken place indicating a clearly progressive course.

(2) Three evident maxima appear on the curve of the Roman era of Egypt. The first is produced by increased changes of living at the age of 4–5, following a high rate of infant and small-child mortality, the second one by such increased chances following the high juvenile mortality at the age of 26–27. The third maximum, appearing after the age of 70, is not so distinct and is probably connected with the normal age at death.

The conclusions drawn from Pearson's relatively small series are supported by other data on Roman Egypt. From the third century B.C. to the sixth A.D. Hombert and Préaux (1945) have collected the ages at death of 813 individuals, who may have belonged to the well-to-do classes. Infants are not represented in this series (there are only 61 cases from the age of 0 to 4), and intense age heaping appears at 50 and 60 years. The abridged life table constructed on the basis of completed and corrected data according to Russell (1958). is given in Table 74. (In this table l_0 is not some power of 10, as in our life tables, but is equal to the total number of the dead, $\sum D_x$.)

TABLE 74

Abridged life table of Roman Egypt (after Russell)

Age (x)	Distribution of deaths		Survivors (l_x)	Probability of death (q_x)	Expectation of life (e_x^0)
	No. (D_x)	Corrected no.			
0			(956)	(0·150)	28·7
1–4	61		813	0·075	32·7
5–9	53		752	0·070	30·8
10–14	58		699	0·083	28·0
15–19	70		641	0·109	25·3
20–24	104		571	0·186	23·1
25–29	86		467	0·185	22·6
30–34	50		381	0·131	22·2
35–39	57		331	0·176	20·2
40–44	48		274	0·175	18·8
45–49	34	45	226	0·200	17·3
50–54	60	40	181	0·221	16·0
55–59	25	34	141	0·241	14·7
60–64	35	28	107	0·261	13·7
65–69	21		79	0·266	12·7
70–74	10	17	58	0·293	11·4
75–79	11		41	0·269	10·0
80–84	11		30	0·366	7·8
85–89	9		19	0·474	5·9
90–94	10	7	10	0·700	4·0
95–99		3	3	1·000	2·5

The life expectancy in Table 74 (28·7 years) is much longer than the 22 years given by Pearson. However, it must be taken into account that when giving the 22 years expectation Pearson did not consider the progress that had taken place in this respect in the evolution of the span. He mentions in his study that it was practically impossible to record infant mortality, and that he has bent down the beginning of the curve in an arbitrary manner. We should mention that he did so in accordance with the values in England at the beginning of the century. But we might attach an equally conceivable beginning to Pearson's curve which would result in a life expectancy of 24–26 years at birth. This value would not be too remote from data obtained from Hombert's and Préaux's series, especially if we take into account that the latter has been computed by assuming an infant mortality of only 150 per thousand, estimated as double the mortality at the age of 1–4. An infant mortality as high as 350 per thousand could be estimated on the basis of the epitaphs of the Roman era, using this assumption. Similarly a mortality of 200–250 per thousand would mean that the expectation of life at the age of 0 would be about 27 years, fairly close to the 24–26 years in Pearson's series. The above example is acceptable as Pearson's computed life spans are lower by 1–2 years throughout than the spans derived from Hombert's and Préaux's series.

Table 74 shows that there is intense age heaping at 50 and 60 years; the distorting effects of such heaping have been discussed in Chapter II (see Figs 11 and 12). Let us now compare the Egyptian data with the smoothed values of epitaphs deriving from the 1st to 4th centuries from Intercisa (Dunaújváros) and Brigetio (Szőny). This combined series consists of 184 gravestones, of which 95 are from Intercisa (some of these had probably been brought from Aquincum), and 89 are from Brigetio. It is interesting to see that while on the Intercisa stones age heaping is most intense at 50, on the stones of Brigetio it is most intense at 25 years, and 30 is the second highest in both series. The ages of 20 and 60, as well as 35 and 45 also show a considerable peak. Age heaping is most intense at the ages of 25 and 30 on the gravestones of men, and at 20 and 30 of women. Among the figures ending in 5, age heaping is noted only between 25 and 55 years, while the years of age ending in 8 also show a certain appeal. The smoothed data of the Intercisa and Brigetio gravestones, completed with an infant mortality of 210 per thousand, are compared with the Egyptian data in Table 75.

TABLE 75

Life expectancy in the Roman era from Egyptian and Intercisa-Brigetio series

Age	Egyptian		Intercisa-Brigetio		
	Pearson	Hombert and Préaux	Total	Males	Females
0	(22–26)	28·7	27·8	30·4	22·9
5	30	30·8	32·3	35·7	26·1
10	26	28·0	30·0	33·2	23·7
15	23	25·3	26·7	29·7	20·5
20	21	23·1	24·6	27·3	18·7
25	23	22·6	23·1	25·0	18·3
30	22	22·2	22·2	23·7	17·7
40	18	18·8	18·8	18·5	20·2
50	14	16·0	15·7	15·3	18·3
60	11	13·7	14·0	13·9	15·5
70	10	11·4	11·4	10·1	16·9
80	8	7·8	7·1	6·1	9·9

Taking into account the estimated infant mortality of 210 per thousand, expectation of life at birth in the combined Intercisa-Brigetio series is lower than the data in Hombert's and Préaux's series, but, following this, it is higher up to the age of 30. Beginning from the age of 30, the data of the three series are identical (some of them agree with an accuracy of one-tenth year!). This indicates that even in the most remote regions of the Roman Empire the characteristics of mortality were highly similar for several centuries, or else that the gravestone erecting habits were uniform.

The collectors of the Egyptian series assumed that the data are characteristic of the wealthier classes of contemporary society; but this is not the case with the

Intercisa-Brigetio series. True, no gravestones erected to slaves have been found, but those included commemorated mostly soldiers or veterans or members of their families, as well as the native civil population. Consequently the population group represented by the series might be regarded as neither subdued nor privileged people.

SEX AND SOCIAL DIFFERENTIATION OF MORTALITY

Life tables have been computed separately for men and women from the Intercisa-Brigetio series (see detailed Tables 121 to 123). According to these tables, expectation of life was 7 years higher for men at birth, and 10 years higher between the ages of 1 and 20. Men had the advantage up to the age of 37, but from there on expectancy was higher for women. Female advantage was especially marked at old age.

Such trends in sex-specific mortality agree with the picture that could be expected on the basis of previous ages. It is questionable, however, whether or not the trend reflected in the Intercisa-Brigetio series was general in the Roman era, or else this trend was mainly due to gravestone erecting habits.

The first question can be answered in the affirmative. The authors studying the epitaphs of the Roman era have found that men as a rule have longer life spans. In Szilágyi's report, the most comprehensive of its kind, this trend can be observed in the entire material of the Roman era (Table 76).

Szilágyi's (1959) material contains mean values computed from age at death that appeared on 24,848 epitaphs of the Roman era collected from 48 cities and regions. Computations were made without completion, weighting or smoothing. The mean ages of men varied between 17·8 and 47·2, those of women between 13·4 and 43·2 years. In 40 out of the 48 series the means for men are several years higher (more than 15 years at Misenum, Ravenna, Aquincum, Colonia Cl. Ara, for instance); identical values for both sexes appear in one series (Burdigala), and the life span of women is somewhat longer only in 7 series containing 2,092 elements.

In the Roman era, practically all over the Empire, the epitaphs usually show that men had longer life spans, although the possible distorting effect of stone erecting habits should always be kept in mind. It is most remarkable in this respect that we know of many more gravestones erected for men than for women. For instance, 60 per cent of the large series from the city of Rome, containing nearly ten thousand elements, are made up of epitaphs for men; the ratio is similar in the series of Ostia, Aquileia, Capua and other Italian series. Sixty-eight per cent of the Pannonian gravestones had been erected for men, and the proportion of epitaphs for men ranges between 50 and 90 per cent in other series, too. As gravestones were erected for dead infants in exceptional cases only, the considerable surplus of epitaphs for men can be explained only by assuming that women had less prospect to be commemorated in epitaphs. (It ought to be noted here that along with

TABLE 76

Average age at death of men and women, based on epitaphs of the Roman era (after Szilágyi)

Town, province	Average age at death			No. of epitaphs
	Males	Females	Together	
Roma	23·9	20·7	22·6	9,980
Ostia	18·6	18·8	18·7	649
Puteoli	24·6	25·6	25·0	626
Misenum	39·2	23·7	37·2	244
Aquileia	21·4	21·2	21·3	236
Brundisium	39·7	37·8	38·9	213
Carales (Sardinia)	38·0	37·0	38·7	178
Capua	28·7	23·5	26·6	147
Mediolanum	34·5	28·0	31·4	139
Tarquinii	47·2	43·2	45·3	129
Ravenna	36·0	20·5	32·2	124
Beneventum	24·3	21·3	23·5	100
Italia, other parts including Sardinia	29·1–2·88	24·9–25·1	27·5–27·4	3,350
Catina	30·0	28·6	29·9	100
Sicilia, other parts	28·1	28·7	28·5	200
Salonae	25·6	23·4	24·7	577
Dalmatia, other parts	33·7	30·6	32·5	578
Viminacium	41·2	30·0	39·2	50
Moesia, other parts	42·5	31·4	38·9	419
Sarmizegetusa	40·7	33·9	37·9	74
Apulum	38·4	32·8	35·6	61
Dacia, other parts	35·9	31·3	34·2	273
Carnuntum	34·5	30·9	33·9	204
Aquincum	36·7	21·3	31·7	162
Emona	40·9	42·1	41·4	116
Brigetio	35·4	29·8	33·4	99
Intercisa	38·6	26·9	33·4	89
Pannonia, other parts	37·6	32·8	35·8	583
Celeia	41·5	39·7	40·7	206
Flavia Solva	35·9	29·6	33·2	74
Virunum	17·8	18·5	18·1	65
Noricum, other parts	36·6	38·3	37·3	356
Raetia	39·3	33·1	37·1	87
Mogontiacum	31·7	28·3	30·9	242
Colonia Cl. Ara	31·5	13·4	28·4	57
Germania, other parts	35·6	32·7	35·0	249
Lugdunum (Lyon)	30·9	23·7	27·8	225
Burdigala	37·5	37·5	37·5	179
Treveri	26·0	21·1	24·2	126
Vienna	32·9	27·5	30·5	123
Arelate	30·5	25·7	28·6	93
Gallia, other parts	28·9	25·6	27·7	458
Britannia	34·6	27·8	32·5	221
Augusta Emerita	40·9	34·5	37·7	144
Gades	41·4	40·6	41·0	137
Saguntum	38·5	36·1	37·4	133
Olisippo	28·4	29·5	28·7	80
Hispania, other parts	39·0	33·8	36·7	1,893

the higher male birth rate there is a higher neo-natal mortality of males, probably caused by biological factors. In Hungary, for example, 106·7 boys were born for every 100 girls in 1963; 54·0 per cent of stillbirths and 56·3 per cent of infant dead were boys; of 1,000 live-born boys 25·3 died in the first week of life, while the comparable number was 19·6 for girls. Among babies dying at the age of 0—for whom gravestones were seldom erected—there must have been more boys in the Roman era, too. But the greater number of men's gravestones is not explained by the higher mortality rate in boys.)

Whether gravestone erecting habits distort the representative character of epitaph series, and, if so, in what manner and to what extent, can only be decided by comparing the epitaph series with an anthropological series. We have not so far been able to conduct detailed, comparative studies, but the possibilities exist and we hope that eventually the highly controversial problem of the Roman epitaphs will be settled in an authentic manner. This question is of paramount importance and we have tried to collect as much information as possible.

We used the incomplete results of the excavations of the cemetery at Intercisa to control the Intercisa-Brigetio epitaphs. Late in the 1940's excavations started in the area of Dunaújváros (Hungary) revealed a large cemetery, where so far over one thousand graves have been uncovered. The original burial place must have contained several thousand graves. The first series of one hundred members was published by Sági, Barkóczy and Nemeskéri. After diagnosing age and sex in this series, the distribution shown in Table 77 was established.

TABLE 77

Sex and age distribution in the first series of the Intercisa cemetery excavations

Age group	Males	Females	Unidentified sex	Total
Infant I (aged 0–6)	—	—	15	15
Infant II (aged 7–14)	—	—	10	10
Juvenile (aged 15–22)	—	6	—	6
Young adult (aged 23–39)	3	3	—	6
Middle adult (aged 40–59)	3	4	—	7
Old adult (aged 60+)	4	1	—	5
Adults of unidentified age	10	12	21	43
Unidentified age	—	—	13	13
Total	20	26	59	105

The first series of cemetery excavations at Intercisa showed a great variety of burial rites (cenotaphs, cremation graves, Christian rite, coffins of wood, graves with sarcophagi, sarcophagi with epitaphs, etc.) About half of the dead of unidentified age and sex—found in cremation graves—were probably of the infant I age. On this basis the ratio of children to adults was 31 : 67, about one-third. This ratio (31·6 per cent) seems to be too low for generalization, but it is still considerably higher than the ratio in the series of epitaphs discussed, not taking into account the completions (Intercisa-Brigetio 34 : 150; Pearrson 31 : 110; Hombert and Préaux 172 : 641; which means 18·5, 22·0 and 21·2 per cent, respectively).

This comparison of children's graves shows that children: especially infants or young children, are not adequately represented in the epitaphs. This factor makes the completion of an epitaph series absolutely necessary. From the obvious absence of children it is reasonable to assume that the erection of gravestones was influenced by 'preferential' and financial matters resulting in a distorted mortality with regard to age, sex and social status. Yet from the comparison of the two series of Intercisa we have the impression that, despite the probable selective influence of stone-erection, the epitaph series of the Roman era express realistic trends, if somewhat distorted or exaggerated.

The same conclusion applies to any inference made from epitaphs relating to the social differentiation of mortality. The emergence of slavery in the Roman Empire following the demographic revolution of the Neolithic age may have given rise to the social differentiation of mortality, shown in the analysis of Roman epitaphs. Based on Szilágyi's collection (1963), Table 78 shows the data of life spans derived from the material of Roman epitaphs where evaluation was made possible according to social and occupational status. In addition to the differences between urban (Rome) and rural areas, social differences appear most characteristically and convincingly, although they are somewhat distorted.

The military class, with its mixed composition, has been omitted to avoid undue disturbance in the comparison of mortality.

Despite the distortions and fluctuations due to differences in the gravestone erecting habits and to the small number of elements in certain groups of population, the data show the emergence of a social differentiation in mortality in the first centuries B.C. and A.D.

TABLE 78

Average life spans in the Roman era, shown by social status and occupation from epitaphs (based on Szilágyi's data)

Social status	Average life span			No. of epitaphs
	Males	Females	Together	
Rome				
Slaves	17·2	17·9	17·5	678
Manumitted	26·9	23·4	25·2	1,413
Tradesmen, artisans	34·1	24·7	31·2	172
Professionals	40·3	23·1	36·9	425
Outside Rome				
Slaves	26·3	24·5	25·5	572
Carthaginian slaves	33·9	26·9	31·6	314
Manumitted	33·7	31·5	32·6	1,022
Tradesmen, artisans	41·0	33·2	39·2	189
Civil servants	39·4	30·9	37·5	992
Physicians, artists	43·0	36·4	41·9	132
Clergy	58·8	58·2	58·6	505

MORTALITY AT THE DECLINE OF THE ROMAN EMPIRE, DATA OF THE EARLY MIDDLE AGES

Mortality in the Roman era has been studied most exhaustively on the basis of epitaphs by earlier investigators. The principal results of previous research work are shown in Table 79 on the basis of Russell's collection (1958). The epitaph series showing obvious misrepresentation have been corrected to some extent. The radix of these tables (cf. Beloch's table) is not 100, but the total, or corrected, number of the analysed cases. Corrected data are shown in brackets, and expectations of life are given only on this basis.

TABLE 79

Survivorship and life expectancy in the Roman Empire from epitaphs

Age (years)	Iberia (MacDonell)		Asia, Graecia Illyricum (Harkness)	Rome (MacDonell)		Africa (MacDonell)	
	Males	Females		Males	Females	Males	Females
			No. of survivors				
0	1,111	885	2,345	4,575	3,490	6,238	4,459
(0)	(1,296)	(1,042)	(2,728)	(6,924)	(4,731)	(7,227)	(5,166)
1	1,107	883	2,333	4,501	3,444	6,206	4,443
(1)	(1,141)	(917)	.	.	.	(6,360)	(4,546)
5	1,076	862	2,164	3,713	2,974	5,978	4,273
10	1,045	822	1,991	2,954	2,518	5,759	4,115
20	899	687	1,695	2,007	1,669	5,188	3,691
30	660	449	1,222	1,259	800	4,382	3,021
40	502	307	762	782	384	3,635	2,376
50	378	215	500	490	212	3,000	1,899
60	269	120	353	344	138	2,389	1,525
70	163	66	191	200	75	1,756	1,079
80	70	23	83	111	34	1,030	616
90	23	7	19	42	10	441	279
100	10	2	.	4	1	177	140
			Life expectancy (e_x^0)				
0	35·3	30·2	29·2	15·3	16·3	42·9	40·7
1	39·1	33·3	33·1	22·5	21·3	47·7	45·3
5	37·0	31·2	31·2	22·4	20·0	46·3	43·7
10	33·1	27·6	28·7	22·5	18·1	42·9	40·3
20	27·5	21·8	22·7	20·6	14·5	37·1	34·3
30	25·7	20·8	19·6	20·0	15·2	33·0	30·6
40	22·4	18·3	18·9	19·4	16·8	28·8	27·8
50	18·2	14·3	16·5	18·5	16·5	23·9	23·7
60	13·7	12·3	11·9	14·4	13·1	18·8	18·4
70	10·1	9·2	9·1	12·0	10·6	13·9	14·2
80	8·1	8·4	6·0	8·3	7·5	10·5	11·2
90	6·0	7·6	5·1	5·4	6·0	8·8	9·5
100	2·5	2·5	.	2·5	2·5	5·3	3·5

TABLE 79 (cont'd)

Age (years)	Gallia Cisalpina (Harkness)	Calabria, Apulia, Samnium, Sabinum, Picenum (Harkness)	Brutii, Lucania, Campagnia, Sicilia, Sardinia, (Harkness)	Aemilia, Umbria, Etruria (Harkness)	Gallia Narbonensis (Harkness)	Latium (Harkness)	Egypt in the Roman era (Hombert–Préaux)
				No. of survivors			
0	9,27	8,92	1,913	631	422	747	.
(0)	(1,210)	(1,060)	(2,349)	(732)	(520)	(1,127)	(956)
1	9,25	8,86	1,903	624	421	730	813
(1)	.	.	.	.	.	.	.
5	816	813	1,722	578	381	599	752
10	718	716	1,553	532	341	483	699
20	534	506	1,197	436	252	310	571
30	296	331	802	301	149	170	381
40	182	222	538	209	93	107	274
50	120	163	332	133	59	65	181
60	85	110	199	82	41	44	107
70	53	63	105	45	24	34	58
80	29	30	42	14	14	19	30
90	10	7	13	6	5	11	10
100	.	.	.	.	.	.	.
				Life expectancy (e_x^0)			
0	20·7	24·6	24·6	28·4	23·0	14·5	28·7
1	26·0	28·4	29·3	32·2	27·4	21·2	32·7
5	24·9	26·5	27·8	29·9	25·7	21·0	30·8
10	23·0	24·7	25·5	27·7	23·5	20·4	28·0
20	18·9	22·7	21·5	22·7	19·8	19·0	23·1
30	20·5	22·3	19·7	20·8	20·5	20·7	22·2
40	20·5	20·9	17·0	17·8	20·1	20·3	18·8
50	18·9	17·0	14·8	15·6	18·8	20·6	16·0
60	14·8	13·0	12·0	12·2	15·0	18·5	13·7
70	11·4	9·0	9·2	8·2	12·5	13·1	11·4
80	7·3	6·2	6·9	7·8	8·6	9·9	7·8
90	4·0	5·4	4·8	3·2	5·6	4·4	4·0
100	.	.	.	.	.	.	.

In connection with Table 79 it ought to be emphasized once more that the distribution computed on the basis of epitaphs is badly distorted by the fact that inscribed stones were erected to certain persons only (depending on sex, age at death as well as social standing), and not every inscription has survived. Apart from this, the epitaph material also shows certain regularities, and on this basis it is possible to obtain information on another type of differentiation in addition to the integration of mortality. It is possible to observe the emergence of differences according to social standing and urban or rural habitation.

The effects of the disintegration of the highly organized Roman Empire and the subsequent settlement of migrant populations in Europe relating to the mortality pattern, must also be investigated. All these factors occurred during the first centuries of the Middle Ages. We have therefore studied four palaeodemographic series: the completely uncovered Keszthely-Dobogó series of the late Roman era, which also serves as a control of epitaph analyses; as well as the series of the Lombardic cemetery of Hegykő, the Avarian cemetery of Zwölfaxing, and the Avarian-Frankish cemetery of Sopronkőhida.

The Keszthely-Dobogó series of 135 graves was excavated by Károly Sági between 1958 and 1963; some of the graves are from the 9th–11th centuries and one is from the early Roman era. Keszthely and its surroundings at the western shore of Lake Balaton, in the centre of Pannonia, hold a special position concerning the evaluation of ethnical processes in the late Roman era and early Middle Ages. At this point of intersection of ethnical intercourse, a few Romanized elements, Burgundians resettled from the western provinces and the western coast of the Balkan Peninsula, migrants from Illyricum, and from the eastern steppes (probably the Sarmatians) formed anamal gamation of three ethnic elements. This particular cultural unit became fully developed as the Keszthely culture in the centuries following the Roman era.

The cemetery has been completely exposed and the series is highly important because it has been possible to date it accurately. The cemetery was used from the middle of the 4th to the first decade of the 5th century A.D. The internal core of the cemetery dates from the period from 340 to 374 A.D.

From the anthropological aspect, two modal groups of the population can be determined; variability between the two groups is very high. This difference is manifest also in the indices computed from the measurements of cranial and postcranial parts of the skeletons.

The first modal group is mesodolichocephalic, i.e. the cranium is long, of medium breadth or broad. The face is high, of medium breadth, orthognath. The stature is tall or tall-medium. The second modal group is eurycephalic, i.e. the cranium is high brachycephalic and broad, the face of medium height, broad, quadratic, and the profile is flat.

On the basis of the taxonomic analysis, the first modal group can be connected with the Protoeuropoid and Nordic variety of the Europoid main race, the second modal group with the components of the Europoid main race, the Europoid-brachycephalic, and the Dinaric. Individuals belonging to the first modal group differ from the second in several ways. For example, characteristic leather-dressing tools are found in the graves of the Burgundian tanners and 'niche graves' are found in the second modal group. The features of the population of this cemetery are closest to the population of the Roman era in the Dunaújváros (Intercisa) cemetery.

The abridged life table of the Keszthely-Dobogó population is shown in Table 80 (the detailed life tables are given in Tables 124 to 126).

The values of the Keszthely-Dobogó table approximate the values computed from the epitaphs as shown in Table 80. The similarity of the data confirms, to a certain extent, the results coming from various sources. There is no doubt, however, that—as appears from Fig. 73—infant mortality is not adequately represented in this series, and this fact distorts the data of the life table.

TABLE 80

Abridged life table of the Keszthely-Dobogó population of the late Roman era

Age (x)	Distribution of deaths: No. (D_x)	Distribution of deaths: Per cent (d_x)	Survivors (l_x)	Probability of death (q_x)	Total no. of years between ages x and $x + 5$ (L_x)	Total after lifetime (T_x)	Life expectancy (e_x^0)
0–4	21·5	17·9	100·0	0·2	455·2	3,528·8	35·3
5–9	9·5	7·9	82·1	0·1	390·6	3,073·6	37·4
10–14	3·0	2·5	74·2	0·0	364·6	2,682·9	36·2
15–19	4·1	3·4	71·7	0·0	349·8	2,318·3	32·4
20–24	4·9	4·0	68·2	0·1	331·1	1,968·6	28·8
25–29	4·9	4·1	64·2	0·1	310·8	1,637·5	25·5
30–34	4·6	3·8	60·1	0·1	291·0	1,326·7	22·1
35–39	9·5	8·0	56·3	0·1	261·5	1,035·7	18·4
40–44	7·9	6·6	48·3	0·1	225·2	774·1	16·0
45–49	12·1	10·1	41·7	0·2	183·5	548·9	13·2
50–54	10·7	8·9	31·7	0·3	136·2	365·4	11·5
55–59	8·9	7·4	22·8	0·3	95·4	229·3	10·1
60–64	5·2	4·3	15·4	0·3	65·9	133·9	8·7
65–69	5·8	4·9	11·0	0·4	43·0	67·9	6·2
70–74	5·1	4·3	6·2	0·7	20·2	25·0	4·0
75–79	2·3	1·9	1·9	1·0	4·8	4·8	2·5
Total	120·0	100·0	—	—	3,528·8	—	—

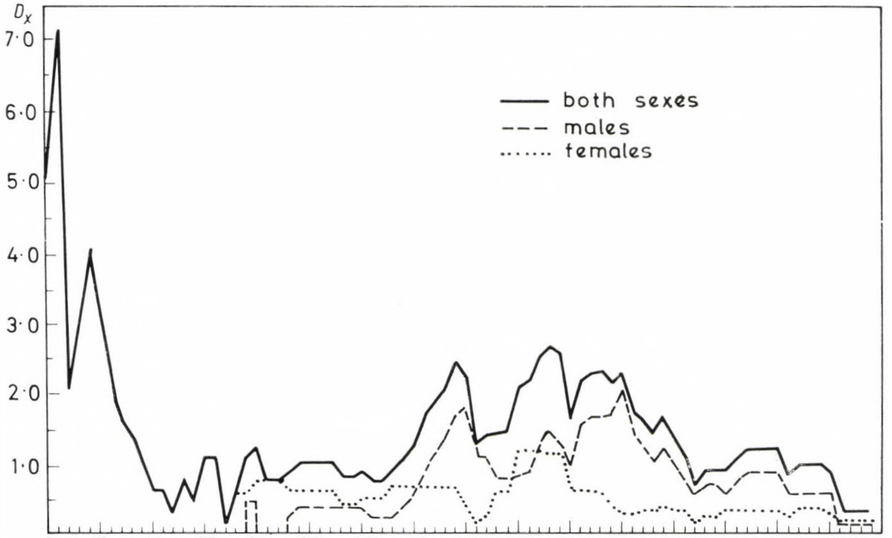


Fig. 49. Age distribution of the dead of the Keszthely-Dobogó population.

Certain data of the Keszthely-Dobogó life table will be discussed in connection with the Sopronkőhida series; but it is already obvious from Fig. 49 that the distribution of the two sexes is different. Males have a better chance of living at least to the first half of middle adult age.

The cemetery of Hegykő was excavated by Nováki in 1957, then by Bóna in 1960, 1961 and 1963; 83 graves were opened up. The Lombards, who had set up this cemetery and used it for about 60–70 years, came from the north-west to settle in the territory of Hungary in the 6th century. They made a short stay in Transdanubia, then migrated south-west to reach North Italy via the territory now known as Jugoslavia.

The Hegykő Lombard ethnic unit survived in this region as a relict, probably longer than the majority of the Lombards. This is not an extraordinary phenomenon, as the presence of the Lombards can be detected even in some of the Avarian cemeteries in this country. The ethnic unit of Hegykő has preserved the original features of the Lombard group, as shown by the uniformity and distinct Lombard character of the finds. Anthropologically this population has differentiated into two essential type elements. About 80 per cent of the population are characterized by dolichocephalic Europoids (Nordic), and about 20 per cent belong to the meso-brachycephalic type. The amalgamation of these can also be demonstrated, especially on the basis of dental deformities and transpositional dental anomalies.

We have found that the age distribution of the dead of the Lombard population of Hegykő is similar to that of the Zwölfaxing Avarian cemetery (Table 81). In 1957–58 the Zwölfaxing cemetery of 212 graves was uncovered by Kromer, and Ehgartner. This cemetery may be regarded as completely uncovered both archaeologically and anthropologically. Ethnically it belongs to the griffin-tendril group of the Avarian; the population is partly Europoid and partly of an extremely differentiated Mongoloid character. The Mongoloid varieties, showing a ratio of 10–15 per cent, belong for the most part to the Baikal and Tungid types determined by Bartucz. A large number of pathological abnormalities appear in the anthropological material of the cemetery.

The material from this cemetery, which was in use for some 120–150 years, has not yet been analysed archaeologically or anthropologically.*

The age distribution of the dead in the Hegykő and Zwölfaxing series is compared in Table 81; a comparison is also made with the data of the Keszthely-Dobogó life tables.

It appears from Table 81 that the mode of mortality can be found in middle adult age, both in the Keszthely-Dobogó series of the late Roman era and in the other series of the migration period. So it is most unlikely that the decline of

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* We hereby express our thanks to the late Dr. W. Ehgartner, Assistant Professor, for having given us permission to study this material, and to Dr. J. Jungwirth, Director of the Anthropological Department of Naturhistorisches Museum, Vienna, for his substantial assistance in the determination of the material.

TABLE 81

Age distribution of the dead from the late Roman era to the early Middle Ages

Age group	Keszthely-Dobogó 4th–5th centuries	Hegykő (Lombard) 6th century	Zwölfaxing (Avarian) 7th–8th centuries	Sopronkőhida (Avarian–Frankish) 9th century
		Number		
0–6	27	8	48	57
7–14	7	13	26	10
15–22	7	4	15	9
23–39	21	19	38	15
40–59	40	20	53	41
60–*x*	18	7	41	13
Total	120	71	221	145
		Per cent		
0–6	22·5	11·3	21·7	39·3
7–14	5·8	18·3	11·8	6·9
15–22	5·8	5·6	6·8	6·2
23–39	17·5	26·8	17·2	10·3
40–59	33·4	28·2	24·0	28·3
60–*x*	15·0	9·8	18·5	9·0
Total	100·0	100·0	100·0	100·0

the Roman Empire and the subsequent migrations have fundamentally modified or increased the mortality. It is true that the ratio of dead children is much higher at Sopronkőhida than in cemeteries from preceding periods, but this may be the result not so much of a deterioration in the mortality pattern but may result from the fact that children (primarily infants) are not adequately represented in the other series.

A certain deterioration of the mortality pattern might be inferred from a decrease in the ratio of middle adult and old adult deaths, and above all from the fact that many of the Hegykő Lombards died before the adult age. The ratio of individuals in the old adult age groups in the Avarian cemetery of Zwölfaxing is higher than in the late Roman era. Nor can the 9–10 per cent ratio of people in this group in the other two cemeteries be considered low, especially at Sopronkőhida, where child mortality is well represented and adults may figure with less weight in the distribution. If we determine the distribution of deaths at the age of 15 or above, we obtain a modified picture of adult mortality.

Considering every argument, the demographhic hypothesis that mortality patterns showed a temporary decline in the first centuries following the disintegration of the Roman Empire cannot be rejected without some reservations. Some corrections, based on future research will have to be made as the hypothesis depends

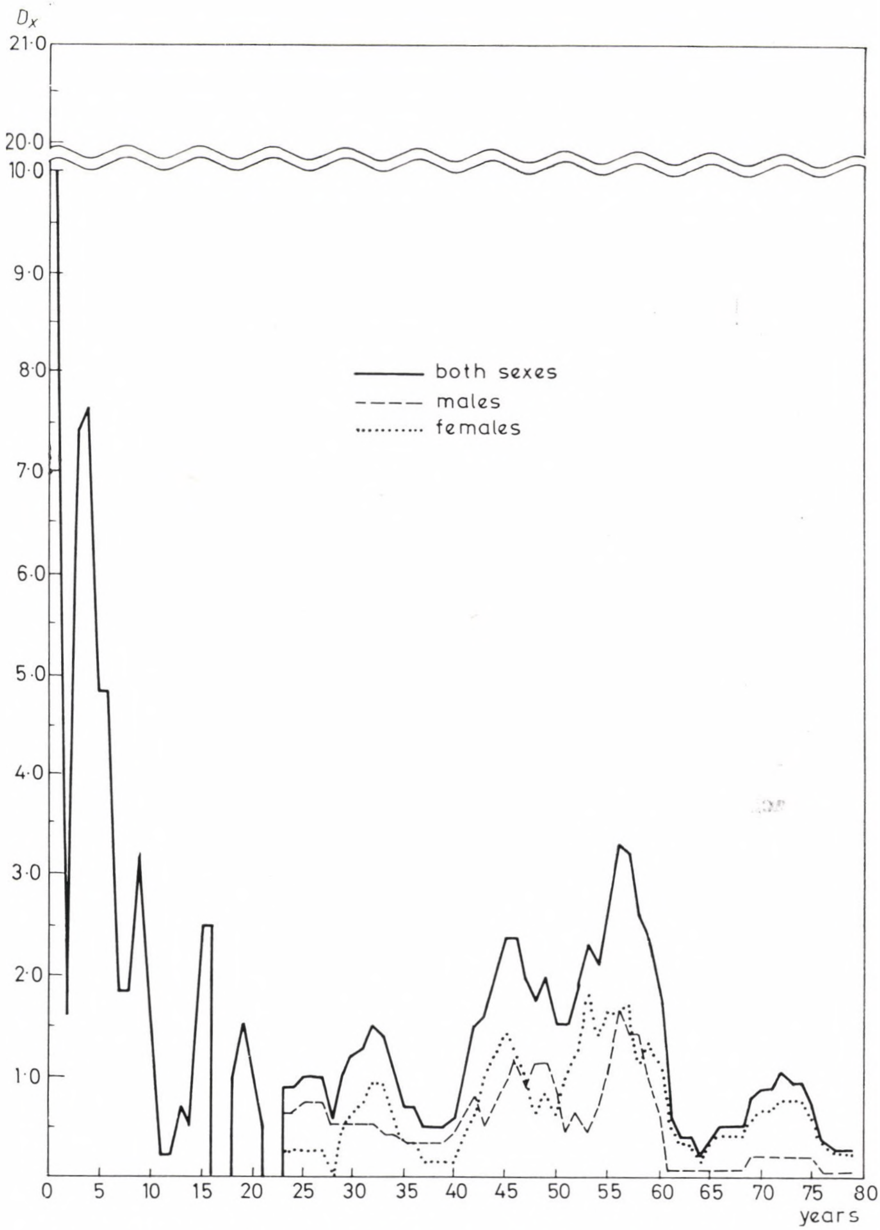

Fig. 50. Age distribution of the dead of the Sopronkőhida population.

mainly on the population decrease in certain large cities (Rome, for example). The Sopronkőhida series (distribution by age at death is shown in Fig. 50) is a good example showing that although mortality rates may have increased temporarily, the increase was inconsiderable.

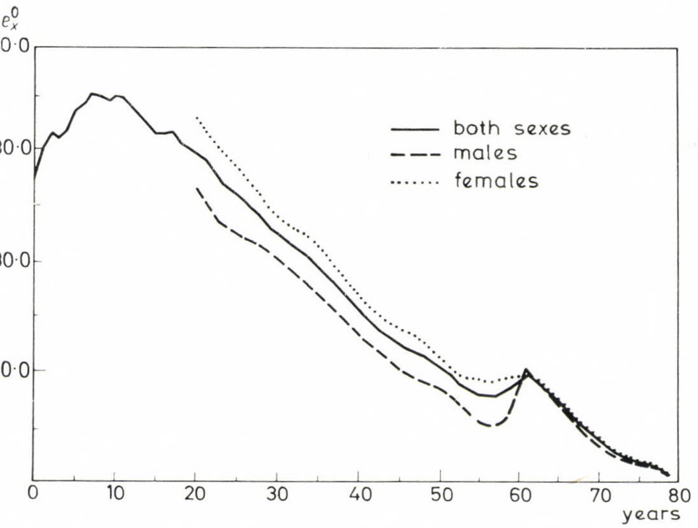

Fig. 51. Expectations of life of the Avarian-Frankish population of Sopronkőhida.

Excavation of the Sopronkőhida cemetery was started by Szőke in 1951, and was completed by Török between 1956 and 1960. The cemetery was used in the 9th century (about 805 to 880). The fate of this population was connected with the defeat of the Avars by Charles the Great when those remaining in the north-west corner of Transdanubia were subjected to Frankish sovereignty. At the Imperial Diet of Aachen the Avars living in that region of Transdanubia asked for help against the harassment by the Slavs and so a settlement area was assigned to them between Carnutum and Savaria, the territory between the rivers Rába and Danube.

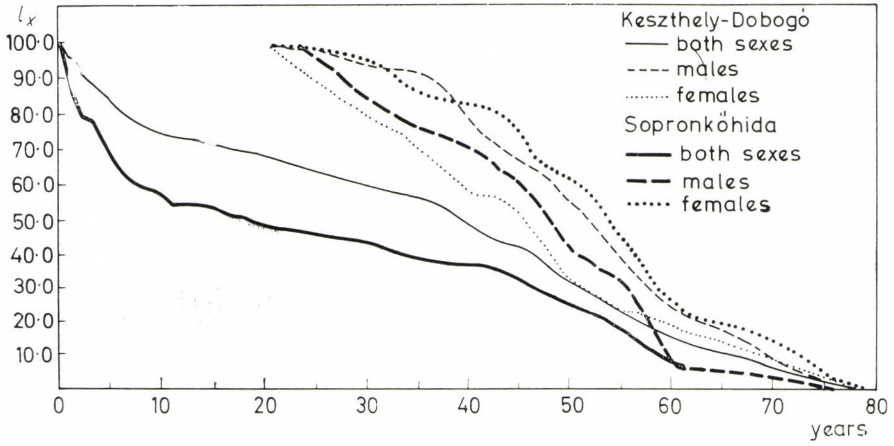

Fig. 52. Survivorship of the Keszthely-Dobogó and Sopronkőhida populations.

In the 9th-century cemetery of Sopronkőhida three anthropological types appear. (*i*) A tall, dolichocephalic element with very high, narrow faces, showing moderate Mongoloid features. This type may be connected mainly with the dolichocephalic variety of the Mongoloid main race. (*ii*) Medium stature, brachycranic, euryprosopic, with moderate flatness. This type has developed at the boundary of the Europoid and Mongoloid main races, and can be classified as belonging to the South-Siberian (Turanoid) type. (*iii*) A mixed variety of the above two types, type *i* dominating. Type *i* had preserved the memories of a heathen cult, as the skulls of cattle with the stumps of horns had been placed above the skeletons in the graves. This burial with animal masks is connected, according to Török, with Shamanism. The heathen cult of animal-mask burial could not be proved with types *ii* and *iii*. Types *i* and *ii* belonged probably to individual age cohorts, and at the time when the cemetery was abandoned the population consisted of the

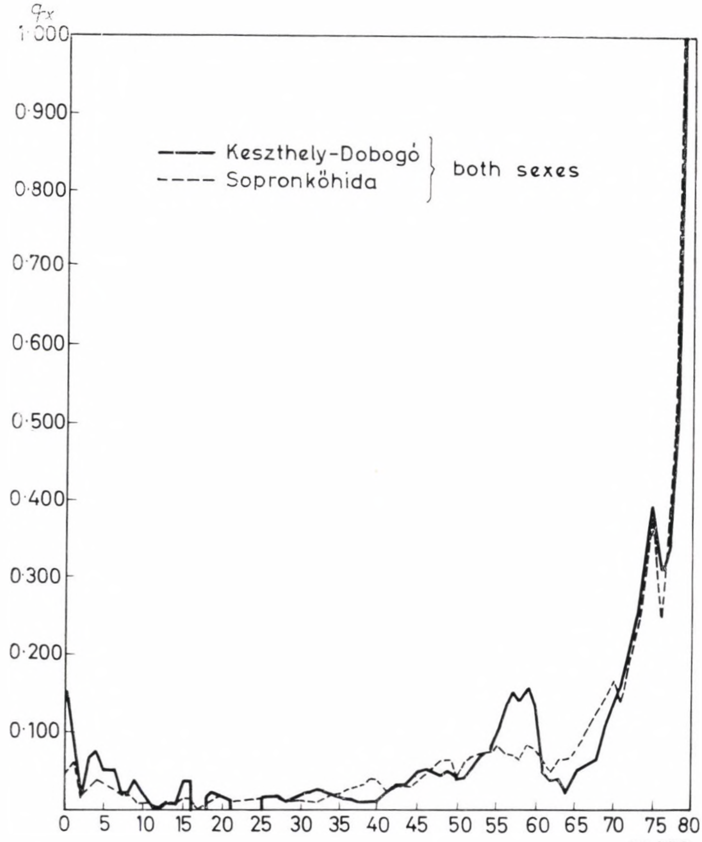

Fig. 53. Probabilities of death in the Keszthely-Dobogó and Sopronkőhida populations.

mixed type (*iii*) representing part of the second, and including the complete third generation.

The detailed life tables of the Sopronkőhida series are to be found in Tables 127 to 129. Owing to the completeness of the Sopronkőhida series, the undistorted picture of expectancies from various ages of life are highly instructive.

The expectation curve at Sopronkőhida (Fig. 51) starts with 26·7 years; and ascends rapidly up to the age of 7, where it shows 35·2 years. The survivorship of Sopronkőhida is shaped in accordance with the expectation of life. Apart from two minor breaks in childhood and at old age (the latter being unjustified), this pattern may be regarded as a representative type. If the survivorship of Keszthely-Dobogó is compared with that of Sopronkőhida, the distorted character of the former series becomes obvious (Fig. 52).

The difference in levels appearing between the survivorship patterns in Fig. 52 vanishes almost completely in Fig. 53, where the probabilities of death of the two series are compared.

There is no substantial difference between the two curves of Fig. 53, and the minor irregularities are of no consequence. Yet it clearly appears that an acceptable infant mortality is contained only in the Sopronkőhida figure, while the temporary peak of mortality between the ages of 55 and 60 in this series (caused by high male mortality) and the low value between 60 and 70 cannot be regarded as 'normal'.

Apart from the anomalies mentioned, the distribution of the Sopronkőhida series represents a type which may be regarded as the beginnings of the mortality of the Middle Ages (see Chapter VII).

CHAPTER VII

HISTORICAL TRENDS OF MORTALITY AND THE 'DEMOGRAPHIC REVOLUTION'

PALAEODEMOGRAPHIC MATERIAL FOR ESTIMATION OF MORTALITY CONDITIONS IN 10TH–12TH-CENTURY HUNGARY

Through lack of adequate sources, the results produced by European historico-demographic research in respect to the Middle Ages are scarcer than those relating to antiquity. This also applies to Hungarian historical demography where widely differing results have been derived from the few, incomplete written sources of uncertain value. Attempts have been made on this basis to estimate the number of the conquering Magyars, the size of populations living in this country between the 9th and 12th centuries and the trends of population size in mediaeval times. The situation is similar to the reconstruction of mediaeval Hungarian mortality patterns, though it is much favourable than with general historical demography. Not much help can be obtained from written historical sources for studying mortality, but limited numbers of palaeodemographic sources (cemetery excavations) are available. An attempt can be made to give an outline of mediaeval mortality in Hungary on this basis (Bartucz, 1931; Éry, 1966–67; Fettich, 1931; Győrffy, 1959, 1963; Kniezsa, 1938; László, 1944; Nemeskéri and Gáspárdy, 1954).

Hungarian mortality patterns in the 10th–12th centuries are particularly easy to study. A fairly large number of cemeteries from this period have been uncovered by Hungarian archaeologists. Many of them are appraisable from the palaeodemographic point of view, and several large series are available where the excavation and analysis have been carried out with due regard to the requirements of palaeodemography.

Needless to say, further research work is needed to make a final analysis of the problems involved. The results produced so far are homogeneous in many respects allowing certain generalization to be made. A complex study of various cemeteries will always yield more dependable results, as in independent series the influence of special, individual factors is frequently expressed more intensely.

On the other hand, generalized results may differ from reality considerably. If we were able to select the skeletal remains and cemeteries to be studied according to the rules of statistical sampling, we could determine the probable error of generalization accurately. Unfortunately, in the selection of palaeodemographic material not the sampling principles, but the actual possibilities have to be considered. The representative character of available series also differs widely. We cannot therefore determine the probable error of the reconstructed values of Hungarian life span and mortality patterns in the 10th–12th centuries, but we can give an idea of the order of magnitude using a parallel example.

The comparison is based on the fact that, from the statistical angle, the possibility of analysing a particular mediaeval cemetery may be regarded as almost accidental.

From a practical point of view a graveyard is excavated entirely independently of the mortality pattern reflected in the cemetery. A number of haphazard circumstances are involved in coming across an ancient, forgotten burial site (road and railway construction, building, agricultural work, mining, cutting canals, etc.). Another hazard is whether competent experts are informed about the find. Then funds, experts, time, etc. have to be made available for the excavation. On this basis, if the skeletal finds from the available 10–20 cemeteries of several hundred graves could be regarded as a true sample and the size of the mediaeval Hungarian population (by 30-year cohorts) had been one million, expectation of life at birth could be estimated— at a 99 per cent probability level—with an accuracy of 1 year. But this relative error of approximately 3 per cent represents the optimum reality to be expected from the results. If the skeletal finds in the various cemeteries are interpreted as series, we must also make allowances for the probable error in group selection which, under similar conditions, would be 4–5 years, i.e. a relative error of about 10 per cent when considering e.g. the expectancy after the age of 20. The probable relative error in estimates regarding the distribution of deaths would be of the same magnitude.

The number of mediaeval cemeteries in Hungary from which archaeological finds have been made available to museums is about one thousand. Nevertheless, there are relatively few series among these which are suitable for scientific analysis from the point of view of mortality. In Székesfehérvár, for example, we know of more than a dozen cemeteries from the 10th–12th centuries. Yet only some 2 or 3 of these series furnish reliable data; for instance, all that is known of the Székesfehérvár-Demkóhegy or the second Maroshegy cemeteries is the age at death of two adults from each cemetery, from among the 5–600 graves found there. Unfortunately no information on the age distribution of the dead can be obtained even from series such as the 10th–11th-century cemetery at the Calvary Hill in Veszprém where there are more than hundred burials. Here the secured 30 skeletal remains (1 juvenile, 19 adult males and 10 adult females) had been selected in 1931 according to current methods, considering the intact condition and morphological characteristics of the skulls and the richness of the graves. (Acsádi and Nemeskéri, 1957, 1958, 1959, 1960; Éry and Kralovánszky, 1960; Fehér, Éry and Kralovánszky, 1962; Marosi, 1920–22, 1923–26, 1936).

As an initial approximation to the age distribution of the dead in mediaeval populations, it would seem advisable to determine the ratio of deaths in childhood and adult age. Relevant data are available not only from series already analysed palaeodemographically, but are usually contained in the excavation records as well. This is so even in cases where the skeletal remains have not been secured. Doubtless, entries of similar character in older excavation records are inaccurate and those relating to ages of life are of uncertain value. But they are suitable for keeping children and adults apart even if the diagnosis had been made by non-experts. When estimating the child-adult ratio of deaths we may also rely on another eight series in addition to the series of Kérpuszta and Halimba, the three 10th–12th-century cemeteries at Székesfehérvár and another three at Zalavár, which we have described in earlier palaeodemographic publications. The analysis of the additional material was based on the secured skeletal remains and the data of the excavation records (Table 82) (Fehér, 1953 to 1957; Sós and Bökönyi, 1963).

The percentage of children varies widely in the series examined (minimum 18·9, maximum 58·0), making the acceptability of the extreme ratios questionable. As there is a relationship between the percentage of children and expectation of life at birth (see Chapter I), the true ratio of dead children may be judged on the basis of the U.N. model life tables. Relying on proofs from the Roman era, the early and late Middle Ages, as well as on completely excavated Hungarian mediaeval cemeteries, it is highly probable that expectation of life at birth may have been between 25 and 35 years in Hungary in the 10th–12th centuries. Accordingly, from the U.N. model life tables the percentage of child deaths must have been as shown in Table 83. Other values corresponding to longer expectancies are also shown in the

TABLE 82

Child–adult ratio in 10th–12th-century Hungarian cemeteries

Site and century	Number				Per cent*		
	Children 0–14 years	Adults aged 15+ years	Undefined	Total	Children 0–14 years	Adults 15+ years	Total
Fiad-Kérpuszta, 11th	152	243	—	395	38·5	61·5	100·0
Halimba-Cseres, 10th–11th	332	600	—	932	35·6	64·4	100·0
Zalavár							
Village, 11th	66	75	—	141	46·8	53·2	100·0
Castle, 9th–11th	95	331	—	426	22·3	77·7	100·0
Chapel, 11th	44	133	—	177	24·9	75·1	100·0
Székesfehérvár							
Bikasziget, 10th–11th	23	47	5	75	32·9	67·1	100·0
Sárkeresztúri út 10th	9	22	—	31	29·0	71·0	100·0
Szárazrét, 11th	65	47	5	117	58·0	42·0	100·0
Ellend I, 10th–11th**	48	206	20	274	18·9	81·1	100·0
Ellend II, 11th**	58	119	7	184	32·8	67·2	100·0
Hencida, 10th	7	16	3	26	30·4	69·6	100·0
Oroszvár,† 10th–11th	28	80	7	115	25·9	74·1	100·0
Palotabozsok, 11th–12th	23	51	17	91	31·0	69·0	100·0
Somogy-Vasas, 11th	66	82	14	162	44·6	55·4	100·0
Sorokpolány, 10th–11th	74	238	—	312	23·7	76·3	100·0
Zsitvabesenyő,†† 10th–11th	24	49	—	73	32·8	67·2	100·0
Total	1,114	2,339	78	3,531	32·3	67·7	100·0

* Excluding those of undefinable age (aged 15–22).

** Adolescents are taken as children.

† Today Rusovce, Czechoslovakia.

†† Today Besenovo, Czechoslovakia.

TABLE 83

Expectation of life at birth and the ratio of dead children according to U.N. model life tables

Life expectancy at birth (e_0^0)	Level	Percentage of child deaths (d_{0-14})
20	0	57·6
.	.	.
25	10	49·5
27·5	15	45·9
30	20	42·6
32·5	25	39·5
35	30	36·6
40	40	31·2
45	50	26·2
.	.	.
73·9	115	2·1

Table because such ratios of dead children have been found in some mediaeval series (Acsádi and Nemeskéri, 1957; Acsádi, Nemeskéri and Harsányi, 1959; Acsádi, Harsányi and Nemeskéri 1962; Acsádi, 1965; Éry, Kralovánszky and Nemeskéri, 1963; Kralovánszky, 1959; Széll, 1941; Török, 1962).

It appears from Table 83 that the ratio of dead children between 36 and 50 per cent may be regarded as authentic, and also between 30 and 36 per cent could be realistic in certain series. How can complete excavations yield ratios between 20 and 30 per cent? The explanation for the low ratio of children in the cemeteries of Zalavár Castle and Chapel can be found—and verified by historical sources—in migration. This settlement was once a principality residence and the population contained many immigrant individuals (soldiers and the clergy) and the child mortality of immigrant generations consisting mainly of adults is reflected in the cemeteries of their place of origin and not in the new residence.

However, Table 82 contains a number of cemeteries—in addition to those of Zalavár—whose low child ratio cannot be accounted for by migration. The explanation that the skeletons of infants and small children decay in the soil without leaving any trace cannot be accepted. Under identical conditions the chances that a child's skeleton will decay completely are no greater than that for an adult. It should be noted, too, that the traces of burial, the graves and most of the objects placed in them are recognizable in most types of Hungarian soil even if the skeleton might have decayed for some 'natural' reason. It is characteristic that reservations of this nature in connection with series suitable for demographic analysis are usually made by non-experts. The expert archaeologist or anthropologist does not question this fact, he only considers it possible to disregard infant mortality where there are special soil conditions or circumstances of excavation. On the other hand, it is possible that certain infants and children were not taken to the usual cemetery at all (special burials), or that their graves were more likely to be destroyed in some cases.

Beginning in the Neolithic, the low ratio of small children may also be explained by the custom of exposure. Other detached burial customs are to be found at certain cultural standards as well. In certain mediaeval populations it may have happened that not much care was devoted to burying infants or the stillborn. The problem of unbaptized children might be raised in case of Christian cemeteries. But in the mediaeval series examined, these questions are of no special consequence. Even more important is the selective destruction found in cemeteries where intensive farming (ploughing) has been conducted for a long time, or where the soil is soft and highly exposed to erosion by wind or water.

It should be kept in mind that the graves dug for adults are as a rule not only larger but also deeper than those of children. A cemetery of 726 graves from the Avarian period (Alattyán-Tulát) (Kovrig, 1963) shows the following recorded picture concerning the depth of the graves:

Items in the excavation records	*Average depth of graves (cm)*	*No. of graves*
Graves of men	142	68
Graves of women	136	64
Graves of adults, without furniture	129	26
Graves of juveniles	130	98
Graves of small children	106	19
Graves of infants	72	89

The measured depths depend on the changes of the surface that had taken place meanwhile, but since the dead of different age and sex are distributed at random in the cemetery, the differences of ground surface do not substantially affect the average grave depth of the various groups. It is obvious, though, that the graves of infants and children are less deep and fall victim to changes in the soil surface sooner than the deeper graves of adults.

A selection of this type and its effects can be traced very clearly in the cemetery of Kérpuszta. At an average grave depth of 62 cm, there were found graves at 15 cm depth, partly ploughed up, as well as graves 145 cm deep. Grouped by sex and age, the average grave depths were as follows:

Sex and age		*Average grave depth (cm)*	*No. of graves*
Graves of men		70	95
Graves of women		70	102
Graves for 15–22	year olds	70	35
7–14		64	26
1–6		54	55
0		44	70

Concerning the relation between the depth of the graves, and age, the same trend appears at Kérpuszta as in the Avarian cemetery of Alattyán. As children grew older and bigger, the graves increased in size and depth.

Although the ratio of infants and children is rather high in the Fiad-Kérpuszta series (38·5 per cent including 18·2 infants), it must be taken for granted that many graves have decayed. In the relief map of the area shown in Fig. 54 the depth of the graves is also indicated. Adult graves vary in depth throughout the cemetery. On this basis eight zones can be delimited. In zones VI and VIII on the flat hilltop grave depth is 95–145 cm and 80–100 cm, respectively. Equally deep graves are

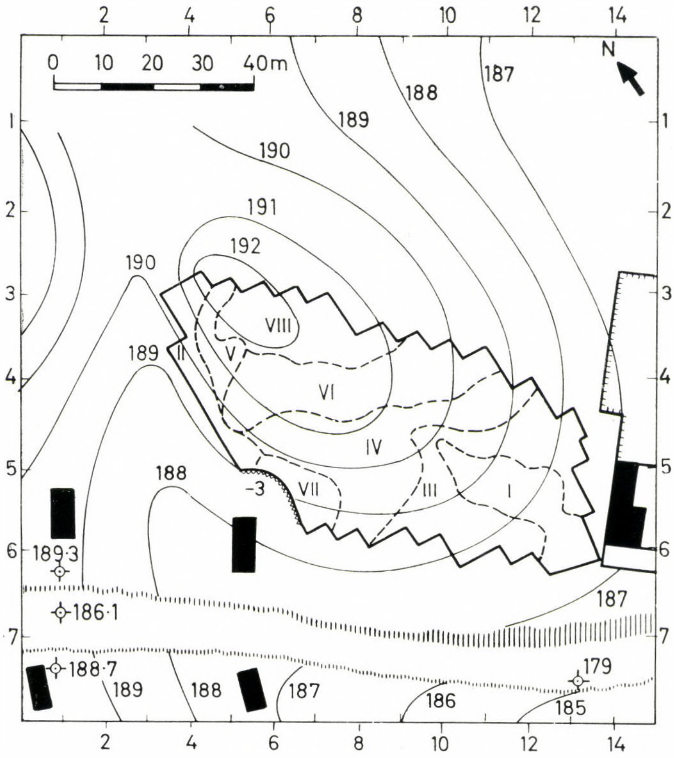

Fig. 54. Relief relations and the depth of graves in the Kérpuszta cemetery.

to be found in zone VII above the worked pit (90–110 cm). Zones II and V, on the more abrupt western slope of the hill, show a gradual decrease in the depth of the graves (70–90 and 15–50 cm). Zones I, III and IV on the southern slope show that the graves have become shallower along the longitudinal axis of the hill. It appears that this distribution of grave depth in areas under agricultural cultivation has been produced by the natural forces, especially water.

The consequences of the varying soil erosion appear clearly in the age distribution of series uncovered from the various areas.

Even without surface changes an identical distribution in the various areas could not possibly be expected. The effects of chance distortion appear from the distribution shown in Table 84. It is unlikely that graves would have been destroyed in zone VII, shown by the fact that the ratio of children aged 7–14 is highest here, while the proportion of infant graves is as low as in zones I and II. Again the ratio of infants is relatively low in zone IV which contains many graves of medium depth, while the ratio of small children (1 to 6) is exceptionally high. Thus the 15·7 per cent ratio of infants does not prove the destruction of infant graves; it only shows that less infants were buried here than in zones VI or VIII.

TABLE 84

Age distribution of the dead in certain zones of the Fiad-Kérpuszta cemetery

Zones	Depth of adult graves (cm)	No. of dead	Distribution of deaths			
			Infant (aged 0)	Infant I (1–6)	Infant II (7–14)	Juvenile and adult (15+)
I	20– 40	21	9·5	4·8	4·8	80·9
II	15– 50	23	4·8	9·5	9·5	76·2
III	40– 60	43	16·3	7·0	2·3	74·4
IV	60– 80	89	15·7	20·2	3·4	60·7
V	70– 90	33	18·2	9·1	6·1	66·6
VI	80–100	83	24·1	15·7	10·8	49·4
VII	90–110	26	7·7	15·4	15·4	61·5
VIII	95–145	77	28·6	10·4	3·9	57·1

Apart from the accidental distortion it also appears from the data of Table 84, that in areas eroded by surface changes, adult graves are shallow and the number of infant and infant II graves, which were not too deep originally, is low. This tendency is especially conspicuous if we pool the data of these areas which contain graves of similar depth (Table 85) (Lipták, Nemeskéri and Szőke, 1953).

It is obvious from these integrated data that no children's graves were destroyed in areas where the graves of adults are deeper than 60 cm. In zones I to III, however, a minor selection of children's graves, determined by their depth, can be taken into account. On the basis of the proportions found in zones IV to VIII, the number of children's graves destroyed as a result of surface changes in the soil may be estimated at about 26 in the whole cemetery. Half of these may have been infant graves, 10 of them belonged to group infant I, and 3 of them to group infant II.

TABLE 85

Age distribution of the dead and depth of graves in the Fiad-Kérpuszta cemetery with the data of some zones pooled

Zones	Depth of adult graves (cm)	Distribution of deaths			
		Infant (aged 0)	Infant I (1–6)	Infant II (7–14)	Juvenile and adult (15+)
I–II	15–50	7·1	7·1	7·1	78·7
III	40–60	16·3	7·0	2·3	74·4
IV–V	60–90	16·4	17·2	4·1	62·3
VI	80–100	24·1	15·7	10·8	49·4
VII–VIII	90–145	23·3	11·7	6·8	58·2
I–III	– 60	11·8	7·1	4·7	76·4
IV–VIII	60–	20·8	14·9	6·8	57·5

This number modifies the age distribution in this cemetery of nearly 400 graves only slightly, so no attempt will be made at correcting the data of earlier publications. Yet such surface changes might have caused more extensive selection in other cemeteries, where this must be considered in palaeodemographic analysis.

In connection with the child–adult ratio in the series examined, mention must be made of the problem of undefinable age and sex. The skeletons of such individuals have not been secured and there are no data on them in the excavation record either so we know nothing definite about them. Most probably many (or even most) of them were children. If the individuals of undefinable age are added to the children, the range of the children's ratio will be somewhat narrowed (minimum 23·7, maximum 60·0 per cent, average 33·8 per cent) but it is still considerable. But even so the children's ratio in the Ellend I and Sorokpolány series remains below 30 per cent.

The influence of differential mortality must also be taken into consideration in the development of the different infant ratios. It may be taken for granted that in this period social status already played a role in forming differences of mortality patterns. It is impossible to include the social standing of the dead within this analysis. But it is easier to define the situation of a series, its wealth, or poverty, by listing the frequency of graves containing 'furniture'.

TABLE 86

Per cent ratio of dead children and furniture graves in some Hungarian cemeteries of the 10th–12th centuries

Series	Ratio of children		Ratio of furniture graves in the cemetery
	including the undefined	without the undefined	
Székesfehérvár-Szárazrét	60·0	58·0	20
Palotabozsok	43·9	31·0	27
Fiad-Kérpuszta	38·5	38·5	34
Székesfehérvár-Bikasziget	37·3	32·9	39
Ellend II	35·3	32·8	39
Somogy-Vasas	49·4	44·6	41
Székesfehérvár-Sárkeresztúri út	29·0	29·0	42
Ellend I	24·8	18·9	48
Oroszvár	30·4	25·9	50
Sorokpolány	23·7	23·7	53

In Table 86 the ratio of children and that of 'furniture' graves show a negative correlation: the wealthier a cemetery, the lower is the ratio of dead children, i.e. the better are the mortality conditions the cemetery reflects. Remembering that 'furniture' is a heterogeneous concept, as the objects placed in graves depended not only on economic but also on cultural and ethnical factors, this correlation is not a close one as shown, for instance, by the dissenting data of the Somogy-

Vasas cemetery. Nevertheless, the trend of the above correlation is apparent from the following and from Fig. 55.

Ratio of furniture graves, %	*Average ratio (unweighted) including the undefined*	*of child graves, % without the undefined*
–34	47·5	42·5
35–44	37·8	34·8
45–	26·3	22·8

This correlation is not contradicted by the series where the 'find statistics' have not been analysed. For instance, the Zalavár Castle and Chapel series with their low child ratios represented the cemeteries of the upper classes within the feudal system, as opposed to the series of Zalavár Village, a cemetery of serfs containing a high ratio of children. The other series represent a medium child ratio—between 30 and 40 per cent—and may be regarded as standing in the middle of any social class structure.

It can also be seen from the series analysed that older cemeteries were usually richer in finds than more recent ones indicating the process of cemetery 'impoverishment'. As suggested by more extensive and thorough archaeological studies, this process is the outcome of the changes in society and parallel changes in burial customs, accompanying the gradual decline of the mortality pattern in the 10th–12th centuries. This, however, does not contradict the assumption about the differentiation of mortality in this period.

On the basis of the above, the scattering of the child–adult ratios cited may be regarded as authentic to a limited extent, irrespective of whether they are the result of contemporary social differences or temporary differences in standards of living. The child ratio of Székesfehérvár-Szárazrét is an exception of extremely high value, and can hardly be generalized. The possibility cannot be excluded, however, that certain populations living in very poor circumstances might have had such high mortality rates. Child ratios between 35 and 50 per cent are usually realistic; most of the series belong to this range, especially if some of the undefinable individuals, or all of them, are taken into account. In estimating the averages of mediaeval Hungary, we shall not take into account the cemeteries of Zalavár Castle and Chapel owing to distortions by migration, and the cemeteries of Ellend I and Sorokpolány because they are presumably incomplete.

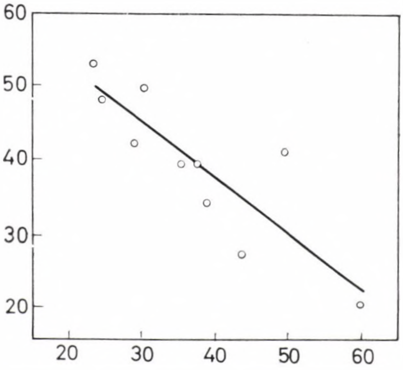

Fig. 55. Correlation between the ratio of dead children (x) and of furniture graves (y).

TABLE 87

Per cent ratio of child and adult deaths in Hungary in the 10th–12th centuries

Series	Age distribution of the deaths	
	0–14 years	15+ years
Fiad-Kérpuszta	38·5	61·5
Halimba-Cseres*	39·3	60·7
Zalavár Village	46·8	53·2
Székesfehérvár-Bikasziget**	35·1	64·9
Székesfehérvár-Sárkeresztúri út	29·0	71·0
Székesfehérvár-Szárazrét**	59·0	41·0
Ellend II†	35·3	64·7
Hencida†	38·4	61·6
Oroszvár†	30·4	69·6
Palotabozsok†	43·9	56·1
Somogy-Vasas††	44·6	55·4
Zsitvabesenyő	32·8	67·2
Total*†	39·4	60·6

*Data completed to infant mortality of 120 per thousand.

**Undefined ages evenly distributed to child and adult age groups.

†Undefined ages counted to children.

††Undefined ages distributed in accordance with the child–adult ratio.

*†Unweighted average.

The neglect of these four series involves the elimination of populations living under favourable conditions, and this, in turn, might lead to a distortion of the average to be determined. But the more complete uncovering of certain cemeteries often results from their 'abundance in finds' and therefore the above omissions will be compensated for. We use the somewhat corrected data of the series shown in Table 87 for determining the child–adult ratio in contemporary Hungary.

In Table 87 the scattering of the ratios is lower. True, the extreme values are still far apart (e.g. child ratio is minimum 29·0, maximum 59·0 per cent), but the child ratio varies between 35 and 47 per cent in the majority of the series (8 out of 12). It is characteristic of the stability of averages calculated unweighted from the series—i.e. taking each series with the same weight—that if the extreme values such as Székesfehérvár-Szárazrét with its extremely high child ratio, and the three series with the lowest child ratio (Székesfehérvár-Sárkeresztúri út, Oroszvár, Zsitvabesenyő) are eliminated, the average child–adult ratio still remains 40 to 60 (40·2 per cent children, 59·8 per cent adults). According to the U.N. model life tables, this proportion corresponds to 30–35 years to be expected at birth, which seems probable if the data of the Roman era and mediaeval England are considered. It is just as probable that this proportion is scattered in the various series territorially (depending on social and ethnical differences), and maybe also temporally, between the indicated limits. There is no doubt that if we knew more about the prevalence of certain cemetery types, i.e. the types of distribution from more extensive archaeological studies, we could weight the various distributions with their frequency and obtain more realistic proportions, nearer to the truth. It may be supposed, however, that average proportions obtained in this way would not differ substantially from the 39–40 to 60–61 per cent proportion determined at present.

We have had to dwell at some length on the determination of the ratio of these two large groups of the dead, as this is fundamental when determining mortality conditions. The conclusions drawn from the distribution within these two large age groups will be referred to these ratios in the following.

The age groups of children, (as there are some series where available age determination is limited to the category of children) will be given in ranges as used in anthropology, adding the juveniles. Data available in such grouping are shown in Table 88. Before analysing the distributions to be derived from Table 88, some corrections must be made. In the Halimba series, for instance, throughout the entire period during wich the cemetery was used (about 900–1150 A.D.) the number of dead infants is very low, here the graves can be classified into periods of about fifty years. On the basis of the number of deaths at the age of 0 actually found the value obtained for infant mortality is as low as 67 per thousand, but the values vary from 40 to 120 per thousand at various ages. So a minimum of 120 per thousand infant mortality can be reasonably assumed in the Halimba series. In this case the number of dead infants must be completed to 119 and the number of individuals in the whole series to 989. Further corrections must be made of series where non-negligible groups of undefinable age were taken into account in determining the child–adult ratio. Consequently all of the individuals of undefinable age of the Oroszvár series, and 50 per cent of them from the Székesfehérvár series may be included in the children of undefinable age, while they can be altogether disregarded in the Somogy-Vasas series. (So in the series the number of children

TABLE 88

Distribution of child deaths by age groups in certain cemeteries of the 10th–12th centuries in Hungary

Series	Children, age undefined	Infant (0)	Inf. I (1–6)	Inf. II (7–14)	Juv. (15–22)	Adults, age undefined	Aged 23+	Total
Fiad-Kérpuszta	—	72	56	25	42	—	201	395
Halimba-Cseres	—	62	193	77	74	—	600	932
Zalavár								
Village	—	19	27	20	5	—	70	141
Castle	—	23	38	34	29	—	302	426
Chapel	—	5	12	27	8	—	125	177
Székesfehérvár								
Bikasziget	11	4	5	3	5	5	47	75
Szárazrét	41	5	13	6	8	5	47	117
Somogy-Vasas	25	8	17	16	4	14	82	162
Oroszvár	1	9	10	8	11	7	80	115
Zsitvabesenyő	—	3	15	6	2	—	49	73

is increased by 12, taken from the undefinable group of 31.) With these corrections the ratio of deaths in the young age groups appears as shown in Table 89. Due partly to the inaccuracies in determining the age at death and partly to the incompleteness of the two Zalavár series, the distributions in Table 89 are not unequivocal. Nevertheless the relative lower ratio of infant II emerges from the various series as a general trend. It is often exceeded by the ratio of juveniles, and the ratio of infants. It is considerably higher as a rule.

TABLE 89

Per cent age distribution of the young deaths in some cemeteries from the 10th–12th centuries

Series	Children of undefined age	Infants (0)	Infant I (1–6)	Infant II (7–14)	Juveniles (15–22)
Fiad-Kérpuszta	—	18·2	14·0	6·3	10·6
Halimba-Cseres	—	12·0	19·5	7·8	7·5
Zalavár					
Village	—	13·5	19·1	14·2	3·5
Castle	—	5·4	8·9	8·0	6·8
Chapel	—	2·8	6·8	15·3	4·5
Székesfehérvár					
Bikasziget	18·1	5·3	6·7	4·0	6·7
Szárazrét	37·1	4·3	11·1	5·1	6·8
Somogy-Vasas	16·9	5·4	11·5	10·8	2·7
Oroszvár	7·0	7·8	8·7	7·0	9·6
Zsitvabesenyő	—	4·1	20·5	8·2	2·7

The greatest scattering appears in the ratio of infant deaths. Even some of the completely uncovered series cannot be taken into account here (the data of Zalavár Castle and Chapel because of the aforesaid distortion by migration). The ratio of infants—equivalent to infant mortality in this case—in the other three series is about 12–19 per cent. If we take into consideration the destruction of a number of infants' graves and increase the ratio accordingly, we obtain an infant mortality of 150–200 per thousand. Although this is rather high, this value seems to be fairly acceptable from the historical aspect and would seem to indicate the lower limit of infant mortality rather than the maximum.

In the Székesfehérvár-Szárazrét series, which represents the highest child ratio, the data relating to mortality at the age of 0 would actually be as low as 43 per cent. It may be asked, however, how we should categorize the children of undefined age who amount to 7–37 per cent of all deaths in the four series. Experience gained during excavations, probably confirmed by conclusions drawn from distributions, would not exclude the possibility that the overwhelming majority of these should have died as infants. This is further supported by the fact that there are hardly any graves among these in which furniture has been found. If all the children of undefined age are grouped with the infants, we obtain the following proportions:

Székesfehérvár-Bikasziget	23·4 per cent
Székesfehérvár-Szárazrét	41·4 per cent
Somogy-Vasas	22·3 per cent
Oroszvár	14·8 per cent

Thus infant mortality in these cemeteries may not have exceeded a maximum of 150–250 per thousand, and it was over 400 per thousand in one instance only (Szárazrét), which seems to be exceptional for the time being. A similar correction may be made with the Zsitvabesenyő series where the extremely high ratio of infant I, determined with a less accurate method, probably conceals many infant deaths. Even if half of the infant I of Zsitvabesenyő are regarded as having died at the age of 0, infant mortality will not be higher than 140–150 per thousand. Summing up, we may consider an infant mortality rate between 150 and 250 per thousand as probable, showing a scattering from 100 to 400 per thousand in the various series.

It appears from Table 89, too, that in series with a relatively high infant II ratio, that of juveniles is low. Higher rates of infant mortality are accompanied by lower infant I mortality, and vice versa. This phenomenon may be brought into connection with environmental and biological selection, and probably expresses actually existing regional differences. Taking this into account, the following distributions (per cent) would seem acceptable in estimating the age groups of small children: The ratios obtained as unweighted averages (20 per cent infants, 12–13 per cent infant I and 7–8 per cent infant II) are not implausible and they stand between the 20–40 levels of the U.N. model tables, reflecting relatively lower infant and higher child mortality. Considering a 20 per cent infant mortality, 12·8 per cent infant I and 6·6 per cent infant II ratios, the distribution corresponds to 39·4 per cent of deaths in childhood. (The excess child ratio in the series examined was reduced from the infant II group.) The survivorship plotted graphically is shown in Fig. 56.

The d_x proportion of the dead belonging to given years of life from the age of 0 to 15 was derived from the above series of data.

Five series determined with adequate methods are available to estimate the age distribution of adult deaths; the three Zalavár series, and those of Kérpuszta and Halimba. In the series of Zalavár Castle and Chapel the distorting effect of migration is hardly felt in the age distribution of adult deaths.

This value has been obtained by averaging the d_x values of the five series. Considering the fact that the

$$\sum_{x=15}^{\omega} d_x$$

values of the individual series differed from one another, the respective d_x values had first to be converted to express the percentages not within the complete series, but within the 60·6 per cent adult ratio.

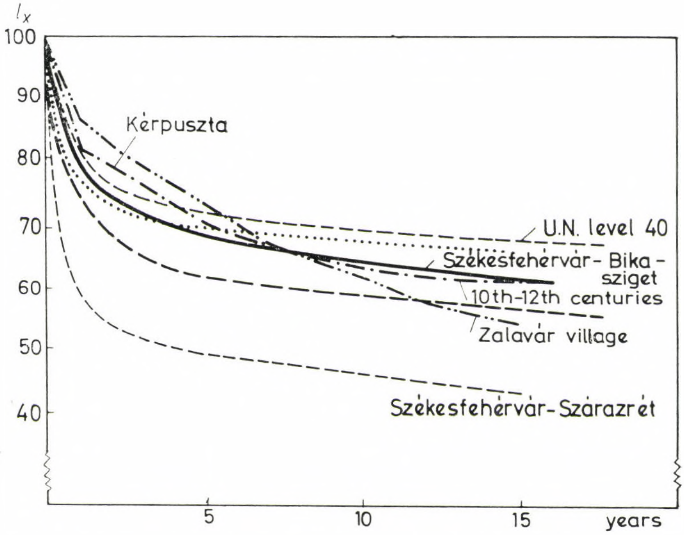

Fig. 56. Survivorship in childhood in the 10th–12th-century Hungary.

The d_x values obtained as unweighted averages fluctuated but very slightly, which was easy to eliminate by means of graphic smoothing.

The estimated age distribution of dead for the 10th–12th centuries is compared in Fig. 57, with the distribution of the Kérpuszta series and Hungarian data of the

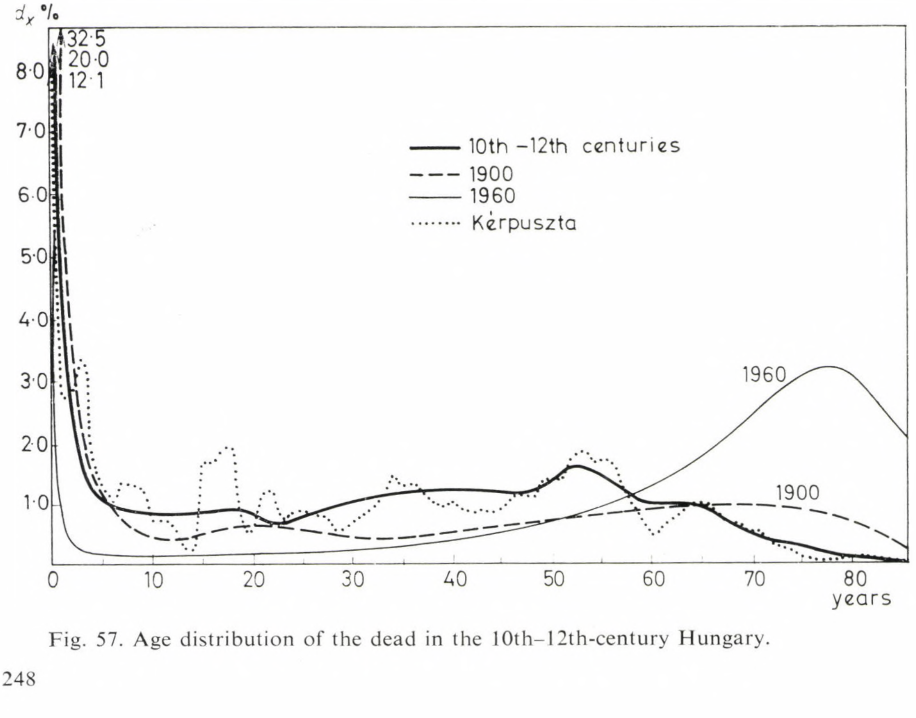

Fig. 57. Age distribution of the dead in the 10th–12th-century Hungary.

years 1900 and 1960. The distribution of the Kérpuszta series differs from the model only in showing random fluctuations, but shows trends that are essentially the same (the higher ratio of child and juvenile deaths in Kérpuszta indicates mortality conditions worse than the average). The distribution in series not shown in the figure—Halimba, Zalavár Village—compares with the model in a similar manner.

The mediaeval series differ from the 20th-century ones considerably as regards age distribution. This may be ascribed to differences in living conditions.

The first difference appears in infant and child mortality. The 20 per cent ratio of dead infants in the 10th–12th centuries is much higher than it is today, but is lower, at the same time, than in 1900. This might be explained by the distribution of 1900 having been taken at random from a developing mortality pattern undergoing profound changes at that time. Infant mortality was much lower (218 per thousand) in the average during the period of 1901–1905. For lack of data to the contrary we only can rely on facts known to us at present, from which we may conclude that in the 10th–12th centuries infant mortality was high in Hungary, but not higher than it was in subsequent centuries under the conditions of feudalism and emerging capitalism.

The curve of child mortality descends to its lowest values between the ages of 10 and 14. These minimum values reflect the age-specific, 'biological' characteristics of mortality, still experienced in our days.

The second, smaller maximum of the curve is the juvenile lateral mode, appearing between 16 and 20 years of age; there are hardly any traces of it in recent data, but at the beginning of the 20th century it still existed as a consequence of tuberculosis and diseases which took their toll especially from among adolescents. Female mortality rates played an important part in shaping the juvenile mortality patterns of mediaeval cemeteries.

In the mediaeval pattern of distribution, the death rates increase rapidly after the age of 23, to be slowed down after the age of 30 and decrease slightly at the beginning of the 40's. The third mode, representing the group attaining normal length of life, appears between the ages of 50 and 55, the end of adult age. Another minor lateral mode of the curve can be observed at the age of 60–65. This may be regarded as the immediate predecessor of the normal age at death in our days.

On the basis of the distribution of deaths we have prepared a life table that can be used as a model for estimating mediaeval mortality; the principal data are shown in Table 90 (the detailed table is to be found in Chapter VIII). To construct such a general model is justified by several practical considerations. Certain modifications might become necessary in the future, in view of the results of further comprehensive excavations, or more accurate data on the frequency of types of cemetery that reflect different mortality patterns. It is obvious that such models are much better suited for comparison of various periods (early Middle Ages, archaeological periods, etc.) and regions than any individual series. The greatest advantage of a general model is that it facilitates the assessing of various series, and that a possible improvement of mortality within the given period might also be ascertained.

TABLE 90

Main data of the model life table for 10th–12th-century Hungary

Age (x)	Distribution of deaths (d_x)	Age (x)	Survivors (l_x)	Probability of death (q_x)	Life expectancy (e_x^0)
0	20·0	0	100·0	0·200	28·7
1	5·3	1	80·0	0·066	34·8
2–4	5·5	2	74·8	0·036	36·2
5–9	4·7	5	69·2	0·015	36·0
10–14	3·9	10	64·6	0·013	33·4
15–19	4·2	15	60·6	0·013	30·4
20–29	7·7	20	56·4	0·013	27·5
30–39	11·3	30	48·7	0·021	21·1
40–49	11·6	40	37·4	0·032	15·8
50–59	13·7	50	25·9	0·054	10·7
60–69	8·7	60	12·2	0·082	7·4
70–79	3·1	70	3·5	0·174	4·5
80+	0·3	80	0·3	0·333	2·2

The values of this model table are steadier than those of the Halimba, Fiad-Kérpuszta and Zalavár Village series and follow the strong fluctuations of the very high infant I and juvenile mortalities, and of the very low infant II mortality only moderately. The adult and old-age mortality rates of the 10th–12th centuries——though considerably higher than today—increased in parallel with the number of years lived at the same rate as at present.

While the U curve of mediaeval age-specific mortality is similar to that of today, the l_x survivorship values give a rapidly descending line that differs from the present one and corresponds to a higher mortality level. With its abrupt descent, the characteristic mediaeval curve departs from present data already in childhood. This rapid decrease in the number of survivors resulted in a very low median length of life, in the 10th–12th centuries. Half of the mediaeval population lived to 28·5 years, while this age is now attained by more than nine-tenths of the population in the economically developed countries.

Expectation of life at birth in mediaeval Hungary (28·7 years) was lower than could be expected from the 40–60 per cent child–adult ratio on the basis of the U.N. model tables. The expectation attached to this kind of distribution is about 33 years in the U.N. models. The difference is due to the level of mediaeval adult mortality being higher than determined in U.N. Model 25. Expectation of about 29 years of life at birth otherwise conform fairly well to the data of the Roman era and to the later data of England.

It is to be remarked that, as we still have it today, after surviving infant age, when mortality was very high, the chances of living improved also in the Middle Ages and those attaining the age of 1 year could expect to live further 34·8 years. Life expectancy reached its maximum, following an early childhood mortality, at the age of 3 (36·5 years). Following this, expectancies decreased gradually and

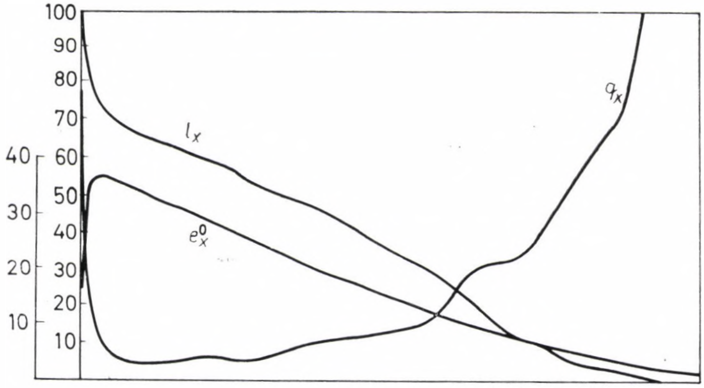

Fig. 58. Mediaeval model life table.

to live to the age of 50 could be expected on the average only by those who attained the age of 28 at least (Fig. 58).

If a stationary population is taken as a basis, the crude mortality rate in mediaeval Hungary may have been about 35 per thousand. This rate, which is very high compared with the mortality of today, agrees more or less with the conditions prevailing prior to the recent drop in mortality at the end of the last century, differing in age structure rather than in general level.

All our series indicate the disadvantage of women in respect of mortality. For instance, expectation of life after the age of 15 or 20 was often several years more for men than for women. Expected age at death at the age of 15 in the Halimba series was as follows (years):

Sex	*Mean*	*Minimum*	*Maximum*
Men	47·9	45·0	53·5
Women	41·9	39·7	48·9

Thus difference between the sexes is about 6 years. Although at the age of 20 the difference is less, expectation of life for men is longer than for women in other cemeteries as well (Table 91).

TABLE 91

Sex differences in expectations of life in the Middle Ages

Series	Expected age at death at 20 (years)		Length of life of males expressed as a percentage of that of females
	males	females	
Halimba-Cseres	49·8	45·4	110
Zalavár Castle	48·9	46·6	105
Zalavár Village	48·3	48·1	100
Fiad-Kérpuszta	47·1	46·4	102
Zalavár Chapel	45·8	45·4	101
Together	48·0	46·4	103

As regards the causes of death, the changes most often noted in mediaeval materials are spondylosis, spondylarthrosis, fractures, arthrosis deformans, osteomyelitis, periostitis, and the like.

As spondylosis seems to have been rather common, and as in addition to various age changes, increased bodily exertion, wear, microtraumas recurring over long periods, and also metabolic disturbances feature among its aetiologic factors, it might be a good indicator of the circumstances of life, economic and social conditions. In Table 92 the incidence of spondylosis (as established by Acsádi, Harsányi and Nemeskéri, 1962) is compared in five series.

TABLE 92

Rates of incidence of spondylosis in 10th–12th-century cemeteries

Series	Males		Females		Total	
	No. of cases	Cases of spondylosis, %	No. of cases	Cases of spondylosis, %	No. of cases	Cases of spondylosis, %
Zalavár						
Castle	174	9·1	91	6·3	268	8·2
Chapel	61	27·9	63	9·5	124	18·5
Village	41	26·8	29	6·9	70	17·8
Fiad-Kérpuszta	95	30·5	93	13·7	188	22·3
Gáva-Market	13	38·4	7	—	20	25·0

It appears from this comparison that spondylosis is rarer in the female population in all of the series. There are substantial differences between the individual series. The incidence of spondylosis was lowest in the population of Zalavár Castle, which had lived in the best circumstances; the incidence in the rest of the series is two or three times as high as in the Castle series. The living conditions of the male population at Kérpuszta and Gáva appear to have been especially poor on this basis (Nemeskéri, Éry and Harsányi, 1961).

Palaeopathological examinations may throw light on the cause of death in certain cases. It is sometimes possible to ascertain the fatal character of bone injuries caused by weapons, and even of interventions of curative intention such as the incomplete, symbolic trephination made on the skull of an older individual buried in grave no. 10 of Zalavár Village. But much more important in respect of causes of death are the cases where the presence of a certain cause of death can be rendered probable. Such are the cases of chronic spondylitis found in the cemeteries of Zalavár; in the vertebral column of an individual, died at the age of 14–15 and buried in grave no. 92 of the Village series, a severe pathological process had involved five dorsal vertebrae resulting in the absorption of most of them and a pathological curvature of the spine. This condition must have been the consequence of a chronic, presumably tuberculous, inflammation and, considering the age of the individual, it might be assumed that the cause of death was tuberculosis.

From the excavation of mediaeval Hungarian material conclusions can be drawn as to certain causes of death, without conducting palaeopathological examinations, merely on the basis of observations made during excavation. In his paper on the cemetery of Székesfehérvár-Sárkeresztúri út Marosi wrote of grave no. 10: 'Plain bracelets on the arms . . . fractions of pendant of thin bronze wire . . . bones of an infant in the pelvis of the skeleton'. This report obviously refers to a women who died during or immediately before childbirth. Similar observations are contained in the excavation record of Oroszvár, where the bones of an infant were found above the left shoulder bones of a young adult woman buried in grave no. 48; a newborn was placed between the right arm and the pelvis of a young adult woman in grave no. 51; the 'skeleton of an embryo' was found between the thigh-bones of a young adult woman in grave no. 69; and the bones of an 'embryo' were found in the pelvis of an adult woman in grave no. 83. Thus in one cemetery alone four young women were found who must have died at the same time as their children (newborn, embryo or infant), during pregnancy or owing to causes of death connected with childbirth. The woman found in grave no. 211 of the Ellend I cemetery was also buried with her infant between her legs, and there are more graves both at Ellend I and Ellend II that are suspect as to maternal mortality. In the multi-layer cemetery of Palotabozsok no such relationship of the dead can be established because of the crammed burials, and none was found in the cemetery of Somogy-Vasas. In connection with graves nos 27, 101 and 152 of the cemeteries of Sorokpolány, Székesfehérvár-Szárazrét and Bikasziget it can be ascertained beyond any doubt that young mothers had been buried with their infants (in grave no. 27 of Bikasziget the infant was found above the skeleton and 'their heads were touching'). Such burials were found in graves nos 130, 196, 331 and of Kérpuszta (it should be noted that all three women buried with their children at Kérpuszta died about the end of the reproductive age).

The number of women who had died of maternal causes varies in the series, but such cases occur in practically every cemetery. If we reckon only with the minimum number of cases (those in which the diagnosis is sure), the distribution shown in Table 93 is obtained.

TABLE 93

Maternal mortality in 10th–12th-century cemeteries

Series	No. of cases	No. of total females	No. of females died of maternal causes
Ellend I	274	103	1
Ellend II	184	57	—(?)
Fiad-Kérpuszta	395	117	3
Oroszvár	115	38	4
Palotabozsok	91	19	—(?)
Somogy-Vasas	162	37	—
Sorokpolány	312	104	1
Székesfehérvár			
Bikasziget	75	27	1
Sárkereszturi út	31	12	1
Szárazrét	117	18	1
Total	1,756	531	12

As a consequence of childbirth, pregnancy and puerperal complications about 30 women die in Hungary every year, which is 0·03 per cent of all deaths. In mediaeval

Hungary this proportion was 0·68 per cent at least, i.e. 23 times higher; of course only the cases where the child had died too are considered. Such causes of death make up at present 0·06 per cent of the causes of all female deaths. It is not possible to define this ratio from mediaeval materials, as the number of maternal deaths there can only be compared with the number of women died at adult or old age, which ratio is 2·26 per cent in the mediaeval cemeteries analysed; and 0·11 per cent today considering woman who died between the ages of 15 and 74. The difference is more than twentyfold even in this comparison.

MORTALITY CONDITIONS BEFORE THE DEMOGRAPHIC REVOLUTION

Mortality conditions found in mediaeval Hungary are not unique in Europe. Moreover the model shown above seems to be reasonably valid not only for the 10th–12th centuries, but also for the entire period preceding the demographic revolution. If allowance is made for the obvious differences which result from varying degrees of thoroughness in uncovering series, together with the methods used for age determination, the distribution in the major mediaeval series reported by various authors generally agrees with the picture drawn by us, apart from possible local differences.

TABLE 94

Age distribution of the dead in European mediaeval series

Age	Bled 7th century (Skerlj, 1952)	Bled 10th–11th centuries (Skerlj, 1952)	Ptuj 10th–11th centuries (Ivaniček, 1951)	Westerhus 1100–1350 A.D. (Gejvall, 1961)	Reckahn 1150–1350 A.D. (Schott, 1963)
			Number		
0–6	10	52	12	163	42
7–14	14	30	54	43	34
15–20	19	6	16	19	17
21–40	23	18	82	69	80
41–60	16	70	95	65	74
61+	5	7	31	5	23
Total	87	183	290	364	270
			Per cent		
0–6	11·5	28·4	4·1	44·8	15·6
7–14	16·1	16·4	18·6	11·8	12·6
15–20	21·8	3·3	5·5	5·2	6·3
21–40	26·4	9·8	28·3	19·0	29·6
41–60	18·4	38·3	32·8	17·8	27·4
61+	5·8	3·8	10·7	1·4	8·5
Total	100·0	100·0	100·0	100·0	100·0

In the series shown in Table 94 the small children of infant I age are widely represented. The proportion of older children—aged 7–14—and juveniles is fairly uniform (the latter is extremely high in the 7th century Bled series). Another general feature is that the adult-age mode appears in middle adult age (12·6 per cent falls to the 41–50 age group in the Westerhus series). Old age deaths are also frequent in these series, especially in those of Ivaniček (1951) and Schott (1963).

A good possibility for comparison is provided by the mediaeval Slav cemeteries in Czechoslovakia, whose data have been published by Stloukal in 1962. The proportion of children in these cemeteries is about 40 per cent and expectation of life at birth is about 30 years. The data published by Stloukal (1963, 1964) are as follows:

Site	*Expectation of life at birth* e_x^0	*Percentage of deaths under the age of 20* $\sum_{x=0}^{20} d_x$
Kouvřim	33·6	39·0
Zobor	33·3	33·7
Stare-Město-Špitálly	32·1	36·1
Modrá	31·7	31·6
Megnárce	31·1	32,0
Mikulčice 1–4	27·9	41·7
Stare-Město-Valy	22·9	53·9
Bešeňov	22·7	36·9
Žitavska Toů	19·8	47·5

The mediaeval Hungarian and Slav palaeodemographic series show similarities in their principal data, their scattering and in the appearance of regional differences.

Compared with the data of the Roman era, mediaeval mortality conditions derived from Hungarian and Central European palaeodemographic sources do not reflect substantial changes. It would seem that expectation of life was no more than 30–35 years during the entire feudal period. This is also indicated by Russell's (1948) historical data from mediaeval England (Table 95).

Although mortality patterns had not substantially changed since the emergence of the antique empires, nevertheless the rates decreased slowly over the many thousand years. True, this progress was not a spectacular one, as ravaging epidemics played havoc with populations to a degree probably unknown even to prehistoric man. Up to the middle of the 14th century, the mediaeval mortality pattern must have been fairly uniform in Europe, apart from some minor regional and temporal fluctuations. Then a plague, spreading all over the continent, increased mortality rates to such an extent that the size of populations was reduced by as much as 40–50 per cent in some regions.

Historical research shows clearly that the mortality rates of the late Middle Ages were raised mainly by epidemic of plague. Such epidemics had occurred in Europe

TABLE 95

Expectation of life in mediaeval England (after Russell)

Age	Birth cohorts							
	Before 1276	1276–1300	1301–1325	1326–1345	1346–1375	1376–1400	1401–1425	1426–1450
0	35·3	31·3	29·8	27·2	17·3	20·5	23·8	32·8
1	40·0	35·8	34·5	31·7	23·7	26·7	28·7	37·0
5	39·9	35·7	34·6	32·3	26·5	28·5	29·4	36·6
10	36·3	32·2	31·0	28·1	25·1	24·5	29·7	34·5
20	28·7	25·2	23·8	22·1	23·9	21·5	29·4	27·7
30	22·8	21·8	20·0	21·1	22·0	22·3	25·0	24·1
40	17·8	16·6	15·7	17·7	18·1	19·2	19·3	20·4
50	12·7	12·3	12·5	14·3	15·9	14·3	14·2	16·4
60	9·4	8·3	9·3	10·8	10·9	10·0	10·5	13·7
70	6·9	6·3	7·0	6·9	6·8	6·3	7·3	10·5
80	5·2	3·8	4·5	6·0	4·7	3·1	4·9	7·9
90	5·0	.	.	2·5	2·5	.	2·5	3·7

even before the "Great Death" in 1347–49, and continued to break out in recurring waves during subsequent centuries. This epidemic, also called the Black Death, spread mainly from the seaports of the continent to the densely inhabited seaside, but its impact was also severe inside the continent. According to Szabó (1963), in Hungarian historical sources covering the period from 1330 to 1526 epidemics had been recorded in the following years: 1347–49, 1360, 1374, 1380, 1381, 1382, 1400, 1412, 1430, 1438, 1441, 1452, 1453, 1454, 1455, 1456, 1457, 1461, 1468, 1475, 1479, 1480, 1494, 1495, 1496, 1497, 1509 and 1520.

As a result (see also Russell's life table), expectation of life dropped to 17–20 years in certain periods in the second half of the 14th century, and was still lower during the 15th century than before the great epidemic. Of course all this was aggravated by wars, which decimated the populations and affected mortality rates with their consequences. Epidemics, wars, famines have been historical impediments, and still are in our time, to the prolongation of human life spans.

From the analysis of palaeodemographic sources and written historical sources found in increasing numbers since antiquity we estimate that the number of deaths per 1,000 inhabitants may have been about 35 per annum in Europe in the 11th–13th centuries. This rose above 40 per thousand by the 14th–15th centuries. Mortality rates were probably stagnating, or decreasing slightly, in the 16th–17th centuries. This can also be seen from the first demographic computations or the crude death rates based on already dependable registrations in Scandinavian countries showing a value of about 30 per thousand. At the same time, expectation of life in the middle of the 18th, and even at the beginning of the 19th century, was not much longer than estimated for the end of the 15th century. For instance, it was 34 years in Sweden in 1755–56, 25 in France in 1795, and 32 in the Netherlands in 1816–1825.

TABLE 96

Graunt's life table

Age	Percentage of the dead (d_x)	Survivors (l_x)
0–5	36	100
6–15	24	64
16–25	15	40
26–35	9	25
36–45	6	16
46–55	4	10
56–65	3	6
66–75	2	3
76–85	1	1

It would be beyond the scope of this work to discuss, or give detailed critical analyses on, the written source material of mortality, available in increasing amounts since the 17th century, or the literature of historical demography featuring a number of extensive monographs. Our knowledge relating to the last three centuries—although still incomplete—is incomparably wider than all we know about the preceding half a million years. So it is not our intention to give a detailed analysis of the period of the demographic revolution, still continuing today. We only wish to give an outline, based on the most often quoted sources, of the mortality level before the demographic revolution and to make a brief survey of the profound changes in the most recent developments of the history of mortality, already assuming the importance of international politics.

The forerunner of modern life tables was published by John Graunt, the founder of demography, in 1662, in his famous book *Natural and Political Observations Made upon the Bills of Mortality* (Table 96).

Graunt had studied the London parish registers from 1604, and his table was based on the conclusion he reached. No wonder, then, that the expectation of life at birth derived from his data was approximately 18·2 years, as has been computed by Dublin, Lotka and Spiegelman (1949). Graunt himself indicated that the mortality conditions in a big city were much worse than in rural districts, and the studied period was also full of outbreaks of plague. It appears that the situation in this respect has not much changed from the time of antique empires (Rome) to the 17th century.

Though it cannot be compared directly with current life tables, Halley's life table, published in 1693 and mentioned in Chapter II, supplies interesting information on mortality patterns of the period preceding the demographic revolution. Halley computed his life table from the 1687–1691 data of Breslau (today Wroclaw), a town in Silesia, assuming—not altogether correctly in the given case—stationary population conditions with no migration. The principal data of Halley's table are as follows:

Age (years)	*Expectation of life*	*Age (years)*	*Expectation of life*
0	33·5	40	21·8
5	41·6	50	16·8
10	40·0	60	12·1
20	33·6	70	7·5
30	27·4	80	5·7

TABLE 97

Male life expectancy at the beginning of the demographic revolution

Country and year	Life expectancy at the age of					
	0	10	20	40	60	80
France, 1795,	23·37	44·12	36·52	24·06	13·14	5·17
1817–1831	38·33	47·00	40·00	27·00	13·25	4·75
The Netherlands,						
1816–1825,	29·32	40·67	32·87	21·86	11·60	4·77
1840–1851	34·94	44·39	36·86	24·06	12·14	4·02
Sweden, 1755–1776,	33·20	43·94	36·95	23·75	12·24	4·27
1816–1840	39·50	45·21	37·32	23·66	12·07	4·03
Chile, 1919–1922	30·90	40·57	33·14	22·05	11·78	4·73
Mexico, 1930	32·44	44·57	37·25	24·84	13·50	5·17
India, 1931	26·91	36·38	29·57	18·60	10·25	3·13
China (rural), 1929–1931	34·85	47·05	40·74	26·84	14·19	6·08
Egypt, 1927–1937	30·20	38·20	33·50	23·70	14·20	6·20
England and Wales, 1841	40·19	47·08	39·88	26·56	13·50	4·92
Austria, 1870–1880	30·98	44·21	36·80	—	12·20	4·42
Germany, 1871–1881	35·58	46·51	38·45	24·46	12·11	4·10
Hungary, 1900–1901*	37·10	48·20	40·60	26·10	12·80	4·30
Japan, 1899–1903	43·97	48·23	40·35	26·03	12·76	4·44

*Computed by the authors

TABLE 98

Female life expectancy at the beginning of the demographic revolution

Country and year	Life expectancy at the age of					
	0	10	20	40	60	80
France, 1795,	27·35	46·77	39·45	27·45	15·73	6·17
1817–1831	40·83	47·42	40·08	26·58	13·16	4·75
The Netherlands,						
1816–1825,	35·12	45·03	36·99	24·84	12·84	4·76
1840–1851	37·76	46·07	38·71	25·77	12·94	4·14
Sweden, 1755–1776,	35·70	46·25	39·15	25·21	13·08	4·47
1816–1840	43·56	48·59	40·75	26·41	13·22	4·46
Chile, 1919–1922	32·21	42·06	34·86	23·71	12·60	5·09
Mexico, 1930	34·07	45·87	38·46	25·66	12·92	4·76
India, 1931	26·56	33·61	27·08	18·23	10·81	3·25
China (rural), 1929–1931	34·63	46·00	40·08	28·05	15·22	6·80
Egypt, 1927–1937	31·50	37·20	32·80	23·90	15·40	7·60
England and Wales, 1841	42·18	47·81	40·81	27·72	14·40	5·20
Austria, 1870–1880	33·77	45·52	38·28	—	12·37	4·44
Germany, 1871–1881	38·45	48·18	40·19	26·32	12·71	4·22
Hungary, 1900–1901*	37·90	46·80	39·90	26·40	12·60	4·40
Japan, 1899–1903	44·85	48·34	41·06	28·19	14·32	4·85

*Computed by the authors

A number of life tables were compiled during the 18th century, for example, by Deparcieux, Buffon, Price, Barton, Wigglesworth, Mourgue, Duvillard. At that time the best known of these was the table published by Deparcieux in 1746 from which Dublin, Lotka and Spiegelman computed a life expectancy of 37·5 years. From Prince's table, which was based on the 1735–1780 data of Northampton (England), 30·0 years of expectation can be derived. Still lower values were contained in Duvillard's table (covering various parts of France prior to 1789): only 28·8 years.

Expectations of life at birth in these tables varied between 23 and 38 years (not counting Buffon's table where it was only 8 years, but rose to 33 years one year later). So these computations, too, indicate that life expectancy in the West European countries did not rise substantially in the 18th century, and may have been still less in other parts of Europe where the feudal system survived longer. According to Fáy's (1854) contemporary life table—which was not based on statistical data—expectation of life in Hungary was 24·2 years in 1837–1846. This period, which did not include the worst years of the cholera epidemics, reflected a less favourable mortality pattern than could be expected for mediaeval Hungary.

Based on compilations by Dublin-Lotka and Spiegelman, we show here some important data of the earliest life tables of three West European countries, originating from the period before the demographic revolution. The countries are France, the Netherlands and Sweden, and the period is the 18th–19th centuries. In the table we have also shown later data of other populations to illustrate that the demographic revolution did not make itself felt at the end of the 19th or even at the beginning of the 20th century in the countries representing the major part of the world population, and that regional differences in the level and, especially, in the age structure of mortality, were considerable also in this period.

If the data of Table 97, relating to men, are compared with those in Table 98, it appears that the advantage of male mortality is disappearing, giving place to female longevity. Table 98 contains the expectations of life for the female population of the countries listed in the previous table. Accordingly, expectation of life for women is 1–2 years longer in most countries, the difference is even 4 years in some of them. In Italy and Japan expectation of the sexes is still fairly similar, while in China and India the advantage of male mortality continues.

TRENDS OF MORTALITY AND LIFE SPAN IN THE PERIOD OF THE DEMOGRAPHIC REVOLUTION

In some European countries it has been possible to observe the mortality trends more accurately since the beginning of the 19th century. It appears that mortality rates went down only slowly in the first half of the century, but were falling rapidly in the second half, the period of the modern demographic revolution (Table 99) (Szabady, 1964).

TABLE 99

Mortality rates from the beginning of the 19th century to the outbreak of World War I (per 1,000 inhabitants, annual average)

Country	1801–1810	1851–1860	1901–1910
Austria	.	31·4	23·3
Denmark	23·7	20·6	14·2
England	.	22·2	15·4
Finland	31·9	28·7	18·0
France	26·1*	23·6	19·4
Germany	.	26·4	18·7
The Netherlands	.	25·4	15·1
Norway	25·2	17·1	14·2
Sweden	27·9	21·7	14·9

*1811–1820.

The decreasing mortality rates in the second half of the 19th century were connected with the profound social and economic changes and the concomitant progress in medicine and hygiene. In previous centuries, populations were decimated by epidemics and communicable diseases, especially those affecting children and young people, against which there was no effective protection. The 19th century, on the other hand, brought the introduction of smallpox vaccination, the discovery of various pathogens, various measures of public health, etc. For instance, the mortality due to typhoid fever dropped as low as one-third (one-fifth on the average), that of diphtheria to one-fourth, between 1850 and the outbreak of World War I.

A dependable picture, showing also the characteristic regional differences, of mortality for the end of the 19th and the beginning of the 20th century could be drawn not only for Europe, but also for the other continents. Taking into account the mortality rates of about 1900, the following types of mortality can be established:

(1) Countries with low mortality rates between 15 and 20 per thousand, including most of the northern and west European countries, the U.S.A. Argentina, Australia and New Zealand.

(2) Countries with medium mortality, i.e rates between 20 and 25 per thousand, including the remaining European countries (except Russia and Spain), the more developed Asiatic countries, and some countries of Central and South America.

(3) Countries with a high mortality, with rates over 25 per thousand. These were mainly the underdeveloped countries of Africa and Asia, some countries of Central America, and Russia and Spain in Europe.

A further considerable decrease in mortality rates has taken place in the 20th century. This has not been restricted to Europe, but affected the world as a whole. The drop in the mortality level is usually the smallest in countries where this level was already low at the beginning of the century. (This applies especially to the last decade, during which stagnation or even a rise has been noted in these countries.) In Asiatic and African countries with high mortality levels, on the other hand, mortality rates dropped rapidly under the effect of the introduction of various sanitary measures. The most recent international advances in mortality are shown in Table 100. As at the beginning of this century, the three mortality types can still be distinguished among the countries of the world. Mortality can be regarded as low in countries where the deaths per 1,000 population are less than 10; where this ratio is between 10 and 15 per thousand, mortality is medium, where it is over 15 per thousand, mortality is termed high. In addition to the decrease in mortality rates in the various categories there is a shift among the categories themselves. For instance, certain west European countries which had low mortality rates at the beginning of the century now belong to the medium group, while Central and South American countries with high rates have also shifted to this group.

It should be emphasized in connection with falling mortality levels that the decrease of infant mortality has played an important part here. In the thirties of this century, the number of deaths under the age of one year per 1,000 live-births was 50 to 100 in western and northern Europe as well as in some American and

TABLE 100

Mortality trends since the turn of the century in some characteristic countries (per 1,000 inhabitants; figures have been rounded)

Country	1900	1930	1959*
Europe			
Belgium	19	13	12
Bulgaria	23	16	8
Czechoslovakia	.	14	10
France	22	16	11
Germany	22	11	13**
Hungary	27	16	10
Italy	24	14	9
Jugoslavia	24	19	10
The Netherlands	18	9	7
Rumania	24	19	9
Soviet Union	31	20	7
Sweden	17	12	10
United Kingdom	18	12	12
Asia			
Ceylon	27	26	10
India	33	25	19
Japan	20	18	8
Overseas			
Egypt (U.A.R.)	27	25	17
U.S.A.	18	11	10
Canada	.	11	8
Argentina	19	.	8
Chile	33	25	12
Venezuela	21	17	9
Australia	11	9	9
New Zealand	9	9	9

*Or in recent years (1957–1958).

**German Democratic Republic; in the German Federal Republic it is 11.

TABLE 101

Comparison of mortality of the continents (the means of 1960–1966)

Continent, country	Death rate (per thousand)
Europe	10
Asia	18
Africa	23
Northern America	9
Latin America	13
Oceania	11
USSR	7
Together	16

Oceanic countries; in the other European countries, as well as in the more developed Central and South American countries the number was 100 to 150, while it was over 150 in the backward countries of Asia, Africa and America. According to the data of 1957–1958, the rate is 20–50 per thousand in countries with the best infant mortality pattern, 50–100 per thousand in regions with medium mortality and over 100 per thousand in the least developed countries. The rate of decrease was about the same in every category, although in recent years the improvement slowed down in countries with the lowest infant mortality. According to estimates for the early 1960's, the lowest mortality rates were seen in Europe (including the USSR), Northern America and Oceania, medium ones in Latin America, and the highest in Asia and Africa (Table 101).

CHAPTER VIII

PALAEODEMOGRAPHIC LIFE TABLES

Many references have been made to detailed life tables in the preceding chapters, but the tables themselves have not yet been shown. Not wishing to interrupt the analytical text with the results of lengthy computations, we have inserted selected data, abridged life tables, or illustrations to demonstrate rather than to prove the subject under discussion. The detailed results and the documentary material are presented in this Chapter which is devoted to summing up the data in a comparative, tabular form.

Depending on the method of computation, there are two types of life table: detailed and abridged. Abridged tables have been used mainly for demonstrating male and female mortality after the age of 20 years, as well as in cases where the series were relatively small. In cases where the dead children were missing from the series (Afalou, Vassilievka), only values from the age of 20 have been included.

The data figuring in these tables have not been smoothed, except for the Maghreb-type and the mediaeval model table, so that the secondary uses of these series should not be precluded. This does not mean, of course, that these series would not require smoothing, or even correction, whenever they are to be used either as models, or if their results are to be generalized.

TABLE 102

Afalou Epipalaeolithic population of age 20+, both sexes

Age (x)	Distribution of deaths		Survivors (l_x)	Probability of death (q_x)	Total no. of years lived between ages x and $x+1$ (L_x)	Total after lifetime (T_x)	Life expectancy (e^0_x)
	No. (D_x)	per cent (d_x)					
20	0·700	1·87	100·00	0·018,7	99·065	2,186·380	21·86
21	0·800	2·14	98·13	0·021,8	97·060	2,087·315	21·27
22	0·900	2·41	95·99	0·025,1	94·785	1,990·255	20·73
23	0·975	2·61	93·58	0·027,9	92·275	1,895·470	20·26
24	0·975	2·61	90·97	0·028,7	89·665	1,803·195	19·82
25	0·975	2·61	88·36	0·029,5	87·055	1,713·530	19·39
26	0·975	2·61	85·75	0·030,4	84·445	1,626·475	18·97
27	0·975	2·61	83·14	0·031,4	81·835	1,542·030	18·55
28	0·175	0·47	80·53	0·005,8	80·295	1,460·195	18·13
29	0·775	2·07	80·06	0·025,9	79·025	1,379·900	17·24
30	0·775	2·07	77·99	0·026,5	76·955	1,300·875	16·68
31	0·975	2·61	75·92	0·034,4	74·615	1,223·920	16·12
32	0·975	2·61	73·31	0·035,6	72·005	1,149·305	15·68
33	0·975	2·61	70·70	0·036,9	69·395	1,077·300	15·24
34	0·775	2·07	68·09	0·030,4	67·055	1,007·905	14·80
35	0·775	2·07	66·02	0·031,4	64·985	940·850	14·25
36	0·775	2·07	63·95	0·032,4	62·915	875·865	13·70
37	0·775	2·07	61·88	0·033,5	60·845	812·950	13·14
38	0·775	2·07	59·81	0·034,6	58·775	752·105	12·57
39	0·575	1·53	57·74	0·026,5	56·975	693·330	12·01
40	0·775	2·07	56·21	0·036,8	55·175	636·355	11·32
41	0·575	1·53	54·14	0·028,3	53·375	581·180	10·73
42	0·575	1·53	52·61	0·029,1	51·845	527·805	10·03
43	0·975	2·61	51·08	0·051,1	49·775	475·960	9·32
44	1·175	3·14	48·47	0·064,8	46·900	426·185	8·79
45	1·175	3·14	45·33	0·069,3	43·760	379·285	8·37
46	1·375	3·68	42·19	0·087,2	40·350	335·525	7·95
47	1·375	3·68	38·51	0·095,6	36·670	295·175	7·66
48	0·975	2·61	34·83	0·074,9	33·525	258·505	7·42
49	0·775	2·07	32·22	0·064,2	31·185	224·980	6·98
50	0·975	2·61	30·15	0·086,6	28·845	193·795	6·43
51	0·975	2·61	27·54	0·094,8	26·235	164·950	5·99
52	0·975	2·61	24·93	0·104,7	23·625	138·715	5·56
53	0·975	2·61	22·32	0·116,9	21·015	115·090	5·17
54	0·975	2·61	19·71	0·132,4	18·405	94·075	4·77
55	0·575	1·53	17·10	0·089,5	16·335	75·670	4·43
56	0·375	1·00	15·57	0·064,2	15·070	59·335	3·81
57	0·575	1·53	14·57	0·105,0	13·805	44·265	3·04
58	1·175	3·14	13·04	0·240,8	11·470	30·460	2·35
59	0·975	2·61	9·90	0·263,6	8·595	18·990	1·92
60	0·975	2·61	7·29	0·358,0	5·985	10·395	1·43
61	0·975	2·61	4·68	0·557,7	3·375	4·410	0·94
62	0·775	2·07	2·07	1·000,0	1·035	1·035	0·50
Total	37·400	100·00	—	—	2,186·380		—

TABLE 103
Taforalt Epipalaeolithic population of age 20+, both sexes

x	D_x	d_x	l_x	q_x	L_x	T_x	e_x^0
0	43·000	23·12	100·00	0·231,2	88·440	2,079·250	20·79
1	20·000	10·75	76·88	0·139,8	71·505	1,990·810	25·90
2	13·834	7·44	66·13	0·112,5	62·410	1,919·305	29·02
3	4·001	2·15	58·69	0·036,6	57·615	1,856·895	31·64
4	1·999	1·08	56·54	0·019,1	56·000	1,799·280	31·82
5	4·966	2·67	55·46	0·048,1	54·125	1,743·280	31·43
6	3·134	1·68	52·79	0·031,8	51·950	1,689·155	32·00
7	0·783	0·42	51·11	0·008,2	50·900	1,637·205	32·03
8	0·783	0·42	50·69	0·008,3	50·480	1,586·305	31·29
9	0·940	0·51	50·27	0·010,1	50·015	1,535·825	30·55
10	1·974	1·06	49·76	0·021,3	49·230	1,485·810	29·86
11	1·473	0·79	48·70	0·016,2	48·305	1,436·580	29·50
12	1·973	1·06	47·91	0·022,1	47·380	1,388·275	28·98
13	0·640	0·35	46·85	0·007,5	46·675	1,340·895	28·62
14	0·500	0·27	46·50	0·005,8	46·365	1,294·220	27·83
15	0·735	0·40	46·23	0·008,7	46·030	1,247·855	26·99
16	0·733	0·40	45·83	0·008,7	45·630	1,201·825	26·22
17	0·733	0·39	45·43	0·008,6	45·235	1,156·195	25·45
18	2·067	1·11	45·04	0·024,6	44·485	1,110·960	24·67
19	2·067	1·11	43·93	0·025,3	43·375	1,066·475	24·28
Total	106·335	57·18	—	—	—	—	—

TABLE 104

Maghreb-type mortality, both sexes

x	l_x	d_x	q_x	L_x	T_x	e_x^0
0	100·0	23·1	0·231,00	88·45	2,114·50	21·145
1	76·9	10·8	0·140,44	71·50	2,026·05	26·347
2	66·1	7·4	0·111,95	62·40	1,954·55	29·570
3	58·7	2·7	0·046,00	57·35	1,892·15	32·234
4	56·0	1·7	0·030,36	55·15	1,834·80	32·764
5	54·3	1·5	0·027,62	53·55	1,779·65	32·774
6	52·8	1·4	0·026,52	52·10	1,726·10	32·691
7	51·4	1·2	0·023,35	50·80	1,674·00	32·568
8	50·2	0·7	0·013,94	49·85	1,623·20	32·335
9	49·5	0·6	0·012,12	49·20	1,573·35	31·785
10	48·9	0·6	0·012,27	48·60	1,524·15	31·169
11	48·3	0·5	0·010,35	48·05	1,475·55	30·550
12	47·8	0·5	0·010,46	47·55	1,427·50	29·867
13	47·3	0·5	0·010,57	47·05	1,379·95	29·174
14	46·8	0·5	0·010,68	46·55	1,332·90	28·481
15	46·3	0·5	0·010,80	46·05	1,286·35	27·783
16	45·8	0·5	0·010,92	45·55	1,240·30	27·081
17	45·3	0·6	0·013,25	45·00	1,194·75	26·374
18	44·7	0·7	0·015,66	44·35	1,149·75	25·721
19	44·0	0·7	0·015,91	43·65	1,105·40	25·123
20	43·3	0·8	0·018,48	42·90	1,061·75	24·521
21	42·5	0·8	0·018,82	42·10	1,018·85	23·973
22	41·7	0·9	0·021,58	41·25	976·75	23·423
23	40·8	0·9	0·022,06	40·35	935·50	22·929
24	39·9	0·9	0·022,56	39·45	895·15	22·435
25	39·0	1·0	0·025,64	38·50	855·70	21·941
26	38·0	1·0	0·026,32	37·50	817·20	21·505
27	37·0	1·0	0·027,03	36·50	779·70	21·073
28	36·0	1·0	0·027,78	35·50	743·20	20·644
29	35·0	1·0	0·028,57	34·50	707·70	20·220
30	34·0	1·0	0·029,41	33·50	673·20	19·800
31	33·0	1·0	0·030,30	32·50	639·70	19·385
32	32·0	1·0	0·031,25	31·60	607·20	18·975
33	31·0	1·0	0·032,26	30·50	575·70	18·571
34	30·0	1·0	0·033,33	29·50	545·20	18·173
35	29·0	1·0	0·034,48	28·50	515·70	17·783
36	28·0	1·0	0·035,71	27·50	487·20	17·400
37	27·0	1·0	0·037,04	26·50	459·70	17·026
38	26·0	1·0	0·038,46	25·50	433·20	16·662
39	25·0	1·0	0·040,00	24·50	407·70	16·308
40	24·0	0·9	0·037,50	23·55	383·20	15·967
41	23·1	0·9	0·038,96	22·65	359·65	15·569
42	22·2	0·9	0·040,54	21·75	337·00	15·180
43	21·3	0·9	0·042,25	20·85	315·25	14·800
44	20·4	0·9	0·044,12	19·95	294·40	14·431
45	19·5	0·9	0·046,15	18·55	274·45	14·074
46	18·6	0·8	0·043,01	18·20	255·90	13·758

TABLE 104 (cont'd)

x	l_x	d_x	q_x	L_x	T_x	e_x^0
47	17·8	0·8	0·044,94	17·40	237·70	13·354
48	17·0	0·8	0·047,06	16·60	220·30	12·959
49	16·2	0·8	0·049,38	15·80	203·70	12·574
50	15·4	0·7	0·045,45	15·05	187·90	12·201
51	14·7	0·7	0·047,62	14·35	172·85	11·759
52	14·0	0·7	0·050,00	13·65	158·50	11·321
53	13·3	0·7	0·052,63	12·95	144·85	10·891
54	12·6	0·7	0·055,51	12·25	131·90	10·468
55	11·9	0·7	0·057,85	11·55	119·65	10·055
56	11·2	0·6	0·052,63	10·90	108·10	9·652
57	10·6	0·6	0·055,56	10·30	97·20	9·170
58	10·0	0·6	0·058,82	9·70	86·90	8·690
59	9·4	0·6	0·062,50	9·10	77·20	8·213
60	8·8	0·6	0·066,67	8·50	68·10	7·739
61	8·2	0·6	0·071,43	7·90	59·60	7·268
62	7·6	0·6	0·076,92	7·30	51·70	6·803
63	7·0	0·6	0·083,33	6·70	44·40	6·343
64	6·4	0·6	0·090,91	6·10	37·70	5·891
65	5·8	0·6	0·100,00	5·50	31·60	5·448
66	5·2	0·6	0·111,11	4·90	26·10	5·019
67	4·6	0·6	0·125,00	4·30	21·20	4·609
68	4·0	0·6	0·142,86	3·70	16·90	4·225
69	3·4	0·5	0·138,89	3·15	13·20	3·882
70	2·9	0·5	0·172,41	2·65	10·05	3·466
71	2·4	0·4	0·166,67	2·20	7·40	3·083
72	2·0	0·4	0·200,00	1·80	5·20	2·600
73	1·6	0·4	0·250,00	1·40	3·40	2·125
74	1·2	0·4	0·333,33	1·00	2·00	1·667
75	0·8	0·4	0·500,00	0·60	1·00	1·250
76	0·4	0·2	0·500,00	0·30	0·40	1·000
77	0·2	0·2	1·000,00	0·10	0·10	0·500
Total	—	—	—	2,114·50	—	—

TABLE 105

Vassilievka III Mesolithic population, aged 20+, both sexes

x	D_x	d_x	l_x	q_x	L_x	T_x	e_x^0
20	0·500	1·59	100·00	0·015,9	99·205	2,279·030	22·79
21	1·000	3·18	98·41	0·032,3	96·820	2,179·825	22·15
22	1·000	3·18	95·23	0·033,4	93·640	2,083·005	21·87
23	0·762	2·42	92·05	0·026,3	90·840	1,989·365	21·61
24	0·761	2·42	89·63	0·027,0	88·420	1,898·525	21·18
25	0·903	2·87	87·21	0·032,9	85·775	1,810·105	20·76
26	1·254	3·98	84·34	0·047,2	82·350	1,724·330	20·44
27	1·254	3·98	80·36	0·049,5	78·370	1,641·980	20·43
28	0·854	2·71	76·38	0·035,5	75·025	1,563·610	20·47
29	0·904	2·87	73·67	0·039,0	72·235	1,488·585	20·21
30	1·004	3·19	70·80	0·045,1	69·205	1,416·350	20·00
31	1·008	3·20	67·61	0·047,3	66·010	1,347·145	19·93
32	0·865	2·75	64·41	0·042,7	63·035	1,281·135	19·89
33	0·865	2·75	61·66	0·044,6	60·285	1,218·100	19·76
34	0·615	1·95	58·91	0·033,1	57·935	1,157·815	19·65
35	0·615	1·95	56·96	0·034,2	55·985	1,099·880	19·31
36	0·515	1·63	55·01	0·029,6	54·195	1,043·895	18·98
37	0·515	1·63	53·38	0·030,5	52·565	989·700	18·54
38	0·515	1·63	51·75	0·031,5	50·935	937·135	18·11
39	0·515	1·63	50·12	0·032,5	49·305	886·200	17·68
40	0·467	1·48	48·49	0·030,5	47·750	836·895	17·26
41	0·243	0·77	47·01	0·016,4	46·625	789·145	16·79
42	0·243	0·77	46·24	0·016,7	45·855	742·520	16·06
43	0·243	0·77	45·47	0·016,9	45·085	696·665	15·32
44	0·243	0·77	44·70	0·017,2	44·315	651·580	14·58
45	0·443	1·41	43·93	0·032,1	43·225	607·265	13·82
46	0·443	1·41	42·52	0·033,2	41·815	564·040	13·27
47	0·809	2·57	41·11	0·062,5	39·825	522·225	12·70
48	0·910	2·89	38·54	0·075,0	37·095	482·400	12·52
49	1·027	3·26	35·65	0·091,4	34·020	445·305	12·49
50	0·827	2·63	32·39	0·081,2	31·075	411·285	12·70
51	0·828	2·63	29·76	0·088,4	28·445	380·210	12·78
52	0·628	1·99	27·13	0·073,4	26·135	351·765	12·97
53	0·461	1·46	25·14	0·058,1	24·410	325·630	12·95
54	0·461	1·46	23·68	0·061,7	22·950	301·220	12·72
55	0·294	0·93	22·22	0·041,9	21·755	278·270	12·52
56	0·294	0·93	21·29	0·043,7	20·825	256·515	12·05
57	0·294	0·93	20·36	0·045,7	19·895	235·690	11·58
58	0·194	0·62	19·43	0·031,9	19·120	215·795	11·11
59	0·196	0·62	18·81	0·033,0	18·500	196·675	10·46
60	0·113	0·36	18·19	0·019,8	18·010	178·175	9·80
61	0·113	0·36	17·83	0·020,2	17·650	160·165	8·98
62	0·213	0·68	17·47	0·038,9	17·130	142·515	8·16
63	0·213	0·68	16·79	0·040,5	16·450	125·385	7·47
64	0·296	0·94	16·11	0·058,3	15·640	108·935	6·76
65	0·296	0·94	15·17	0·062,0	14·700	93·295	6·15
66	0·396	1·26	14·23	0·088,5	13·600	78·595	5·52
67	0·396	1·26	12·97	0·097,1	12·340	64·995	5·01
68	0·473	1·50	11·71	0·128,1	10·960	52·655	4·50

TABLE 105 (cont'd)

x	D_x	d_x	l_x	q_x	L_x	T_x	e^0_x
69	0·473	1·50	10·21	0·146,9	9·460	41·695	4·08
70	0·473	1·50	8·71	0·172,2	7·960	32·235	3·70
71	0·473	1·50	7·21	0·208,0	6·460	24·275	3·37
72	0·374	1·19	5·71	0·208,4	5·115	17·815	3·12
73	0·314	1·00	4·52	0·221,2	4·020	12·700	2·81
74	0·314	1·00	3·52	0·284,1	3·020	8·680	2·47
75	0·314	1·00	2·52	0·396,8	2·020	5·660	2·25
76	0·102	0·32	1·52	0·210,5	1·360	3·640	2·39
77	0·102	0·32	1·20	0·266,7	1·040	2·280	1·90
78	0·102	0·32	0·88	0·363,6	0·720	1·240	1·41
79	0·102	0·32	0·56	0·571,4	0·400	0·520	0·93
80	0·076	0·24	0·24	1·000,0	0·120	0·120	0·50
Total	31·500	100·00	—	—	2,279·030	—	—

TABLE 106

Vassilievka III, aged 20+, abridged

x	D_x	d_x	l_x	q_x	L_x	T_x	e^0_x
				Male			
20–24	2·065	13·32	100·00	0·133,2	466·700	2,395·650	23·96
25–29	2·274	14·67	86·68	0·169,2	396·725	1,928·950	22·25
30–34	1·950	12·58	72·01	0·174,7	328·600	1,532·225	21·28
35–39	1·165	7·52	59·43	0·126,5	278·350	1,203·625	20·25
40–44	0·701	4·52	51·91	0·087,1	248·250	925·275	17·82
45–49	1·963	12·67	47·39	0·267,4	205·275	677·025	14·29
50–54	1·734	11·19	34·72	0·322,3	145·625	471·750	13·59
55–59	0·700	4·51	23·53	0·191,7	106·375	326·125	13·86
60–64	0·265	1·71	19·02	0·089,9	90·825	219·750	11·55
65–69	0·819	5·28	17·31	0·305,0	73·350	128·925	7·45
70–74	1·150	7·42	12·03	0·616,8	41·600	55·575	4·62
75–79	0·638	4·12	4·61	0·893,7	12·750	13·975	3·03
80–	0·076	0·49	0·49	1·000,0	1·225	1·225	2·50
Total	15·500	100·00	—	—	2,395·650	—	—
				Female			
20–24	1·838	14·14	100·00	0·141,4	464·650	2,033·150	20·33
25–29	2·595	19·96	85·86	0·232,5	379·400	1,568·500	18·27
30–34	2·107	16·21	65·90	0·246,0	288·975	1,189·100	18·04
35–39	1·210	9·31	49·69	0·187,4	225·175	900·125	18·11
40–44	0·438	3·37	40·38	0·083,5	193·475	674·950	16·71
45–49	1·369	10·53	37·01	0·284,5	158·725	481·475	13·01
50–54	1·171	9·01	26·48	0·340,3	109·875	322·750	12·19
55–59	0·272	2·09	17·47	0·119,6	82·125	212·875	12·19
60–64	0·383	2·95	15·38	0·191,8	69·525	130·750	8·50
65–69	0·915	7·04	12·43	0·566,4	44·550	61·225	4·93
70–74	0·618	4·75	5·39	0·881,3	15·075	16·675	3·09
75–79	0·084	0·64	0·64	1·000,0	1·600	1·600	2·50
80–	—	—	—	—	—	—	—
Total	13·000	100·00	—	—	2,033·150	—	—

TABLE 107

Fofonovo Mesolithic Eneolithic population, both sexes

x	D_x	d_x	l_x	q_x	L_x	T_x	e_x^0
0	—	—	100·00	—	100·000	4,435·590	44·36
1	0·334	1·39	100·00	0·013,9	99·305	4,335·590	43·36
2	0·334	1·39	98·61	0·014,1	97·915	4,236·285	42·96
3	0·334	1·39	97·22	0·014,3	96·525	4,138·370	42·57
4	0·334	1·39	95·83	0·014,5	95·135	4,041·845	42·18
5	0·332	1·38	94·44	0·014,6	93·750	3,946·710	41·79
6	0·332	1·38	93·06	0·014,8	92·370	3,852·960	41·40
7	0·125	0·52	91·68	0·005,7	91·420	3,760·590	41·02
8	0·125	0·52	91·16	0·005,7	90·900	3,669·170	40·25
9	0·125	0·52	90·64	0·005,7	90·380	3,578·270	39·48
10	0·125	0·52	90·12	0·005,8	89·860	3,487·890	38·70
11	0·125	0·52	89·60	0·005,8	89·340	3,398·030	37·92
12	0·125	0·52	89·08	0·005,8	88·820	3,308·690	37·14
13	0·125	0·52	88·56	0·005,9	88·300	3,219·870	36·36
14	0·125	0·52	88·04	0·005,9	87·780	3,131·570	35·57
15	—	—	87·52	—	87·520	3,043·790	34·78
16	—	—	87·52	—	87·520	2,956·270	33·78
17	—	—	87·52	—	87·520	2,868·750	32·78
18	—	—	87·52	—	87·520	2,781·230	31·78
19	—	—	87·52	—	87·520	2,693·710	30·78
20	—	—	87·52	—	87·520	2,606·190	29·78
21	0·833	3·47	87·52	0·039,6	85·785	2,518·670	28·78
22	0·833	3·47	84·05	0·041,3	82·315	2,432·885	28·95
23	0·474	1·97	80·58	0·024,4	79·595	2,350·570	29·17
24	0·140	0·58	78·61	0·007‘4	78·320	2,270·975	28·89
25	0·140	0·58	78·03	0·007,4	77·740	2,192·655	28·10
26	0·140	0·58	77·45	0·007,5	77·160	2,114·915	27·31
27	0·140	0·58	76·87	0·007,5	76·580	2,037·755	26·51
28	0·140	0·58	76·29	0·007,6	76·000	1,961·175	25·71
29	0·140	0·58	75·71	0·007,7	75·420	1,885·175	24·90
30	0·172	0·72	75·13	0·009,6	74·770	1,809·755	24·09
31	0·172	0·72	74·41	0·009,7	74·050	1,734·985	23·32
32	0·172	0·72	73·69	0·009,8	73·330	1,660·935	22·54
33	0·072	0·30	72·97	0·004,1	72·820	1,587·605	21·76
34	0·072	0·30	72·67	0·004,1	72·520	1,514·785	20·84
35	0·222	0·93	72·37	0·012,9	71·905	1,442·265	19·93
36	0·222	0·93	71·44	0·013,0	70·975	1,370·360	19·18
37	0·222	0·93	70·51	0·013,2	70·045	1,299·385	18·43
38	0·222	0·93	69·58	0·013,4	69·115	1,229·340	17·67
39	0·222	0·93	68·65	0·013,5	68·185	1,160·225	16·90
40	0·329	1·37	67·72	0·020,2	67·035	1,092·040	16·13
41	0·329	1·37	66·35	0·020,6	65·665	1,025·005	15·45
42	0·329	1·37	64·98	0·021,1	64·295	959·340	14·76
43	0·329	1·37	63·61	0·021,5	62·925	895·045	14·07
44	0·329	1·37	62·24	0·022,0	61·555	832·120	13·37
45	0·429	1·79	60·87	0·029,4	59·975	770·565	12·66
46	0·429	1·79	59·08	0·030,3	58·185	710·590	12·03

TABLE 107 (cont'd)

x	D_x	d_x	l_x	q_x	L_x	T_x	e_x^0
47	0·484	2·02	57·29	0·035,3	56·280	652·405	11·39
48	0·484	2·02	55·27	0·036,5	54·260	596·125	10·79
49	0·684	2·85	53·25	0·053,5	51·825	541·865	10·18
50	0·749	3·12	50·40	0·061,9	48·840	490·040	9·72
51	0·849	3·54	47·28	0·074,9	45·510	441·200	9·33
52	0·949	3·95	43·74	0·090,3	41·765	395·690	9·05
53	0·950	3·96	39·79	0·099,5	37·810	353·925	8·89
54	0·850	3·54	35·83	0·098,8	34·060	316·115	8·82
55	0·601	2·50	32·29	0·077,4	31·040	282·055	8·74
56	0·601	2·50	29·79	0·083,9	28·540	251·015	8·43
57	0·601	2·50	27·29	0·091,6	26·040	222·475	8·15
58	0·600	2·50	24·79	0·100,8	23·540	196·435	7·92
59	0·600	2·50	22·29	0·112,2	21·040	172·895	7·76
60	0·550	2·29	19·79	0·115,7	18·645	151·855	7·67
61	0·417	1·74	17·50	0·099,4	16·630	133·210	7·61
62	0·317	1·33	15·76	0·084,4	15·095	116·580	7·40
63	0·318	1·33	14·43	0·092,2	13·765	101·485	7·03
64	0·218	0·91	13·10	0·069,5	12·645	87·720	6·70
65	0·262	1·09	12·19	0·089,4	11·645	75·075	6·16
66	0·262	1·09	11·10	0·098,2	10·555	63·430	5·71
67	0·262	1·09	10·01	0·108,9	9·465	52·875	5·28
68	0·262	1·09	8·92	0·122,2	8·375	43·410	4·87
69	0·262	1·09	7·83	0·139,2	7·285	35·035	4·47
70	0·262	1·09	6·74	0·161,7	6·195	27·750	4·12
71	0·229	0·95	5·65	0·168,1	5·175	21·555	3·82
72	0·229	0·95	4·70	0·202,1	4·225	16·380	3·49
73	0·190	0·79	3·75	0·210,7	3·355	12·155	3·24
74	0·190	0·79	2·96	0·266,9	2·565	8·800	2·97
75	0·090	0·38	2·17	0·175,1	1·980	6·235	2·87
76	0·090	0·38	1·79	0·212,3	1·600	4·255	2·38
77	0·090	0·38	1·41	0·269,5	1·220	2·655	1·88
78	0·090	0·38	1·03	0·368,9	0·840	1·435	1·39
79	0·090	0·38	0·65	0·584,6	0·460	0·595	0·92
80	0·065	0·27	0·27	1·000,0	0·135	0·135	0·50
Total	24·000	100·00	—	—	4,435·590	—	

TABLE 108

Fofonovo, aged 20+, abridged

x	D_x	d_x	l_x	q_x	L_x	T_x	e_x^0
Male							
20–24	—	—	100·00	—	500·000	3,584·750	35·85
25–29	—	—	100·00	—	500·000	3,084·750	30·85
30–34	—	—	100·00	—	500·000	2,584·750	25·85
35–39	0·250	3·13	100·00	0·031,3	492·175	2,084·750	20·85
40–44	0·500	6·25	96·87	0·064,5	468·725	1,592·575	16·44
45–49	1·365	17·06	90·62	0·188,3	410·450	1,123·850	12·40
50–54	2·340	29·25	73·56	0·397,6	294·675	713·400	9·70
55–59	1·193	14·91	44·31	0·336,5	184·275	418·725	9·45
60–64	0·840	10·50	29·40	0·357,1	120·750	234·450	7·97
65–69	0·660	8·25	18·90	0·436,5	73·875	113·700	6·02
70–74	0·660	8·25	10·65	0·774,6	32·625	39·825	3·74
75–79	0·160	2·00	2·40	0·833,3	7·000	7·200	3·00
80–	0·032	0·40	0·40	1·000,0	0·200	0·200	0·50
Total	8·000	100·00	—	—	3,584·750	—	—
Female							
20–24	2·240	24·89	100·00	0·248,9	437·775	2,274·000	22·74
25–29	0·600	6·67	75·11	0·088,8	358·875	1,836·225	24·45
30–34	0·560	6·22	68·44	0·090,9	326·650	1,477·350	21·59
35–39	0·510	5·67	62·22	0·091,1	296·925	1,150·700	18·49
40–44	0·635	7·05	56·55	0·124,7	265·125	853·775	15·10
45–49	0·635	7·05	49·50	0·142,4	229·875	588·650	11·89
50–54	1·337	14·86	42·45	0·350,1	175·100	358·775	8·45
55–59	1·390	15·44	27·59	0·559,6	99·350	183·675	6·66
60–64	0·558	6·20	12·15	0·510,3	45·250	84·325	6·94
65–69	0·225	2·50	5·95	0·420,2	23·500	39·075	6·57
70–74	0·185	2·06	3·45	0·597,1	12·100	15·575	4·51
75–79	0·125	1·39	1·39	1·000,0	3·475	3·475	2·50
80–	—	—	—	—	—	—	—
Total	9·000	100·00	—	—	2,274·000	—	—

TABLE 109

Volni Neolithic population, both sexes

x	D_x	d_x	l_x	q_x	L_x	T_x	e_x^0
0	0·286	0·64	100·00	0·006,4	99·680	2,491·600	24·92
1	0·453	1·01	99·36	0·010,2	98·855	2,391·920	24·07
2	0·786	1·75	98·35	0·017,8	97·475	2,293·065	23·32
3	0·786	1·75	96·60	0·018,1	95·725	2,195·590	22·73
4	1·786	3·97	94·85	0·041,9	92·865	2,099·865	22·14
5	2·452	5·45	90·88	0·060,0	88·155	2,007·000	22·08
6	2·950	6·56	85·43	0·076,8	82·150	1,918·845	22·46
7	1·958	4·35	78·87	0·055,2	76·695	1,836·695	23·29
8	0·458	1·02	74·52	0·013,7	74·010	1,760·000	23·62
9	0·459	1·02	73·50	0·013,9	72·990	1,685·990	22·94
10	1·125	2·50	72·48	0·034,5	71·230	1,613·000	22·25
11	1·125	2·50	69·98	0·035,7	68·730	1,541·770	22·03
12	0·625	1·39	67·48	0·020,6	66·785	1,473·040	21·83
13	0·625	1·39	66·09	0·021,0	65·395	1,406·255	21·28
14	0·125	0·28	64·70	0·004,3	64·560	1,340·860	20·72
15	—	—	64·42	—	64·420	1,276·300	19·81
16	0·568	1·26	64·42	0·019,6	63·790	1,211·880	18·81
17	0·572	1·27	63·16	0·020,1	62·525	1,148·090	18·18
18	0·572	1·27	61·89	0·020,5	61·255	1,085·565	17·54
19	0·572	1·27	60·62	0·021,0	59·985	1,024·310	16·90
20	0·572	1·27	59·35	0·021,4	58·715	964·325	16·25
21	0·572	1·27	58·08	0·021,9	57·445	905·610	15·59
22	0·572	1·27	56·81	0·022,4	56·175	848·165	14·93
23	0·610	1·36	55·54	0·024,5	54·860	791·990	14·26
24	0·610	1·36	54·18	0·025,1	53·500	737·130	13·61
25	0·910	2·02	52·82	0·038,2	51·810	683·630	12·94
26	0·910	2·02	50·80	0·039,8	49·790	631·820	12·44
27	1·110	2·47	48·78	0·050,6	47·545	582·030	11·93
28	1·110	2·47	46·31	0·053,3	45·075	534·485	11·54
29	1·147	2·55	43·84	0·058,2	42·565	489·410	11·16
30	1·179	2·62	41·29	0·063,5	39·980	446·845	10·82
31	1·061	2·36	38·67	0·061,0	37·490	406·865	10·52
32	1·003	2·23	36·31	0·061,4	35·195	369·375	10·17
33	1·004	2·23	34·08	0·065,4	32·965	334·180	9·81
34	1·146	2·55	31·85	0·080,1	30·575	301·215	9·46
35	0·847	1·88	29·30	0·064,2	28·360	270·640	9·24
36	0·847	1·88	27·42	0·068,6	26·480	242·280	8·84
37	1·047	2·33	25·54	0·091,2	24·375	215·800	8·45
38	1·047	2·33	23·21	0·100,4	22·045	191·425	8·25
39	0·904	2·01	20·88	0·096,3	19·875	169·380	8·11
40	1·129	2·51	18·87	0·133,0	17·615	149·505	7·92
41	0·594	1·32	16·36	0·080,7	15·700	131·890	8·06
42	0·594	1·32	15·04	0·087,8	14·380	116·190	7·73
43	0·694	1·54	13·72	0·112,2	12·950	101·810	7·42
44	0·694	1·54	12·18	0·126,4	11·410	88·860	7·30
45	0·494	1·10	10·64	0·103,4	10·090	77·450	7·28
46	0·494	1·10	9·54	0·115,3	8·990	67·360	7·06

TABLE 109 (cont'd)

x	D_x	d_x	l_x	q_x	L_x	T_x	e_x^0
47	0·494	1·10	8·44	0·130,3	7·890	58·370	6·92
48	0·394	0·88	7·34	0·119,9	6·900	50·480	6·88
49	0·394	0·88	6·46	0·136,2	6·020	43·580	6·75
50	0·394	0·88	5·58	0·157,7	5·140	37·560	6·73
51	0·394	0·88	4·70	0·187,2	4·260	32·420	6·90
52	0·194	0·43	3·82	0·112,6	3·605	28·160	7·37
53	0·195	0·43	3·39	0·126,8	3·175	24·555	7·24
54	0·195	0·43	2·96	0·145,3	2·745	21·380	7·22
55	0·196	0·43	2·53	0·170,0	2·315	18·635	7·37
56	0·158	0·35	2·10	0·166,7	1·925	16·320	7·77
57	0·158	0·35	1·75	0·200,0	1·575	14·395	8·23
58	0·058	0·13	1·40	0·092,9	1·335	12·820	9·16
59	0·058	0·13	1·27	0·102,4	1·205	11·485	9·04
60	0·058	0·13	1·14	0·114,0	1·075	10·280	9·02
61	0·025	0·06	1·01	0·059,4	0·980	9·205	9·11
62	0·025	0·06	0·95	0·063,2	0·920	8·225	8·66
63	0·025	0·06	0·89	0·067,4	0·860	7·305	8·21
64	0·025	0·06	0·83	0·072,3	0·800	6·445	7·77
65	0·025	0·06	0·77	0·077,9	0·740	5·645	7·33
66	0·025	0·06	0·71	0·084,5	0·680	4·905	6·91
67	0·025	0·05	0·65	0·076,9	0·625	4·225	6·50
68	0·025	0·05	0·60	0·083,3	0·575	3·600	6·00
69	0·025	0·05	0·55	0·090,9	0·525	3·025	5·50
70	0·025	0·05	0·50	0·100,0	0·475	2·500	5·00
71	0·025	0·05	0·45	0·111,1	0·425	2·025	4·50
72	0·025	0·05	0·40	0·125,0	0·375	1·600	4·00
73	0·025	0·05	0·35	0·142,9	0·325	1·225	3·50
74	0·025	0·05	0·30	0·166,7	0·275	0·900	3·00
75	0·025	0·05	0·25	0·200,0	0·225	0·625	2·50
76	0·025	0·05	0·20	0·250,0	0·175	0·400	2·00
77	0·025	0·05	0·15	0·333,3	0·125	0·225	1·50
78	0·025	0·05	0·10	0·500,0	0·075	0·100	1·00
79	0·025	0·05	0·05	1·000,0	0·025	0·025	0·50
80	—	—	—	—	—	—	—
Total	45·000	100·00	—	—	2,491·600	—	—

TABLE 110

Volni aged 20+, abridged

x	D_x	d_x	l_x	q_x	L_x	T_x	e_x^0
Male							
20–24	0·899	6·70	100·00	0·067,0	483·250	1,583·940	15·84
25–29	2·812	20·94	93·30	0·224,4	414·150	1,100·690	11·80
30–34	2·838	21·13	72·36	0·292,0	308·975	686·540	9·49
35–39	2·632	19·60	51·23	0·382,6	207·150	377·565	7·37
40–44	2·440	18·17	31·63	0·574,5	112·725	170·415	5·39
45–49	1·185	8·82	13·46	0·655,3	45·250	57·690	4·29
50–54	0·585	4·36	4·64	0·939,7	12·300	12·440	2·68
55–59	0·038	0·28	0·28	1·000,0	0·140	0·140	0·50
60–64	—	—	—	—	—	—	—
65–69	—	—	—	—	—	—	—
70–74	—	—	—	—	—	—	—
75–79	—	—	—	—	—	—	—
Total	13·429	100·00	—	—	1,583·940	—	—
Female							
20–24	2·037	15·33	100·00	0·153,3	461·675	1,680·450	16·80
25–29	2·375	17·88	84·67	0·211,2	378·650	1,218·775	14·39
30–34	2·555	19·23	66·79	0·287,9	285·875	840·125	12·58
35–39	2·060	15·50	47·56	0·325,9	199·050	554·250	11·65
40–44	1·265	9·52	32·06	0·296,9	136·500	355·200	11·08
45–49	1·085	8·17	22·54	0·362,5	92·275	218·700	9·70
50–54	0·787	5·92	14·37	0·412,0	57·050	126·425	8·80
55–59	0·590	4·44	8·45	0·525,4	31·150	69·375	8·21
60–64	0·158	1·19	4·01	0·296,8	17·075	38·225	9·53
65–69	0·125	0·94	2·82	0·333,3	11·750	21·150	7·50
70–74	0·125	0·94	1·88	0·500,0	7·050	9·400	5·00
75–79	0·125	0·94	0·94	1·000,0	2·350	2·350	2·50
Total	13·287	100·00	—	—	1,680·450	—	—

TABLE 111

Tiszapolgár-Basatanya, Copper Age population, both sexes

x	D_x	d_x	l_x	q_x	L_x	T_x	e_x^0
0	2·000	1·24	100·00	0·012,4	99·380	3,636·920	36·37
1	1·134	0·70	98·76	0·007,1	98·410	3,537·540	35·82
2	2·633	1·64	98·06	0·016,7	97·240	3,439·130	35·07
3	2·633	1·64	96·42	0·017,0	95·600	3,341·890	34·66
4	2·468	1·53	94·78	0·016,1	94·015	3,246·290	34·25
5	3·966	2·46	93·25	0·026,4	92·020	3,152·275	33·80
6	4·666	2·90	90·79	0·031,9	89·340	3,060·255	33·71
7	0·625	0·39	87·89	0·004,4	87·695	2,970·915	33·80
8	2·125	1·32	87·50	0·015,1	86·840	2,883·220	32·95
9	0·625	0·39	86·18	0·004,5	85·985	2,796·380	32·45
10	2·125	1·32	85·79	0·015,4	85·130	2,710·395	31·59
11	1·625	1·01	84·47	0·012,0	83·965	2,625·265	31·08
12	1·958	1·22	83·46	0·014,6	82·850	2,541·300	30·45
13	1·958	1·22	82·24	0·014,8	81·630	2,458·450	29·89
14	0·459	0·28	81·02	0·003,5	80·880	2,376·820	29·34
15	4·625	2·87	80·74	0·035,5	79·305	2,295·940	28·44
16	5·625	3·49	77·87	0·044,8	76·125	2,216·635	28·47
17	1·625	1·01	74·38	0·013,6	73·875	2,140·510	28·78
18	0·625	0·39	73·37	0·005,3	73·175	2,066·635	28·17
19	0·625	0·39	72·98	0·005,3	72·785	1,993·460	27·32
20	0·625	0·39	72·59	0·005,4	72·395	1,920·675	26·46
21	2·125	1·32	72·20	0·018,3	71·540	1,848·280	25·60
22	2·125	1·32	70·88	0·018,6	70·220	1,776·740	25·07
23	1·296	0·80	69·56	0·011,5	69·160	1,706·520	24·53
24	1·439	0·89	68·76	0·012,9	68·315	1,637·360	23·81
25	1·638	1·02	67·87	0·015,0	67·360	1,569·045	23·12
26	1·781	1·11	66·85	0·016,6	66·295	1,501·685	22·46
27	1·781	1·11	65·74	0·016,9	65·815	1,435·390	21·83
28	1·882	1·17	64·63	0·018,1	64·045	1,370·205	21·20
29	2·082	1·29	63·46	0·020,3	62·158	1,306·160	20·58
30	2·841	1·76	62·17	0·028,3	61·290	1,243·345	20·00
31	2·863	1·78	60·41	0·029,5	59·520	1,182·055	19·57
32	2·863	1·78	58·63	0·030,4	57·740	1,122·535	19·15
33	2·583	1·60	56·85	0·028,1	56·050	1,064·795	18·73
34	2·771	1·72	55·25	0·031,1	54·390	1,008·745	18·26
35	2·504	1·55	53·53	0·029,0	52·755	954·355	17·83
36	3·005	1·87	51·98	0·036,0	51·045	901·600	17·35
37	3·018	1·87	50·11	0·037,3	49·175	850·555	16·97
38	3·119	1·94	48·24	0·040,2	47·270	801·380	16·61
39	3·119	1·94	46·30	0·041,9	45·330	754·110	16·29
40	3·248	2·02	44·36	0·045,5	43·350	708·780	15·98
41	2·464	1·53	42·34	0·036,1	41·575	665·430	15·72
42	2·403	1·49	40·81	0·036,5	40·065	623·855	15·29
43	2·204	1·37	39·32	0·034,8	38·635	583·790	14·85
44	2·306	1·43	37·95	0·037,7	37·235	545·155	14·37
45	2·106	1·31	36·52	0·035,9	35·865	507·920	13·91

TABLE 111 (cont'd)

x	D_x	d_x	l_x	q_x	L_x	T_x	e_x^0
46	2·348	1·46	35·21	0·041,5	34·480	472·055	13·41
47	2·046	1·27	33·75	0·037,6	33·115	437·575	12·97
48	2·445	1·52	32·48	0·046,8	31·720	404·460	12·45
49	2·443	1·52	30·96	0·049,1	30·200	372·740	12·04
50	2·684	1·67	29·44	0·056,7	28·605	342·540	11·64
51	2·694	1·67	27·77	0·060,1	26·935	313·935	11·30
52	2·697	1·67	26·10	0·064,0	25·265	287·000	11·00
53	2·485	1·54	24·43	0·063,0	23·660	261·735	10·71
54	2·486	1·54	22·89	0·067,3	22·120	238·075	10·40
55	2·243	1·39	21·35	0·065,1	20·655	215·955	10·11
56	2·043	1·27	19·96	0·063,6	19·325	195·300	9·78
57	1·932	1·20	18·69	0·064,2	18·090	175·975	9·42
58	1·931	1·20	17·49	0·068,6	16·890	157·885	9·03
59	1·933	1·20	16·29	0·073,7	15·690	140·995	8·66
60	1·349	0·84	15·09	0·055,7	14·670	125·305	8·30
61	1·097	0·68	14·25	0·047,7	13·910	110·635	7·76
62	1·126	0·70	13·57	0·051,6	13·220	96·725	7·13
63	1·152	0·72	12·87	0·055,9	12·510	83·505	6·49
64	1·594	0·99	12·15	0·081,5	11·655	70·995	5·84
65	1·794	1·11	11·16	0·099,5	10·605	59·340	5·32
66	1·896	1·18	10·05	0·117,4	9·460	48·735	4·85
67	1·894	1·18	8·87	0·133,0	8·280	39·275	4·43
68	1·900	1·18	7·69	0·153,4	7·100	30·995	4·03
69	1·900	1·18	6·51	0·181,3	5·920	23·895	3·67
70	1·741	1·08	5·33	0·202,6	4·790	17·975	3·37
71	1·269	0·79	4·25	0·185,9	3·855	13·185	3·10
72	1·263	0·78	3·46	0·225,4	3·070	9·330	2·70
73	1·143	0·71	2·68	0·264,9	2·325	6·260	2·34
74	1·143	0·71	1·97	0·360,4	1·615	3·935	2·00
75	0·903	0·56	1·26	0·444,4	0·980	2·320	1·84
76	0·305	0·19	0·70	0·271,4	0·605	1·340	1·91
77	0·305	0·19	0·51	0·372,5	0·415	0·735	1·44
78	0·250	0·16	0·32	0·500,0	0·240	0·320	1·00
79	0·250	0·16	0·16	1·000,0	0·080	0·080	0·50
80	—	—	—	—	—	—	—
Total	161·000	100·00	—	—	3,636·920	—	—

TABLE 112

Tiszapolgár-Basatanya, male population, aged 20+

x	D_x	d_x	l_x	q_x	L_x	T_x	e_x^0
20	0·500	0·87	100·00	0·008,7	99·565	2,706·200	27·06
21	0·500	0·87	99·13	0·008,8	98·695	2,606·635	26·30
22	0·500	0·87	98·26	0·008,9	97·825	2,507·940	25·52
23	0·481	0·84	97·39	0·008,6	96·970	2,410·115	24·75
24	0·624	1·09	96·55	0·011,3	96·005	2,313·145	23·96
25	0·824	1·43	95·46	0·015,0	94·745	2,217·140	23·23
26	0·824	1·43	94·03	0·015,2	93·315	2,122·395	22·57
27	0·823	1·43	92·60	0·015,4	91·885	2,029·080	21·91
28	0·824	1·43	91·17	0·015,7	90·455	1,937·195	21·25
29	0·992	1·72	89·74	0·019,2	88·880	1,846·740	20·58
30	1·468	2·55	88·02	0·029,0	86·745	1,757·860	19·97
31	1·324	2·30	85·47	0·026,9	84·320	1,671·115	19·55
32	1·324	2·30	83·17	0·027,7	82·020	1,586·795	19·08
33	1·335	2·32	80·87	0·028,7	79·710	1,504·775	18·61
34	1·621	2·82	78·55	0·035,9	77·140	1,425·065	18·14
35	1·254	2·18	75·73	0·028,8	74·640	1,347·925	17·80
36	1·555	2·70	73·55	0·036,7	72·200	1,273·285	17·31
37	1·554	2·70	70·85	0·038,1	69·500	1,201·085	16·95
38	1·555	2·70	68·15	0·039,6	66·800	1,131·585	16·60
39	1·555	2·70	65·45	0·041,3	64·100	1,064·785	16·27
40	1·720	2·99	62·75	0·047,6	61·255	1,000·685	15·95
41	1·235	2·15	59·76	0·036,0	58·685	939·430	15·72
42	1·124	1·96	57·61	0·034,0	56·630	880·745	15·29
43	1·124	1·96	55·65	0·035,2	54·670	824·115	14·81
44	1·124	1·96	53·69	0·036,5	52·710	769·445	14·33
45	0·924	1·61	51·73	0·031,1	50·925	716·735	13·86
46	1·023	1·78	50·12	0·035,5	49·230	665·810	13·28
47	1·022	1·78	48·34	0·036,8	47·450	616·580	12·76
48	1·276	2·22	46·56	0·047,7	45·450	569·130	12·22
49	1·275	2·22	44·34	0·050,1	43·230	523·680	11·81
50	1·275	2·22	42·12	0·052,7	41·010	480·450	11·41
51	1·330	2·31	39·90	0·057,9	38·745	439·440	11·01
52	1·332	2·32	37·59	0·061,7	36·430	400·695	10·66
53	1·347	2·34	35·27	0·066,3	34·100	364·265	10·33
54	1·347	2·34	32·93	0,071,1	31·760	330·165	10·03
55	1·347	2·34	30·59	0·076,5	29·420	298·405	9·75
56	1·147	1·99	28·25	0·070,4	27·255	268·985	9·52
57	1·036	1·80	26·26	0·068,5	25·360	241·730	9·21
58	1·035	1·80	24·46	0·073,6	23·560	216·370	8·85
59	1·037	1·80	22·66	0·079,4	21·760	192·810	8·51
60	0·653	1·14	20·86	0·054,7	20·290	171·050	8,20
61	0·627	1·09	19·72	0·055,3	19·175	150·760	7·65
62	0·706	1·23	18·63	0·066,0	18·015	131·585	7·06
63	0·607	1·06	17·40	0·060,9	16·870	113·570	6·53
64	0·800	1·39	16·34	0·085,1	15·645	96·700	5·92
65	0·800	1·39	14·95	0·093,0	14·255	81·055	5·42
66	0·902	1·57	13·56	0·115,8	12·775	66·800	4·93

TABLE 112 (cont'd)

x	D_x	d_x	l_x	q_x	L_x	T_x	e_x^0
67	0·900	1·57	11·99	0·130,9	11·205	54·025	4·51
68	0·903	1·57	10·42	0·150,7	9·635	42·820	4·11
69	0·903	1·57	8·85	0·177,4	8·065	33·185	3·75
70	0·844	1·47	7·28	0·201,9	6·545	25·120	3·45
71	0·622	1·08	5·81	0·185,9	5·270	18·575	3·20
72	0·619	1·08	4·73	0·228,3	4·190	13·305	2·81
73	0·499	0·87	3·65	0·238,4	3·215	9·115	2·50
74	0·499	0·87	2·78	0·312,9	2·345	5·900	2·12
75	0·499	0·87	1·91	0·455,5	1·475	3·555	1·86
76	0·150	0·26	1·04	0·250 0	0·910	2·080	2·00
77	0·150	0·26	0·78	0·333,3	0·650	1·170	1·50
78	0·150	0·26	0·52	0·500,0	0·390	0·520	1·00
79	0·150	0·26	0·26	1·000,0	0·130	0·130	0·50
80	—	—	—	—	—	—	—
Total	57·500	100·00	—	—	2,706·200	—	—

TABLE 113

Tiszapolgár-Basatanya, female, population, aged 20+

x	D_x	d_x	l_x	q_x	L_x	T_x	e^0_x
20	—	—	100·00	—	100·000	2,662·250	26·62
21	1·500	2·83	100·00	0·028,3	98·585	2,562·250	25·62
22	1·500	2·83	97·17	0·029,1	95·755	2,463·665	25·35
23	0·623	1·18	94·34	0·012,5	93·750	2,367·910	25·10
24	0·623	1·18	93·16	0·012,7	92·570	2,274·160	24·41
25	0·622	1·17	91·98	0·012,7	91·395	2,181·590	23·72
26	0·765	1·44	90·81	0·015,9	90·090	2,090·195	23·02
27	0·766	1·45	89·37	0·016,2	88·645	2,000·105	22·38
28	0·866	1·63	87·92	0·018,5	87·105	1,911·460	21·74
29	0·898	1·69	86·29	0·019,6	85·445	1,824·355	21·14
30	1·182	2·23	84·60	0·026,4	83·485	1,738·910	20·55
31	1·348	2·54	82·37	0·030,8	81·100	1,655·425	20·10
32	1·348	2·54	79·83	0·031,8	78·560	1,574·325	19·72
33	1·056	1·99	77·29	0·025,7	76·295	1,495·765	19·35
34	0·958	1·81	75·30	0·024,0	74·395	1,419·470	18·85
35	1·058	2·00	73·49	0·027,2	72·490	1,345·075	18·30
36	1·258	2·37	71·49	0·033,2	70·305	1,272·585	17·80
37	1·272	2·40	69·12	0·034,7	67·920	1,202·280	17·39
38	1·372	2·59	66·72	0·038,8	65·425	1,134·360	17·00
39	1·372	2·59	64·13	0·040,4	62·835	1,068·935	16·67
40	1·395	2·63	61·54	0·042,7	60·225	1,006·100	16·35
41	1·096	2·07	58·91	0·035,1	57·875	945·875	16·06
42	1·146	2·16	56·84	0·038,0	55·760	888·000	15·62
43	0·946	1·78	54·68	0·032,6	53·790	832·240	15·22
44	1·048	1·98	52·90	0·037,4	51·910	778·450	14·72
45	1·048	1·98	50·92	0·038,9	49·930	726·540	14·27
46	1·191	2·25	48·94	0·046,0	42·815	676·610	13·83
47	0·890	1·68	46·69	0·036,0	45·850	633·795	13·57
48	1·035	1·95	45·01	0·043,3	44·035	587·945	13·06
49	1·034	1·95	43·06	0·045,3	42·085	543·910	12·63
50	1·275	2·41	41·11	0·058,6	39·905	501·825	12·21
51	1·230	2·32	38·70	0·059,9	37·540	461·920	11·94
52	1·231	2·32	36·38	0·063,8	35·220	424·380	11·67
53	1·038	1·96	34·06	0·057,5	33·080	389·160	11·43
54	1·039	1·96	32·10	0·061,1	31·120	356·080	11·09
55	0·796	1·50	30·14	0·049,8	29·390	324·960	10·78
56	0·796	1·50	28·64	0·052,4	27·890	295·570	10·32
57	0·796	1·50	27·14	0·055,3	26·390	267·680	9·86
58	0·796	1·50	25·64	0·058,5	24·890	241·290	9·41
59	0·796	1·50	24·14	0·062,1	23·390	216·400	8·96
60	0·596	1·12	22·64	0·049,5	22·080	193·010	8·53
61	0·370	0·70	21·52	0·032,5	21·170	170·930	7·94
62	0·320	0·60	20·82	0·028,8	20·520	149·760	7·19
63	0·545	1·03	20·22	0·050,9	19·705	129·240	6·39
64	0·794	1·50	19·19	0·078,2	17·440	109·535	5·71
65	0·994	1·88	17·69	0·106,3	16·750	92·095	5·21
66	0·994	1·88	15·81	0·118,9	14·870	75·345	4·77

TABLE 113 (cont'd)

x	D_x	d_x	l_x	q_x	L_x	T_x	e_x^0
67	0·994	1·88	13·93	0·135,0	12·990	60·475	4·34
68	0·997	1·88	12·05	0·156,0	11·110	47·485	3·94
69	0·997	1·88	10·17	0·184,9	9·230	36·375	3·58
70	0·897	1·69	8·29	0·203,9	7·445	27·145	3·27
71	0·647	1·22	6·60	0·184,8	5·990	19·700	2·98
72	0·644	1·22	5·38	0·226,8	4·770	13·710	2·55
73	0·644	1·22	4·16	0·293,3	3·550	8·940	2·15
74	0·644	1·22	2·94	0·415,0	2·330	5·390	1·83
75	0·404	0·76	1·72	0·441,9	1·340	3·060	1·78
76	0·155	0·29	0·96	0·302,1	0·815	1·720	1·79
77	0·155	0·29	0·67	0·432,8	0·525	0·905	1·35
78	0·100	0·19	0·38	0·500,0	0·285	0·380	1·00
79	0·100	0·19	0·19	1·000,0	0·095	0·095	0·50
80	—	—	—	—	—	—	—
Total	53·000	100·00	—	—	2,662·250	—	—

TABLE 114

Alsónémedi Copper Age population, both sexes

x	D_x	d_x	l_x	q_x	L_x	T_x	e^0_x
0	5·5	13·1	100·0	0·131,0	93·45	2,886·20	28·86
1	3·0	7·2	86·9	0·082,9	83·30	2,792·75	32·14
2	2·5	6·0	79·7	0·075,3	76·70	2,709·45	34·00
3	0·5	1·2	73·7	0·016,3	73·10	2,632·75	35·72
4	1·0	2·4	72·5	0·033,1	71·30	2,559·65	35·31
5	0·5	1·2	70·1	0·017,1	69·50	2,488·35	35·50
6	—	—	68·9	—	68·90	2,418·85	35·11
7	—	—	68·9	—	68·90	2,349·95	34·11
8	0·5	1·2	68·9	0·017,4	68·30	2,281·05	33·11
9	0·5	1·2	67·7	0·017,7	67·10	2,212·75	32·68
10	0·5	1·2	66·5	0·018,0	65·90	2,145·65	32·27
11	0·5	1·2	65·3	0·018,4	64·70	2,079·75	31·85
12	—	—	64·1	—	64·10	2,015·05	31·44
13	—	—	64·1	—	64·10	1,950·95	30·44
14	—	—	64·1	—	64·10	1,886·85	29·44
15	1·0	2·4	64·1	0·037,4	62·90	1,822·75	28·44
16	1·0	2·4	61·7	0·038,9	60·50	1,759·85	28·52
17	—	—	59·3	—	59·30	1,699·35	28·66
18	—	—	59·3	—	59·30	1,640·05	27·66
19	—	—	59·3	—	59·30	1,580·75	26·66
20	—	—	59·3	—	59·30	1,521·45	25·66
21	0·5	1·2	59·3	0·020,2	58·70	1,462·15	24·66
22	0·5	1·2	58·1	0·020,7	57·50	1,403·45	24·16
23	0·2	0·5	56·9	0·008,8	56·65	1,345·95	23·65
24	0·2	0·5	56·4	0·008,9	56·15	1,289·30	22·86
25	0·4	0·9	55·9	0·016,1	55·45	1,233·15	22·06
26	0·2	0·5	55·0	0·009,1	54·75	1,177·70	21·41
27	0·4	0·9	54·5	0·016,5	54·05	1,122·95	20·60
28	0·2	0·5	53·6	0·009,3	53·35	1,068·90	19·94
29	0·6	1·4	53·1	0·026,4	52·40	1,015·55	19·13
30	0·6	1·4	51·7	0·027,1	51·00	963·15	18·63
31	0·8	1·9	50·3	0·037,8	49·35	912·15	18·13
32	0·7	1·7	48·4	0·035,1	47·55	862·80	17·83
33	0·7	1·7	46·7	0·036,4	45·85	815·25	17·46
34	0·3	0·7	45·0	0·015,6	44·65	769·40	17·10
35	0·3	0·7	44·3	0·015,8	43·95	724·75	16·36
36	0·5	1·2	43·6	0·027,5	43·00	680·80	15·61
37	0·5	1·2	42·4	0·028,3	41·80	637·80	15·04
38	0·5	1·2	41·2	0·029,1	40·60	596·00	14·47
39	0·5	1·2	40·0	0·030,0	39·40	555·40	13·89
40	0·3	0·7	38·8	0·018,0	38·45	516·00	13·30
41	0·1	0·2	38·1	0·005,2	38·00	477·55	12·53
42	0·6	1·4	37·9	0·036,9	37·20	439·55	11·60
43	1·1	2·6	36·5	0·071,2	35·20	402·35	11·02
44	1·0	2·4	33·9	0·070,8	32·70	367·15	10·83
45	1·3	3·1	31·5	0·098,4	29·95	334·45	10·62
46	1·4	3·3	28·4	0·116,2	26·75	304·50	10·72

TABLE 114 (cont'd)

x	D_x	d_x	l_x	q_x	L_x	T_x	e_x^0
47	0·9	2·2	25·1	0·087,6	24·00	277·75	11·07
48	0·4	0·9	22·9	0·039,3	22·45	253·75	11·08
49	0·7	1·7	22·0	0·077,3	21·15	231·30	10·51
50	0·4	0·9	20·3	0·044,3	19·85	210·15	10·35
51	0·3	0·7	19·4	0·036,1	19·05	190·30	9·81
52	0·4	0·9	18·7	0·048,1	18·25	171·25	9·16
53	0·5	1·2	17·8	0·067,4	17·20	153·00	8·60
54	0·6	1·4	16·6	0·084,3	15·90	135·80	8·18
55	0·7	1·7	15·2	0·111,8	14·35	119·90	7·89
56	0·6	1·4	13·5	0·103,7	12·80	105·55	7·82
57	0·5	1·2	12·1	0·099,2	11·50	92·75	7·67
58	0·6	1·4	10·9	0·128,4	10·20	81·25	7·45
59	0·3	0·7	9·5	0·073,7	9·15	71·05	7·48
60	0·2	0·5	8·8	0·056,8	8·55	61·90	7·03
61	0·3	0·7	8·3	0·084,3	7·95	53·35	6·43
62	0·4	0·9	7·6	0·118,4	7·15	45·40	5·97
63	0·2	0·5	6·7	0·074,6	6·45	38·25	5·71
64	0·4	0·9	6·2	0·145,2	5·75	31·80	5·13
65	0·4	0·9	5·3	0·169,8	4·85	26·05	4·92
66	0·4	0·9	4·4	0·204,5	3·95	21·20	4·82
67	0·2	0·5	3·5	0·142,9	3·25	17·25	4·93
68	0·2	0·5	3·0	0·166,7	2·75	14·00	4·67
69	—	—	2·5	—	2·50	11·25	4·50
70	—	—	2·5	—	2·50	8·75	3·50
71	0·2	0·5	2·5	0·200,0	2·25	6·25	2·50
72	0·2	0·5	2·0	0·250,0	1·75	4·00	2·00
73	0·2	0·5	1·5	0·333,3	1·25	2·25	1·50
74	0·2	0·5	1·0	0·500,0	0·75	1·00	1·00
75	0·2	0·5	0·5	1·000,0	0·25	0·25	0·50
Total	42·0	100·0	—	—	2,886·20	—	—

TABLE 115

Alsónémedi, aged 20+, abridged

x	D_x	d_x	l_x	q_x	L_x	T_x	e_x^0
				Male			
20–24	1·1	7·3	100·0	0·073,0	481·75	2,869·00	28·69
25–29	0·1	0·7	92·7	0·007,6	461·75	2,387·25	25·75
30–34	0·1	0·7	92·0	0·007,6	458·25	1,925·50	20·93
35–39	2·0	13·4	91·3	0·146,8	423·00	1,467·25	16·07
40–44	1·7	11·3	77·9	0·145,1	361·25	1,044·25	13·41
45–49	3·5	23·3	66·6	0·349,8	274·75	683·00	10·26
50–54	1·3	8·6	43·3	0·198,6	195·00	408·25	9·43
55–59	2·6	17·4	34·7	0·501,4	130·00	213·25	6·15
60–64	1·4	9·3	17·3	0·537,6	63·25	83·25	4·81
65–69	1·2	8·0	8·0	1·000,0	20·00	20·00	2·50
70–74	—	—	—	—	—	—	—
75–79	—	—	—	—	—	—	—
Total	15·0	100·0	—	—	2,869·00	—	—
				Female			
20–24	0·3	3·3	100·0	0·033,0	491·75	2,089·00	20·89
25–29	1·5	16·7	96·7	0·172,7	441·75	1,597·25	16·52
30–34	2·9	32·2	80·0	0·402,5	319·50	1,155·50	14·44
35–39	0·2	2·2	47·8	0·046,0	233·50	836·00	17·49
40–44	1·3	14·5	45·6	0·318,0	191·75	602·50	13·21
45–49	1·0	11·1	31·1	0·356,9	127·75	410·75	13·21
50–54	0·8	8·9	20·0	0·445,0	77·75	283·00	14·15
55–59	—	—	11·1	—	55·65	205·25	18·49
60–64	—	—	11·1	—	55·50	149·75	13·49
65–69	—	—	11·1	—	55·50	94·25	8·49
70–74	0·8	8·9	11·1	0·801,8	33·25	38·75	3·49
75–79	0·2	2·2	2·2	1,000,0	5·50	5·50	2·50
Total	9·0	100·0	—	—	2,089·00	—	—

TABLE 116

Mezőcsát Bronze Age population, both sexes

x	D_x	d_x	l_x	q_x	L_x	T_x	e_x^0
0	1·786	4·83	100·00	0·048,3	97·585	2,897·320	28·97
1	0·786	2·12	95·17	0·022,3	94·110	2,799·735	29·42
2	0·286	0·77	93·05	0·008,3	92·665	2,705·625	29·08
3	0·786	2·12	92·28	0·023,0	91·220	2,612·960	28·32
4	1·286	3·48	90·16	0·038,6	88·420	2,521·740	27·97
5	0·786	2·12	86·68	0·024,5	85·620	2,433·320	28·07
6	0·784	2·12	84·56	0·025,1	83·500	2,347·700	27·76
7	1·250	3·38	82·44	0·041,0	80·750	2,264·200	27·46
8	0·750	2·03	79·06	0·025,7	78·045	2,183·450	27·62
9	0·250	0·68	77·03	0·008,8	76·690	2,105·405	27·33
10	0·583	1·57	76·35	0·020,6	75·565	2,028·715	26·57
11	0·583	1·57	74·78	0·021,0	73·995	1,953·150	26·12
12	1·084	2·93	73·21	0·040,0	71·745	1,879·155	25·67
13	0·750	2·03	70·28	0·028,9	69·265	1,807·410	25·72
14	0·250	0·68	68·25	0·010,0	67·910	1,738·145	25·47
15	0·125	0·34	67·57	0·005,0	67·400	1,670·235	24·72
16	0·625	1·69	67·23	0·025,1	66·385	1,602·835	23·84
17	0·625	1·69	65·54	0·025,8	64·695	1,536·450	23·44
18	0·625	1·69	63·85	0·026,5	63·005	1,471·755	23·05
19	1·125	3·04	62·16	0·048,9	60·640	1,408·750	22·66
Total	15·125	40·88	—	—	1,549·210	—	—

TABLE 117

Mezőcsát, both sexes, aged 20+, abridged

x	D_x	d_x	l_x	q_x	L_x	T_x	e_x^0
20–24	1·915	8·75	100·00	0·087,5	478·125	2,280·830	22·81
25–29	4·100	18·74	91·25	0·205,4	409·400	1,802·705	19·76
30–34	1·920	8·78	72·51	0·121,1	340·600	1,393·305	19·22
35–39	2·950	13·49	63·73	0·211,7	284·925	1,052·705	16·52
40–44	1·895	8·66	50·24	0·172,4	229·550	767·780	15·28
45–49	1·587	7·25	41·58	0·174,4	189·775	538·230	12·94
50–54	2·290	10·47	34·33	0·305,0	145·475	348·455	10·15
55–59	1·990	9·10	23·86	0·381,4	96·550	202·980	8·51
60–64	1·028	4·70	14·76	0·318,4	62·050	106·430	7·21
65–69	1·420	6·49	10·06	0·645,1	34·075	44·380	4·41
70–74	0·680	3·11	3·57	0·871,1	10·075	10·305	2·89
75–79	0·100	0·46	0·46	1·000,0	0·230	0·230	0·50
Total	21·875	100·00	—	—	2,280·830	—	—

TABLE 118

Mezőcsát, aged 20+, abridged

x	D_x	d_x	l_x	q_x	L_x	T_x	e_x^0
Male							
20–24	0·450	4·50	100·00	0·045,0	488·750	2,509·200	25·09
25–29	2·425	24·25	95·50	0·253,9	416·875	2,020·450	21·16
30–34	0·225	2·25	71·25	0·031,6	350·625	1,603·575	22·51
35–39	1·550	15·50	69·00	0·224,6	306·250	1,252·950	18·16
40–44	0·985	9·85	53·50	0·184,1	242·875	946·700	17·70
45–49	0·387	3·87	43·65	0·088,7	208·575	703·825	16·12
50–54	0·890	8·90	39·78	0·223,7	176·650	495·250	12·45
55–59	0·640	6·40	30·88	0·207,3	138·400	318·600	10·32
60–64	0·728	7·28	24·48	0·297,4	104·200	180·200	7·36
65–69	1·120	11·20	17·20	0·651,2	58·000	76·000	4·42
70–74	0·500	5·00	6·00	0·833,3	17·500	18·000	3·00
75–79	0·100	1·00	1·00	1·000,0	0·500	0·500	0·50
Total	10·000	100·00	—	—	2,509·200	—	—
Female							
20–24	0·970	12·93	100·00	0·129,3	467·675	1,773·800	17·74
25–29	1·375	18·33	87·07	0·210,5	389·525	1,306·125	15·00
30–34	1·395	18·60	68·74	0·270,6	297·200	916·600	13·33
35–39	1·100	14·67	50·14	0·292,6	214·025	619·400	12·35
40–44	0·360	4·80	35·47	0·135,3	165·350	405·375	11·43
45–49	0·650	8·67	30·67	0·282,7	131·675	240·025	7·83
50–54	0·850	11·33	22·00	0·515,0	81·675	108·350	4·93
55–59	0·800	10·67	10·67	1·000,0	26·675	26·675	2·50
60–64	—	—	—	—	—	—	—
Total	7·500	100·00	—	—	1,773·800	—	—

TABLE 119

Mezőcsát early Iron Age population, both sexes, partly abridged

x	D_x	d_x	l_x	q_x	L_x	T_x	e_x^0
0	—	—	100·00	—	100·000	4,403·350	44·03
1	—	—	100·00	—	100·000	4,303·350	43·03
2	—	—	100·00	—	100·000	4,203·350	42·03
3	—	—	100·00	—	100·000	4,103·350	41·03
4	0·500	1·11	100·00	0·011,1	99·445	4,003·350	40·03
5	0·500	1·11	98·89	0·011,2	98·335	3,903·905	39·48
6	0·833	1·85	97·78	0·018,9	96·855	3,805·570	38·92
7	1·333	2·96	95·93	0·030,9	94·450	3,708·715	38·66
8	0·834	1·86	92·97	0·020,0	92·040	3,614·265	38·88
9	—	—	91·11	—	91·110	3,522·225	38·66
10	0·333	0·74	91·11	0·008,1	90·740	3,431·115	37·66
11	0·833	1·85	90·37	0·020,5	89·445	3,340·375	36·96
12	0·834	1·86	88·52	0·021,0	87·590	3,250·930	36·73
13	—	—	86·66	—	86·660	3,163·340	36·50
14	—	—	86·66	—	86·660	3,076·680	35·50
15	0·500	1·11	86·66	0·012,8	86·105	2,990·020	34·50
16	0·500	1·11	85·55	0·013,0	84·995	2,903·915	33·94
17	—	—	84·44	—	84·440	2,818·920	33·38
18	0·500	1·11	84·44	0·013,1	83·885	2,734·480	32·38
19	1·000	2·22	83·33	0·026,6	82·220	2,650·595	31·81
20–24	1·300	2·89	81·11	0·035,6	398·325	2,568·375	31·67
25–29	2·800	6·22	78·22	0·079,5	375·550	2,170·050	27·74
30–34	2·314	5·14	72·00	0·071,4	347·150	1,794·500	24·92
35–39	2·271	5·05	66·86	0·075,5	321·675	1,447·350	21·65
40–44	4·041	8·98	61·81	0·145,3	286·600	1,125·675	18·21
45–49	5·285	11·75	52·83	0·222,4	234·775	839·075	15·88
50–54	3·179	7·06	41·08	0·171,9	187·750	604·300	14·71
55–59	3·218	7·15	34·02	0·210,2	152·225	416·550	12·24
60–64	2·728	6·06	26·87	0·225,5	119·200	264·325	9·84
65–69	3·286	7·30	20·81	0·350,8	85·800	145·125	6·97
70–74	3·778	8·40	13·51	0·621,8	46·550	59·325	4·39
75–79	2·300	5·11	5·11	1·000,0	12·775	12·775	2·50
Total	45·000	100·00	—	—	4,403·350	—	—

TABLE 120

Mezőcsát, aged 20+, abridged

x	D_x	d_x	l_x	q_x	L_x	T_x	e_x^0
				Male			
20–24	0·240	2·00	100·00	0·020,0	495·000	3,197·030	31·97
25–29	0·900	7·50	98·00	0·076,5	471·250	2,702·030	27·57
30–34	0·100	0·83	90·50	0·009,2	450·425	2,230·780	24·65
35–39	0·385	3·21	89·67	0·035,8	440·325	1,780·355	19·85
40–44	1·921	16·01	86·46	0·185,2	392·275	1,340·030	15·50
45–49	2·694	22·45	70·45	0·318,7	296·125	947·755	13·45
50–54	1·400	11·67	48·00	0·243,1	210·825	651·630	13·58
55–59	0·600	5·00	36·33	0·137,6	169·150	440·805	12·13
60–64	0·742	6·18	31·33	0·197,3	141·200	271·655	8·67
65–69	1·538	12·81	25·15	0·509,3	93·725	130·455	5·19
70–74	1·245	10·38	12·34	0·841,2	35·750	36·730	2·98
75–79	0·235	1·96	1·96	1·000,0	0·980	0·980	0·50
Total	12·000	100·00	—	—	3,197·030	—	—
				Female			
20–24	0·900	4·62	100·00	0·046,2	488·450	3,136·200	31·36
25–29	1·500	7·69	95·38	0·080,6	457·675	2,647·750	27·76
30–34	1·814	9·30	87·69	0·106,1	415·200	2,190·075	24·98
35–39	1·446	7·42	78·39	0·094,7	373·400	1,774·875	22·64
40–44	1·670	8·56	70·97	0·120,6	333·450	1,401·475	19·75
45–49	2·141	10·98	62·41	0·175,9	284·600	1,068·025	17·11
50–54	1·329	6·82	51·43	0·132,6	240·100	783·425	15·23
55–59	2·168	11·11	44·61	0·249,0	195·275	543·325	12·18
60–64	1·536	7·88	33·50	0·235,2	147·800	348·050	10·39
65–69	1·298	6·66	25·62	0·260,0	111·450	200·250	7·82
70–74	2·083	10·68	18·96	0·563,3	68·100	88·800	4·68
75–79	1·615	8·28	8·28	1·000,0	20·700	20·700	2·50
Total	19·500	100·00	—	—	3,136·200	—	—

TABLE 121

Intercisa and Brigetio Roman era population, (1st–4th-centuries), both sexes*

x	D_x	d_x	l_x	q_x	L_x	T_x	e_x^0
0	49·2	21·10	100·00	0·211,0	89·450	2,775·365	27·75
1	2·2	0·94	78·90	0·011,9	78·430	2,685·915	34·04
2	3·4	1·46	77·96	0·018,7	77·230	2,607·485	33·45
3	3·0	1·29	76·50	0·016,9	75·855	2,530·255	33·11
4	3·4	1·46	75·21	0·019,4	74·480	2,454·400	32·63
5	2·6	1·11	73·75	0·015,1	73·190	2,379·920	32·27
6	3·2	1·37	72·64	0·018,9	71·955	2,306·730	31·76
7	2·8	1·20	71·27	0·016,8	70·670	2,234·775	31·36
8	3·2	1·37	70·07	0·019,6	69·385	2,164·105	30·88
9	2·8	1·20	68·70	0·017,5	68·100	2,094·720	30·49
10	3·0	1·29	67·50	0·019,1	66·855	2,026·620	30·02
11	2·0	0·86	66·21	0·013,0	65·780	1,959·765	29·60
12	1·8	0·77	65·35	0·011,8	64·965	1,893·985	28·98
13	0·8	0·34	64·58	0·005,3	64·410	1,829·020	28·32
14	1·2	0·52	64·24	0·008,1	63·980	1,764·610	27·47
15	1·6	0·69	63·72	0·010,8	63·375	1,700·630	26·69
16	2·6	1·11	63·03	0·017,6	62·475	1,637·255	25·98
17	3·0	1·29	61·92	0·020,8	61·275	1,574·780	25·43
18	4·6	1·98	60·63	0·032,7	59·640	1,513·505	24·96
19	4·2	1·82	58·65	0·031,0	57·740	1,453·865	24·79
20	4·0	1·72	56·83	0·030,3	55·970	1,396·125	24·57
21	3·2	1·37	55·11	0·024,9	54·425	1,340·155	24·32
22	3·0	1·29	53·74	0·024,0	53·095	1,285·730	23·93
23	4·0	1·72	52·45	0·032,8	51·590	1,232·635	23·50
24	4·0	1·72	50·73	0·033,9	49·870	1,181·045	23·28
25	3·6	1·55	49·01	0·031,6	48·235	1,131·175	23·08
26	4·0	1·72	47·46	0·036,2	46·600	1,082·940	22·82
27	3·8	1·63	45·74	0·035,6	44·925	1,036·340	22·66
28	3·8	1·63	44·11	0·037,0	43·295	991·415	22·48
29	3·6	1·55	42·48	0·036,5	41·705	948·120	22·32
30	3·8	1·63	40·93	0·039,8	40·115	906·415	22·15
31	3·2	1·37	39·30	0·034,9	38·615	866·300	22·04
32	3·4	1·46	37·93	0·038,5	37·200	827·685	21·82
33	2·2	0·94	36·47	0·025,8	36·000	790·485	21·67
34	2·6	1·11	35·53	0·031,2	34·975	754·485	21·24
35	2·4	1·03	34·42	0·029,9	33·905	719·510	20·90
36	2·4	1·03	33·39	0·030,9	32·875	685·605	20·53
37	2·2	0·94	32·36	0·029,1	31·890	652·730	20·17
38	2·0	0·86	31·42	0·027,4	30·990	620·840	19·76
39	1·8	0·77	30·56	0·025,2	30·175	589·850	19·30
40	2·0	0·86	29·79	0·028,9	29·360	559·675	18·79
41	2·2	0·94	28·93	0·032,5	28·460	530·315	18·33
42	2·2	0·94	27·99	0·033,6	27·520	501·855	17·93
43	2·4	1·03	27·05	0·038,1	26·535	474·335	17·54
44	2·6	1·11	26·02	0·042,7	25·465	447·800	17·21

* Data completed with 200 per thousand female mortality and 220 per thousand male mortality. D_x factor smoothed with moving averages.

TABLE 121 (cont'd)

x	D_x	d_x	l_x	q_x	L_x	T_x	e_x^0
45	2·2	0·94	24·91	0·037,7	24·440	422·335	16·95
46	2·0	0·86	23·97	0·035,9	23·540	397·895	16·60
47	2·0	0·86	23·11	0·037,2	22·680	374·355	16·20
48	3·2	1·37	22·25	0·061,6	21·565	351·675	15·81
49	2·8	1·20	20·88	0·057,5	20·280	330·110	15·81
50	3·2	1·37	19·68	0·069,6	18·995	309·830	15·74
51	3·4	1·46	18·31	0·079,7	17·580	290·835	15·88
52	3·4	1·46	16·85	0·086,7	16·120	273·255	16·22
53	1·2	0·52	15·39	0·033,8	15·130	257·135	16·71
54	1·2	0·52	14·87	0·035,0	14·610	242·005	16·27
55	1·0	0·43	14·35	0·030,0	14·135	227·395	15·85
56	0·6	0·26	13·92	0·018,7	13·790	213·260	15·32
57	0·8	0·34	13·66	0·024,9	13·490	199·470	14·60
58	2·0	0·86	13·32	0·064,6	12·890	185·980	13·96
59	2·2	0·94	12·46	0·075,4	11·990	173·090	13·89
60	2·0	0·86	11·52	0·074,7	11·090	161·100	13·98
61	2·2	0·94	10·66	0·088,2	10·190	150·010	14·07
62	2·2	0·94	9·72	0·096,7	9·250	139·820	14·38
63	0·6	0·26	8·78	0·029,6	8·650	130·570	14·87
64	0·6	0·26	8·52	0·030,5	8·390	121·920	14·31
65	0·6	0·26	8·26	0·031,5	8·130	113·530	13·74
66	0·4	0·17	8·00	0·021,3	7·915	105·400	13·18
67	0·2	0·09	7·83	0·011,5	7·785	97·484	12·45
68	1·4	0·60	7·74	0·077,5	7·440	89·700	11·59
69	1·2	0·52	7·14	0·072,8	6·880	82·260	11·52
70	1·2	0·52	6·62	0·078,6	6·360	75·380	11·39
71	1·2	0·52	6·10	0·085,3	5·840	69·020	11·31
72	1·2	0·52	5·58	0·093,2	5·320	63·180	11·32
73	—	—	5·06	—	5·060	57·860	11·43
74	—	—	5·06	—	5·060	52·800	10·43
75	—	—	5·06	—	5·060	47·740	9·43
76	0·4	0·16	5·06	0·031,6	4·980	42·680	8·43
77	0·4	0·16	4·90	0·032,7	4·820	37·700	7·69
78	1·4	0·60	4·74	0·126,6	4·440	32·880	6·94
79	1·6	0·69	4·14	0·166,7	3·795	28·440	6·87
80	1·8	0·77	3·45	0·223,2	3·065	24·645	7·14
81	1·4	0·60	2·68	0·223,9	2·380	21·580	8·05
82	1·4	0·60	2·08	0·288,5	1·780	19·200	9·23
83	0·4	0·16	1·48	0·108,1	1·400	17·420	11·77
84	0·2	0·08	1·32	0·060,6	1·280	16·020	12·14
85	—	—	1·24	—	1·240	14·740	11·89
86	—	—	1·24	—	1·240	13·500	10·89
87	—	—	1·24	—	1·240	12·260	9·89
88	0·2	0·08	1·24	0·064,5	1·200	11·020	8·89
89	0·2	0·08	1·16	0·069,0	1·120	9·820	8·47
90	0·2	0·08	1·08	0·074,1	1·040	8·700	8·06
91	0·2	0·08	1·00	0·080,0	0·960	7·660	7·66
92	0·2	0·08	0·92	0·087,0	0·880	6·700	7·28
93	—	—	0·84	—	0·840	5·820	6·93

TABLE 121 (cont'd)

x	D_x	d_x	l_x	q_x	L_x	T_x	e_x^0
94	—	—	0·84	—	0·840	4·980	5·93
95	—	—	0·84	—	0·840	4·140	4·93
96	—	—	0·84	—	0·840	3·300	3·93
97	—	—	0·84	—	0·840	2·460	2·93
98	0·4	0·16	0·84	0·190,5	0·760	1·620	1·93
99	0·4	0·16	0·68	0·235,3	0·600	0·860	1·26
100	1·2	0·52	0·52	1·000,0	0·260	0·260	0·50
Total	233·2	100·00					

TABLE 122

Intercisa and Brigetio male population

x	D_x	d_x	l_x	q_x	L_x	T_x	e_x^0
0	32·7	22·00	100·00	0·220,0	89·000	3,034·700	30·35
1	1·0	0·67	78·00	0·008,6	77·665	2,945·700	37·77
2	1·8	1·21	77·33	0·015,7	76·725	2,868·035	37·09
3	1·4	0·95	76·12	0·012,5	75·695	2,791·310	36·67
4	1·8	1·21	75·17	0·016,1	74·565	2,715·615	36·13
5	1·4	0·95	73·96	0·012,8	73·485	2,641·050	35·71
6	1·6	1·08	73·01	0·014,8	72·470	2,567·565	35·17
7	1·4	0·95	71·93	0·013,2	71·455	2,495·095	34·69
8	1·8	1·21	70·98	0·017,1	70·375	2,423·640	34·15
9	1·6	1·08	69·77	0·015,5	69·730	2,353·265	33·73
10	1·4	0·94	68·69	0·013,7	63·220	2,283·535	33·24
11	1·0	0·67	67·75	0·009,9	67·415	2,220·315	32·77
12	1·0	0·67	67·08	0·010,0	66·745	2,152·900	32·09
13	0·4	0·27	66·41	0·004,1	66·275	2,086·155	31·41
14	0·6	0·40	66·14	0·006,1	65·940	2,019·880	30·54
15	1·0	0·67	65·74	0·010,2	65·405	1·953·940	29·72
16	1·6	1·08	65·07	0·016,6	64·530	1,888·535	29·02
17	1·8	1·21	63·99	0·018,9	63·385	1,824·005	28·50
18	2·2	1·48	62·78	0·023,6	62·040	1,760·620	28·04
19	1·8	1·21	61·30	0·019,7	60·695	1,698·580	27·71
20	1·6	1·08	60·09	0·018,0	59·550	1,637·885	27·26
21	1·0	0·67	59·01	0·011,4	58·675	1,578·335	26·75
22	1·0	0·67	58·34	0·011,5	58·005	1,519·660	26·05
23	2·6	1·75	57·67	0·030,4	56·795	1,461·655	25·35
24	2·8	1·88	56·92	0·033,6	54·980	1,404·860	25·12
25	2·6	1·75	54·04	0·032,4	53·165	1,349·880	24·98
26	2·8	1·88	52·29	0·036,0	51·350	1,296·715	24·80
27	2·6	1·75	50·41	0·034,7	49·535	1,245·365	24·70
28	1·8	1·21	48·66	0·024,9	48·555	1,195·830	24·58
29	1·6	1·08	47·45	0·022,8	46·960	1,147·275	24·18

TABLE 122 (cont'd)

x	D_x	d_x	l_x	q_x	L_x	T_x	e_x^0
30	1·8	1·21	46·37	0·026,1	45·765	1,100·315	23·73
31	1·6	1·08	45·16	0·023,9	44·620	1,054·550	23·35
32	1·8	1·21	44·08	0·027,5	43·475	1,009·930	22·91
33	1·2	0·81	42·87	0·018,9	42·465	966·455	22·54
34	1·2	0·81	42·06	0·019,3	41·655	923·990	21·97
35	1·2	0·81	41·25	0·019,6	40·895	882·335	21·39
36	1·2	0·81	40·44	0·020,0	40·035	841·440	20·81
37	1·0	0·67	39·63	0·016,9	39·295	801·405	20·22
38	1·4	0·94	38·96	0·024,1	38·990	762·110	19·56
39	1·4	0·94	38·02	0·024,7	37·550	723·120	19·02
40	1·6	1·08	37·08	0·029,1	36·540	685·570	18·49
41	1·4	0·94	36·00	0·026,1	35·530	649·030	18·03
42	1·4	0·94	35·06	0·026,8	34·590	613·500	17·50
43	1·8	1·21	34·12	0·035,5	33·515	578·910	16·97
44	2·2	1·48	32·91	0·045,0	32·170	545·395	16·57
45	1·8	1·21	31·43	0·038,5	30·825	513·225	16·33
46	2·0	1·34	30·22	0·044,3	29·550	482·400	15·96
47	2·0	1·34	28·88	0·046,4	28·210	452·850	15·68
48	2·6	1·75	27·54	0·063,5	26·665	424·640	15·42
49	2·2	1·48	25·79	0·057,4	25·050	397·975	15·43
50	2·6	1·75	24·31	0·072,0	23·435	372·925	15·34
51	2·8	1·88	22·56	0·083,3	21·620	349·490	15·49
52	2·8	1·88	20·68	0·090,9	19·740	327·870	15·85
53	1·2	0·81	18·80	0·043,1	18·395	308·130	16·39
54	1·2	0·81	17·99	0·045,0	17·585	289·735	16·11
55	1·0	0·67	17·18	0·039,0	16·895	272·150	15·84
56	0·6	0·40	16·51	0·024,2	16·310	255·255	15·46
57	0·6	0·40	16·11	0·024,8	15·910	238·945	14·83
58	1·2	0·81	15·71	0·051,6	15·305	223·035	14·20
59	1·4	0·94	14·90	0·063,1	14·430	207·730	13·94
60	1·2	0·81	13·96	0·058,0	13·555	193·300	13·85
61	1·4	0·94	13·15	0·071,5	12·680	179·745	13·67
62	1·6	1·08	12·21	0·088,5	11·670	167·065	13·68
63	0·6	0·40	11·13	0·035,9	10·930	155·395	13·96
64	0·4	0·27	10·73	0·025,2	10·595	144·465	13·46
65	0·4	0·27	10·46	0·025,8	10·325	133·870	12·80
66	0·2	0·13	10·19	0·012,8	10·125	123·545	12·12
67	—	—	10·06	—	10·060	113·420	11·27
68	1·2	0·81	10·06	0·080,5	9·655	103·360	10·27
69	1·2	0·81	9·25	0·087,6	8·845	93·705	10·13
70	1·2	0·81	8·44	0·096,0	8·035	84·860	10·05
71	1·2	0·81	7·63	0·106,2	7·225	76·825	10·07
72	1·2	0·81	6·82	0·118,8	6·415	69·600	10·21
73	—	—	6·01	—	6·010	63·185	10·51
74	—	—	6·01	—	6·010	57·175	9·51
75	—	—	6·01	—	6·010	51·165	8·51
76	0·4	0·27	6·01	0·044,9	5·875	45·155	7·51
77	0·4	0·27	5·74	0·047,0	5·605	39·280	6·84
78	1·0	0·67	5·47	0·122,5	5·135	33·675	6·16

TABLE 122 (cont'd)

x	D_x	d_x	l_x	q_x	L_x	T_x	e_x^0
79	1·2	0·81	4·80	0·168,8	4·395	28·540	5·95
80	1·4	0·94	3·99	0·235,6	3·020	24·145	6·05
81	1·0	0·67	3·05	0·219,7	2·715	21·125	6·93
82	1·0	0·67	2·38	0·281,5	2·045	18·410	7·74
83	0·4	0·27	1·71	0·157,9	1·575	16·365	9·57
84	0·2	0·13	1·44	0·090,3	1·375	14·790	10·27
85	—	—	1·31	—	1·310	13·415	10·24
86	—	—	1·31	—	1·310	12·105	9·24
87	—	—	1·31	—	1·310	10·795	8·24
88	0·2	0·13	1·31	0·099,2	1·245	9·485	7·24
89	0·2	0·13	1·18	0·110,2	1·115	8·240	6·98
90	0·2	0·13	1·05	0·123,8	0·985	7·125	6·79
91	0·2	0·13	0·92	0·141,3	0·855	6·140	6·67
92	0·2	0·13	0·79	0·164,6	0·725	5·285	6·69
93	—	—	0·66	—	0·660	4·560	6·91
94	—	—	0·66	—	0·660	3·900	5·91
95	—	—	0·66	—	0·660	3·240	4·91
96	—	—	0·66	—	0·660	2·580	3·91
97	—	—	0·66	—	0·660	1·920	2·91
98	0·2	0·13	0·66	0·197,0	0·595	1·260	1·91
99	0·2	0·13	0·53	0·245,3	0·465	0·665	1·25
100	0·6	0·40	0·40	1·000,0	0·200	0·200	0·50

TABLE 123

Intercisa and Brigetio female population

x	D_x	d_x	l_x	q_x	L_x	T_x	e_x^0
0	16·5	20·00	100·00	0·200,0	90·000	2,291·650	22·92
1	1·2	1·46	80·00	0·018,3	79·270	2,201·650	27·52
2	1·6	1·94	78·54	0·024,7	77·570	2,122·380	27·02
3	1·6	1·94	76·60	0·025,3	75·630	2,044·810	26·69
4	1·6	1·94	74·66	0·026,0	73·690	1,969·180	26·38
5	1·2	1·46	72·72	0·020,1	71·990	1,895·490	26·07
6	1·4	1·70	71·26	0·023,9	70·410	1,823·500	25·59
7	1·2	1·46	69·56	0·021,0	68·830	1,753·090	25·20
8	1·2	1·46	68·10	0·021,4	67·370	1,682·460	24·71
9	1·0	1·21	66·64	0·018,2	66·035	1,616·890	24·26
10	1·4	1·70	65·43	0·026,0	64·580	1,550·855	23·70
11	1·0	1·21	63·73	0·019,0	63·125	1,486·275	23·32
12	0·8	0·92	62·52	0·014,7	62·060	1,423·150	22·76
13	0·4	0·49	61·60	0·008,0	61·355	1,361·090	22·10
14	0·6	0·73	61·11	0·012,0	60·745	1,299·735	21·27
15	0·6	0·73	60·38	0·012,1	60·015	1,238·990	20·52
16	1·0	1·21	59·65	0·020,3	59·045	1,178·975	19·76
17	1·2	1·46	58·44	0·025,0	57·710	1,119·930	19·16
18	2·4	2·91	56·98	0·051,1	55·525	1,062·220	18·64
19	2·4	2·91	54·07	0·053,8	52·615	1,006·695	18·62
20	2·4	2·91	51·16	0·056,9	49·705	954·080	18·65
21	2·2	2·67	48·25	0·055,3	46·965	904·375	18·74
22	2·0	2·43	45·58	0·053,3	44·365	857·410	18·81
23	1·4	1·70	43·15	0·039,4	42·250	813·045	18·84
24	1·2	1·46	41·45	0·035,2	40·720	770·795	18·60
25	1·0	1·21	39·99	0·030,3	39·385	730·075	18·26
26	1·2	1·46	38·78	0·037,7	38·050	690·690	17·81
27	1·2	1·46	37·32	0·039,1	36·590	652·640	17·49
28	2·0	2·43	35·86	0·067,8	34·645	616·050	17·19
29	2·0	2·43	33·43	0·072,7	32·215	581·405	17·39
30	2·0	2·43	31·00	0·078,4	29·785	549·190	17·72
31	1·6	1·94	28·57	0·067,9	27·600	519·405	18·18
32	1·6	1·94	26·63	0·072,9	25·660	491·805	18·47
33	1·0	1·21	24·69	0·049,0	24·085	466·145	18·88
34	1·4	1·70	23·48	0·072,4	22·630	442·060	18·83
35	1·2	1·46	21·78	0·067,0	21·050	419·430	19·26
36	1·2	1·46	20·32	0·071,9	19·590	398·380	19·61
37	1·2	1·46	18·86	0·077,4	18·130	378·790	20·08
38	0·6	0·73	17·40	0·042,0	17·035	360·660	20·73
39	0·4	0·49	16·67	0·029,4	16·425	343·625	20·61
40	0·4	0·49	16·18	0·030,3	15·935	327·200	20·22
41	0·8	0·92	15·69	0·058,6	15·230	311·265	19·84
42	0·8	0·92	14·77	0·062,3	14·310	296·035	20·04
43	0·6	0·73	13·85	0·052,7	13·485	281·725	20·34
44	0·4	0·49	13·12	0·037,4	12·875	268·240	20·45
45	0·4	0·49	12·63	0·038,8	12·385	255·365	20·22
46	—	—	12·14	—	12·140	242·980	20·01
47	—	—	12·14	—	12·140	230·840	19·01

TABLE 123 (cont'd)

x	D_x	d_x	l_x	q_x	L_x	T_x	e_x^0
48	0·6	0·73	12·14	0·060,1	11·775	218·700	18·01
49	0·6	0·73	11·41	0·064,0	11·045	206·925	18·14
50	0·6	0·73	10·68	0·068,4	10·315	195·880	18·34
51	0·6	0·73	9·95	0·073,4	9·585	185·565	18·65
52	0·6	0·73	9·22	0·079,2	8·855	175·980	19·09
53	—	—	8·49	—	8·490	167·125	19·68
54	—	—	8·49	—	8·490	158·635	18·68
55	—	—	8·49	—	8·490	150·145	17·68
56	—	—	8·49	—	8·490	141·655	16·68
57	—	—	8·49	—	8·490	133·165	15·68
58	0·6	0·73	8·49	0·086,0	8·125	124·675	14·68
59	0·6	0·73	7·76	0·094,1	7·395	116·550	15·02
60	0·6	0·73	7·03	0·103,8	6·665	109·155	15·53
61	0·6	0·73	6·30	0·115,9	5·935	102·490	16·27
62	0·6	0·73	5·57	0·131,1	5·205	96·555	17·33
63	—	—	4·84	—	4·840	91·350	18·87
64	0·2	0·24	4·84	0·049,6	4·720	86·510	17·87
65	0·2	0·24	4·60	0·052,2	4·480	81·790	17·78
66	0·2	0·24	4·36	0·055,1	4·240	77·310	17·73
67	0·2	0·24	4·12	0·058,3	4·000	73·070	17·74
68	0·2	0·24	3·88	0·061,9	3·760	69·070	17·80
69	—	—	3·64	—	3·640	65·310	17·94
70	—	—	3·64	—	3·640	61·670	16·94
71	—	—	3·64	—	3·640	58·030	15·94
72	—	—	3·64	—	3·640	54·390	14·94
73	—	—	3·64	—	3·640	50·750	13·94
74	—	—	3·64	—	3·640	47·110	12·94
75	—	—	3·64	—	3·640	43·470	11·94
76	—	—	3·64	—	3·640	39·830	10·94
77	—	—	3·64	—	3·640	36·190	9·94
78	0·4	0·49	3·64	0·134,6	3·395	32·550	8·94
79	0·4	0·49	3·15	0·155,6	2·905	29·155	9·26
80	0·4	0·49	2·66	0·184,2	2·415	26·250	9·87
81	0·4	0·49	2·17	0·225,8	1·930	23·835	10·98
82	0·4	0·49	1·69	0·289,9	1·450	21·905	12·96
83	—	—	1·21	—	1·210	20·455	16·90
84	—	—	1·21	—	1·210	19·245	15·90
85	—	—	1·21	—	1·210	18·035	14·90
86	—	—	1·21	—	1·210	16·825	13·90
87	—	—	1·21	—	1·210	15·615	12·90
88	—	—	1·21	—	1·210	14·405	11·90
89	—	—	1·21	—	1·210	13·195	10·90
90	—	—	1·21	—	1·210	11·985	9·90
91	—	—	1·21	—	1·210	10·775	8·90
92	—	—	1·21	—	1·210	9·565	7·90
93	—	—	1·21	—	1·210	8·355	6·90
94	—	—	1·21	—	1·210	7·145	5·90
95	—	—	1·21	—	1·210	5·935	4·90

TABLE 123 (cont'd)

x	D_x	d_x	l_x	q_x	L_x	T_x	e_x^0
96	—	—	1·21	—	1·210	4·725	3·90
97	—	—	1·21	—	1·210	3·515	2·90
98	0·2	0·24	1·21	0·198,4	1·090	2·305	1·90
99	0·2	0·24	0·97	0·247,4	0·850	1·215	8·25
100	0·6	0·73	0·73	1·000,0	0·365	0·365	0·50

TABLE 124

Keszthely-Dobogó population of the late Roman era, both sexes

x	D_x	d_x	l_x	q_x	L_x	T_x	e_x^0
0	5·097	4·25	100·00	0·042,5	97·875	3,519·150	35·19
1	7·095	5·91	95·75	0·061,7	92·795	3,421·275	35·73
2	2·096	1·75	89·84	0·019,5	88·965	3,328·480	37·05
3	3·096	2·58	88·09	0·029,3	86·800	3,239·515	36·78
4	4·092	3·41	85·51	0·039,9	83·805	3,152·715	36·87
5	3·095	2·58	82·10	0·031,4	80·810	3,068·910	37·38
6	2·263	1·89	79·52	0·023,8	78·575	2,988·100	37·58
7	1·667	1·39	77·63	0·017,9	76·935	2,909·525	37·48
8	1·500	1·25	76·24	0·016,4	75·615	2,832·590	37·15
9	1·000	0·83	74·99	0·011,1	74·575	2,756·975	36·76
10	0·666	0·55	74·16	0·007,4	73·885	2,682·400	36·17
11	0·666	0·55	73·61	0·007,5	73·335	2,608·515	35·44
12	0·334	0·28	73·06	0·003,8	72·920	2,535·180	34·70
13	0·833	0·69	72·78	0·009,5	72·435	2,462·260	33·83
14	0·500	0·42	72·09	0·005,8	71·880	2,389·825	33·15
15	1·125	0·94	71·67	0·013,1	71·200	2,317·945	32·34
16	1·125	0·94	70·73	0·013,3	70·260	2,246·745	31·77
17	0·125	0·10	69·79	0·001,4	69·740	2,176·485	31·19
18	0·625	0·52	69·69	0·007,5	69·430	2,106·745	30·23
19	1·125	0·94	69·17	0·013,6	68·700	2,037·315	29·45
20	1·291	1·07	68·23	0·015,7	67·695	1,968·615	28·85
21	0·792	0·66	67·16	0·009,8	66·830	1,900·920	28·30
22	0·792	0·66	66·50	0·009,9	66·170	1,834·090	27·58
23	0·916	0·76	65·84	0·011,5	65·460	1,767·920	26·85
24	1·058	0·88	65·08	0·013,5	64·640	1,702·460	26·16
25	1·059	0·88	64·20	0·013,7	63·760	1,637·820	25·51
26	1·060	0·88	63·32	0·013,9	62·880	1,574·060	24·86
27	1·060	0·88	62·44	0·014,1	62·000	1,511·180	24·20
28	0·858	0·72	61·56	0·011,7	61·200	1,449·180	23·54
29	0·858	0·72	60·84	0·011,8	60·480	1,387·980	22·81
30	0·924	0·77	60·12	0·012,8	59·735	1,327·500	22·08
31	0·787	0·66	59·35	0·011,1	59·020	1,267·765	21·36
32	0·787	0·66	58·69	0·011,2	58·360	1,208·745	20·60
33	0·970	0·81	58·03	0·014,0	57·625	1,150·385	19·82

TABLE 124 (cont'd)

x	D_x	d_x	l_x	q_x	L_x	T_x	e_x^0
34	1·115	0·93	57·22	0·016,3	56·755	1,092·760	19·10
35	1·315	1·10	56·29	0·019,5	55·740	1,036·005	18·40
36	1·715	1·43	55·19	0·025,9	54·475	980·265	17·76
37	1·915	1·60	53·76	0·029,8	52·960	925·790	17·22
38	2·115	1·76	52·16	0·033,7	51·280	872·830	16·73
39	2·481	2·07	50·40	0·041,1	49·365	821·550	16·30
40	2·260	1·88	48·33	0·038,9	47·390	772·185	15·98
41	1·328	1·11	46·45	0·023,9	45·895	724·795	15·60
42	1·413	1·18	45·34	0·026,0	44·750	678·900	14·97
43	1·457	1·21	44·16	0·027,4	43·555	634·150	14·36
44	1·457	1·21	42·95	0·028,2	42·345	590·595	13·75
45	2·091	1·74	41·74	0·041,7	40·870	548·250	13·13
46	2·190	1·82	40·00	0·045,5	39·090	507·380	12·68
47	2·532	2·11	38·18	0·055,3	37·125	468·290	12·27
48	2·674	2·23	36·07	0·061,8	34·955	431·165	11·95
49	2·589	2·16	33·84	0·063,8	32·760	396·210	11·71
50	1·625	1·35	31·68	0·042,6	31·005	363·450	11·47
51	2·226	1·86	30·33	0·061,3	29·400	332·445	10·96
52	2·326	1·94	28·47	0·068,1	27·500	303·045	10·64
53	2·326	1·94	26·53	0·073,1	25·560	275·545	10·39
54	2·168	1·81	24·59	0·073,6	23·685	249·985	10·17
55	2·326	1·94	22·78	0·085,2	21·810	226·300	9·93
56	1·792	1·49	20·84	0·071,5	20·095	204·490	9·81
57	1·649	1·37	19·35	0·070,8	18·665	184·395	9·53
58	1·450	1·21	17·98	0·067,3	17·375	165·730	9·22
59	1·699	1·41	16·77	0·084,1	16·065	148·355	8·85
60	1·428	1·19	15·36	0·077,5	14·765	132·290	8·61
61	1·145	0·95	14·17	0·067.0	13·695	117·525	8·29
62	0·750	0·63	13·22	0·047,7	12·905	103·830	7·85
63	0·951	0·79	12·59	0·062,7	12·195	90·925	7·22
64	0·936	0·78	11·80	0·066,1	11·410	78·730	6·67
65	0·935	0·78	11·02	0·070,8	10·630	67·320	6·11
66	1·135	0·95	10·24	0·092,8	9·765	56·690	5·54
67	1·248	1·04	9·29	0·111,9	8·770	46·925	5·05
68	1·246	1·04	8·25	0·126,1	7·730	38·155	4·62
69	1·246	1·04	7·21	0·144,2	6·690	30·425	4·22
70	1·246	1·04	6·17	0·168,6	5·650	23·735	3·85
71	0·870	0·73	5·13	0·142,3	4·765	18·085	3·53
72	0·995	0·83	4·40	0·188,6	3·985	13·320	3·03
73	0·995	0·83	3·57	0·232,5	3·155	9·335	2·61
74	0·995	0·83	2·74	0·302,9	2·325	6·180	2·26
75	0·896	0·75	1·91	0·392,7	1·535	3·855	2·02
76	0·353	0·29	1·16	0·250,0	1·015	2·320	2·00
77	0·353	0·29	0·87	0·333,3	0·725	1·305	1·50
78	0·353	0·29	0·58	0·500,0	0·435	0·580	1·00
79	0·353	0·29	0·29	1·000,0	0·145	0·145	0·50
Total	120·000	100·00	—	—	3,519·150	—	—

TABLE 125

Keszthely-Dobogó male population, aged 20+

x	D_x	d_x	l_x	q_x	L_x	T_x	e^0_x
20	0·500	1·01	100·00	0·010,1	99·495	3,134·210	31·34
21	—	—	98·99	—	98·990	3,034·715	30·66
22	—	—	98·99	—	98·990	2,935·725	29·66
23	0·247	0·50	98·99	0·005,1	98·740	2,836·735	28·66
24	0·389	0·78	98·49	0·007,9	98·100	2,737·995	27·80
25	0·390	0·79	97·71	0·008,1	97·315	2,639·895	27·02
26	0·390	0·79	96·92	0·008,2	96·525	2,542·580	26·23
27	0·390	0·79	96·13	0·008,2	95·735	2,446·055	25·45
28	0·389	0·78	95·34	0·008,2	94·950	2,350·320	24·65
29	0·389	0·78	94·56	0·008,2	94·170	2,255·370	23·85
30	0·389	0·78	93·78	0·008,3	93·390	2,161·200	23·05
31	0·247	0·50	93·00	0·005,4	92·750	2,067·810	22·23
32	0·247	0·50	92·50	0·005,4	92·250	1,975·060	21·35
33	0·246	0·50	92·00	0·005,4	91·750	1,882·810	20·47
34	0·389	0·78	91·50	0·008,5	91·110	1,791·060	19·57
35	0·589	1·19	90·72	0·013,1	90·125	1,699·950	18·74
36	0·989	2·00	89·53	0·022,3	88·530	1·609·825	17·98
37	1·189	2·40	87·53	0·027,4	86·330	1,521·295	17·38
38	1·389	2·81	85·13	0·033,0	83·725	1,434·965	16·86
39	1·755	3·54	82·32	0·043,0	80·550	1,351·240	16·41
40	1·829	3·69	78·78	0·046,8	76·935	1,270·690	16·13
41	1·177	2·38	75·09	0·031,7	73·900	1,193·755	15·90
42	1·119	2·26	72·71	0·031,1	71·580	1,119·855	15·40
43	0·820	1·66	70·45	0·023,6	69·620	1,048·275	14·88
44	0·820	1·66	68·79	0·024,1	67·960	978·655	14·23
45	0·854	1·72	67·13	0·025,6	66·270	910·695	13·57
46	0·953	1·92	65·41	0·029,4	64·450	844·425	12·91
47	1·295	2·62	63·49	0·041,3	62·180	779·975	12·29
48	1·496	3·02	60·87	0·049,6	59·360	717·795	11·79
49	1·353	2·73	57·85	0·047,2	56·485	658·435	11·38
50	0·987	1·99	55·12	0·036,1	54·125	601·950	10·92
51	1·587	3·21	53·13	0·060,4	51·525	547·825	10·31
52	1·687	3·41	49·92	0·068,3	48·215	496·300	9·94
53	1·687	3·41	46·51	0·073,3	44·805	448·085	9·63
54	1·729	3·49	43·10	0·081,0	41·355	403·280	9·36
55	2·030	4·10	39·61	0·103,5	37·560	361·925	9·14
56	1·496	3·02	35·51	0·085,0	34·000	324·365	9·13
57	1·296	2·62	32·49	0·080,6	31·180	290·365	8·94
58	1·097	2·22	29·87	0·074,3	28·760	259·185	8·68
59	1·263	2·55	27·65	0·092,2	26·375	230·425	8·33
60	1·060	2·14	25·10	0·085,3	24·030	204·050	8·13
61	0·777	1·57	22·96	0·068,4	22·175	180·020	7·84
62	0·582	1·18	21·39	0·055,2	20·800	157·845	7·38
63	0·707	1·43	20·21	0·070,8	19·495	137·045	6·78
64	0·691	1·40	18·78	0·074,5	18·080	117·550	6·26
65	0·590	1·19	17·38	0·068,5	16·785	99·470	5·72
66	0·790	1·60	16·19	0·098,8	15·390	82·685	5·11

TABLE 125 (cont'd)

x	D_x	d_x	l_x	q_x	L_x	T_x	e_x^0
67	0·902	1·82	14·59	0·124,7	13·680	67·295	4·61
68	0·900	1·82	12·77	0·142,5	11·860	53·615	4·20
69	0·900	1·82	10·95	0·166,2	10·040	41·755	3·81
70	0·900	1·82	9·13	0·199,3	8·220	31·715	3·47
71	0·608	1·23	7·31	0·168,3	6·695	23·495	3·21
72	0·608	1·23	6·08	0·202,3	5·465	16·800	2·76
73	0·608	1·23	4·85	0·253,6	4·235	11·335	2·34
74	0·608	1·23	3·62	0·339,8	3·005	7·100	1·96
75	0·609	1·23	2·39	0·514,6	1·775	4·095	1·71
76	0·143	0·29	1·16	0·250,0	1·015	2·320	2·00
77	0·143	0·29	0·87	0·333,3	0·725	1·305	1·50
78	0·143	0·29	0·58	0·500,0	0·435	0·580	1·00
79	0·143	0·29	0·29	1·000,0	0·145	0·145	0·50
Total	49·500	100·00	—	—	3,134·210	—	—

TABLE 126

Keszthely-Dobogó female population, aged 20+

x	D_x	d_x	l_x	q_x	L_x	T_x	e_x^0
20	0·791	2·44	100·00	0·024,4	98·780	2,505·630	25·06
21	0·792	2·45	97·56	0·025,1	96·335	2,406·850	24·67
22	0·792	2·45	95·11	0·025,8	93·885	2,310·515	24·29
23	0·669	2·07	92·66	0·022,3	91·625	2,216·630	23·92
24	0·669	2·07	90·59	0·022,9	89·555	2,125·005	23·46
25	0·669	2·07	88·52	0·023,4	87·485	2,035·450	22·99
26	0·670	2·07	86·45	0·023,9	85·415	1,947·965	22·53
27	0·670	2·07	84·38	0·024,5	83·345	1,862·550	22·07
28	0·469	1·45	82·31	0·017,6	81·585	1,779·205	21·62
29	0·469	1·45	80·86	0·017,9	80·135	1,697·620	20·99
30	0·535	1·65	79·41	0·020,8	78·585	1,617·485	20·37
31	0·540	1·67	77·76	0·021,5	76·925	1,538·900	19·79
32	0·540	1·67	76·09	0·021,9	75·255	1,461·975	19·21
33	0·724	2·24	74·42	0·030,1	73·300	1,386·720	18·63
34	0·726	2·24	72·18	0·031,0	71·060	1,313·420	18·20
35	0·726	2·24	69·94	0·032,0	68·820	1,242·360	17·76
36	0·726	2·24	67·70	0·033,1	66·580	1,173·540	17·33
37	0·726	2·24	65·46	0·034,2	64·340	1,106·960	16·91
38	0·726	2·24	63·22	0·035,4	62·100	1,042·620	16·49
39	0·726	2·24	60·98	0·036,7	59·860	980·520	16·08
40	0·431	1·33	58·74	0·022,6	58·075	920·660	15·67
41	0·151	0·47	57·41	0·008,2	57·175	862·585	15·02
42	0·294	0·91	56·94	0·016,0	56·485	805·410	14·14
43	0·637	1·97	56·03	0·035,2	55·045	748·925	13·37
44	0·637	1·97	54·06	0·036,4	53·075	693·880	12·84
45	1·237	3·82	52·09	0·073,3	50·180	640·805	12·30
46	1·237	3·82	48·27	0·079,1	46·360	590·625	12·24
47	1·237	3·82	44·45	0·085,9	42·540	544·265	12·24
48	1·178	3·64	40·63	0·089,6	38·810	501·725	12·35
49	1·236	3·82	36·99	0·103,3	35·080	462·915	12·51
50	0·638	1·97	33·17	0·059,4	32·185	427·835	12·90
51	0·639	1·97	31·20	0·063,1	30·215	395·650	12·68
52	0·639	1·97	29·23	0·067,4	28·245	365·435	12·50
53	0·639	1·97	27·26	0·072,3	26·275	337·190	12·37
54	0·439	1·36	25·29	0·053,8	24·610	310·915	12·29
55	0·296	0·91	23·93	0·038,0	23·475	286·305	11·96
56	0·296	0·91	23·02	0·039,5	22·565	262·830	11·42
57	0·353	1·09	22·11	0·049,3	21·565	240·265	10·87
58	0·353	1·09	21·02	0·051,9	20·475	218·700	10·40
59	0·436	1·35	19·93	0·067,7	19·255	198·225	9·95
60	0·368	1·14	18·58	0·061,4	18·010	178·970	9·63
61	0·368	1·14	17·44	0·065,4	16·870	160·960	9·23
62	0·168	0·52	16·30	0·031,9	16·040	144·090	8·84
63	0·244	0·75	15·78	0·047,5	15·405	128·050	8·11
64	0·245	0·76	15·03	0·050,6	14·650	112·645	7·49
65	0·345	1·06	14·27	0·074,3	13·740	97·995	6·87
66	0·345	1·06	13·21	0·080,2	12·680	84·255	6·38

TABLE 126 (cont'd)

x	D_x	d_x	l_x	q_x	L_x	T_x	e_x^0
67	0·346	1·07	12·15	0·088,1	11·615	71·575	5·89
68	0·346	1·07	11·08	0·096,6	10·545	59·960	5·41
69	0·346	1·07	10·01	0·106,9	9·475	49·415	4·94
70	0·346	1·07	8·94	0·119,7	8·405	39·940	4·47
71	0·262	0·81	7·87	0·102,9	7·465	31·535	4·01
72	0·387	1·19	7·06	0·168,6	6·465	24·070	3·41
73	0·387	1·19	5·87	0·202,7	5·275	17·605	3·00
74	0·387	1·19	4·68	0·254,3	4·085	12·330	2·63
75	0·287	0·89	3·49	0·255,0	3·045	8·245	2·36
76	0·210	0·65	2·60	0·250,0	2·275	5·200	2·00
77	0·210	0·65	1·95	0·333,3	1·625	2·925	1·50
78	0·210	0·65	1·30	0·500,0	0·975	1·300	1·00
79	0·210	0·65	0·65	1·000,0	0·325	0·325	0·50
Total	32·375	100·00	—	—	2,505·630	—	—

TABLE 127

Sopronkőhida 9th-century Avarian-Frankish population, both sexes

x	D_x	d_x	l_x	q_x	L_x	T_x	e_x^0
0	21·250	14·66	100·00	0·146,6	92·670	2,664·920	26·65
1	9·250	6·38	85·34	0·074,8	82·150	2,572·250	30·14
2	1·584	1·09	78·96	0·013,8	78·415	2,490·100	31·54
3	7·419	5·12	77·87	0·065,8	75·310	2,411·685	30·97
4	7·665	5·29	72·75	0·072,7	70·105	2,336·375	32·12
5	4·832	3·33	67·46	0·049,4	65·795	2,266·270	33·59
6	4·833	3·33	64·13	0·051,9	62·465	2,200·475	34·31
7	1·833	1·26	60·80	0·020,7	60·170	2,138·010	35·16
8	1·834	1·26	59·54	0·021,2	58·910	2,077·840	34·90
9	3·200	2·21	58·28	0·037,9	57·175	2,018·930	34·64
10	1·700	1·17	56·07	0·020,9	55·485	1,961·755	34·99
11	0·200	0·14	54·90	0·002,6	54·830	1,906·270	34·72
12	0·200	0·14	54·76	0·002,6	54·690	1,851·440	33·81
13	0·700	0·48	54·62	0·008,8	54·380	1,796·750	32·90
14	0·500	0·34	54·14	0·006,3	53·970	1,742·370	32·18
15	2·500	1·72	53·80	0·032,0	52·940	1,688·400	31·38
16	2·500	1·72	52·08	0·033,0	51·220	1,635·460	31·40
17	—	—	50·36	—	50·360	1,584·240	31·46
18	1·000	0·69	50·36	0·013,7	50·015	1,533·880	30·46
19	1·500	1·03	49·67	0·020,7	49·155	1,483·865	29·87
20	1·000	0·69	48·64	0·014,2	48·295	1,434·710	29·50
21	0·500	0·34	47·95	0·007,1	47·780	1,386·415	28·91
22	—	—	47·61	—	47·610	1,338·635	28·12
23	0·880	0·61	47·61	0·012,8	47·305	1,291·025	27·12
24	0·880	0·61	47·00	0·013,0	46·695	1,243·720	26·46
25	0·980	0·68	46·39	0·014,7	46·050	1,197·025	25·80
26	0·980	0·68	45·71	0·014,9	45·370	1,150·975	25·18
27	0·980	0·68	45·03	0·015,1	44·690	1,105·605	24·55
28	0·580	0·40	44·35	0·009,0	44·150	1,060·915	23·92
29	0·980	0·68	43·95	0·015,5	43·610	1,016·765	23·13
30	1·180	0·81	43·27	0·018,7	42·865	973·155	22·49
31	1·280	0·88	42·46	0·020,7	42·020	930·290	21·91
32	1·480	1·02	41·58	0·024,5	41·070	888·270	21·36
33	1·380	0·95	40·56	0·023,4	40·085	847·200	20·89
34	0·980	0·68	39·61	0·017,2	39·270	807·115	20·38
35	0·680	0·47	38·93	0·012,1	38·695	767·845	19·72
36	0·680	0·47	38·46	0·012,2	38·225	729·150	18·96
37	0·480	0·33	37·99	0·008,7	37·825	690·925	18·19
38	0·480	0·33	37·66	0·008,8	37·495	653·100	17·34
39	0·480	0·33	37·33	0·008,8	37·165	615·605	16·49
40	0·580	0·40	37·00	0·010,8	36·800	578·440	15·63
41	1·080	0·74	36·60	0·020,2	36·230	541·640	14·80
42	1·480	1·02	35·86	0·028,4	35·350	505·410	14·09
43	1·580	1·09	34·84	0·031,3	34·295	470·060	13·49
44	1·980	1·37	33·75	0·040,6	33·065	435·765	12·91
45	2·380	1·64	32·38	0·050,6	31·560	402·700	12·44
46	2·380	1·64	30·74	0·053,4	29·920	371·140	12·07

TABLE 127 (cont'd)

x	D_x	d_x	l_x	q_x	L_x	T_x	e_x^0
47	1·980	1·37	29·10	0·047,1	28·415	341·220	11·73
48	1·780	1·23	27·73	0·044,4	27·115	312·805	11·28
49	1·980	1·37	26·50	0·051,7	25·815	285·690	10·78
50	1·513	1·04	25·13	0·041,4	24·610	259·875	10·34
51	1·513	1·04	24·09	0·043,2	23·570	235·265	9·77
52	1·913	1·32	23·05	0·057,3	22·390	211·695	9·18
53	2·313	1·60	21·73	0·073,6	20·930	189·305	8·71
54	2·113	1·46	20·13	0·072,5	19·400	168·375	8·36
55	2·713	1·87	18·67	0·100,2	17·735	148·975	7·98
56	3·313	2·28	16·80	0·135,7	15·660	131·240	7·81
57	3·213	2·22	14·52	0·152,9	13·410	115·580	7·96
58	2·613	1·80	12·30	0·146,3	11·400	102·170	8·31
59	2·413	1·66	10·50	0·158,1	9·670	90·770	8·64
60	1·813	1·25	8·84	0·141,4	8·215	81·100	9·17
61	0·613	0·42	7·59	0·055,3	7·380	72·885	9·60
62	0·413	0·29	7·17	0·040,4	7·025	65·505	9·14
63	0·413	0·29	6·88	0·042,2	6·735	58·480	8·50
64	0·213	0·15	6·59	0·022,8	6·515	51·745	7·85
65	0·413	0·29	6·44	0·045,0	6·295	45·230	7·02
66	0·513	0·35	6·15	0·056,9	5·975	38·935	6·33
67	0·513	0·35	5·80	0·060,3	5·625	32·960	5·68
68	0·513	0·35	5·45	0·064,2	5·275	27·335	5·02
69	0·798	0·55	5·10	0·107,8	4·825	22·060	4·33
70	0·900	0·62	4·55	0·136,3	4·240	17·235	3·79
71	0·900	0·62	3·93	0·157,8	3·620	12·995	3·31
72	1·025	0·71	3·31	0·214,5	2·955	9·375	2·83
73	0·945	0·65	2·60	0·250,0	2·275	6·420	2·47
74	0·945	0·65	1·95	0·333,3	1·625	4·145	2·13
75	0·744	0·51	1·30	0·392,3	1·045	2·520	1·94
76	0·359	0·25	0·79	0·316,5	0·665	1·475	1·87
77	0·259	0·18	0·54	0·333,3	0·450	0·810	1·50
78	0·259	0·18	0·36	0·500,0	0·270	0·360	1·00
79	0·259	0·18	0·18	1·000,0	0·090	0·090	0·50
Total	145·000	100·00	—	—	2,664·920	—	—

TABLE 128

Sopronkőhida male population, aged 20+

x	D_x	d_x	l_x	q_x	L_x	T_x	e_x^0
20	—	—	100·00	—	100·000	2,660·430	26·60
21	—	—	100·00	—	100·000	2,560·430	25·60
22	—	—	100·00	—	100·000	2,460·430	24·60
23	0·620	2·14	100·00	0·021,4	98·930	2,360·430	23·60
24	0·620	2·14	97·86	0·021,9	96·790	2,261·500	23·11
25	0·720	2·48	95·72	0·025,9	94·480	2,164·710	22·62
26	0·720	2·48	93·24	0·026,6	92·000	2,070·230	22·20
27	0·720	2·48	90·76	0·027,3	89·520	1,978·230	21·80
28	0·520	1·79	88·28	0·020,3	87·385	1,888·710	21·39
29	0·520	1·79	86·49	0·020,7	85·595	1,801·325	20·83
30	0·520	1·79	84·70	0·021,1	83·805	1,715·730	20·26
31	0·520	1·79	82·91	0·021,6	82·015	1,631·925	19·68
32	0·520	1·79	81·12	0·022,1	80·225	1,549·910	19·11
33	0·420	1·45	79·33	0·018,3	78·605	1,469·685	18·53
34	0·420	1·45	77·88	0·018,6	77·155	1,391·080	17·86
35	0·320	1·10	76·43	0·014,4	75·880	1,313·925	17·19
36	0·320	1·10	75·33	0·014,6	74·780	1,238·045	16·43
37	0·320	1·10	74·23	0·014,8	73·680	1,163·265	15·67
38	0·320	1·10	73·13	0·015,0	72·580	1,089·585	14·90
39	0·320	1·10	72·03	0·015,3	71·480	1,017·005	14·12
40	0·420	1·45	70·93	0·020,4	70·205	945·525	13·33
41	0·620	2·14	69·48	0·030,8	68·410	875·320	12·60
42	0·820	2·83	67·34	0·042,0	65·925	806·910	11·98
43	0·520	1·79	64·51	0·027,7	63·615	740·985	11·49
44	0·720	2·48	62·72	0·039,5	61·480	677·370	10·80
45	0·920	3·17	60·24	0·052,6	58·655	615·890	10·22
46	1·120	3·86	57·07	0·067,6	55·140	557·235	9·76
47	0·920	3·17	53·21	0·059,6	51·625	502·095	9·44
48	1·120	3·86	50·04	0·077,1	48·110	450·470	9·00
49	1·120	3·86	46·18	0·083,6	44·250	402·360	8·71
50	0·853	2·94	42·32	0·069,5	40·850	358·110	8·46
51	0·453	1·56	39·38	0·039,6	38·600	317·260	8·06
52	0·653	2·25	37·82	0·059,5	36·695	278·660	7·37
53	0·453	1·56	35·57	0·043,9	34·790	241·965	6·80
54	0·653	2·25	34·01	0·066,2	32·885	207·175	6·09
55	1·053	3·63	31·76	0·114,3	29·945	174·290	5·49
56	1·653	5·70	28·13	0·202,6	25·280	144·345	5·13
57	1·453	5·01	22·43	0·223,4	19·925	119·065	5·31
58	1·453	5·01	17·42	0·287,6	14·915	99·140	5·69
59	1·053	3·63	12·41	0·292,5	10·595	84·225	6·79
60	0·653	2·25	8·78	0·256,3	7·655	73·630	8·39
61	0·053	0·19	6·53	0·029,1	6·435	65·975	10·10
62	0·053	0·19	6·34	0·030,0	6·245	59·540	9·39
63	0·053	0·19	6·15	0·030,9	6·055	53·295	8·67
64	0·053	0·19	5·96	0·031,9	5·865	47·240	7·93
65	0·053	0·19	5·77	0·032,9	5·675	41·375	7·17
66	0·053	0·19	5·58	0·034,1	5·485	35·700	6·40

TABLE 128 (cont'd)

x	D_x	d_x	l_x	q_x	L_x	T_x	e^0_x
67	0·053	0·19	5·39	0·035,3	5·295	30·215	5·61
68	0·053	0·19	5·20	0·036,5	5·105	24·920	4·79
69	0·195	0·66	5·01	0·131,7	4·680	19·815	3·96
70	0·197	0·68	4·35	0·156,3	4·010	15·135	3·48
71	0·197	0·68	3·67	0·185,3	3·330	11·125	3·03
72	0·197	0·68	2·99	0·227,4	2·650	7·795	2·61
73	0·177	0·61	2·31	0·264,1	2·005	5·145	2·23
74	0·177	0·61	1·70	0·358,8	1·395	3·140	1·85
75	0·177	0·61	1·09	0·559,6	0·785	1·745	1·60
76	0·034	0·12	0·48	0·250,0	0·420	0·960	2·00
77	0·034	0·12	0·36	0·333,3	0·300	0·540	1·50
78	0·034	0·12	0·24	0·500,0	0·180	0·240	1·00
79	0·034	0·12	0·12	1·000,0	0·060	0·060	0·50
Total	29·000	100·00	—	—	2,660·430	—	—

TABLE 129

Sopronkőhida female population, aged 20+

x	D_x	d_x	l_x	q_x	L_x	T_x	e_x^0
20	—	—	100·00	—	100·000	3,293·030	32·93
21	—	—	100·00	—	100·000	3,193·030	31·93
22	—	—	100·00	—	100·000	3,093·030	30·93
23	0·220	0·58	100·00	0·005,8	99·710	2,993·030	29·93
24	0·220	0·58	99·42	0·005,8	99·130	2,893·320	29·10
25	0·220	0·58	98·84	0·005,9	98·550	2,794·190	28·27
26	0·220	0·58	98·26	0·005,9	97·970	2,695·640	27·43
27	0·220	0·58	97·68	0·005,9	97·390	2,597·670	26·59
28	0·020	0·05	97·10	0·000,5	97·075	2,500·280	25·75
29	0·420	1·11	97·05	0·011,4	96·495	2,403·205	24·76
30	0·620	1·63	95·94	0·017,0	95·125	2,306·710	24·04
31	0·720	1·89	94·31	0·020,0	93·365	2,211·585	23·45
32	0·920	2·42	92·42	0·026,2	91·210	2,118·220	22·92
33	0·920	2·42	90·00	0·026,9	88·790	2,027·010	22·52
34	0·520	1·37	87·58	0·015,6	86·895	1,938·220	22·13
35	0·320	0·84	86·21	0·009,7	85·790	1,851·325	21·47
36	0·320	0·84	85·37	0·009,8	84·950	1,765·535	20·68
37	0·120	0·32	84·53	0·003,8	84·370	1,680·585	19·88
38	0·120	0·32	84·21	0·003,8	84·050	1,596·215	18·96
39	0·120	0·32	83·89	0·003,8	83·730	1,512·165	18·03
40	0·120	0·32	83·57	0·003,8	83·410	1,428·435	17·09
41	0·420	1·11	83·25	0·013,3	82·695	1,345·025	16·16
42	0·620	1·63	82·14	0·019,8	81·325	1,262·330	15·37
43	1·020	2·68	80·51	0·033,3	79·170	1,181·005	14·67
44	1·220	3·21	77·83	0·041,2	76·225	1,101·835	14·16
45	1·420	3·74	74·62	0·050,1	72·750	1,025·610	13·74
46	1·220	3·21	70·88	0·045,3	69·275	952·860	13·44
47	1·020	2·68	67·67	0·039,6	66·330	883·585	13·06
48	0·620	1·63	64·99	0·025,1	64·175	817·255	12·58
49	0·820	2·16	63·36	0·034,1	62·280	753·080	11·89
50	0·620	1·63	61·20	0·026,6	60·385	690·800	11·29
51	1·020	2·68	59·57	0·045,0	58·230	630·415	10·58
52	1·220	3·21	56·89	0·056,4	55·285	572·185	10·06
53	1·820	4·79	53·68	0·089,2	51·285	516·900	9·63
54	1·420	3·74	48·89	0·076,5	47·020	465·615	9·52
55	1·620	4·26	45·15	0·094,4	43·020	418·595	9·27
56	1·620	4·26	40·89	0·104,2	38·760	375·575	9·19
57	1·720	4·53	36·63	0·123,7	34·365	336·815	9·20
58	1·120	2·95	32·10	0·091,9	30·625	302·450	9·42
59	1·320	3·47	29·15	0·119,0	27·415	271·825	9·33
60	1·120	2·95	25·68	0·114,9	24·205	244·410	9·52
61	0·520	1·37	22·73	0·060,3	22·045	220·205	9·69
62	0·320	0·84	21·36	0·039,3	20·940	198·160	9·28
63	0·320	0·84	20·52	0·040,9	20·100	177·220	8·64
64	0·120	0·32	19·68	0·016,3	19·520	157·120	7·98
65	0·320	0·84	19·36	0·043,4	18·940	137·600	7·11
66	0·420	1·11	18·52	0·059,9	17·965	118·660	6·41

TABLE 129 (cont'd)

x	D_x	d_x	l_x	q_x	L_x	T_x	e_x^0
67	0·420	1·11	17·41	0·063,8	16·855	100·695	5·78
68	0·420	1·11	16·30	0·068,1	15·745	83·840	5·14
69	0·563	1·48	15·19	0·097,4	14·450	68·095	4·48
70	0·663	1·74	13·71	0·126,9	12·840	53·645	3·91
71	0·663	1·74	11·97	0·145,4	11·100	40·805	3·41
72	0·788	2·07	10·23	0·202,3	9·195	29·705	2·90
73	0·768	2·02	8·16	0·247,5	7·150	20·510	2·51
74	0·768	2·02	6·14	0·329,0	5·130	13·360	2·18
75	0·567	1·49	4·12	0·361,7	3·375	8·230	2·00
76	0·325	0·86	2·63	0·327,0	2·200	4·855	1·85
77	0·225	0·59	1·77	0·333,3	1·475	2·655	1·50
78	0·225	0·59	1·18	0·500,0	0·885	1·180	1·00
79	0·225	0·59	0·59	1·000,0	0·295	0·295	0·50
Total	38·000	100·00	—	—	3,293·030	—	—

TABLE 130

Model life table based on 10th–12th-century Hungarian series

x	d_x*	l_x*	q_x	L_x	T_x	e_x^0
0	2,000	10·000	0·200,0	90·000	2,872·650	28·73
1	525	8·000	0·065,6	77·375	2,782·650	34·78
2	270	7·475	0·036,1	73·400	2,705·275	36·19
3	165	7·205	0·022,9	71·225	2,631·875	36·53
4	120	7·040	0·017,0	69·800	2,560·650	36·37
5	105	6·920	0·015,2	68·675	2,490·850	35·99
6	95	6·815	0·013,9	67·675	2,422·175	35·54
7	90	6·720	0·013,4	66·750	2,354·500	35·04
8	90	6·630	0·013,6	65·850	2,287·750	34·51
9	85	6·540	0·013,0	64·975	2,221·900	33·97
10	85	6·455	0·013,2	64·125	2,156·925	33·41
11	80	6·370	0·012,6	63·300	2,092·800	32·85
12	75	6·290	0·011,9	62·525	2,029·500	32·27
13	75	6·215	0·012,1	61·775	1,966·975	31·65
14	80	6·140	0·013,0	61·000	1,905·200	31·03
15	80	6·060	0·013,2	60·200	1,844·200	30·43
16	85	5·980	0·014,2	59·375	1,784·000	29·83
17	85	5·895	0·014,4	58·525	1,724·625	29·26
18	85	5·810	0·014,6	57·675	1,666·100	28·68
19	86	5·725	0·014,8	56·825	1,608·425	28·09
20	75	5·640	0·013,3	56·025	1,551·600	27·51
21	70	5·565	0·012,6	55·300	1,495·575	26·87
22	65	5·495	0·011,8	54·625	1,440·275	26·21
23	65	5·430	0·012,0	53·975	1,385·650	25·52
24	70	5·365	0·013,0	53·300	1,331·675	24·82
25	75	5·295	0·014,2	52·575	1,278·375	24·14
26	80	5·220	0·015,3	51·800	1,225·800	23·48
27	90	5·140	0·017,5	50·950	1,174·000	22·84
28	90	5·050	0·017,8	50·050	1,123·050	22·24
29	95	4·960	0·019,2	49·125	1,073·000	21·63
30	100	4·865	0·020,6	48·150	1,023·875	21·05
31	105	4·765	0·022,0	47·125	975·725	20·48
32	110	4·660	0·023,6	46·050	928·600	19·93
33	110	4·550	0·024,2	44·950	882·550	19·40
34	115	4·440	0·025,9	43·825	837·600	18·86
35	115	4·325	0·026,6	42·675	793·775	18·35
36	115	4·210	0·027,3	41·525	751·100	17·84
37	115	4·095	0·028,1	40·375	709·575	17·33
38	120	3·980	0·030,2	39·200	669·200	16·81
39	120	3·860	0·031,1	38·000	630·000	16·32
40	120	3·740	0·032,1	36·800	592·000	15·83
41	115	3·620	0·013,8	35·625	555·200	15·34
42	115	3·505	0·032,8	34·475	519·575	14·82
43	115	3·390	0·033,9	33·325	485·100	14·31
44	115	3·275	0·035,1	32·175	451·775	13·79
45	110	3·160	0·034,8	31·050	419·600	13·28
46	110	3·050	0·036,1	29·950	388·550	12·74

*Rounded to end in 0 or 5.

TABLE 130 (cont'd)

x	d_x*	l_x*	q_x	L_x	T_x	e^0_x
47	115	2·940	0·039,1	28·825	358·600	12·20
48	115	2·825	0·040,7	27·675	329·775	11·67
49	125	2·710	0·046,1	26·475	302·100	11·15
50	140	2·585	0·054,2	25·150	275·625	10·66
51	150	2·445	0·061,3	23·700	250·475	10·24
52	160	2·295	0·069,7	22·150	226·775	9·88
53	160	2·135	0·074,9	20·550	204·625	9·58
54	150	1·975	0·075,9	19·000	184·075	9·32
55	140	1·825	0·076,7	17·550	165·075	9·05
56	135	1·685	0·080,1	16·175	147·525	8·76
57	120	1·550	0·077,4	14·900	131·350	8·47
58	110	1·430	0·076,9	13·750	116·450	8·14
59	105	1·320	0·079,5	12·675	102·700	7·78
60	100	1·215	0·082,3	11·650	90·025	7·41
61	100	1·115	0·089,7	10·650	78·375	7·03
62	100	1·015	0·098,5	9·650	67·725	6·67
63	95	915	0·103,8	8·675	58·075	6·35
64	95	820	0·115,9	7·725	49·400	6·02
65	90	725	0·124,1	6·800	41·675	5·75
66	85	635	0·133,9	5·925	34·875	5·49
67	75	550	0·136,4	5·125	28·950	5·26
68	70	475	0·147,4	4·400	23·825	5·02
69	60	405	0·148,1	3·750	19·425	4·80
70	60	345	0·173,9	3·150	15·675	4·54
71	45	285	0·157.9	2·625	12·525	4·39
72	40	240	0·166.7	2·200	9·900	4·13
73	35	200	0·175.0	1·825	7·700	3·85
74	30	165	0·181.8	1·500	5·875	3·56
75	30	135	0·222,2	1·200	4·375	3·24
76	25	105	0·238,1	925	3·175	3·02
77	20	80	0·250,0	700	2·250	2·81
78	15	60	0·250.0	525	1·550	2·58
79	15	45	0·333,3	375	1·025	2·28
80	10	30	0·333,3	250	0·650	2·17
81	5	20	0·250,0	175	0·400	2·00
82	5	15	0·333,3	125	0·225	1·50
83	5	10	0·500,0	75	0·100	1·00
84	5	5	1·000,0	25	0·25	0·50
Total	10,000	—	—	2,872·650	—	—

*Rounded to end in 0 or 5.

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