The Physiology of Violin Playing

by

Ottó Szende

and

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Ottó Szende and *Mihály Nemessuri*

The art of violin playing has reached great heights over the last two or three centuries. The violin is one of the most difficult instruments to master and, except for the unexplained miracle of the prodigy, demands years of concentrated study.

The fundamental question posed in this book is how much of the hard work and drudgery might have been avoided, had we known more exactly the demands made on the body by the particular requirements of violin technique.

It is not a book of technical instruction, but, far more original, it aims to explain the activities of the body which support or impede technical progress. The numerous illustrations clarify the subject matter and both players and teachers of the violin will profit from the actions provoked by the authors' investigations and thought.

AKADÉMIAI KIADÓ
Budapest

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OF VIOLIN PLAYING

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by

OTTÓ SZENDE and MIHÁLY NEMESSURI

With a foreword by

YEHUDI MENUHIN

Preface by

PAUL ROLLAND

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FOREWORD

This book provides an extremely useful framework of reference for those violinists and teachers wishing to ascertain the validity of a given approach. How good it is to read such objective evidence of the complexity, subtlety and refinement of this most exacting art. In what other art indeed does the whole body from toes to head contribute to the delicacy and power, the infinite range and sensation of fingertip motion; in what other art does the balanced body, together with the tools, become one vibrating entity? Where else indeed does one find such balanced and poised co-ordination as must needs be the violinist's?

What places the whole exercise in its right proportion is the fact that the object and purpose is perceived and guided by the ear, and the ear is serving to recast in the aesthetic counterpart of vibrating sound the dreams, the passions, the thoughts as well of our very experience and existence.

The real artist will not spurn this exhaustive, painstaking study of the essential concomitants, the essential requirements of violin technique, for he knows, as does every artist, that his work is as much the meticulous housekeeper's, the housemaid's with broom and duster, the launderer's removing spots and blemishes, as it is the continued search for more and more perfect means so that the very means may match the ends, which in themselves are means to greater ends.

It was heartening for me personally to find supported my own conviction that the teaching of the violin must proceed from the *very* beginning with *complete motions* of *each* hand and fingers and *both together;* my conviction that the activity of toes and indeed of *every* articulation in the body in co-ordinated harmony is part and parcel of the art, that there is *no single* correct, rigid position, but that every possible exploration of twist and bend, forwards and backwards, holds a grain of self-discovery for the searcher and brings him one step along the road to perfection.

I know that this serious and illuminating study, this book written in the spirit of reverence and humility which the subject demands, and presented with an exemplary clarity of exposition, will not only itself become the contemporary required scientific apologia and guardian of common sense, but will lead to its promised successors and to others which in a subtler and more evolved human future will trace the elusive interaction which lies at the heart of the matter between image, inspiration, message and physical form which together constitute the cosmic-cellular system of interwoven vibrations.

London 14/10/70 — Yehudi Menuhin

PREFACE

The Szende–Nemessuri book, *The Physiology of Violin Playing*, offers new and exciting vistas to the string teacher and player. The collaboration of violin pedagogues and scientists has produced a viable offspring. This book will justly take its place among the most important works of theoretical pedagogy, those written by Steinhausen, Trendelenburg, Flesch, Hodgson, and Polnauer.

Significant is the application of principles from the fields of sports, medicine, neurology, psychology, and physiology. Yet, the authors guide the reader with a strong hand, keeping the vast material within practical bounds, assuring its relevancy to the teacher and performer.

Especially valuable are the chapters on breathing, sense of touch, the psychology of practising, intonation, and the psychological and physiological disposition of the students at various ages. Significant is the 'Gestalt' orientation of the book: the whole player is considered, not only his hands and arms—a common tendency of pedagogical literature dealing with violin techniques.

The authors have admirably avoided methodological bias, keeping the principles above the usual debates of the violin teaching fraternity.

Urbana, Ill., April 5, 1970

Paul Rolland

Professor of Music
University of Illinois, Urbana

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INTRODUCTION

Art and Science are sisters: they are the means of human cognition, reflections of objective reality. In the course of their evolution, their influence on each other had been mutually fertilizing, and this is equally true today. Their tools, methods and effects are certainly different, but they have a common feature, since both are the products of the highest order of conscious human action.

Leonardo da Vinci (re-issued 1891), the outstanding artist and scholar, said that every action is of necessity manifested by motion, and his statement holds good for the performing arts to an increasing extent. The most complicated of human movements are those involved in the performance of instrumental music. The study and recognition of these movements are somewhat difficult, but they are indispensable for the teaching or learning of instrumental practice and performance. A passive musical identification differs from an artistic performance in that the latter is unconditionally coupled with actions, i.e. actions which impart the experience of subjective emotions to other people. The sequence of actions is obviously accompanied by movements. Hence, from a physiological aspect, the art of musical performance implies that excitation must be cyclically reverberated from the sensory centres to the cortical and other areas of motor system. The more perfect and adequate the response and function of the motor apparatus and hence, the totality of expressive motions, the more successfully refined its realization in performance, i.e. in the communication of its message. Thus, an artistic performance is a senso-motor activity, and as such is inseparable from its framework, namely, from the process of motion. It is no mere accident that all instrumental methodologies devote some space to the questions of motor physiology.

The literature of violin playing has failed to keep abreast with the current progress in physiology and psychology. Few have dealt with the motor physiology of violin playing, still fewer have pursued experimental research into the problem, so that many published views, and even accepted information, have become obsolete. Accordingly, when some years ago we decided on an experimental study of the physiological changes taking place during violin playing, we had to seek appropriate methods. For the study of subtle movements we needed techniques which (1) would be capable of recording the rapid and complicated movements of violin performance, (2) would not be too disturbing for those subject to experiments, (3) would yield objective data, and (4) could meet modern requirements.

These were the considerations we had in mind when working out our method which, with the use of electro-myography, i.e. of the automatic photoregistration of muscle action potentials, proved to be appropriate for the above requirements. In this way objective data were collected for the purpose of answering some of the main questions of muscular activity involved in violin playing. We did not, however, content ourselves only with an investigation of the neuromuscular processes of violin performance, but, with the expert assistance of Dr E. Stadler, proceeded to study also the changes in respiratory gas exchange, and cardiac functions, occurring in the course of violin performance. Thus, we were able to form a more complex picture of the interconnections of processes taking place in the human organism during violin playing.

The series of investigations on violin playing have not been completed as yet. Many important questions—including also the challenge to analyse the intricacies of learning to play the violin, etc.—still remain unanswered. All these will require work extending over a period of several years. Art and Science are never complete as a whole, nor does this book claim to be so. The body of this volume consists of the results and practical consequences of experiments conducted so far. Thus we could not avoid offering information on anatomy, physiology, psychology and pedagogics, which we believe to be inherently interesting in our age of unexampled human achievements.

Although we have arrived at certain conclusions concerning methods on the basis of our experimental data, our book does not deal with the methodology of violin playing. It has been our intention to give a summary of the problems existing in its physiology and psychology, a study of which may be useful for violinists (professional players as well as amateurs), for teachers of the present and future, and for all friends of music who are interested in the art and physiology of violin playing. We have endeavoured to give an up-to-date review of, and opinion on, questions ranging in scope from motion analysis and the technique of practice, to the proper way of living—that is to say, of all the problems which we thought might interest the reader.

We wish to thank Dr L. Kardos, Professor of Psychology, Eötvös Loránd University, Budapest, and Dr K. Lissák, Academician, Professor of Physiology, University Medical School of Pécs, and F. Sándor, Professor of the Hungarian Academy of Music, Budapest, for their expert help and invaluable advice.

Chapter One

VIOLIN PLAYING AS A DELICATELY DIFFERENTIATED HIGH-GRADE MUSCULAR MOVEMENT

VIOLIN PLAYING AS A PHENOMENON OF HUMAN KINESIS

Movement is a regular phenomenon of life. For many millions of years the evolution of life has proceeded from the simplest amoeboid locomotion up to the most refined and very complex kinds of motion, to muscular movement. The type, differentiation of movement is closely correlated with the evolutionary status and the relevant mode of life of the being. Standing at the summit of the realm of life, Man—the being—is able to perform the most diverse and precise movements. This diversity, intricacy, social dependence of human motion implies also the difficulties of studying it.

Human movements may be classified in a number of ways. Owing perhaps to this very fact, classification, nomenclature of movements is far from uniform even in the literature. With respect to functional purpose, human movements are classifiable into four groups: (1) vegetative movements (e.g. ingestion, bowel motion, coughing, etc.); (2) instinctive movements (defensive and orientative reflexes, etc.); (3) expressive movements (mimics, gestures); and (4) operative movements (various manipulations and concomitant locomotion).

Distinction may be made according to the principle of function among: (1) motor reflexes; (2) reflex chains, instinctive movements; (3) automated motor performance (dynamic stereotype); (4) voluntary movements.

These groups cannot be separated categorically. Deglutition, for example, is a reflex movement, but we can swallow as deliberately as induce voluntary coughing. Expressive and operative movements have a number of common elements, too; there is no clear delineation between them. It will be seen later that in a considerable number of the movements listed above we shall have to deal with mechanism activities which are, neurophysiologically, frequently identical. This often causes overlapping among the respective movement categories even when classification is based on other systems.

In regard to purpose and intention, instrumental playing ranks among the expressive movements, but it cannot be strictly separated from operative or working movements. Instrumental movements are endowed with the mark of musical character primarily in the intention to convey a musical message by producing concrete tones on a definite musical instrument.

Forms of movement may be described more precisely if we analyse the manner in which such movements are performed. According to the motor process four classes of movements in sport are identified by Farfely (1960): (1) cyclical motion; (2) single acyclical motor actions; (3) compound acyclical motion; (4) movements of an inconstant character.

Since this classification recognizes the element of dynamism, it may be conveniently applied to other manifestations of human movement, too.

(1) Cyclical motions are characterized by a pattern in which the cycle phases as well as respective cycles have always the same order of succession and are

consequently inseparable. Cycle series resemble circular motion in that cycles have no definite beginning, except the first one, and have no definite end-point except the last one. In regard of the direction and co-ordination in upper and lower limb motion, distinction can be made between crossed and uncrossed movements. When the upper limbs, or the lower ones, move in unison, the resulting cyclical motion is called uncrossed cyclical motion. The motion is crossed when the contralateral pairs of limbs (e.g. right arm together with left leg) move in the same direction. Breast stroke, rowing, hammering, sawing, etc. are uncrossed actions. Walking, running, cycling, etc. are examples of the crossed type of cyclical movement.

Cyclical movement represents the simplest form of motion, so that it can be quickly and easily mastered and automatized. Since the inertia momentum has a significant part in the linking of motion phases and cycles, bringing about an abrupt stoppage is rather difficult.

(2) In the case of single acyclical motor actions this natural transition and linking is absent. However, the separate acyclical phases may be welded into fluent motion. Even if they are less easy to master than cyclical motions, they are, by the required practice, nevertheless, automatizable. Cyclical and acyclical movements may be combined as shown by run-up and broad jump. Running is cyclical, jumping is a single acyclical action.

(3) Compound acyclical movement consists in fact of several distinct movements which are interlinked like a chain. Gymnastic exercises on apparatus or on the floor are good examples of how complicated combinations may develop in this way. Each part of the movement has a different structure of phases, which is another characteristic of the compound acyclical motion. With practice, even this form of motion could become automatic.

(4) Continuous adjustment to unforeseen conditions is the main distinguishing mark of movements that have no constant pattern. They cannot be completely pre-dispositioned and their habituation is restricted to certain of their parts. Every game of sport, but many operative movements (car-driving), too, are examples of this type of motor actions.

According to the rules valid for any action, instrumental music is likewise associated with the motion sequences that create the physical (mechanical, acoustical, etc.) conditions of tone production.

The sequence of these movements may be considered a sort of accommodating (adaptive) motion because it has always to observe the peculiarities of structure, material, and of the manner in which the respective musical instrument is made to sound. In fact, this very intricacy of adaptation is the hidden source of many of the difficulties encountered in instrumental technique. Tone production, faults and technical stumbling blocks find a common root in it.

Attempting to produce tones of different pitch, volume and quality, both hands and both arms must perform definite movements. Next to the qualitative requisites of the tone to be produced, it is the particular structure of the violin and the bow that specify the execution of those movements and the forces arising from them. Relevant particulars available to us in the literature seem to be rather deficient and contradictory. In the following a brief review is given of the physical conditions that must be fulfilled by the playing mechanism in order to make the instrument sound.

MECHANICS OF LEFT-HAND TECHNIQUE

The mean pressure which is necessary to shorten the strings varies between 150 and 400 g, and increases according to the respective strings and positions, as W. H. Diestel (1912) reports. A. Basler and K. Kawaletz (1943) have found, however, that this force is equal to 500–1500 g. Though the difference between the statements of these two reports is considerable, the matter has no relevance as far as energy is concerned, since human fingers are capable of far greater pressure in a suitable position. Violin playing has no particular problems of energy in respect of left-hand technique.

When placed on the strings, the fingers must be adjusted to the structural conditions of the instrument. The mean measurements of string diameters are: E-string = 0·65 mm, A-string = 0·81 mm, D-string = 1·016 mm, G-string = 0·88 mm. At the nut the strings are 5·7–6 mm apart; their distance increases to 11·8–13 mm towards the bridge. By comparing these data to the finger-tip establishing a 10 mm contact with the strings, we can realize once more that left-hand technique presents first of all a challenge to skill. The fingers must be placed on the string accurately enough to avoid the possibility of touching the adjacent string, even if we disregard, for the moment, the question of correct intonation.

In order to depress the strings with the necessary accuracy, the fingers must be bent. According to an analysis of Basler and Kawaletz (1943), the fingers act as levers of the third order if stabilized in this manner by the flexion. The long arm of the lever extends from the base of the finger (metacarpophalangeal joint to the string, and the short arm extends from the proximal joint axis to the intercept with the flexor muscle (Fig. 1). As regards effort, the relationship between the lever arms improves with the closeness of the axis of the proximal joint of the stopping finger to the string. If we are able to make the long lever arm shorter, the strain imposed on the flexor digitorum will be less. This is necessary, because finger flexors are occupied not with the effort of producing tones, but with the requirement of speed and accuracy of motion. The lever arms of the 3rd and 4th fingers (i.e. ring and little fingers) would be shortest if the row of the finger-tips were parallel to the strings. In general, however, the lines of the finger-tips and the strings enclose an acute angle with its opening towards the face. The greater this angle the less favourable the leverage for the 3rd and 4th fingers (Fig. 2). That finger-tips and strings should enclose the smallest possible angle is thus an important condition for economical finger-work. Mechanically, the ideal position would be obtained if the hand were parallel to the fingerboard as in playing the guitar or violoncello. In playing the violin, however, this would make the hand inflexible, and would be superfluous, even if feasible, as it is unnecessary for the effort of stopping with the 3rd and

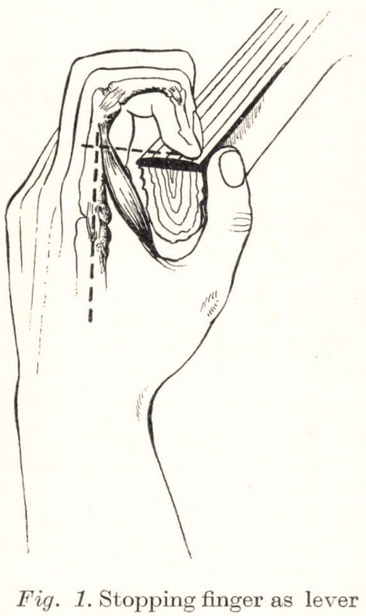


Fig. 1. Stopping finger as lever

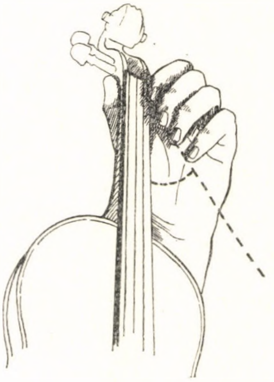


Fig. 2. The acute angle formed by the row of fingers and the strings

4th fingers. Nevertheless, a strong supination of the forearm is indispensable. Thus the motor-mechanism of the left hand works in a strongly supinated arm position because of the structure of the violin and the manner of its being held. We shall return to this in the second chapter. The finger-work of the left hand requires, in spite of the tiring arm position, less muscular force than skill, for which reason the co-ordination of muscles is of decisive importance in solving technical problems of the left hand.

MECHANICS OF RIGHT-HAND TECHNIQUE

The mean weight of a bow in action is 270 g at the nut and 17 g at the point (according to Jahn 1951, p. 21). To lift a weight like that in the air will not present any difficulty to the arm muscles, and even less when it is supported by the strings. However, the task of continuous compensation for the unequal weight distribution of the moving bow is all the greater. In order to achieve evenness in dynamics, the bow must exert a steady pressure on the strings, regardless of its position. During a sustained whole-bow mezzoforte this pressure is about 60 g. The relationship of pressure and leverage changes continuously in the course of a stroke, so that the muscles of the right arm and hand must act as constant pressure controllers. Essentially this is an action of an opposing pair of leverages: (a) the thumb pressing upwards and the forefinger pressing downwards have a combined effect which increases the weight of the bow; (b) the combined effect of the thumb pressing upwards, and of the little finger pressing downwards, tends to separate the bow from the strings, i.e. the bow weight is effectively reduced.

The extent of this pressure control is quite large. In accordance with the way the bow is held, the fulcrum of leverage may lie between the thumb and the second finger, or in the part of the stick which lies between the thumb and first and second fingers. The ring finger may support the function of either the little or the second finger according to the direction of the strokes, and it may take over eventually the whole duty of the little finger. These will leave the mechanism of leverage practically unaffected. At a distance of about 19 cm from the nut the pressure to be exerted by the right-hand fingers for the production of mezzoforte dynamics is equal to zero (i.e. the dead weight of the bow will suffice). In the volume range of forte a force of 114–120 g is needed at a 9·5 cm distance from the nut, while a range of piano dynamics played 40 cm away from the nut requires about 28·5–30 g.

The figures, which give approximations, are valid for strokes drawn parallel to the bridge and at a right angle to the strings. An inclination of the bow towards the string, or an oblique stroke may change the numerical value but the characteristic ratios remain the same for any case. As reflected by the values quoted, bow pressures needed to increase dynamics at the nut are brought about by a decrease in counter-pressure of little and ring fingers with the thumb and index finger resting more heavily against the stick at the point. Bow and right-hand fingers thus constitute another system of leverage, the function of which is again mainly a problem of muscular co-ordination and not one of effort.

The physical problems that are to be tackled by the left and right hands make it apparent that an analysis of the mechanical relationships alone will not bring us closer to an understanding of movements, since both right-hand and left-hand techniques have to be treated as co-ordinating mechanisms, and that is why physical data lose their importance as regards the quality of performance. By contrast, the fluency or obstruction in the flow of movements, i.e. the adaptive capacity of movements appropriate to the given technical task, will exert a fundamental influence upon the actual quality of the tone envisaged.

MOTOR ANALYSIS OF VIOLIN PLAYING

Motor analysis of instrumental performance has so far been done solely with regard to movements associated with instrumental manipulations in a narrow sense (fingering, bowing, change of bow direction, change of position, vibrato, etc.). As yet no one has ventured to compare the chain of these movements with the general properties of human motion.

As regards construction, and constituent system, and despite their specificity, instrumental movements belong to the broad domain of human motion. By utilizing common traits they obviously could be mastered with greater ease. Violin playing, as one of the complex motion processes, derives from these forms of movement and of certain special modifications of these movements. Taken as a whole, playing of the violin may be considered a compound acyclical motion made up of various cyclical and single acyclical movements (Table I and Fig. 3).

By grouping the movements of violin playing in this way, an order of increasing difficulty arises that may furnish us with new considerations. For the left fingers repetition of stopping with the same finger is the easiest. For the right hand the repetition of simple strokes is most easily ingrained. The favourable cyclical character can naturally be preserved only if breakdown into phases is avoided

Fig. 3. Examples to Table I

Table I

*Forms of movements in violin playing**

I. Cyclical movements		*II. Single acyclical movements*	
Left hand	Right hand	Left hand	Right hand
I/1 Repeated isolated stopping	I/1 Repeated simple bowing	II/1 Sustained notes	II/1 Martelé
1st phase: stopping	1st phase: upbow	1st phase: stopping sustaining	1st phase: downbow pause
2nd phase: raising	2nd phase: downbow	2nd phase: raising	2nd phase: upbow
I/2 Shake (trill)	I/2 Symmetrical bowing	II/2 Change of position	II/2 Broad détaché (portato)
1st phase: stopping	1st phase: first half	cyclical: execution of change	1st phase: movement pause
2nd phase: raising	2nd phase: back to start	acyclical: continuing the playing in new position	2nd phase: movement
I/3 Repeated notes in identical fingering	I/3 Ricochet and tremolo bowing	II/3 Ornaments	
1st phase: playing	spiccato		
2nd phase: return to initial note	staccato		
	saltato and tremolo		
I/4 Vibrato Elbow, wrist, finger	I/4 Arpeggio		
1st phase: flexion			
2nd phase: extension			

III. Compound acyclical movements		*IV. Movements of inconstant pattern*	
Left hand	Right hand	Left hand	Right hand
Continuous left-hand operation	Continuous right-hand operation	Prima vista (sight-reading) and improvisation	
Violin performance as a uniform process			

* Numbers are references to the examples in Fig. 3.

and the motion is performed from the first starting position to the next starting position. Thus stopping must be done from a finger position above the strings and returning to it, while simple bowing must include both upbow and downbow or vice versa, back to the starting position of the stroke. In the case of stopped notes the standstill of the finger on the string will separate the two phases of motion. If in the beginning long notes are played, the finger will tend to adhere to the string. Similarly, the most essential technical requirement of violin performance, namely the fluency in changing bow, is jeopardized if breaks are allowed between strokes. The reason is obvious from what is said above: we have begun with an acyclical form of motion instead of a cyclical one. It might be recommended to teach bow balancing as a separate observation, involving also the technique of changing bow direction. This would correspond to the generally accepted modern methods of movement-oriented education which prescribes the teaching, as far as possible, of complete motions.

Fig. 4. (a) Isorhythmic movements; (b) polyrhythmic movements; (c) teaching step towards polyrhythmic movement

Likewise, the easiest way of connecting the work of both hands seems to be the application of both cyclical motions concurrently: repeated stopping linked to a petit détaché. This would mean also a symmetry of motions, to which all our movements are inclined, owing to the symmetry in the construction of the body. The physiological reasons for this view and the mechanism that it implies will be treated in the second chapter. The suggested symmetry of movements also implies a kind of isorhythm: left-hand fingers and bowing arm move in the same rhythm. As for that, even a legato bowing of two notes will disclose a polyrhythm in movements, and set a more difficult task. The intricacy of polyrhythmic movements in bi-manual note production is one of the main reasons for technical problems in playing the violin. The well-known tendency of strings to play rhythmless is, at least in part, certainly due to this fact. (Examples of isorhythmic and polyrhythmic movements associated with violin playing are shown in Fig. 4.)

Movements of inconstant pattern occur during instrumental playing in the cases of prima vista (sight-reading) performance when acquired elements of motion are to be applied in an unexpected manner and without previous formulation. It is a point of great importance that such exercises be included early in the systematic plan of tuition. To promote this, violin schools should contain some pieces instructed 'to be played prima vista only', with every new set of problems. The student should play these during the lesson, and the exercises should not be assigned for home-work at all. If the student has enjoyed playing the piece, he may retain it for his own amusement. This will also help him to develop his self-reliance. The only pitfall of this concept might arrive when the student is confronted by tasks which he had already forgotten to master, or by such that he cannot yet tackle. Care must therefore be taken in the selection of material, so that the pieces could be tackled and mastered by methods already well known and currently employed.

According to the outline already described, the comparison of instrumental movements with the properties of human movements in general presents new methodological points of view. These aspects seem to deserve proper attention, and the practical application of relevant principles should be examined in detail. Some of the considerations deviate from traditional practice and disagree with certain opinions found in the literature on the subject. Moreover the evidence of the latter appears often conflicting and sometimes originates in an inaccurate interpretation of motor physiology. Whatever form of approach motion analysis and motor education may take, a knowledge of the motor system will be inseparable from it. This is the reason why in the following pages we give a brief survey of the basic structural and functional aspects of the motor system, in the framework of which we shall return to the various questions of our new system of motion analysis.

MUSCLE ACTIVITY AS ELEMENTARY FUNCTION OF VIOLIN PLAYING

Each of the movements is carried out by an organ of our body, developed to this end, viz. by the motor apparatus. The motor system of humans has reached a higher state of evolution than that of any other creature. This achievement lays the anatomical foundation and physiological basis for the execution of such intricate and subtle movements as we find in art.

In the motor system the main structural elements are the following: (1) the solid framework divided into sections by the joints; (2) the muscle system, generator of motions; (3) the nervous system also governing muscular function; (4) circulation, the system also satisfying the metabolic needs of the motor system.

In the generation and maintenance of motion the solid framework, the muscular apparatus, the nervous system and circulation are integrated to respond anatomically as well as physiologically as a whole. In fact, the motor apparatus consists only of the solid framework (the bones making up the skeleton), interosseal joints, and muscles which cause the joints to move. That the motor apparatus represents from 65 to 75 per cent of our body mass is another aspect adding to the importance of its contribution to the construction and activity of the organism.

Muscles display a diversity of form and size, yet the basic properties, for example, of the broad laminar muscles of the trunk, of the long fusiform muscles of arm and forearm, or of the small, worm-like muscles of the hand that come into play when subtle finger movements have to be made, are in fact identical (Fig. 5). Every muscle has a fleshy touch, and some shade of red colour, owing to the myoglobin content and to the rich supply of blood. When relaxed the muscle is soft, but when activated it grows tense and tough. Muscle consists of a fleshy part, the belly of the muscle, and of sinewy or membranaceous endings. Limb muscles are mostly spindle-shaped, and attached by their ends (the tendons) to definite areas of the periosteum (the membrane of the bones). The ends of muscle fibres converge to continue in tendinous fibres. The connexion between the tendons and the bones is established through the periosteum, the fibres of which penetrate into the respective canaliculi of the bones. Muscular power is transmitted to the joints by the tendon fibres that intertwine and coalesce with the periosteum. That part of the tendinous attachments of the muscle where the scope of movement is less, is usually called origin, while the other, where the amplitude of movement brought about by muscular activity is greater, is called insertion. In some muscles two or more tendinous heads unite to form a common belly. The double-headed flexor and the triple-headed extensor of the elbow, or the four-headed extensor of the knee, belong to this kind of muscles. Among the flexor and extensor muscles of the hand there are also muscles whose united belly divides into several tendons to serve the respective fingers. On the trunk there are broad muscles attached to the periosteum by tendinous laminae. In other areas, for example around the eyes and the mouth, ring-shaped muscles are also found.

The elementary structural and functional units of muscles are the fibres. A fibre is a single gigantic cell that has several hundred nuclei. Being discernible only through the microscope, its shape resembles a long cylindrical thread. Single fibres have a mean length of 5 cm and an average diameter of 50 μ. A thread of fibre shows a succession of transverse stripes across its length. This cross-striation is brought about by a regular repetition of optically isotropic and anisotropic segments within the filaments composing the fibres. This is the reason why we call skeletal muscles striped, in contrast with the smooth muscles which participate in the construction of hollow visceral organs (Fig. 6).

The connective tissue joins the columns of muscle fibres into successively greater units of primary, secondary, tertiary bundles. Among the fibre bundles, a certain difference in colour is observable: some are of a lighter shade of red, others are darker. For the sake of simplicity they are called pale or red muscles respectively. Minute analysis of the structure reveals that the red colour of the fibres is due to an abundance in cell masses (sarcoplasm), while pale muscles contain a greater quantity of myofibrils. These structural differences manifest themselves in their function. Pale fibre bundles contract more rapidly, but become fatigued sooner; on the other hand, the red bundles are capable of slower but more sustained work. In addition to the fine cobweb of connective tissue investing the fibre bundles, the muscles have a further envelope. This is called the sheath or fascia. During muscular contraction the sheath becomes tense and promotes the stabilizing effect and efficiency of muscular activity.

Our muscles are provided with a rich network of blood and lymph vessels. The vigorous metabolism of muscles is safeguarded by this dense network of capillaries embracing each muscle fibre. The draining effect of rhythmical muscle contraction and relaxation contributes generously to the work of recirculating venous blood: another reason why violonists should not keep their body stiff while playing. A strainless and rhythmical muscular activity will promote the circulation in the lower limbs. Rigid anchorage in the centre of gravity will too soon lead to exhaustion, whereas a reciprocating motion proves to be more expedient and causes less strain.

Muscles have also a rich supply of nerves. Muscles are activated by the succession of impulses that come from the nerve centres (innervation), while in the opposite process (denervation) the nerve centres, and so also the

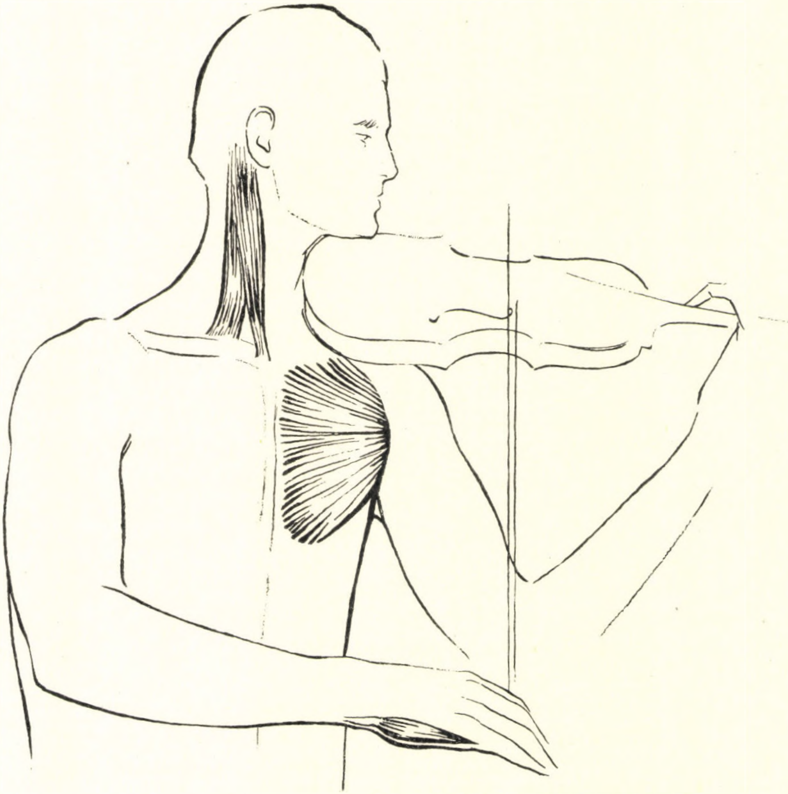


Fig. 5. Examples of broad laminar, long fusiform, and small muscles

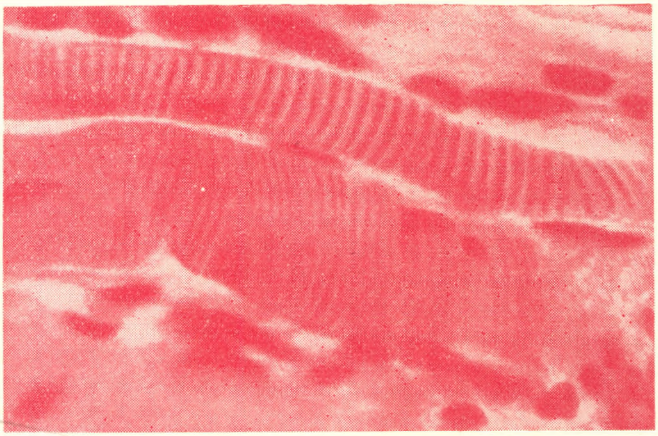


Fig. 6. Cross-striated muscle fibre under the microscope

muscle, cease to be active and relaxation takes place. The nerves of the muscles are either sensory, motor, or autonomic.

In addition to the discharge of nerve endings located in the joints and in the skin, the sensation of muscular tension, or muscle sense for short, is communicated by nerve endings within the muscle and tendon fibres (muscle and tendon spindles). It is due to them that we are informed of the position of the body's parts, and about the conditions established by, and characteristic of, the particular motion. In this way, muscles constitute also a kind of sense organ which, by making us aware of position and motion, allows certain spatial orientation. For instance the sense of touch, palpation, is not restricted to the cutaneous sensory endings: the impressions gained are also coloured by the extent of muscular tension. The electrical excitation conducted by the motor nerve activates our muscles directly. Some sort of muscular activity, tonus, is nevertheless also maintained while resting. Autonomous nerve fibres control the capacity of muscle's blood vessels, and in this way also muscular metabolism.

Sensory and motor functions cannot be separated from one another. Pavlov in 1911 described the motor analysor which includes sensory endings, communicating nervous pathways, and central nervous representation, in the following manner: "It is obvious that the list of analysors we generally refer to, such as eyes, ears, skin, nose, and mouth, must be complemented with the motor analysor concerned with the centripetal excitatory processes that have arisen in the bones, muscles, etc., i.e. in the motor apparatus proper. This analysor of remarkable refinement, which signalizes every event of motion to the central nervous system, and which reports on the position and tension of every part of the body participating in the motion, must be adopted to the family of the five exteroceptive ones!" (Pavlov re-issued 1951, Vol. III/1, p. 176.) Sensory function is a prerequisite for, and at the same time an inseparable concomitant of, any motor activity; accordingly, we may speak of the motor apparatus as having an integrated sensory motor function.

TONIC AND PHASIC MUSCLE ACTIVITY

All the muscles of our body are more or less always under tension. So even while at rest they exhibit some basic tension, muscular tone. Thus, our movements do not commence from a condition of complete slackness (zero tension), but begin their contraction with a tonic background. It is advisable to be careful about this in view of the practice of relaxation and slackening so fashionable nowadays. As man is capable also of exerting some voluntary influence on muscular tension, over-relaxation might produce a flabby condition in which active movements would start less easily than from one of slight tension. The neuromuscular concentration, which is necessary to convey musical concepts by suitable motor processes, is therefore reflected by a state of active tone and readiness for movement. This is the only means to arrive at our end. However, the tonic contraction just mentioned serves the maintenance of body position only. As soon as movements are performed the tension of active muscles will rise. This phasic contraction induces concrete displacement, and extends to all the muscles that partake in the movement. Our movements are characterized by this phasic contraction since its duration affects the velocity, and its force defines the energy, of the motion.

According to the two types of muscular activity, we distinguish between static and dynamic nervous activities. The basic prerequisite of phasic innervation is static innervation. Wachholder (1928, p. 73) distinguishes between two groups of movements, according to the respective position they have started from and ended at: (1) when a resting position is left by the moving part to reach a new position of rest, he speaks of a single motion (Einzelbewegung); (2) when a resting position is left by the moving part to return to the same position of rest, he refers to a reciprocal motion (Hin- und Herbewegung).

The starting and terminal points of single motions are always postures. The execution of single motions means therefore a transition of the static innervation into the phasic one followed in turn by a re-establishment of the static innervation. This fact necessitates a complex interaction of the two mechanisms of innervation. In the case of reciprocation the movement is performed more than once, and repetition occurs in a sequence unbroken in both rhythm and continuity. The limb moves constantly in a position defined by the initial posture, and since it returns to the same, there is no need for the establishment of a new static innervation. Obviously, the simplest form of motion is the rhythmical and reciprocal movement which corresponds to a cyclical process of motion.

It is customary for the introductory phase of teaching bow technique to insert a pause between upbow and downbow. According to Seling (1952, p. 14) this is necessary. He says this: "Whenever the direction of bowing is changed, the muscle that has been active for the greatest part of the stroke must cease to be active in an instant and yield to the dominance of its counterpart, the antagonistic muscle that has remained as yet relaxed. Since few are capable of performing such a swift switch-over, the beginner is mostly found dragging the bow up and down under persistent tension engaging both kinds of muscles. He should be told therefore to pause briefly each time the stroke reaches its terminal point, and to prepare himself without haste for switching over. In the meantime the bow stays on the string without changing its pressure."

Though being quite common, not merely in the otherwise excellent method of Seling, but also in the prevailing practice of violin instruction, the requirement just quoted is unjustified from the aspect of motor physiology and motor education. Most likely it is a misinterpretation of the concept of pause, if we disregard the unwarranted simplification ascribing the generation of movements exclusively to the effects of agonistic and antagonistic muscles. A mastery and fluent execution of movements is not promoted by any sort of pause; quite on the contrary, they might be even handicapped by artificial pauses. As a matter of fact, it is only mere appearance that a single movement is simple and easily executable. Actually it is more complicated than a reciprocated one for it implies an artificial break in the continuity of movement and, in this way, necessitates the establishment of a new static innervation. As discussed previously, these are the reasons why we think that the most easily acquirable form of movement and, accordingly, the best beginning to motor education, must be a slow, rhythmical and reciprocal motion which is not broken by arbitrary pauses. One may even arrive, for that matter, at the conclusion that Seling himself regarded the pause as a transitory emergency measure since, in contrast to other methods, there are no signs for pause in the score of his first bowing exercises. He begins to teach the acyclical change of bow to be interrupted by rest only from the 7th exercise.

FUNDAMENTAL TYPES OF MUSCULAR CO-ORDINATION

It is quite exceptional for our muscles to work alone: almost every movement is a result of many muscles acting in co-operation. However, there are differences in the functions of the muscles that bring about motion. Muscular function may seem to be easily analysable: it shortens in one direction or, to be more exact, along the main line of force. Growing tension will fixate the points of origin and insertion (tonic work of the muscle), and during phasic contractions these points are brought closer to each other. For example, when the violinist wants to raise his left arm into the playing position, the origin at the shoulder girdle, and the insertion at the arm bone of the deltoid muscle that covers the shoulder like a cap, come closer together as the contraction proceeds: with the movement taking place in the shoulder joint, the arm rises.

In most cases, however, the task of analysing a given muscular function is not so simple. In the first place, the result of activity depends on the position assumed at the start, be the joint fixed or moving. Further, owing to an alteration in joint position, the effect will also change during movement. Finally, adjacent or sometimes even distant muscles may also influence the activity under observation. Some muscles bridge only one joint, others pass along several joints. A muscle extending over several joints will influence the whole limb, but even single-joint muscles affect adjacent joints. So, for example, the brachial muscle is of the single-joint type and bridges only the elbow. A flexion of the elbow will, however, move the arm backwards by translating the centre of gravity of the arm. Consequently, it may extend the shoulder joint unless the latter is held in place by other muscles. Thus while we have to know exactly what is produced by the basic structural and functional elements of fine muscular activity (the motor unit of Sherrington, 1906), further how the individual muscles function severally, we have yet to realize that in each practical instance many muscles are concurrently active and isolated activity hardly ever occurs.

Many parts of the body are covered by muscles as by an envelope. Two or more muscles which may have different or antagonistic effects are inserted in close proximity on the bone, opposite to one another. This arrangement of the muscles helps to perform movements in a harmonic manner. It used to be thought that while one of the muscles (the agonist) was active, the other, acting against it (the antagonist), stayed relaxed. (Undoubtedly, this is the most elementary form of muscular activity; Liddel and Sherrington 1924.) Today we know, however, that the antagonist will generally exert an active braking, an influence on the adjustment to modulate the movements during the action of the agonist. This is most conspicuous in the case of playing the violin where precise control is required.

In principle, a single-axis limb joint is made to move by one pair (or one pair of groups) of muscles, i.e. by flexors and extensors, or outward and inward rotators. A double-axis joint is worked by two pairs (or two pairs of groups) of muscles, i.e. by pairs of flexors–extensors, and of adductors–abductors respectively. A free joint having three main axes is surrounded by an explicit conoid of muscles paired into three groups that can produce also rotatory movement besides those mentioned previously.

Flexors are muscles to be found anterior to the axis of a joint and make the bones of the joint come closer to each other, i.e. the angle enclosed by them diminishes, as for example on bending the elbow. The opposite movement is brought about by extensors which lie behind the fulcrum of the joint and make the angle of the joint larger by moving the bones further apart. This action is exemplified by the knee extension, by which the thigh extensor located at the anterior side of the thigh is made to contract. A muscle, which has its point of insertion in the neighbourhood of the intercept of skin and joint axis, may act either as an adductor or as an abductor according to its placement with respect to the medial plane of the body. Muscles which cross the axis of a joint obliquely, exert a rotary influence.

Training elicits formal and functional changes in muscles. Investigation has shown that as a result of training even their intramuscular chemical composition may undergo alterations. Though the number of muscle fibres already existing will not increase, the modifications induced in them by regular activity are rather important. In weight-lifters, or more generally, in every type of sustained muscular work that requires great effort, a conspicuous thickening of muscles is found. In other activities the change is less demonstrable so that conclusions about the transformation are inferred only from the increase in working capacity. In playing the violin, for example, fixators have to adapt to the suitable posture and maintain it as long as required. Phasic muscles in their turn have to learn and improve an activity that at times consists of very swift, rhythmical, and very subtly co-ordinated muscular actions.

According to their participation and co-operation in movements, our muscles are classified into four groups. (1) Agonists: muscles whose activity produces the movement directly. Directions of contraction and movement are mostly concordant. Such is the biceps when it bends the elbow. (2) Antagonists: muscles which counterbalance and regulate other movements. The direction of pull is opposite to that of the agonists, yet the activity is not restricted only to braking or reversing of the motion, but implies also an exact regulation of the motor process. (3) Synergists: acting in co-operation with agonists they help in completing movements. Direction of the pull may vary, though mostly it is the same as that of the agonists. Example: the muscles moving the wrist during finger flexion. (4) Fixators: muscles which stabilize other parts of the body or limb during the motion. Their task is to maintain firmness during the respective movement.

Fig. 7. Muscular co-ordination in bowing: agonist, antagonist, synergist, fixator muscles

The above groups cannot be distinguished strictly. For the execution of motions, muscles combine in rows to fulfil the respective duties outlined above in producing the whole of the required motion, so muscle rows of agonists, modulators, synergists and fixators emerge (Fig. 7). Such muscle rows should not be taken as rigidly constant contrivances, because conditions change in every moment and in each phase of movement. They are rather a means for controlled co-operation characterized by dynamism. They might exchange duties as the phases of motion alternate: those acting hitherto synergetically become fixators, etc. Exactly this dynamic character of the organization of human motor-system is the foundation of the variety of our movements, which machinery could hardly imitate. The type of motion generated by muscular contraction is determined by the operation of the moving joint, and by the organized activity of the muscles as just described. The organization of activity brought about and maintained under the control of the central nervous system is called muscular co-ordination. Success and failure, economy or unnecessary consumption of powers in motion, all depend on the accuracy displayed in the co-ordination of muscles which participate in the generation of movement. Action implies motion, thus success in learning some new activity depends on the muscular co-ordination which has developed while we have learned and exercised it. The more accurate the movement required, the more accurate must be the co-ordination.

Instrumental playing belongs to the most complicated human activities also in respect of motor activity. This fact supports the need for a specified analysis of its fundamental motor elements, the need for a thorough investigation into the relationships of muscle co-ordination and for the establishment of its particular kinetics.

CHAPTER TWO

KINETICS OF VIOLIN PLAYING

BIO-STATICS OF HOLDING THE VIOLIN

Structural and functional properties of postural relationships constitute the domain of complex bio-statical investigation, while the coherent description of the anatomy and physiology of movements belongs to research in bio-dynamics. We have compiled the kinetics of violin playing by making allowance for both.

Maintenance of body position requires complicated chains of postural and righting reflexes, also the co-ordination of a great number of mechanisms. In order to increase efficiency in muscular work one has to strive to maintain a posture which does not demand too great an effort from the muscles. The body position assumed in playing the violin must therefore be such as to give firm and at the same time elastic support for the body parts that participate in the performance, both when at rest or in vigorous motion. When we are standing or sitting, considerable muscular power must be applied to overcome the force of gravity, consequently it is highly important that the muscular work of the trunk and legs, which is necessary to balance the movements of the arm during violin playing, should be confined to an indispensable amount of effort. Muscles in the shoulder-girdle affect the tone-distribution of other skeletal muscle areas; these, in their turn, re-affect the tonus of the shoulder muscles. Cramped stiffness in the postural musculature hampers the movement of the shoulder-girdle, whereas a suitable tone-distribution favours its muscular work.

In regard to mass relations, the two upper limbs make 13 per cent of the total body mass. This seems to be negligible in comparison with the 87 per cent mass that is relatively quiet in violin playing. In case of movements, however, this 13 per cent of total mass gains considerable momentum whose continued balancing is an intricate task and also requires particular effort.

The nature of these balancing movements was experimentally studied by Basler and Kawaletz (1943), while Flesch (1928) approached the problem by relying on his experience as teacher and performing artist. According to Basler and Kawaletz (1943) up-bow strokes are compensated by bending the trunk to the right. The same is true for a changing of position upwards. According to Flesch (1928), swing direction of the trunk depends on the duration of the stroke. Vigorous bowing elicits body movement in the opposite direction, while playing long, sustained notes induces one that follows the direction of bowing. The function of these balancing movements is to restore the body's centre of gravity to its original position as soon as possible, and to stabilize the body. For a further analysis we must briefly review the solid framework of the trunk and lower limbs.

SOLID FRAMEWORK AND JOINTS OF THE TRUNK AND LOWER LIMBS

The spine is the supporting pillar of the trunk. It transmits the weight of our body to the hip bones, and to the lower extremities joined to the latter, with the aid of the rump bone (sacrum). The spine is not straight, it shows a slight S-shaped curvature. The curves are physiological and natural, their radius differs from individual to individual. The vertebral column can be firm and mobile as conditions require. It becomes firm if the trunk needs support. In this case the weight of the upper body is transferred through it to the pelvis and legs. However, it becomes mobile when we have to perform any bending or twisting movement of the trunk during everyday life. As a whole, the spine is movable in every direction, acting like a free joint. With reference to an upright body position the possible directions of spine movement may be grouped into four main functional classes. These are: (1) bending forward and backward; (2) bending sideways; (3) twisting; and (4) a spring-like movement. In most instances these occur in combination.

The range covered by forward and backward flexibility makes up to an angle of about 140 degrees. This kind of movement as well as that of bending sideways is most marked in the cervical and lumbar segments of the vertebral column. The torsion of the spine has a perpendicular axis. Vertebrae of the thoracic segment are best suited to performing such motion. The range of twist is 45 degrees in each direction.

The vertebral column is moved by several muscles, part of which insert directly at the vertebrae, while others run to the ribs. Those inserting at the ribs exert a relatively stronger effect since the ribs act like levers. We shall return to this when analysing respiratory movements.

The lower limb is connected to the trunk by a belt-like formation, the pelvic girdle. The lower free extremity has several constructional similarities with the upper one. Here, too, the constituents are one great bone (thigh bone, femur) and two others joined to it (shin bone, tibia, and calf bone, fibula) and, distally, the bones of the foot. In addition to similarities, constructional dissimilarities are also discerned. These are caused by the difference in function of the pairs

Table II

Solid framework, joints and interior movements of the trunk

Name of joint	Bones of joint	Movement
Lumbo-sacral	Last lumbar vertebrae (sacrum)	Stiff joint (no movement)
Sacro-iliacal	Sacrum and ileal bones	Stiff joint (no movement)
Hip joint	Hip bone and thigh bone	Flexion and stretch Adduction and abduction Inward rotation Outward rotation
Knee joint	Thigh bone and shin bone	Flexion and stretch Inward rotation } when knee Outward rotation } joint is flected
Ankle joint	Distal parts of shin and splint bones Tarsal bones Proximal parts of metatarsal bones	Plantar flexion Dorsiflexion Adduction and abduction Supination and pronation

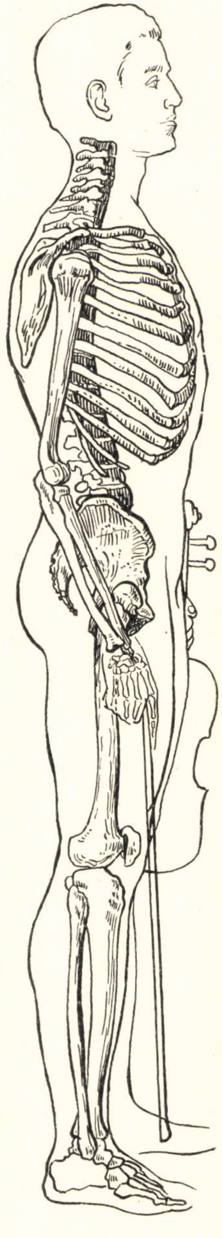


Fig. 8. Solid framework of the trunk and its joints; side view

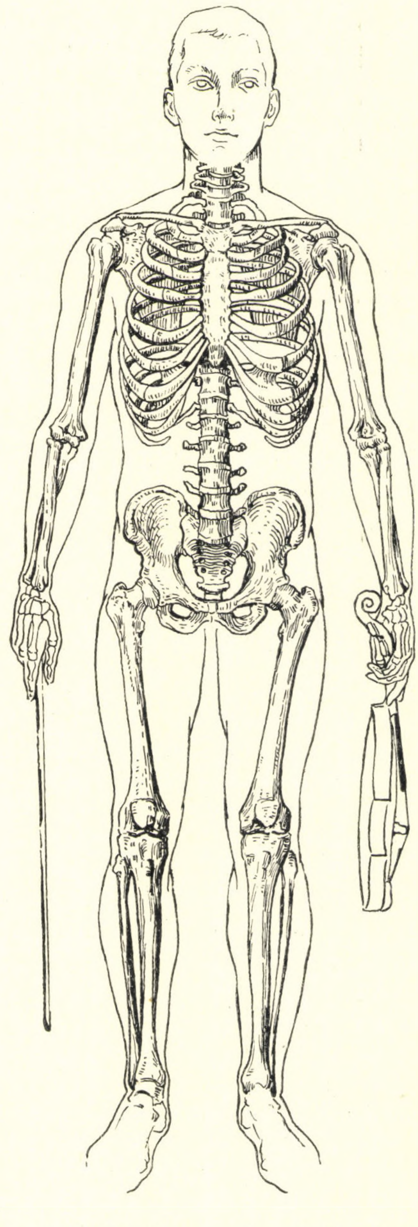


Fig. 9. Solid framework of the trunk and its joints; front view

of limbs. For the upper extremity a dynamism of movement is characteristic, whereas the lower ones generally do static work. The bones, the joints, and the movements occurring in the joints of the trunk and lower limbs are listed in Table II (see also Figs 8–9).

THE BODY'S RELATIONS OF BALANCE

In standing upright the resultant gravitational line runs in the medial plane of the body. Starting from the centre of gravity of the head (at the level of the eyes), and passing before the first cervical spondyle it traverses from the second to the sixth cervical vertebrae. In the rib cage it lies before the thoracic vertebrae, then intersects from the second through the fifth lumbar ones. In the pelvis it halves the line connecting the hip joints. The centre of gravity of the trunk proper is located at the upper edge of the abdominal surface of the first lumbar spondyle, while those of the limbs lie more proximally than the middle of the respective longitudinal axis (see Figs 10–11).

In the living body not even sleep can bring the centre of gravity to a perfect standstill, and moving about will make it swing considerably. When the arms and shoulders are raised, the centre of gravity of the whole body moves upward. This transitory motion of the centre causes the pressure on the soles to increase. Any displacement of the centre of gravity is impeded by inertia. The lower the body's centre of gravity, and the broader the supporting surface, the more stable the posture. The supporting apparatus constitutes a static unit. The spine works like a spring, and the hip bones as well as the lower limbs carry elastically the weight of the body. The weight of the standing body is distributed so that 75 per cent of it falls on the heels and only 25 per cent on the contacting points of the soles. In sitting posture the weight is carried by the ischial tuberosities, the thighs and the soles. The weight of the head, arms and trunk is borne by the thighs and ischial tuberosities, and the legs and feet are supported by the soles.

MUSCLE ROWS OF UPRIGHT POSTURE

The involuntary (reflex) changes in tone that take place within the rows of static muscles found along the abdomen, dorsal area, and limbs control the condition of stability which is indispensable for executing movements, and guard our body against injuries due to the loss of equilibrium arising from extreme displacements of the centre of gravity. The static muscles play a fundamental part in the maintenance of upright posture, and they are active also in any other body positions when working (see Figs 12–13).

The two broad rows of dorsal muscles comprise the fibres of the latissimus dorsi that run from the hipbone to the proximal part of the arm bone in the same direction as those of the contralateral gluteus maximus. The muscle rows of each side (as seen in Fig. 13) cross each other exactly at the level of the centre of gravity. The neck and the cephalic portion of the back are stabilized by the fibres of the trapezius which covers the latissimus dorsi. Along both sides of the posterior surface of the vertebral column massive bundles of muscle run from the sacrum up to the nape; phylogenetically this musculature is of considerable age: it controls the expansion of the trunk and maintains the erect posture of the spine. When it contracts on one side only, the vertebral column is bent sidewards.

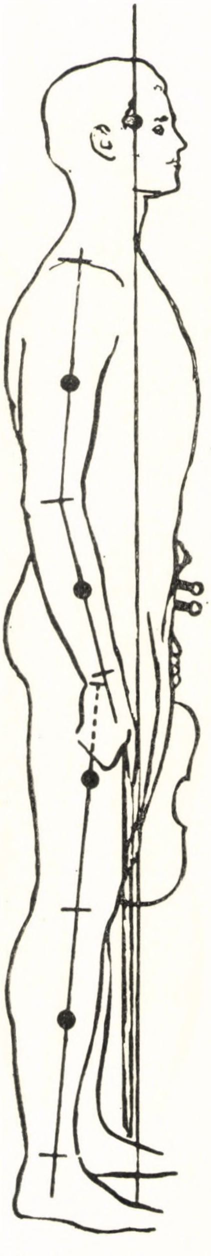


Fig. 10. Centres of gravity of the trunk and limbs in upright position, gravitational lines; side view

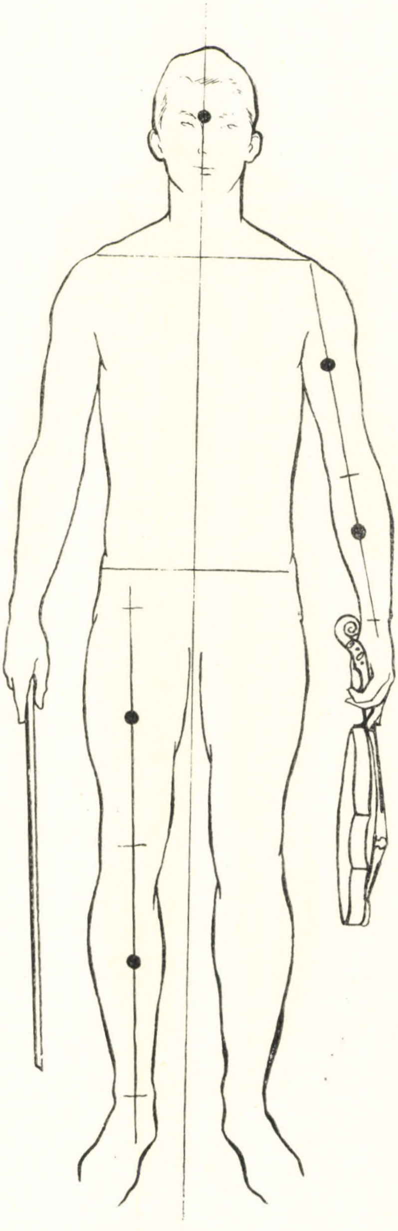


Fig. 11. Centres of gravity of the trunk and limbs in upright position, gravitational lines; front view

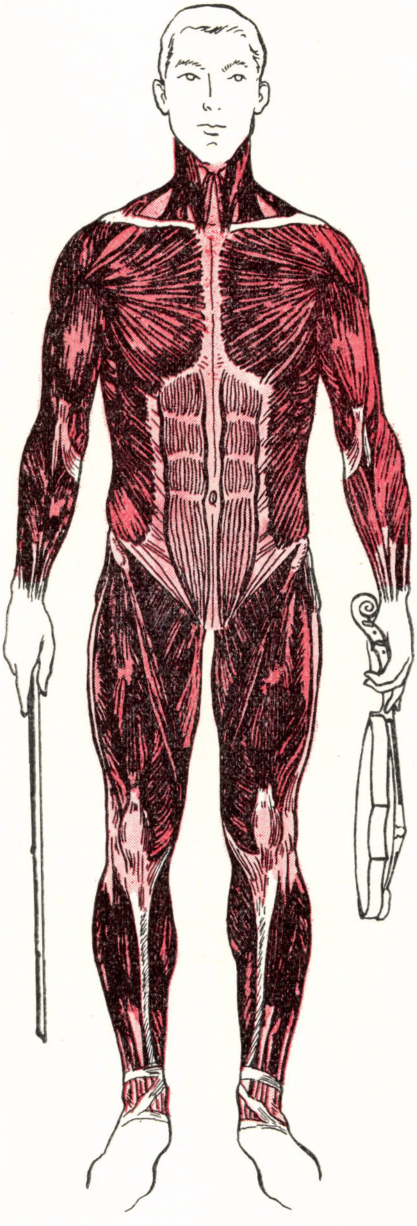


Fig. 12. Anterior muscles of upright posture

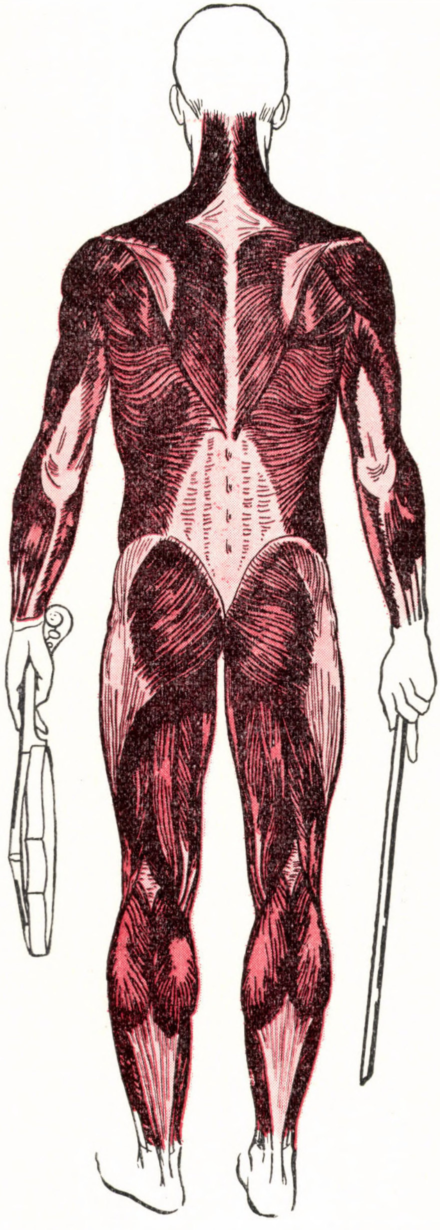


Fig. 13. Posterior muscles of upright posture

The pectoralis major constitutes a broad fanlike sheet, whose fibres run from the breast bone to the arm bone. The three layers of muscle on the abdominal wall form a similar sheet embracing the rectus abdominis in the frontal plane. This bridges the lower end of the breast bone and the os pubis.

Thus the superficial muscle sheet covering the back of the trunk (latissimus dorsi and trapezius) together with the pair of muscle bundles underneath and the gluteal muscles, which are a continuation of the fibres in the erector trunci and in the contralateral latissimus, all co-operate in extending the trunk and keeping it firm.

The antagonists of the above muscular mechanism are the muscles running over the frontal surface of the chest and abdomen which bring about a forward bending of the trunk. The different grades of bending forward or backward are the result of an alternating activity in smaller or greater areas of this muscle system, while bending sideward is brought about by unilateral activity.

Twisting to either side of the trunk depends on a more complicated mechanism. In playing the violin, trunk movements are, in most cases, not pure flexions forward, backward or sideward, but combined movements with torsions of the trunk, hence the affected muscle parts need an activation of differently graded intensity. During violin playing the periodical activation of trunk muscles will irradiate, i.e. extend to the muscles of the lower limbs. In a comfortable standing position the thigh adductors, biceps femoris and peroneus longus muscles constitute a static muscle row. Our electro-physiological studies have shown that in playing the violin, while the body is swinging to and fro, the calf muscles too are activated always in the direction of body motion.

ELECTRO-MYOGRAPHICAL STUDY

Before entering upon the particulars of muscular activity in playing the violin, we shall describe our method of study. In examining the properties of muscular activity, we have employed in our investigations the means of electro-myography, i.e. of the most modern electro-physiological apparatus available at present. Our analyses and the inferences are based upon the data obtained in this way.

Electromyography consists in registering electric muscle potentials by a suitable device. Suitably amplified, the electric phenomena—which accompany muscular contraction—can be made visible on the screen of a cathode-ray oscilloscope and recorded by a built-in photographical apparatus synchronized with it. This apparatus is called EMG. Usually several cathode-ray tubes work both visually and photographically so that a number of muscles engaged in the respective motion process can be observed and their action potentials recorded. The EMG has found world-wide application in the analysis of co-ordinated conditions occurring in sports and working movements, as well as for diagnostic purposes. The systematic motor analysis of playing a musical instrument as well as the elaboration of the necessary technique had been performed—for the first time, as far as we know—in the Central Institute for Medicine of Physical Education and Sports of the Hungarian Ministry for Public Health, by the present authors.

The subject of our study consisted in investigating the manner in which the movements of tone-production are performed when playing the violin. Each of these movements produces musical tones. Accordingly, our method was based upon a musical, instrumental foundation. All instructions given to the subjects to be tested referred to the particulars of playing the violin (which notes and in what sequence, rhythm, tempo and volume should be played). Consequently the events observed, in fact, reflected properties of the neuromuscular system engaged in tone-producing, when the 'intention' of the subject was fully concentrated on tackling the given task of tone-production, i.e. on solving the musical problem and excluding anything else.

We made several records of the same muscle action potentials with alternate leads in each test-subject, who repeatedly performed an identical series of tone-producing movements. In this way we were able to determine the individual motor functions which had an identical, well-fixed, habit-pattern and then compare the results obtained in the various subjects, who naturally were performing an identical exercise. Thus, since we registered well-established dynamic stereotypes, we can say that the common features were representative of such neuromuscular actions as were really necessary for performing the tone-producing movements under study and in a well-established manner. These common features were then used in evaluating the performance of the same tone-producing movements by the test subjects. The following static and phasic motor patterns were studied in conjunction with violin playing: (1) muscular function of maintaining body posture; (2) left arm raising into playing position; (3) left arm position in holding the violin; (4) isolated and continued stopping, using each of the four fingers; (5) muscular activity in forming intervals and respective finger placings; (6) positional and motional influence of the thumb on the tone conditions of hand muscles; (7) finger motions applying light and full pressure (harmonic and proper, i.e. stopped tone); (8) muscular function in changing positions; (9) vibrato motion (using each of the four fingers); (10) muscle activity in double stopping; (11) muscle rows in bowings (fundamental bowing, martelé, arpeggio, etc.); (12) co-operation of right and left hands.

We studied the action potentials of the superficial dorsal and ventral thoracic muscles, serratus lateralis, and of the shoulder, arm, forearm, hand and lower limb muscles, with respect to the time of beginning, duration and ending, pattern and amplitude of the electrical activity as well as to the interrelationship of individual muscle activities. Twelve pairs of surface electrodes were placed on the skin at suitable points above the muscles to be studied. Action potentials were recorded concurrently through three leads by a 3-channel DISA electromyograph. Amplification was adjusted to obtain well-readable records of the action potentials. If activity was weak, the amplification was set to a sensitivity of 10 or 20 μV/mm, for a medium activity, to 30–50 μV/mm, and in the case of an intense activity amplification was set to 100 μV/mm. Generally a time-base of 20 msec/mm was selected; however, in certain instances, we used a time-base of 5 msec/mm (Fig. 14).

We intended to answer the question whether the most subtle and isolated finger movements, i.e. those performed by the individual fingers separately, were due merely to the function of finger muscles, or whether the movements executed by the finger muscles necessitated an intricate co-ordination of muscles also in the shoulder girdle and in the whole arm. It was supposed that even in the smallest finger movements certain muscle rows, and not only solitary muscles, were active, because any kind of co-ordinated activity of the fingers such as encountered in working could take place only when postural conditions had

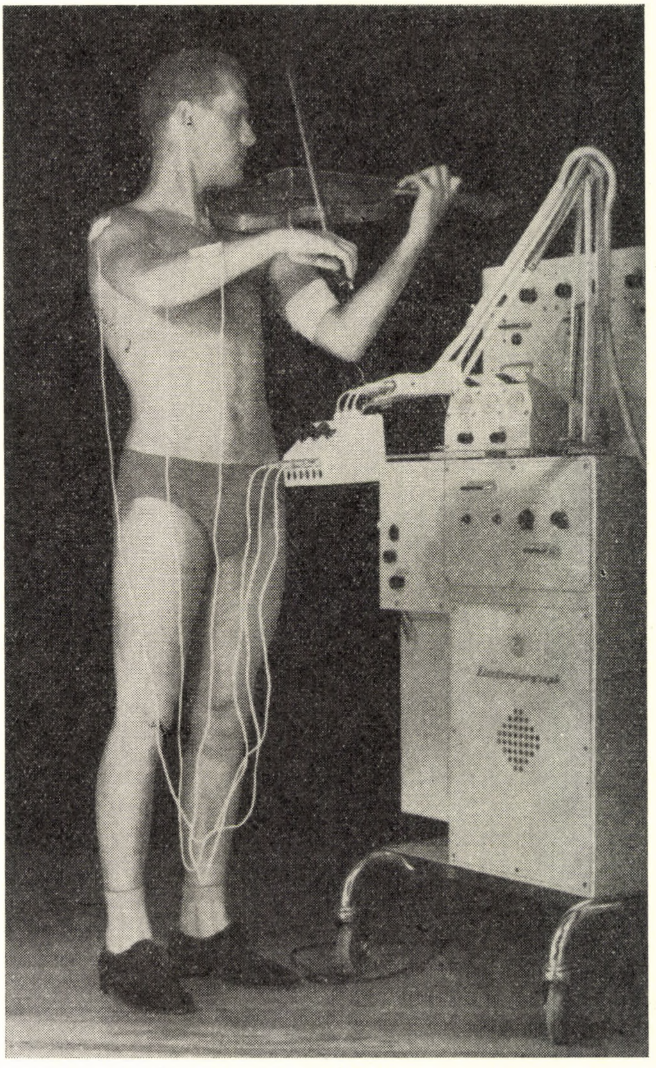


Fig. 14. EMG equipment and electrodes conducting the action potentials of the right-hand muscles of the subject

already been fulfilled. (The role of muscle rows has been pointed out by Benninghoff 1954, Hoepke 1957 and Tittel 1962.) It was further presumed in our experiments that during artistic work the motor processes were of necessity exactly co-ordinated, and that the performance of qualified instrumental artists might allow the investigation of economized and variegated stereotypes. The EMG records made during violin playing were compared with those of other kinds of activity (standing and sitting positions, raising the arms into sideway spread, clutching, clenching and spreading of the fingers, etc.).

STATIC RELATIONS IN POSTURAL CONDITIONS IN VIOLIN PLAYING

After the above informative digression let us return to our main line of discussion. In general, one plays the violin either standing up or sitting, i.e. in two positions. In specifying an economic body position it is advisable to have regard for the tone distribution found in the mid-position of joints. The mid-position of every joint is defined as the characteristic situation in which the respective tensions of articular capsule, ligaments and muscles producing movement and fixation are minimal. Hence postural economy is characterized by the maintenance of the least possible tension of muscles, ligaments and joint capsules necessary for the body position which is suitable for the task of movement required. It should be noted further that the longitudinal axis of the leg does not coincide with that of the limb, but deviates from it by 15–18 degrees. The heel bone (calcaneus) falls outside the longitudinal axis of the limb, so that the line of generation passes along the inner side of the leg. Having considered all these, the most expedient body position will be the following.

Playing the violin in upright position (see Fig. 15). (1) The legs are slightly apart, the weight of the body resting equally on both feet (symmetric body position, the line of gravitation falls in the sagittal plane of the body and intersects the supportive surface in the middle). The two halves of the body are each other's mirror image. (2) The knee is slightly bent; hyper-extension of thigh and leg as well as excessive flexion should be avoided in order to profit by the support of bones and ligaments and conserve muscular energy. (3) The frontal plane of the trunk should be level with the legs (avoidance of torsion in the trunk). (4) The abdominal and erector spinal muscles hold the spine corresponding to the characteristic constitutional and physiological curvatures (normal or athlete's stance, the mid-position between standing comfortably and 'to attention'). The line of gravitation falls on the middle of the supportive surface. (5) It is advised to reduce the action of the latissimus dorsi by deliberate relaxation. Because of the downward pull exerted on the arm, this will be dealt with under arm position.

Playing the violin in sitting position (see Fig. 16). (1) The body weight on the seat is divided between the buttocks and the thigh. (2) The legs are slightly apart, left-sole on the floor, right-foot is placed (bouncing) loosely springing aside the chair. (3) The frontal plane of the trunk and the frontal and lateral planes of the thighs are at approximately right angles. (4) Trunk position agrees with that of upright posture.

In both of the above violin-playing positions it is the frontal plane to which the spatial location of the fiddle is adjusted. Holding the violin in the manner outlined above will pay its dividend firstly by giving a safe and elastic support both for the body from the sole to the instrument, and for left-hand play of the instrument; secondly, by allowing adequate space for right-hand movements; and finally, by providing continuous counterbalance to the vigorous motions of the whole playing mechanism at a relatively negligible expense of muscular work. It is advisable to place the music-stand so that the eyes should be capable of sighting the whole score comfortably in the direction of the holding position. If a displacement were needed to this end, it should be made by moving the body as a whole (e.g. with a step). When playing seated, it is not expedient to lean back. If that were necessary, however, at least the shoulder blades should stay free. Chairs with a low back, supporting the hipback only, are suitable in this case.

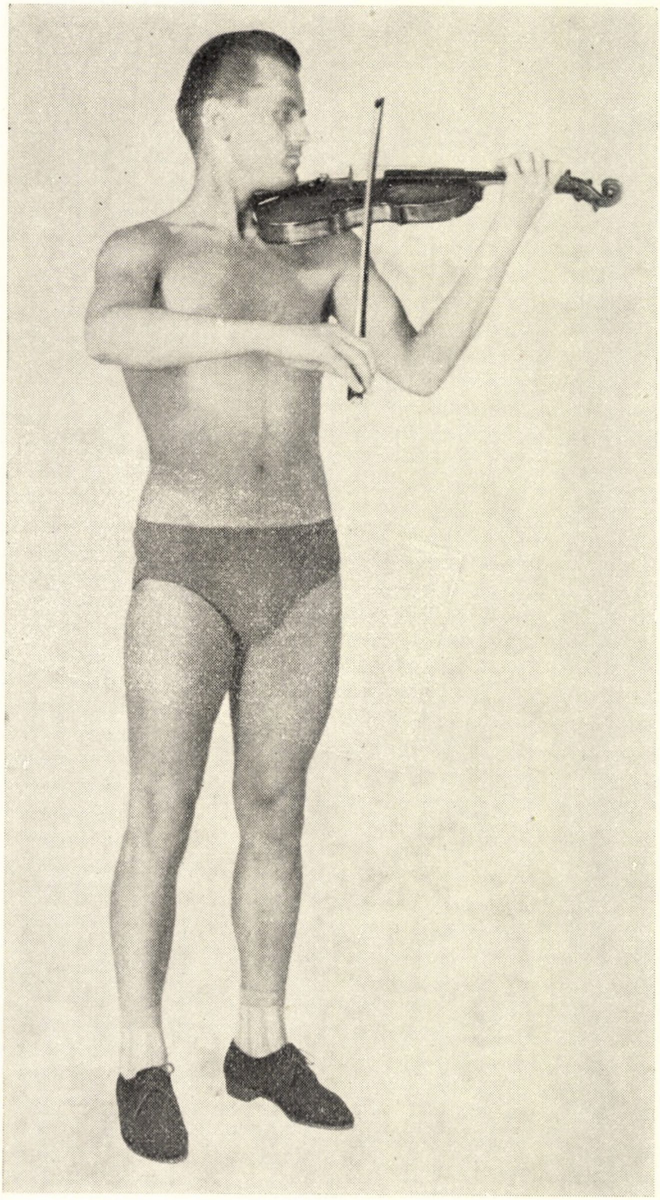


Fig. 15. Playing the violin in upright position (right side view)

The body's centre of gravity is continually changing owing to the movements of the arms and hands. Its prevention by straining the legs and trunk would mean an unnecessary muscle work and a handicap for arm operations.

The standing and sitting positions described here are therefore points of departure, with allowance for periodical equilibrating movements. In practice

Fig. 16. Playing the violin in sitting position
(right side view)

these may occasionally become too extended or too violent, and thus cause further superfluous muscular work. Consequently, both postural rigidity and violent body movements are disadvantageous; the movements of the playing mechanism must be counterbalanced by effortless periodical translations of the centre of gravity.

MUSCULAR WORK IN MAINTAINING HEAD POSITION

Stabilising and moving the head is the task of the muscles of the neck and the upper parts of the trapezius and erector spinae muscles. In upright-trunk position the centre of gravity of the head lies forward of the spine: consequently it would tilt forward unless the muscles are activated. (This is why the head drops forward in falling asleep while sitting.)

The muscles of the neck, mostly ribbonlike and arranged in layers predominantly in symmetry with the axis of the neck, connect the skull to the shoulder girdle and to the trunk respectively. Their action makes the head raised, turned to either side, or bent forward and backward. Their unilateral contraction bends and/or turns the head to the respective side, and also helps the head perform precise and fine movements. In view of the cephalic location of the principal sense organs, these movements are of paramount importance for the control of other movements.

The head secures the violin to the clavicle by pressing from above by the left side of the jaw. Of the muscles maintaining head position when playing the violin we studied the activity of the superficial layer, i.e. the sternomastoids and the ascending part of the trapezius which covers the neck from behind (Figs 17 and 18). Sternomastoid activity was found to be unequal: in the muscle on the left it was considerably less than in the muscle on the right. This fact indicates that to secure the violin, the head is turned to the left and also that for stabilizing the instrument the weight of the head is important. The left sternomastoid acts equidirectionally with the weight of the head, while the right one regulates the pressure exerted on the violin. This head position is obtained not by passive 'drop-on', but as the result of a very accurately regulated co-ordination of muscles. Within the compass of this co-ordination the weight of the head is one of the essential factors; it is, however, subordinated to the control of a regulated muscular tension. The muscles holding the head participate in violin playing in a dynamic and not in a static manner. This is manifested by the tone increase found in the left sternomastoid and trapezius when arpeggio or vibrato are executed, and even more in the case of energic movements (martelé). The activity-increase in the left sternomastoid indicates mounting fixation. In addition to holding the head, the upper third of the right trapezius also takes part in drawing the bow.

Available data indicate that purposeful muscular co-operation can be deliberately promoted by the head and the left side of the mandible being turned to the left and placed (but not left lying) on the violin. This should produce no feeling of tension in the nape, i.e. the backward straining of the neck should be avoided. Thus both the weight of the head could be optimally utilized, and the conditions for the delicate periodic activity of the muscles that participate in regulating the pressure exerted on the violin adequately secured.

BIO-DYNAMICS OF ARM MOVEMENTS

A DESCRIPTION OF THE UPPER LIMB

In upright posture, the upper limbs are relieved from carrying the weight of the body and become freely movable. The evolution of their structure corresponds to these dynamic peculiarities, while the structure of the lower limbs is similarly conditioned by the static duties they are to bear.

The upper limb is connected to the trunk through the shoulder girdle; it has three sections: arm, forearm and hand. The shoulder girdle includes two pairs of bones: the collar bones in front, the shoulder blades behind. In front the clavicles are connected by the breast bone, but at the back the girdle of bones is open, because muscles are interposed between the shoulder blades; the scapulae are freely embedded in the muscles. The shoulder girdle owes its remarkable

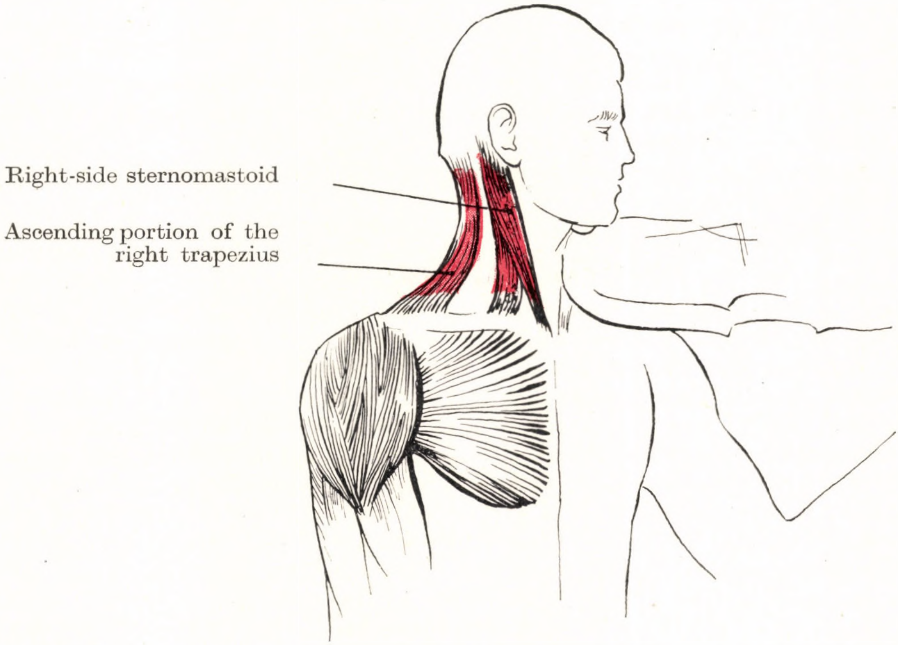


Fig. 17. Muscular function in securing the instrument and holding the head during violin playing, viewed from the bowing side

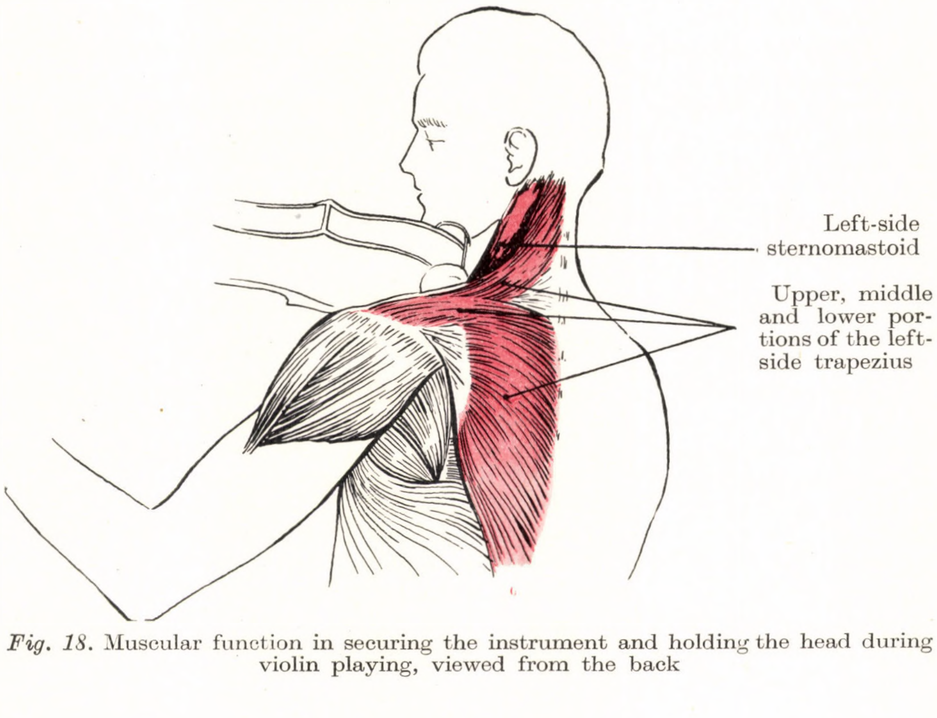


Fig. 18. Muscular function in securing the instrument and holding the head during violin playing, viewed from the back

Table III

Joints, mobility and muscles of the upper limb

Name of joint	Bones of joint	Movements	Effector muscles
Sternoclavicular	Clavicle and breast bone	Shoulder drawn	
		forwards	Serratus lat., pectoralis major and minor
		backwards	Middle part of trapezius, upper part of latissimus dorsi, rhomboidei, upper part of sternomastoid
		upwards	Middle and upper part of trapezius, rhomboidei, levator scapulae
		downwards	Pectoralis major, serratus lat., lower part of trapezius, latissimus dorsi by the mediation of the arm
Acromioclavicular	Shoulder blade and clavicle	Shoulder drawn forwards backwards upwards downwards	Most movements take place owing to the activity of the above muscles together with the sternoclavicular joint
Shoulder joint	Shoulder blade and arm bone	Arm	
		raising	Deltoid (clavicular and acromial parts), pectoralis major, coracobrachialis
		drawing backwards	Deltoid (acromial and scapular parts), teres major, latissimus dorsi
		adduction	Deltoid (clavicular and scapular parts), pectoralis major, teres major, latissimus dorsi
		abduction	Deltoid (acromial part), supraspinatus
		rotation outwards	Deltoid (scapular part), infraspinatus, teres minor
		rotation inwards	Deltoid (clavicular part), subscapular, teres major, latissimus dorsi

Table III (cont.)

Name of joint	Bones of joint	Movements	Effector muscles
Elbow joint	Arm bone and ulna	Flexion	Biceps brachii, brachialis, brachioradialis
	Arm bone and radius	Stretch	Triceps brachii
	Ulna and radius	Pronation	Pronator teres, pronator quadratus
		Supination	Biceps brachii, supinator
Wrist joint	Carpal bones and radius	Volar flexion	Flexor carpi radialis et ulnaris, palmaris longus, flexor digitorum profundus et superficialis
	Carpal and metacarpal bones	Dorsiflexion	Extensores carpi radialis et ulnaris brevis and longus, extensor digitorum communis
	Metacarpal bones	Radial abduction	Flexor carpi radialis, extensores carpi radialis
		Ulnar abduction	Flexor carpi ulnaris, extensores carpi ulnaris
Finger base joints (metacarpophalangeal)	Metacarpal bones and proximal phalanges	Flexion	Interossei palmaris, lumbricales
		Stretch	Extensor digitorum communis
		Adduction	Interossei palmares
		Abduction	Interossei dorsales
2nd interphalangeal joint	1st and 2nd phalanges	Flexion	Flexor digitorum superficialis
		Stretch	Interossei dorsales, lumbricales
Nail joint	2nd and 3rd phalanges	Flexion	Flexor digitorum profundus
		Stretch	Lumbricales

mobility to its ligaments, joints, and muscles, which naturally affect the limbs attached to it. Free mobility of our hands and their ability to reach almost any point of the body are due not only to the joints of the hand but to the joints of the shoulder girdle, shoulder, and elbow as well. The skeleton of the upper limb, its bones and joints, the movements brought about in the joints, and the muscles giving rise to these motions are tabulated in Table III, so in analysing the movements in playing the violin the reader will be referred to the table. (The arrangement of muscles is shown in Figs 19–28.)

The expedient arm position is one which maximally promotes the motor tasks, causes the least possible increase in muscle tone and relatively slight excess tension in the articular capsules and ligaments. This position should be considered the 'natural' starting position in which power expenditure is at a minimum. The starting positions of elbow, wrist and fingers in playing the violin approximate the anatomical mid-position in which the aforementioned conditions of tension are the most favourable.

In the first position, which is the first step in violin teaching, the elbow is held just about this mid-position. This is to be considered the starting position; hence commences a nearing motion in changing for higher position, and a movement towards this position is made in changing to lower positions. In playing the violin the limit of left arm extension coincides with the mid-position. Decision about the necessary violin size for children should rely upon this fact. The axis of the elbow is tilted, accordingly, by bending the forearm (as in the ascent along the fingerboard) and the dorsal plane of the forearm will turn towards the chest.

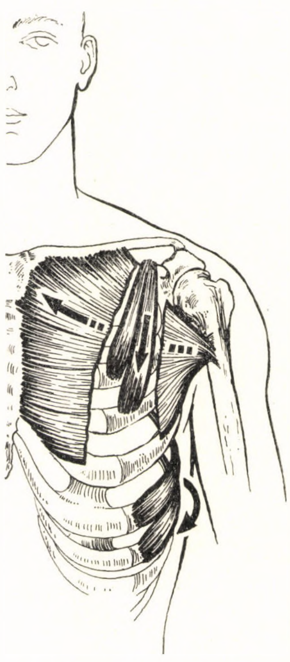


Fig. 19. Moving the shoulder forwards

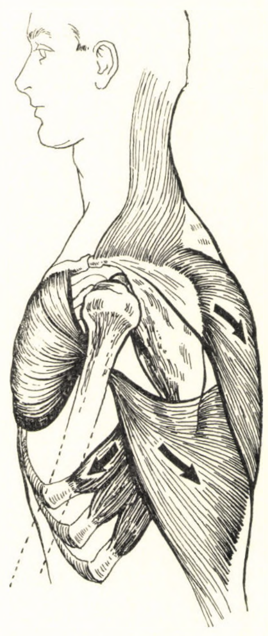


Fig. 20. Moving the shoulder downwards

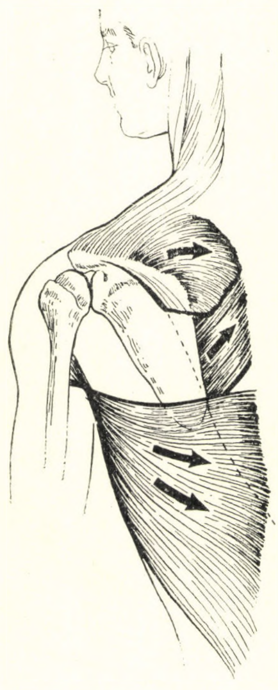


Fig. 21. Moving the shoulder backwards

Fig. 22. Raising the shoulder

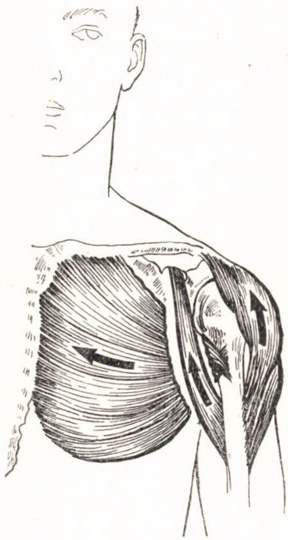


Fig. 23. Forward swing of the arm

Fig. 24. Forearm flexion

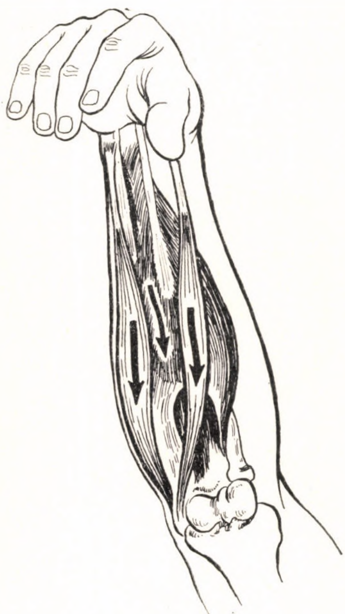


Fig. 25. Palmar flexion of the hand

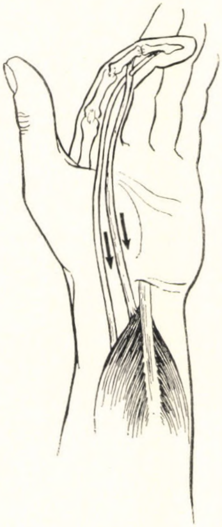


Fig. 26. Finger flexion

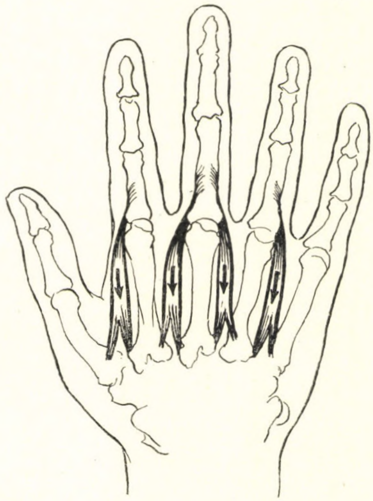


Fig. 27. Spreading the fingers

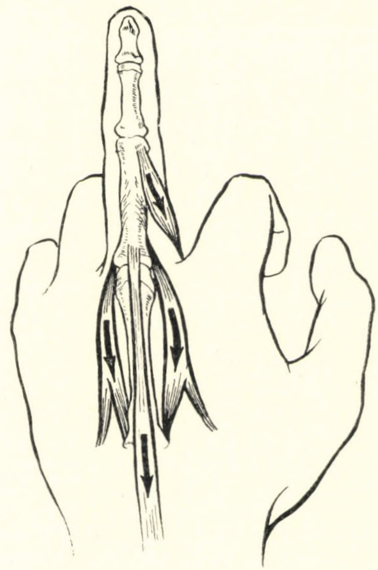


Fig. 28. Finger extension

This physiological abduction may be utilized in change of position on the fingerboard, provided that the direction, the inclination of the instrument is suitably managed. In this case it is easier to avoid touching the body of the violin during change to higher position, and to alleviate the task of the forearm which is already strongly supinated.

In drills of finger placement another factor concerning the structure of the joint has to be considered. As the fingers become more flexed at the metacarpophalangeal joint, abduction and adduction get more and more restricted. When the fingers touch the palm (as in clenching the fist) these movements practically cease. Accordingly, the ideal position for the fingers will be one which agrees with the mid-position, i.e. a slightly bent curvilinear position in the proximal joint, causing the fingers to be neither strained backwards, nor, what is more important, bent into the palm. Faulty intonation, a 'low' fourth finger, and distoning whole-note intervals, are all caused mainly by a finger position of excessive flexion in the proximal joint, which disallows finger spreading. Bending the fingers into the palm may arise also from holding the arm too far to the right. In this case the shoulder joint will also leave its mid-position. To correct such faults, it is advisable to make a complete re-positioning of the entire arm.

FUNCTIONS OF THE UPPER LIMB MUSCLES

The textbooks of anatomy classify the muscles of the shoulder girdle and upper limb according to their position, viz. whether the main mass of the respective muscle can be found in the area of the shoulder girdle, on the arm, forearm, or on the hand. Instrumental tutors usually follow the same line of thought. However, an anatomy-based functional division, which takes account of the mechanism of muscular activity, seems to be more appropriate. On this basis the musculature of the upper limb can be subdivided as follows: (1) muscles moving the shoulder girdle, (2) muscles acting upon the shoulder joint, (3) muscles moving the elbow, (4) muscles moving the wrist, and (5) muscles acting upon the fingers. (In Table III the muscles are listed according to the respective motions.)

This classification applies, however, only with certain restrictions in regard to the muscles which act upon two or more joints. The biceps brachii, for example, moves both the shoulder and the elbow. In view of the fact that during the motions of everyday life, and in playing the violin, its action is more conspicuous upon the elbow, we described it in Table III among the muscles moving the elbow. It should be noted here that, since the leverages of the upper limb parts are closely interrelated, even muscles acting on a single joint exert some influence on the adjacent joints.

The thumb, the index, and little fingers have also some extra muscles in addition to those listed in Table III; thus they are more mobile. These muscles and the respective motions will be reviewed in the section dealing with the analysis of violin playing; those of the thumb also in a separate table.

THE MUSCLE ROW FOR LEFT ARM POSTURE

The manner of fingering needed in playing the violin, as mentioned in Chapter One, is the main reason for the initial position the left arm has to assume: it is held at an angle of 30–45 degrees made by the frontal and sagittal planes; the forearm is considerably supinated and moderately flexed in the elbow and the left shoulder too is drawn slightly forwards. The left arm is to be raised and maintained in the proximity of this position (Figs 29–30).

As seen in Table III, the agonist muscle which supports left arm raising is the deltoid which covers the shoulder like a cap. Morphologically as well as functionally there are three portions in it: clavicular, acromial and scapular. Relative partial activities depend on the direction in space towards which we want the arm to be raised. When the arm is raised to, and maintained in, the position of violin playing, the clavicular portion is the most active of the three. It is supported by the acromial portion, while the posterior scapular portion is the least active. The auxiliary muscles of raising the arm and maintaining it in position are the serratus lateralis and the supraspinatus. Their part during the raising motion is to move the shoulder blade, and while the arm is in position, to keep the shoulder girdle in the proper place together with other stabilizing muscles, viz. the trapezius, the pectoralis and the subclavius. As outward rotators, the infraspinatus and teres minor muscles neutralize inward rotation.

One of the principal muscles in playing the violin is the biceps brachii. Originating from the shoulder blade to which it is attached by two tendons, it forms a joint belly over the middle third of the arm bone. Since the biceps tendons are bridging both shoulder and elbow (the latter is bridged by a joint tendon), both joints are affected by their motion; we demonstrated biceps' participation, in addition, in the finger movements of stopping and holding as well (Nemessuri–Szende 1963). The two heads of this muscle have different functions in the shoulder joint. Contraction of the short head draws the arm near the body, whereas the long head abducts the arm. Thus adjusting arm position, and determining that of the forearm as well, the biceps, together with the deltoid and other muscles, has an important part to play. When playing the violin, there is a marked activity in both heads. In the elbow the biceps strongly supinates the forearm, and in addition draws and turns it towards the arm. Though supination is assisted also by the supinator and brachioradialis muscles, the strongest supinator is the biceps.

Other important flexors of the elbow are the brachialis which is situated below the biceps, and the brachioradialis, most of which belongs to the forearm. The role of the latter muscle is more important in the technical manoeuvres of the left hand. The triceps brachii muscle is the antagonist of the flexors; it stabilizes and extends the elbow. Since violin-playing involves the left forearm functioning in a flexed position and with a loose unstrained elbow, the active role of the triceps is confined, as our investigations have shown, to certain definite left-hand technical tasks such as vibrato. The parts played by latissimus dorsi and pectoralis major in raising the arm, and holding and playing the violin are relatively small. Arm raising and the maintenance of its position represent a muscular work which is executed primarily against the antagonistic force of gravity.

In the last analysis, the agonists enumerated raise and stabilize the arm in the playing position against this force. Though in the course of training this regulative function becomes automatic, the teacher is supposed to take it into account by consciously striving to relax those muscles that act in the direction of the force of gravity. The pectoralis major and the latissimus dorsi belong to

Fig. 29. X-ray photo of the left arm in playing the violin in the first position

Fig. 30. X-ray photo of the left arm in playing the violin in the fifth position

this group in the first place. Concurrently, care is to be taken for an optimum tension in the anterior part of the deltoid, in the serratus lateralis, and the biceps. A practical way is to make the pupil aware of feeling the freedom of the armpit. It means that he must avoid either pressing his arm against the body, or bracing it in a stiff manner (Figs 31–34).

It is evident from what has been said that in playing the violin the technical tasks of the left hand are unfolded concurrently with maintaining an active arm position against gravitation. This does not mean, however, that in the tone-producing work of the left hand the force of gravity plays a notable part. The tone-producing of the fingers does not result from an interaction between arm weight and the force of finger flexors, but is brought about by a complicated co-ordination of muscles that is specific and characteristic of the human hand only. In agreement with Trendelenburg (1925), the idea of 'free-fall play' is an inadmissible explanation for left-hand motions (Fig. 35).

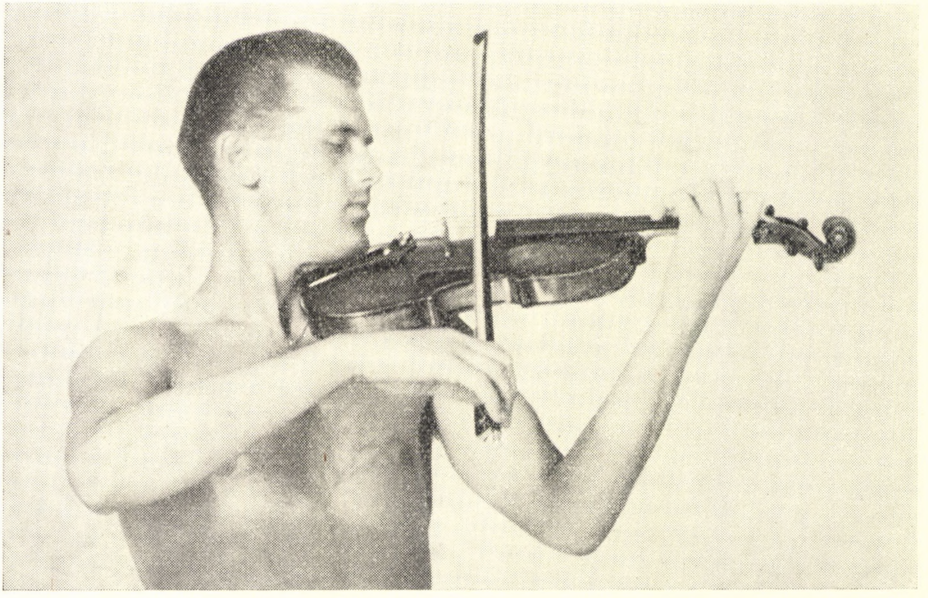


Fig. 31. Left arm position in playing the violin (right side view)

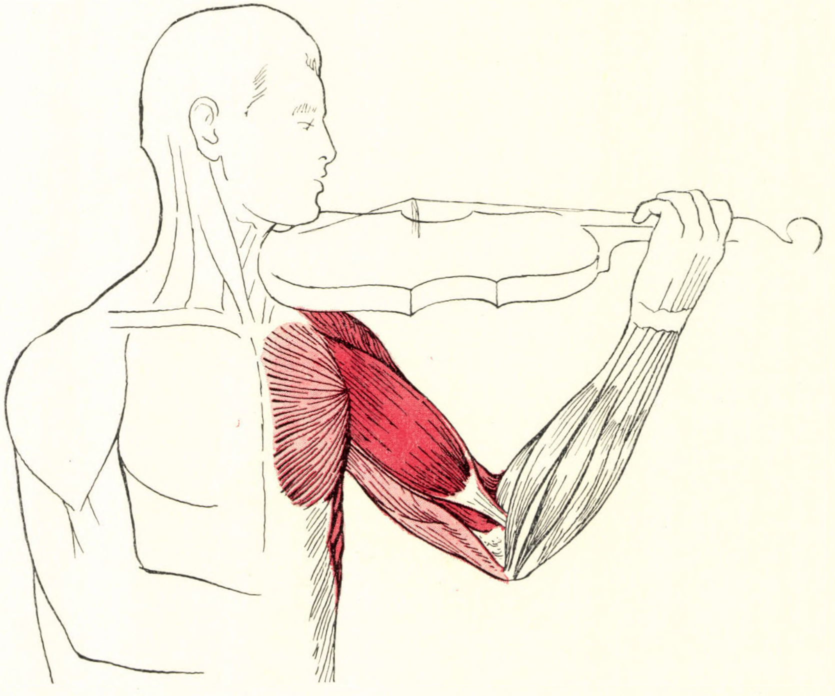


Fig. 32. Muscle rows of the left arm in playing the violin (right side view)

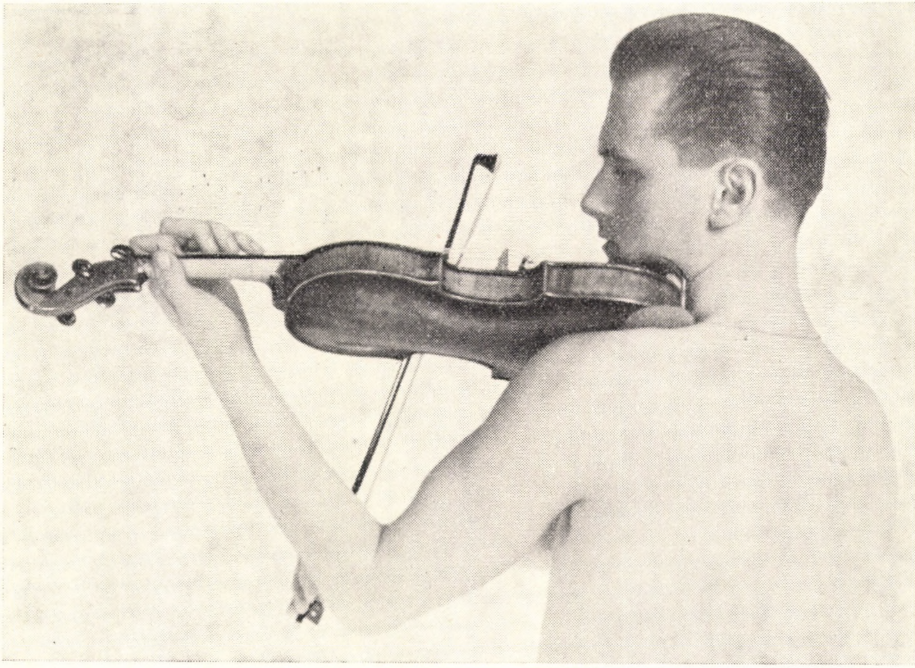


Fig. 33. Left arm position in playing the violin (left side view)

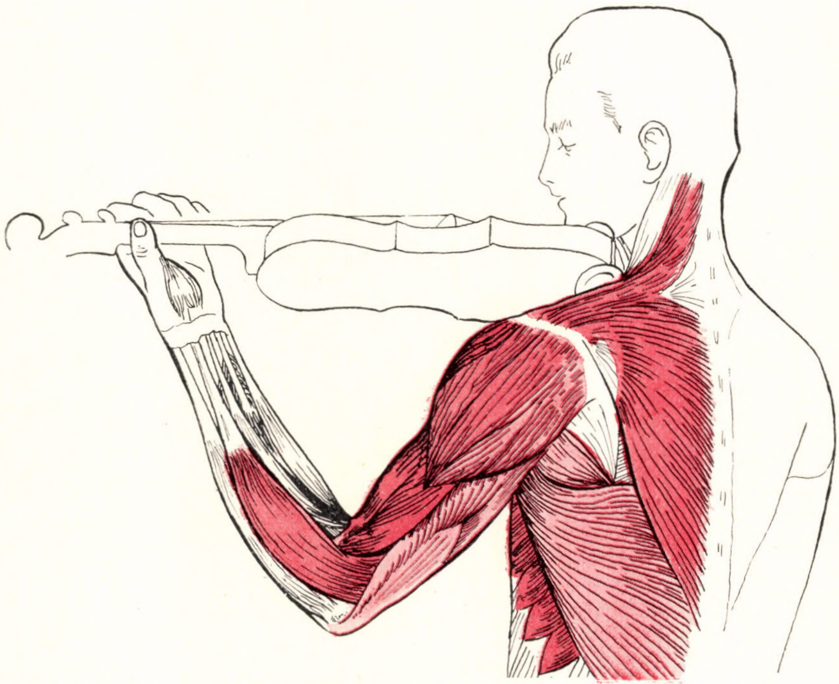
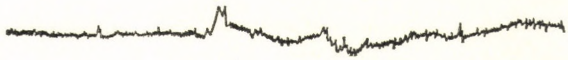
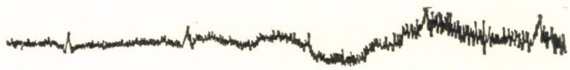


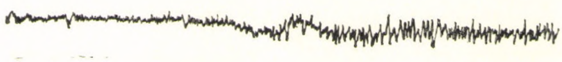
Fig. 34. Muscle rows of the left arm in playing the violin (left side view)



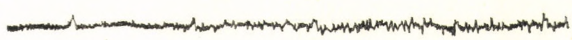
Left latissimus dorsi, 15 $\mu V/mm$



Left teres major, 10 $\mu V/mm$

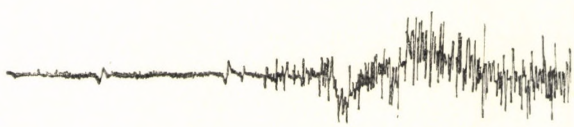


Upper portion of left trapezius, 10 $\mu V/mm$

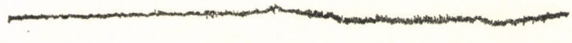


Lower portion of left trapezius, 10 $\mu V/mm$

Left pectoralis major, 10 $\mu V/mm$

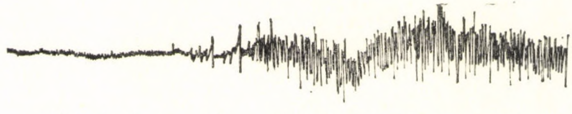


Left serratus lateralis, 30 $\mu V/mm$



Scapular portion of left deltoid, 30 $\mu V/mm$

Acromial portion of left deltoid, 30 $\mu V/mm$



Clavicular portion of left deltoid, 30 $\mu V/mm$

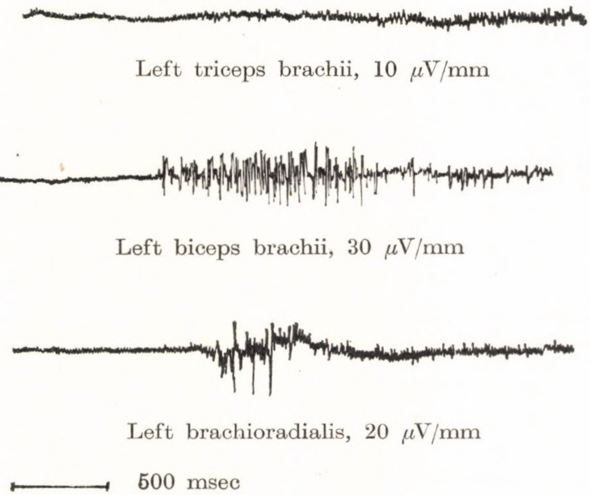


Fig. 35. EMG record of the muscle rows maintaining left hand position. The traces are superimposed to show active and relatively passive muscles, the starting point and the amplitude of activity

MUSCLE FUNCTIONS IN LEFT-HAND TECHNIQUE

SPECIAL PROPERTIES OF FINE FINGER MOVEMENTS

An analysis of fine finger movements offers a deeper insight into the correlation of muscular activity in left-hand technique. Work of a delicate nature, as well as playing most musical instruments, requires highly differentiated motion of the hand and, in particular, of the fingers. In such manoeuvres arm and forearm muscles participate in directing the hand into, and maintaining it in, a favourable position. The motor task of the fingers is executed by the finger flexors of which the longer ones are on the forearm and the short ones are in the hand. Finger flexors exert their maximum force when the object is clutched by the whole palm (clenching the fist) or when the fingertips are used for grasping (closing the fingertips). The fundamental motion in the left-hand technique of violin playing is a finger movement resembling a closing, grasping movement. As shown in Chapter One, the pressure necessary to shorten the strings does not require the exertion of any great force from the finger flexors. In performing finger movements during delicate manual work or in playing musical instruments the difficulty must therefore lie in the intricacy of co-ordination that permits isolated finger movements. Isolated finger movements are made possible primarily by the activity of the interossei. Some of the relevant problems were resolved by our EMG examinations. In regard to playing musical instruments we came to the conclusion, in full conformity with Jahn (1951) and Seling (1952), that one of the main efforts in teaching should aim at the functional refinement of the 'minor' muscles in the hand. This is explained in detail in the analysis of stopping motion.

MUSCLE ROWS OF STOPPING MOVEMENT

In the execution of stopping the brachialis and all muscles located in the forearm and hand take part. Their function is periodic (phasic) according to the requirements of tone-production. To execute stopping with precision, the shoulder, the elbow and the wrist must be stabilized.

The shoulder is stabilized by a continuous tonic work of those muscles which take part in the maintenance of arm position. The other two joints are secured by the muscles of the arm and forearm when required. The abrupt fixation of the elbow during the action of the flexor digitorum superficialis is performed from above by the biceps and during the raising of the finger by the extensor digitorum communis from below. In fast stopping motion the stabilizing action of the biceps in the elbow precedes the finger movement by a duration of time between 20 and 50 msec. According to our EMG data this muscle is an active participant also in the execution of finger movements (Figs 36–37).

On studying the muscles that move the wrist we found full dorsiflexion and partial volar flexion as well as partial radial and ulnar flexion, respectively, during the act of stopping. While finger flexors are active, these muscle rows of synchronous and variable activity drive the wrist into a definite position that will have a considerable influence on the function of finger muscles. For the finger muscles on the forearm a dorsiflexion of the hand is most favourable, since they become elongated and thus capable of exerting greater force. This position

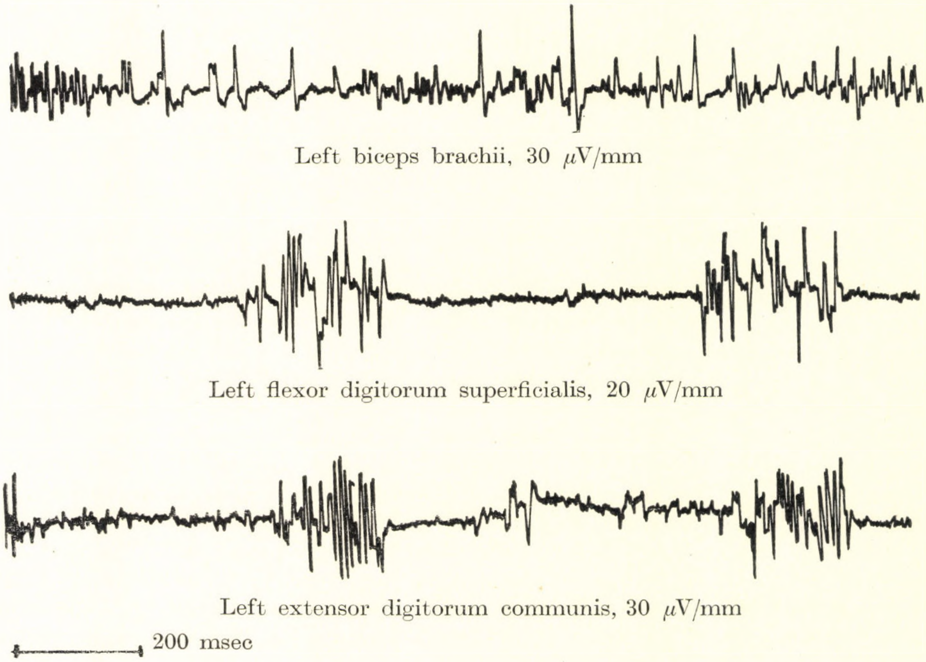


Fig. 36. EMG record of muscular activity in the motion of stopping. The traces show the respective activities of biceps brachii, flexor digitorum superficialis and extensor digitorum communis during an isolated stopping by the second finger on the D-string

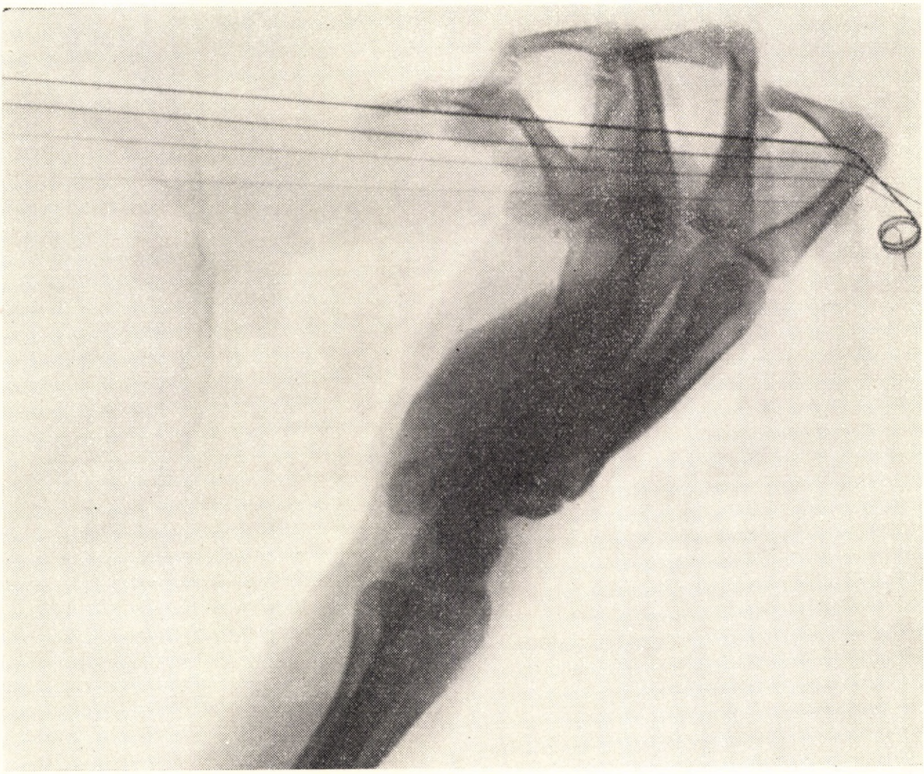


Fig. 37. X-ray picture of the left hand: typical angle of the finger joints and the phalanges of the fingers

promotes also the action of the lumbrical muscles which originate from the tendons of the flexor digitorum profundus, while the palmar flexion will compress these muscles, so that they become steadily weaker. Consequently, the position of the wrist exerts definite influence on the working capacity of the finger muscles. This fact can be utilized for the correction of mismanaged stopping.

If the force of stopping were too great, the finger flexors could be deflected to a more volar position of the wrist and so the string would be depressed less forcefully. Obversely, a feeble, dainty stopping can be corrected by greater dorsiflexion of the wrist: the finger muscles will exert a greater force. Naturally, a transposition of the wrist results in a correlated translation of the whole arm from the elbow and shoulder. A dorsiflexion of the wrist will decrease the angle of the elbow when the finger is stopping, and the arm will slide farther back in the shoulder joint. A volar flexion of the wrist opens the angle of the elbow, and the arm is brought forward. Thus a new position of the arm is obtained, which will have to be taken into account when corrections are made. In respect of muscular functions, the wrist should lie in the plane of the arm, as its most expedient position. This only seems permanent, however, to the casual observer; in reality a fine adjusting movement takes place during every stopping movement. Upwards from the fifth position the volar flexion of the wrist is quite conspicu-

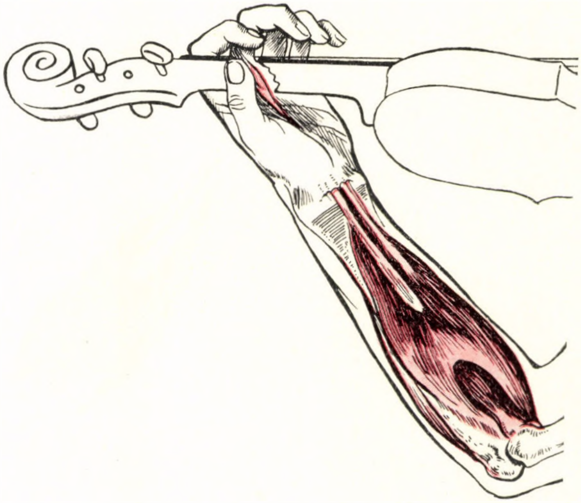


Fig. 38. First phase of stopping

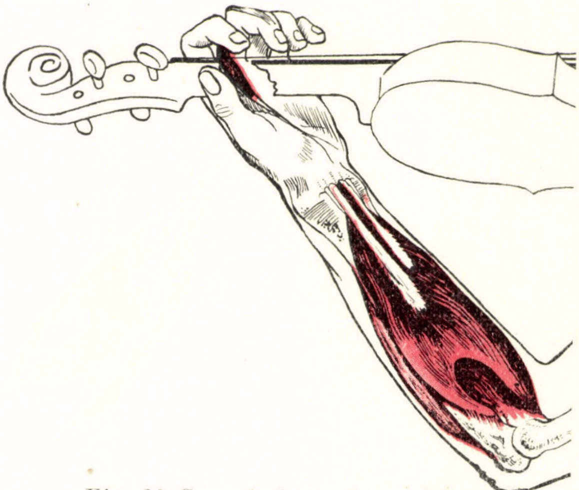


Fig. 39. Second phase of stopping

ous, and a weakening of finger muscles is also subjectively felt. Largely this is the reason why the need is felt to apply greater force in higher positions: not only does the requirement for greater pressure grow because of the increasing string-tension, but the available muscular force itself also decreases. Stopping is a finger motion, requiring three joints, and the result of mutual activity of finger muscles both on the forearm and in the hand. The process of stopping can be divided into four phases of which the following muscular activities are characteristic according to our data.

Phase 1. — Finger muscles of both forearm and hand maintain a tonic equilibrium. The effect of superficial and deep flexors on the second and third phalanges is compensated for by the lumbricales, the flexor effect of the lumbricales on the proximal joint by the common extensor digitorum. The outcome will be a position of rest (Fig. 38).

Phase 2. — Owing to a partial relaxation of the common finger extensor, the three-joint flexion begins to take place. The proximal joint is bent by the lumbricales, the middle phalanx by the superficial finger flexor, and the nail joint by the deep flexor (Fig. 39).

Phase 3. — The delicate regulation of stopping is performed by the common extensor which becomes again intensely activated, and so reduces the influence of the lumbricales bending the proximal joint; in this way the extensor effect of the lumbricales exerted on the middle and distal phalanges is augmented. This situation will affect also the finger flexors of the forearm. The final result will be a precisely regulated pressure of the distal joint on the string. The almost incessant activity of the common finger extensor during stopping is especially conspicuous in rapid fingering (Fig. 40).

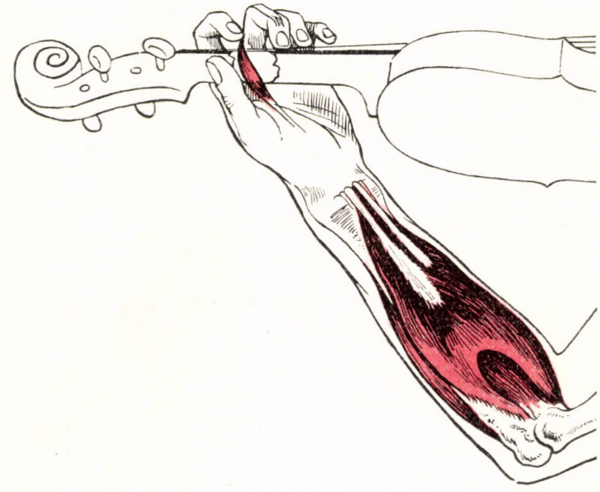


Fig. 40. Third phase of stopping

Phase 4. — The common extensor raises the proximal joint, and this is supported by the lumbricales extending the middle and nail joints. In this case the resistance to be overcome is represented by the forearm flexors (Fig. 41).

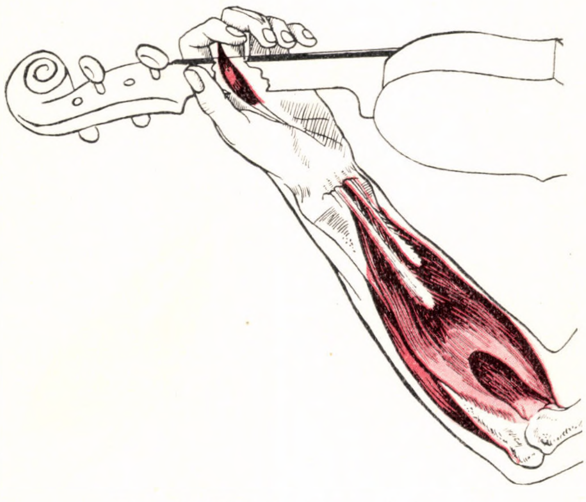


Fig. 41. Fourth phase of stopping

The mechanism outlined above will be operative during the motion of all the four stopping fingers. The common flexors and extensors of the fingers on the forearm participate in every stopping movement of the fingers. In an effort to refine muscular co-ordination in the shortest time possible, any teaching of the violin ought to begin by introducing concurrently the usage of all four fingers. Index and little fingers have some extra muscles in addition to those already described: both are supplied by an extensor muscle situated on the forearm; the little finger has, in addition, a separate adductor and abductor in the hypothenar. These muscles ensure the independence of index and little fingers and the precision of their movements. In consequence of these anatomical and physiological attributes the little finger becomes a member of equal value in the complex combinative motor activity of the fingers. Since its muscles are weaker, it needs particular exercise. It was Auer (1929) who emphasized the significance of the first and fourth fingers, in executing intervals of fourths and in the tone-producing work of the left hand. The reliability and, at the same time, the adaptability of fingering fourths in various positions is understood by the anatomical structure and physiological mechanism of the 1st and 4th fingers. A modification of fingering for the benefit of the 3rd finger is justifiable particularly in higher positions, when the tone requires intense vibrato, or when this manoeuvre promotes the fluency of certain technical tasks. In higher positions the strength of the little finger is bound to decrease because the excessive palmar flexion and supination will compress and thus weaken mostly those muscles which lie in the hypothenar ridge. The EMG activity of the hypothenar muscles is shown in Fig. 42. The lumbrical muscles participate actively in each phase of the stopping motion. Consequently, they require vigorous training.

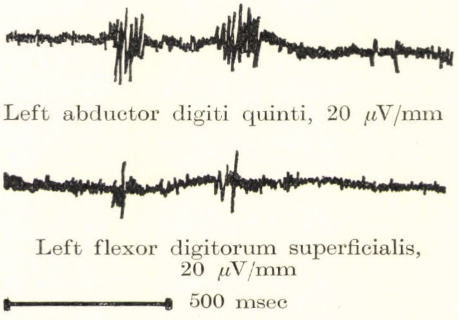


Fig. 42. EMG record of hypothenar activity during an isolated stopping motion of the fourth finger

Our analysis (by the method indicated above) makes it possible to localize faults in stopping. A rigid, hook-shaped flexion of the fingers is due to an excessive activity of forearm finger flexors. On the other hand, a concave collapse of the nail joints derives from a weakness of the forearm finger flexors. Exaggerated lumbrical and weak common extensor activities lead to a 'roof-like' stopping. Here the proximal joint is fully bent while the more distant joints are wholly extended. These faults are corrected by making the pupil aware of the position of his hand and fingers. Thus, for example, the teacher should gently knead the respective muscle bellies on the pupil's forearm to demonstrate the excessive tonus in the forearm muscles. To make him feel the activity of the common finger extensor we should point to 'a sensation of tension at the back side of the forearm'.

MUSCULAR FUNCTION IN INTERVAL PRODUCING

Stopping requires also isolated finger motions, in addition to what has been said previously. Klingler (1921) has already referred to the tension which develops between the respective fingers, and its difference in respect of the various finger foundations (finger patterns in the American usage). In violin playing, too, isolated finger movements are secured first of all by the interosseal muscles. The interossei can be trained best by attention to accuracy of distance between the fingers representing the different positions. This has a paramount importance also for the purity of intonation. Pure intonation of semitones is of cardinal importance in the left-hand technique of playing the violin. The interossei have a decisive role in exactly adjusting the distance of whole and semitones: the palmar ones for finger adduction, the dorsal ones for abduction.

We have performed EMG studies in respect of tonus distribution among finger muscles. The work of the dorsal interossei has been investigated while playing the intervals D–E flat–E–F–F sharp–G–G sharp–A on the D-string, in the first position, both during a chromatic gliding movement and in the case of isolated stoppings. According to the results, it is the third dorsal interosseus mainly which 'aims' the second finger; this aiming takes place in close co-operation with the second dorsal interosseus, also belonging to the second finger. In producing F sharp, activity in the first dorsal interosseus is conspicuously low; this muscle belongs to the index finger, but comes also from the first metacarpal bone. From this it may be inferred that in playing an isolated F sharp, the thumb–index finger fork of the left hand leans on the fingerboard with less force. On the other hand, in playing the note E flat a relatively strong activity is found in the interosseus and superficial flexor muscles. This indicates that a retraction of the first finger makes the grip of the thumb–index finger fork firmer on the fingerboard.

The foregoing may lead to re-consider the sequential order in teaching the various finger foundations. Though this order is determined not merely by physiological points of view, the efficiency of the system of finger foundations, in their capacity of being the means to acquire the elements of left-hand technique, may considerably be influenced by physiological processes. Beginning with what is now called first finger foundation seems to be correct. It is open to discussion, however, whether third finger foundation should retain its place in the curricular order of progression. The firmness of grip in the thumb–index finger fork is effectively reduced only by a retraction of the thumb, i.e. the whole hand. While it is generally agreed that the current first, second and fourth finger foundations seem to be playable from the same hand position, in teaching the third finger foundation it is more expedient to draw the whole hand backwards. This would make the third finger foundation a version of the fourth transformed by a semitone descent (E flat–F–G–A flat). The third finger foundation ought to be taken, therefore, before playing in positions is introduced, in place of the fourth one. This suggestion is supported by the fact that for the fourth finger foundation the hand is required to leave its permanent position.

This modification in sequence will bring along another change, namely, that the introduction of the second position would begin by a whole tone shift instead of the present semitone interval (from E- to F-distance on the D-string). This is, however, an advantage and not a drawback, because 'to glide up' into the second position with a thumb left behind in the first position, i.e. without a displacement of the hand, will be hardly possible. The shift of the hand, and so one of the important incidents in utilizing positions in performance, is indispensable. Since necessity is one of the most important guarantees for the execution of movements, including changes of position, our statement applies also to cases where teaching is concerned not with the system of finger foundations.

APPROPRIATE POSITION FOR HAND AND FINGERS

We have now to face the problem where the hand and the stopping fingers should be placed relative to the fingerboard. As has been seen, the energy consumption of left-hand technique does not demand that the hand be parallel to the edge of the fingerboard, nor in the excessively curved finger position, deriving therefrom. Yet decidedly a three-joint execution of stopping must be guaranteed for all four fingers. The extent of the necessary supination is governed by two conditions: (1) freedom of movement for the first finger, (2) the possibility also for the fourth finger to perform a three-joint motion.—Freedom of the first finger is ensured by the activity of the extensor indicis muscle which draws the proximal joint away from the fingerboard. The same is also indispensable as regards the freedom of the whole hand.

The conditions for the disposition of fingers are stated fairly satisfactorily by Klingler's formulation (1921): the string should be touched by the first finger, to the left of the centre of the fingertip, by the second in the centre of the fingertip, by the third, slightly to the right of the centre of the fingertip, and by the fourth, with the whole fingertip. The last point is, however, slightly inaccurate, as even the fourth finger touches the string by a relatively small portion of the finger's exterior. We consider it important that the fourth finger should not tilt over towards the ulnar (lateral) side. In laying the foundations of left-hand technique, Seling adopts the same principles. When the left hand has to cross over the strings, the arm must move in such a direction that stopping be performed from a possibly identical finger position. According to our EMG investigations, this does not require any greater muscular exertion, but a precise innervation is essential.

There is a conflict of opinions in the literature on the subject as to whether the fingers which are actually out of action should be raised or left in place. In our opinion, which agrees with Klingler's (1921), Trendelenburg's (1925) and Seling's (1952), to keep such fingers lying in position cannot be recommended as a general principle of left-hand technique. Stopping relies on the motor coordination of the respective fingers, and not a mechanical support obtained from other fingers. Finger fixation would but add to the muscular work that is already required to maintain the non-playing fingers above the string. It impedes the elastic joint motion of the fingers in and out of play, and induces stiffening. Certain finger placement combinations require fingers to be left in place, but situations like these must be judged individually, to determine whether the execution of the task will be promoted by it or not. We have a case in point when after some other notes the tune returns to the finger that began it. In general, to keep fingers lying on the string is only reasonable when it is indispensable for succeeding finger intonating or motor orientation. One of the important means of violinistic expression, viz. vibrato, will be seriously imperilled if the fingers remain depressed. But before we discuss vibrato we have to survey the unctions of the thumb.

MOVEMENTS AND ROLE OF THE THUMB IN VIOLIN PLAYING

The thumb can perform a great diversity of movements thanks to its joints and well-articulated muscles. It is moved by eight separate muscles of which four are on the forearm and the others in the thenar eminence. Thumb movements are tabulated in Table IV with eight types of motion indicated for the three joints. The specific motion, which permits the action of gripping by the hand, is the opposability of the thumb to the other fingers. This movement is really not a clear-cut contraposition, because it is produced by rotation around the index finger. In its normal position the thumb faces the outer side of the index finger. In this case the muscles bringing about its motion are relaxed.

The extraordinary mobility of the thumb explains why the different methodologies treat these motions and their functions in the left-hand technique of violin playing in great detail. Flesch (1923) and Seling (1952) considered the thumb to have three functions: (1) support and counterbalance of the stopping fingers, and thus prevention of their slipping from the fingerboard; (2) guarantee of path for changes of position; (3) support occasionally to the instrument.

Two main types of thumb holding are distinguished in the literature of teaching methods: (1) the lateral and (2) the inferior thumb holding. — In the

Table IV

Joints and muscles of the thumb and their motor function

Name of joint	Bones of the joint	Movements	Effector muscles
1st carpometacarpal	Multangulum majus and 1st metacarpal	Abduction	Abductor pollicis longus et brevis, flexor pollicis brevis
		Adduction	1st interosseus dorsalis, adductor pollicis, flexor pollicis brevis, opponens, extensor et flexor pollicis longus
		Opposition	Adductor pollicis, abductor pollicis brevis, opponens, flexor pollicis brevis
		Retraction	Abductor pollicis longus, extensor pollicis brevis
Metacarpophalangeal	1st metacarpal and 1st phalanx	Flexion	Flexor pollicis brevis, abductor pollicis brevis
		Stretch	Extensor pollicis brevis
Nail joint	1st and 2nd phalanges	Flexion	Flexor pollicis longus
		Stretch	Extensor pollicis longus

former case the thumb touches the side of the violin neck, in the latter it glides below it. In the course of playing both and even other positions are adopted quite naturally.

Methods usually discourage allowing the thumb to grip the fingerboard lest the left hand be forced to perform a manoeuvre similar to clutching (Jahn 1951). Seling (1952) is of the opinion that the role of the thumb in the technique of the left hand has been considerably overestimated previously; recently, however the subject is being neglected in his view; as if violin playing could subsist without it. Trendelenburg (1925), for instance, noted that the four stopping fingers could produce the tones even without making use of the thumb. Views are similarly conflicting concerning the initial position of the thumb. Flesch (1923) suggests to place the left hand and thumb in such a way that the thumb touches the index finger at about the third phalanx, and while maintaining this position, we should slip in the neck of the violin between them. Küchler (1911) defines thumb position with even greater accuracy: the volar side of the distal thumb phalanx should be located on the side of the fingerboard opposite to tone A produced by the first finger on the G-string. Seling (1952) places the thumb between the first and second fingers in the lateral thumb holding.

In order to secure some point of reference among the different views, and since the importance of the problem is indisputable, we have performed an electromyographical study on the motor functions of the thumb engaged in various left-hand actions (stopping, vibrato, change of position, etc.). As far as motor functions of the thumb are concerned, the thumb of the well-educated violinist supports periodically the left hand according to our tests. During isolated stopping movements it is active for the phase of strong depression, i.e., it co-operates with the finger flexors. Occasionally it is activated also in the phase of raising the finger clear of the string, i.e., it co-operates with the common finger extensor

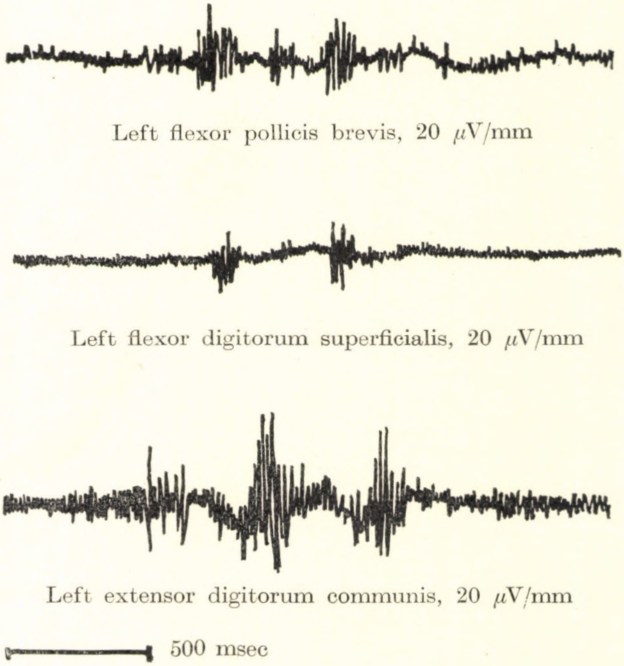


Fig. 43. EMG record of thenar activity during an isolated stopping

Fig. 44. Thumb in resting (normal) position adjacent to the fingerboard, first position

(Fig. 43). This elastic and adaptive function of the thumb is the fundamental precondition for solid stopping. As has been seen in the analysis of interval production (p. 61) the retraction of the first (index) finger caused an increase in the tension in the thumb–index finger fork. The relationship of thumb and index finger, in the position suggested by Seling (1952) is a similar one. The normal position is best approached by the Flesch placing. According to our studies the suitable starting position for the thumb in violin playing is one of relaxation so that it faces the side of the index finger. Retraction as well as a fork-like opposition of the thumb require muscular work and are thus less economical. These manoeuvres might be needed in certain cases (extensions, certain double stops, etc.), but they should be applied only as long as necessary, even in such instances (Figs 44–50).

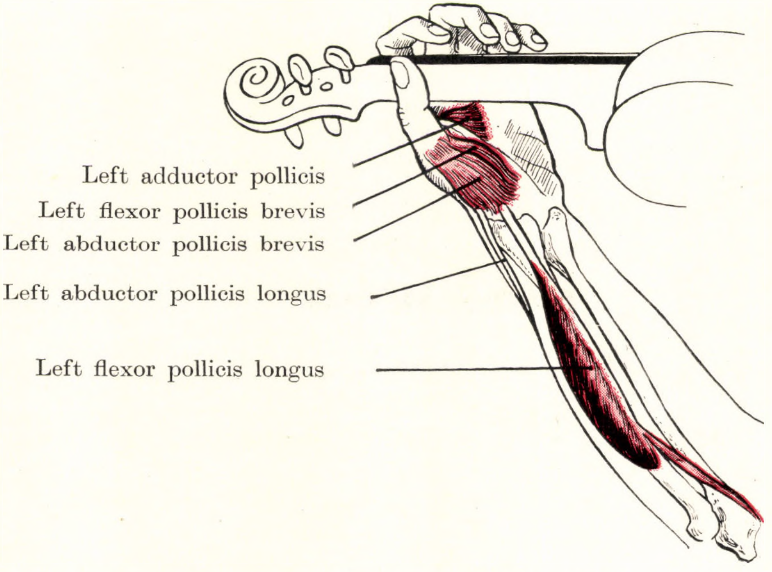


Fig. 45. Functional state of thumb muscles in normal position adjacent to the fingerboard, first position

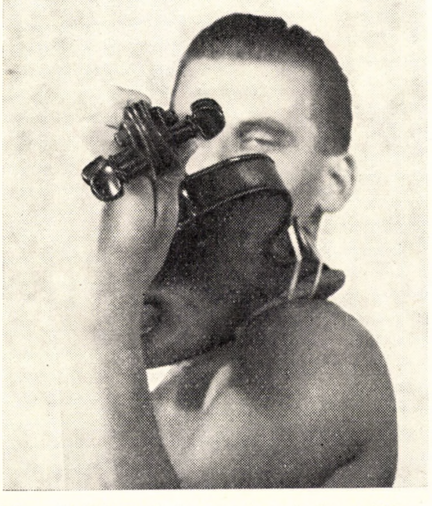


Fig. 46. Thumb in a retracted position, first position during playing the violin

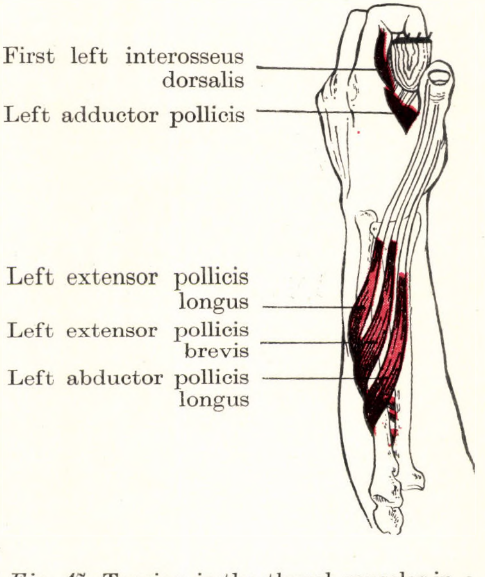


Fig. 47. Tension in the thumb muscles in a retracted position during playing the violin

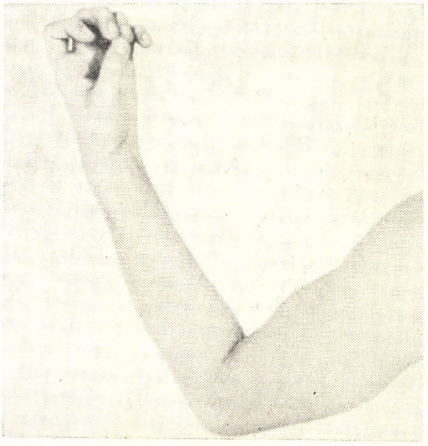


Fig. 48. Thumb position during the gripping movement of the hand (without violin)

Fig. 49. Thumb position resembling a gripping motion during playing the violin

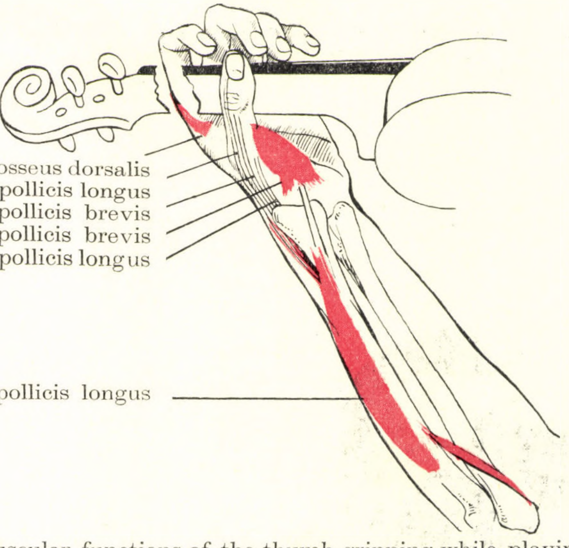


Fig. 50. Muscular functions of the thumb gripping while playing the violin

MUSCLE ROWS OF VIBRATO MOTION

The methodological literature of violin teaching deals exhaustively with the vibrato, both in regard to its aesthetics and its technique, but in doing so it mostly neglects the study of actual muscular functions involved. As reported by Paul Rolland (1961), Cheslock (1931) analyzed the vibrato movement by cinematography and succeeded in clarifying certain phases of the motion. According to our EMG inquiries, the action of stopping and finger raising in producing vibrato takes place as already described. Only after stopping has taken place, i.e. during the maintenance of the finger on the string, will vibrato start. This is proved by allowing the nail joint of the tone-producing finger to perform a periodic rocking motion around the fulcrum of stopping. The contact with the string is established by alternating points of the finger-tip, and in this way an oscillation of the pitch is induced.

The principal difference between vibrato and a simple stopping performed by standing on the string is the periodic alternation of activity in the muscles

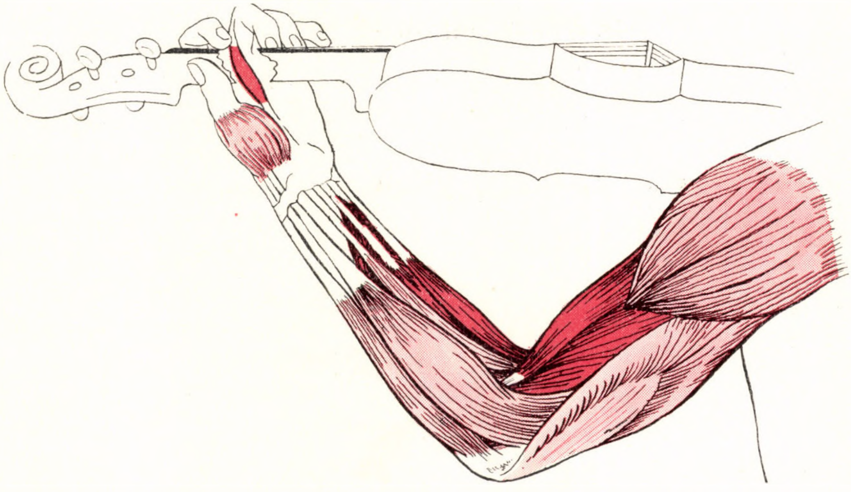


Fig. 51. Vibrato, first phase: the stopping finger stands on the string gradually gripping on

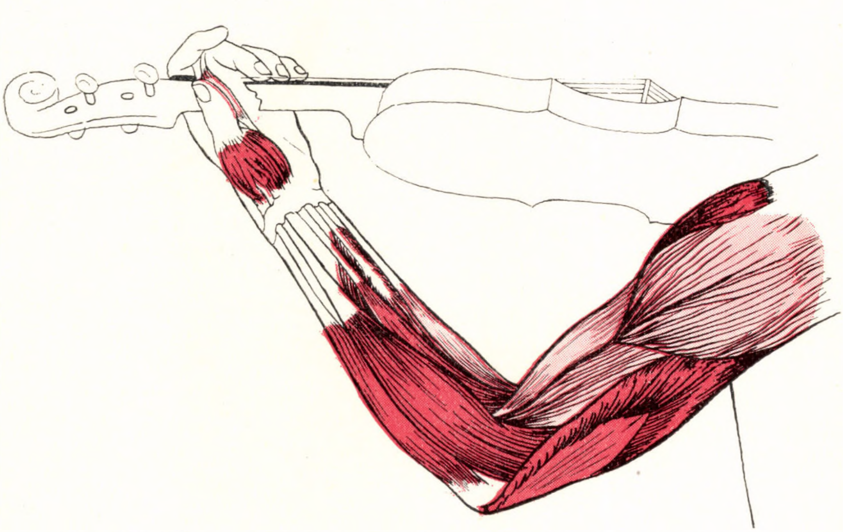
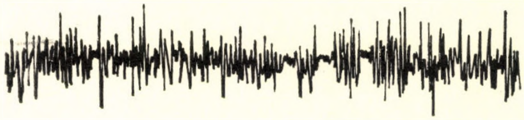
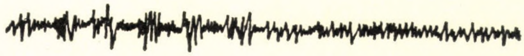


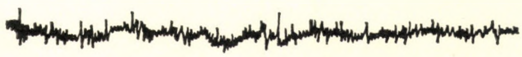
Fig. 52. Vibrato, second phase: the stopping finger straightens the fingertip broadly lying on the string



Left clavicular portion of the deltoid, 20 μV/mm



Left biceps brachii, 20 μV/mm



Left flexor digitorum superficialis, 10 μV/mm

500 msec

Fig. 53. Construction of the muscle rows producing vibrato motion. Synergic and alternating groups of muscles are seen clearly

of the arm, and to a certain extent, also in those of the trunk muscles that insert at the arm bone. This will develop new muscle rows which execute the swinging motion of the vibrato by their alternating activity and inactivity. The process of learning how to play vibrato means, therefore, the functional development of these muscle rows, an improving regulation of the central nervous impulses stimulating them. Our records show the two muscle rows becoming active in the respective phases of motion as follows: (1) The phase of flexion (the stopping finger stands on the string gradually gripping on).—Biceps, flexor carpi ulnaris, flexor digitorum superficialis, lumbricalis, interosseus and abductor digiti V. Result: extension of the first joint, flexion of the distal interphalangeal joints (Fig. 51). (2) The phase of extension (the finger straightens up).—Clavicular portion of the deltoid, triceps, brachioradialis, flexor carpi radialis and ulnaris, extensor digitorum communis, flexor and abductor pollicis brevis. Result: flexion of the metacarpophalangeal joint, extension of the second and nail joints (Fig. 52).

We conclude on the basis of this analysis that vibrato is a periodical muscular function involving the whole arm and all of its muscles. It is not merely a simple flexion and extension of the elbow as was claimed by Eberhardt (1922a) and Trendelenburg (1925). A muscle row may also involve the concurrent activity of muscles that give rise to rotary motion. During the vibratos examined, this was indicated by the presence of a total dorsiflexion and radial abduction, but of only partial volar flexion and ulnar abduction of the hand. It is the finger extensor co-operating with the thumb that shows that it will give support only during the backward swing of the finger, and support will cease when it is the flexor's turn to exert the force (Figs 53–56).

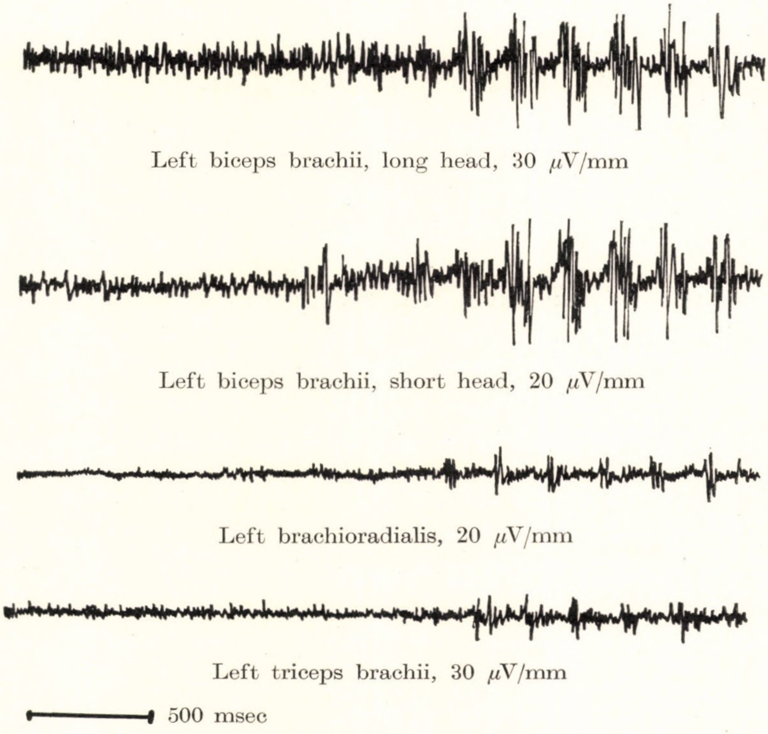


Fig. 54. Activities of the brachial muscles

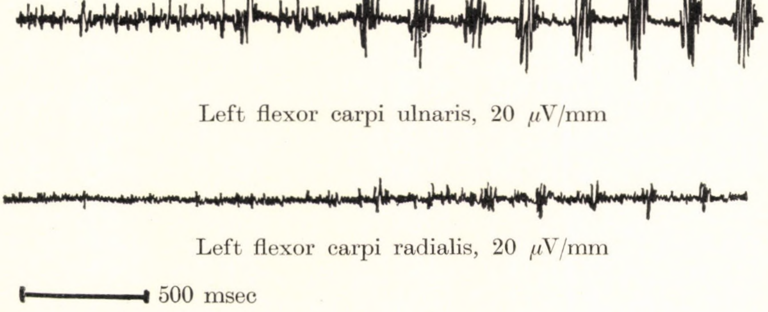
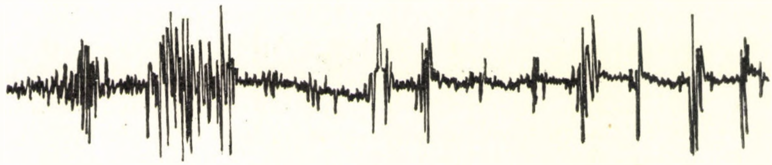
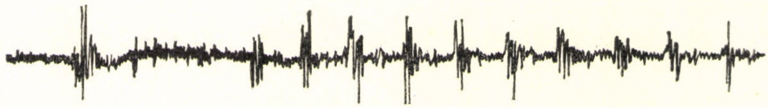


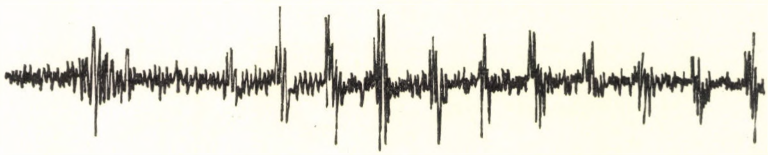
Fig. 55. Bioelectrical activities of forearm muscles



Left flexor pollicis brevis, 30 μV/mm



Left flexor digitorum superficialis, 20 μV/mm



Left extensor digitorum communis, 20 μV/mm

500 msec

Fig. 56. Co-operation of finger muscles

BIO-DYNAMICS OF POSITION CHANGING

The action of changing position has been investigated by playing two and three octave scales on each of the four strings. The change of position, too, is an intermittent action but, unlike vibrato, it is not periodic. Nevertheless, it is essential in respect of the line of melody of passage that the change should fit into the continuity of the movement series. The balanced and continuous character of the muscular function will be reflected if the change of position has been learned correctly. Both heads of the biceps brachii are intensely activated, whereas the activity of the concurrently contracting triceps and brachioradialis is significantly lower. The simultaneous activity of these three muscles indicates that the change of position takes place under a precise control of the muscles attached to the elbow; the change is either upwards or downwards. At the points of position changing, nodes of intensified activity appear suddenly upon the continuous fundamental activity. In higher positions the activity of the arm muscles decreases, which signifies a weaker maintenance of arm position, owing to the leaning on the body of the violin. Stopping takes place with an almost wholly synchronous operation of the superficial flexor and common extensor muscles of the fingers, i.e. the finger movement has no vibrato character. This is the guarantee for the clarity of intonation during continuous change of positions and underlines the practical experience that vibrato must be suspended during changes.

Trendelenburg (1925) believes the change of position to be an opening or closing motion of the elbow; this, in our view, is a simplification of things. Our records have shown that, while they transport the hand upwards from a lower position and downwards from a higher one, the wrist muscles perform a complicated rotary motion to manoeuvre it into the optimum position of holding. Within the compass of this series of movement all four directions of hand motion can be found. This fact has failed to evoke corresponding interest in the literature until recently. During change of position the thumb muscles become relaxed and allow free displacement of the hand. As soon as the new position is taken up, however, a sudden increase in activity is noted: the thumb supports again. This is so marked that by inspecting the peaks of action potentials of the thenar eminence it is possible to determine where the execution of the scale under examination required changes of position. The EMG record gives evidence that in the new position it is the stopping finger which is activated first (Figs 57–58).

When the temporal conditions of thumb motion are compared with the fingering performed by the flexor and extensor muscles of the forearm, the commuta-

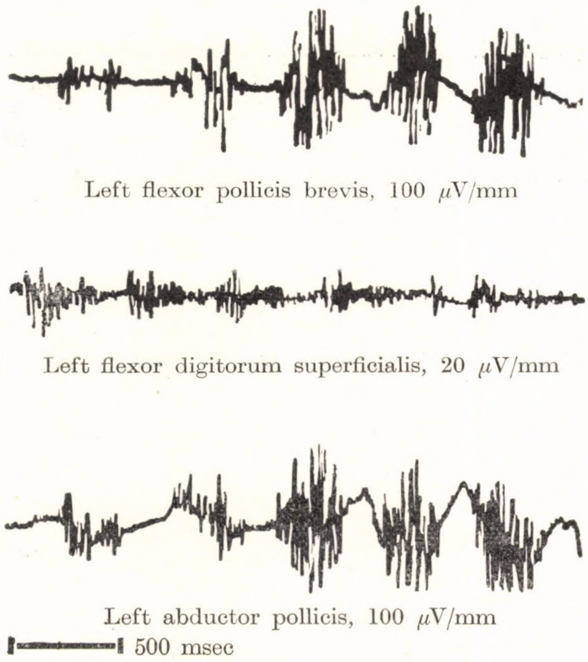


Fig. 57. Activity of the thenar muscles during continuous violin playing (3-octave scale)

tion will be found to resemble the motion phases of climbing. As in climbing a pole, either the feet or the hands yield the support while the other pair of limbs searches for the next grip, so will the thumb and the stopping fingers co-operate during the transport of the hand. Since by drawing the pupil's attention to the movement of the arm we have not shown him yet the method of changing position, we must remind him, further, to pay close attention to the suitable development of co-ordinated finger activity and hand rotation.

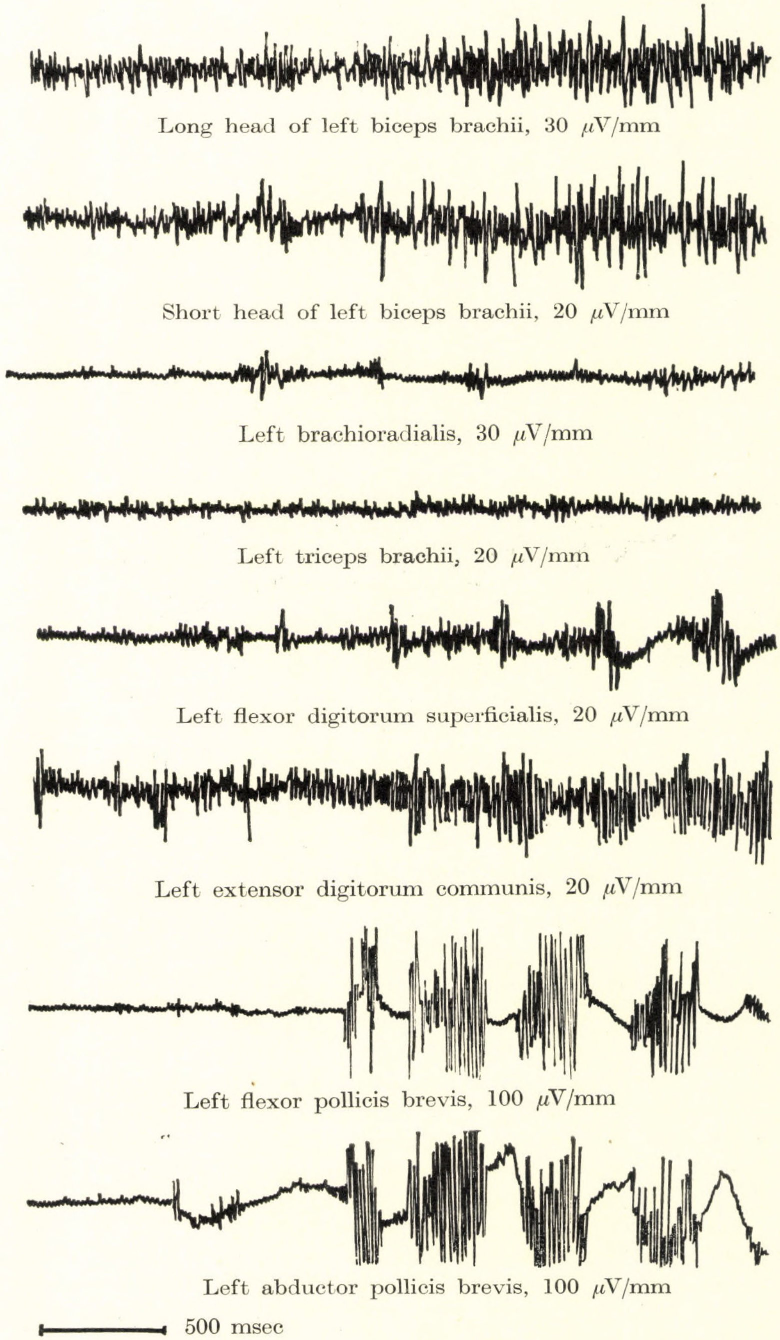


Fig. 58. Muscular activity in performing a change of position. In performing stopping and change of position the activity of arm muscles as well as that of thenar and finger muscles increases with upward progression of the scale

CONCLUSIONS IN LEFT-HAND TECHNIQUE

On the basis of the EMG investigation of stopping, vibrato, and change of position, a few conclusions may be drawn in respect of advance in the course of teaching. To attain the thumb relaxing its clutch-like action constitutes a persistent problem. To this end teachers apply special exercises (such as stroking the fingerboard with the thumb during stopping, etc.). This might, however, make thumb motion un-co-ordinated. Actual practice only helps in acquiring the correct proportions of activity which the pupil needs especially in vibrato and in change of position. The holding of the violin itself becomes really responsive only after vibrato and changes of position have been mastered.

This line of thought is bound to make one wonder whether the didactic order of sequence in teaching the vibrato after the introduction of changing position was absolutely correct. It is worth considering if it would not have been more correct to begin teaching vibrato at an earlier point of time; in this way, too, the change of position could be mastered with greater ease. The pupil would, in addition, enjoy it more if he could play vibrato tones. This is the principle that the Seling School (1952) has adopted, independently of us. Nor does the advantage of supporting the wrist in the third position seem to be unequivocal. Vibrato implies an elastic manipulation of the whole arm; its development will be impeded if the elbow and shoulder joints are stabilized.

MUSCLE FUNCTIONS IN RIGHT-HAND TECHNIQUE

Technical movements of the right hand may be classified as follows: (1) arm movement in the shoulder joint in which the shoulder girdle also participates to some extent, (2) movements of the forearm in the elbow, (3) hand movements in the wrist joint, (4) movements of the fingers.

The two fundamental motions are the lowering and the raising of the arm, and the flexion and extension, respectively, of the elbow. The other motions may be considered supplementary ones to the direction and continuous balancing of the bow. This classification has didactic purposes. When playing the violin, co-ordinated, complex and concurrent motions take place in every joint (Figs 59–64).

MUSCLE FUNCTIONS IN FUNDAMENTAL BOWING

Simple bowing was investigated during playing whole-bow vibrato semibreves. The activity ratios of the respective deltoid parts show that bowing is directed from left to right. The movement direction is, however, not parallel to the plane of the chest, but, at first, departs from it, and then approaches it again later. Taking a bowing direction parallel to the bridge is consistent with holding the violin obliquely to the left. Bowing is not, therefore, a laterally directed arm movement, but one which takes place before the right chest. Activity in the deltoid is the greatest when the bow is at the nut, and the smallest when it is at the point. Latissimus dorsi and pectoralis major act in a similar sense, but much weaker. The biceps is active both during up- and downbow, but its action is more forceful in upbowing and reaches its peak at the nut. Thus upbowing is not merely a raising but also a flexion of the arm, while downbowing is both a lowering of the arm and an extension of the elbow. All the triceps remain passive,

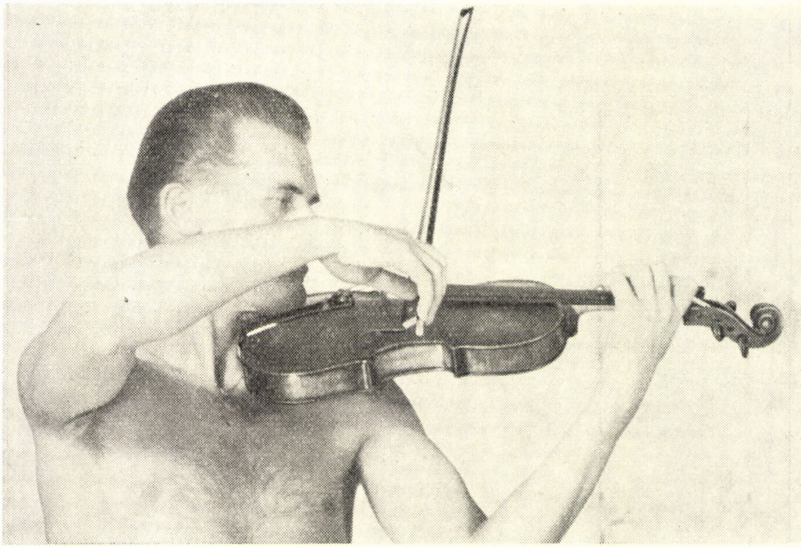


Fig. 59. Position of the right arm and of its parts at the nut

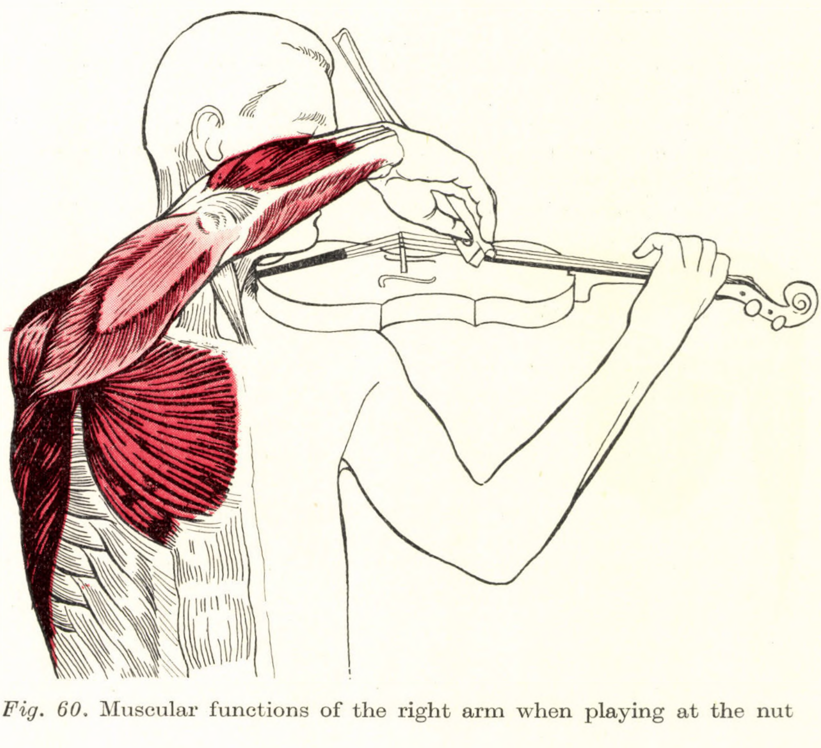


Fig. 60. Muscular functions of the right arm when playing at the nut

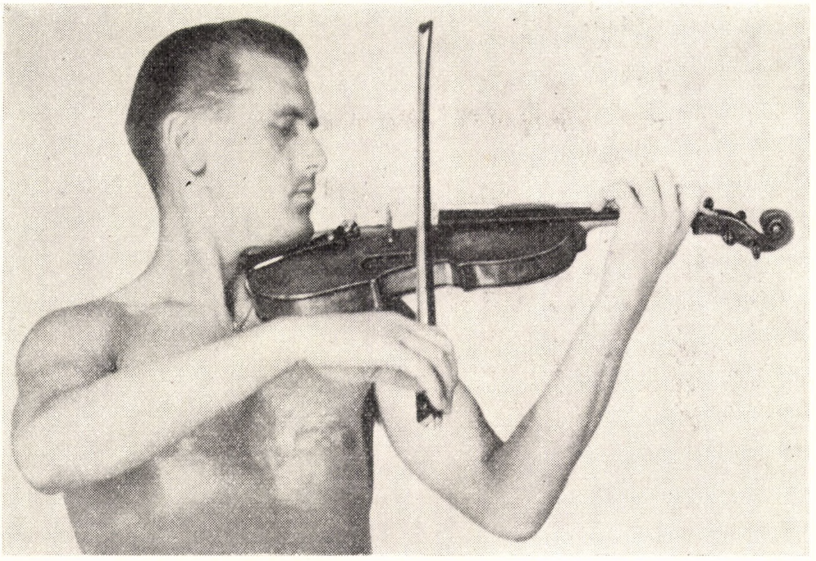


Fig. 61. Position of the right arm and of its parts at the middle of the bow

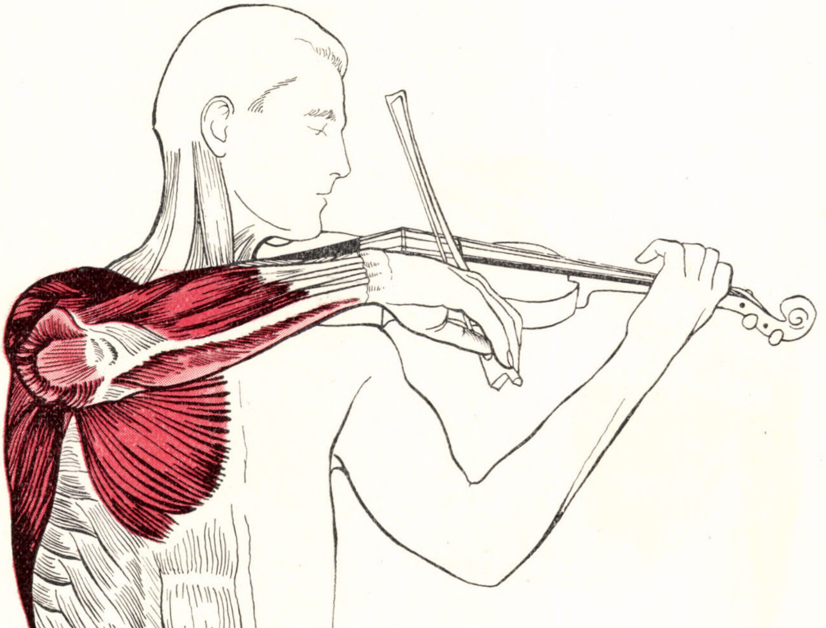


Fig. 62. Muscular functions of the right arm when playing at the middle of the bow

Fig. 63. Position of the right arm and of its parts at the point of the bow

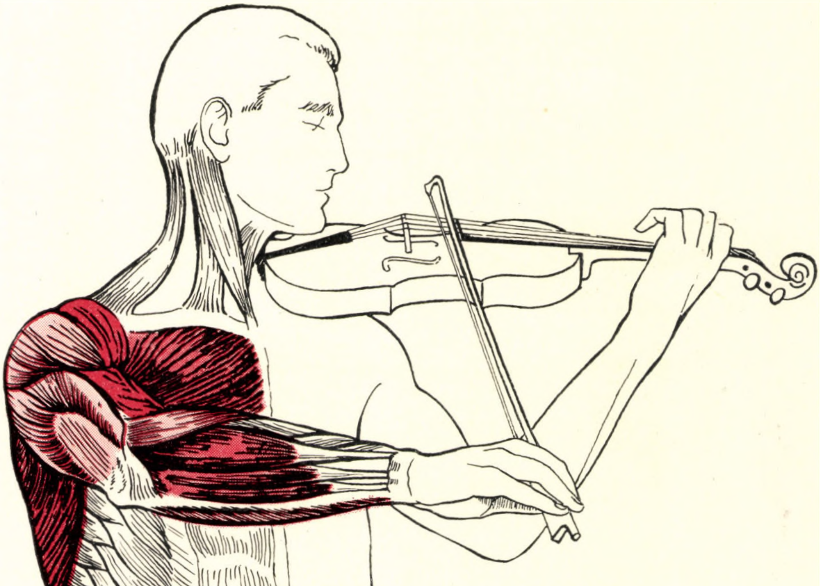


Fig. 64. Muscular functions of the right arm when playing at the point of the bow

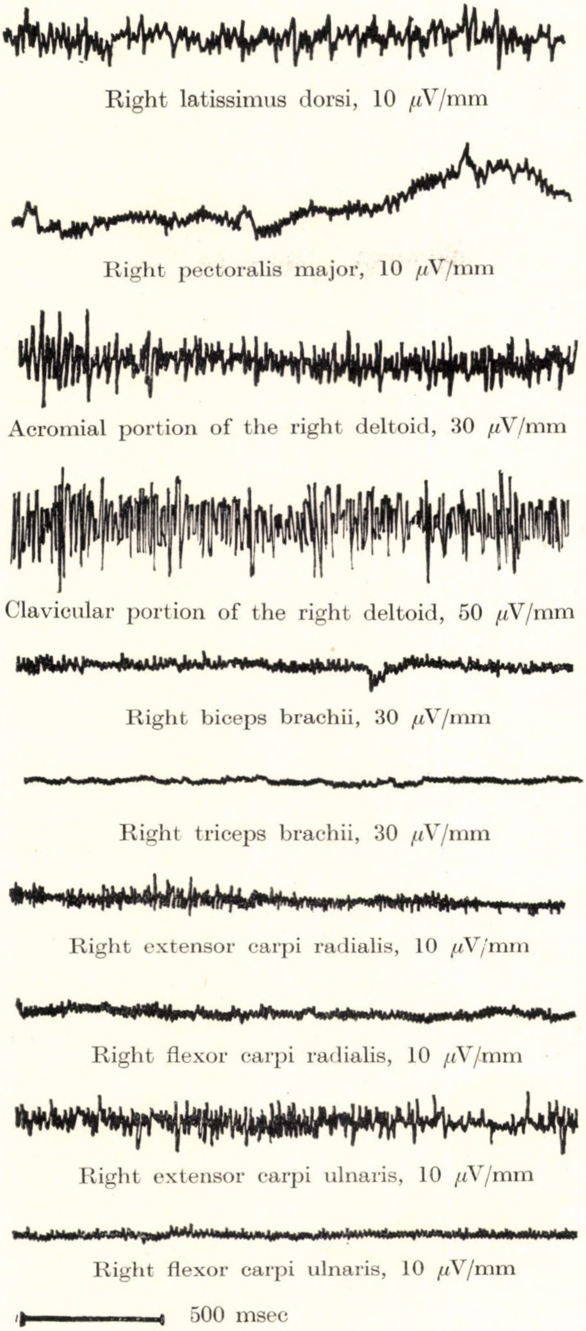


Fig. 65. Muscular activity in fundamental bowing on one string. The traces are superimposed to show the relationships of muscle activities affecting right arm motion

and do not function as an antagonist. This, and another fact, viz., that the latissimus dorsi and pectoralis major increase their tonus not during downbowing but during the upbow, show that during the downbow the deltoid and the biceps work jointly against gravitation. Tonus increase in the latissimus dorsi and the pectoralis major during the upbow is explained only by their participation in the delicate regularization of pressure, to prevent the bow from departing from the string in case the two arm muscles referred to above are excessively activated.

On the wrist movers the radial and ulnar extensors are active when the downbow reaches the point and when the upbow reaches the nut. In the flexores carpi only minimum activity is found. In the wrist joint, it is once more the weight of the hand, i.e., gravitation, against which extensors must act. The activity of the wrist extensors indicates a dorsiflexion of the hand which, during change of bow, tends to lift it from the string and so, incidentally, promotes a noiseless and smooth change in bow. The balancing of changes at the nut is regulated by the opposing activity of ventral and dorsal thoracic muscles, and of the carpal extensors respectively. Muscular activity, as outlined above, is indicative of very delicately regulated operation in which the respective arm muscles participate with different functions, but in full agreement and concord (Fig. 65).

MUSCLE FUNCTIONS IN ARPEGGIO AND IN CROSSING OVER STRINGS

In the case of usual arpeggio, viz., when we play the arpeggio downbow by proceeding from a lower string to a higher, or upbow in the opposite direction, there is an increasing activity in the latissimus dorsi when playing on the

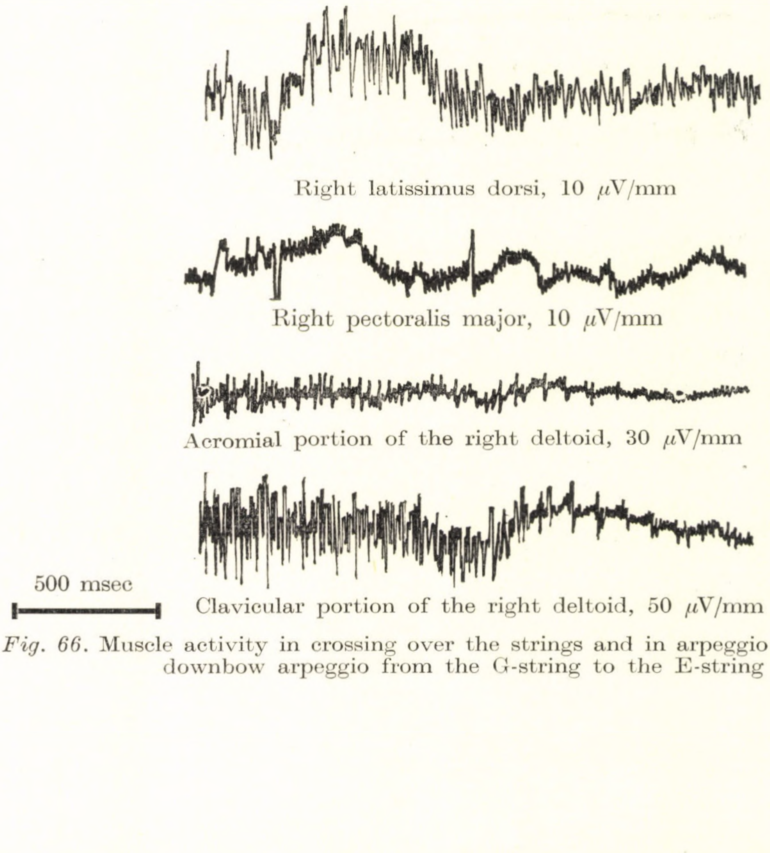


Fig. 66. Muscle activity in crossing over the strings and in arpeggio in the case of downbow arpeggio from the G-string to the E-string

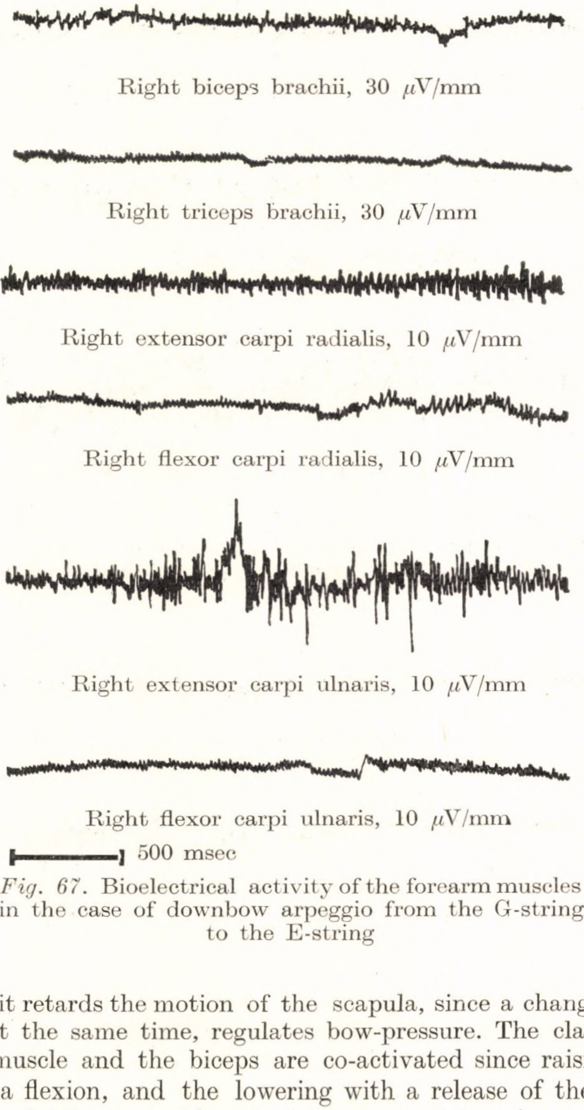


Fig. 67. Bioelectrical activity of the forearm muscles in the case of downbow arpeggio from the G-string to the E-string

G-string. Thus it retards the motion of the scapula, since a change in direction follows, and, at the same time, regulates bow-pressure. The clavicular portion of the deltoid muscle and the biceps are co-activated since raising of the arm coincides with a flexion, and the lowering with a release of the forearm. The fundamental mechanism resembles playing on one string. A synergic operation of the two muscles means synchronous innervation and relaxation for which an identical rhythm of central nervous discharge is needed. The wrist extensors operate similarly to the manner described in connexion with simple bowing (Figs 66–67).

MUSCLE FUNCTIONS IN PLAYING MARTELÉ

Martelé is a prototype of energetic strokes. Vigorous impact requires a different kind of muscle function, and this is reflected in the synergic activity of the deltoid and the biceps. Together with the biceps the deltoid gives a sudden impetus,

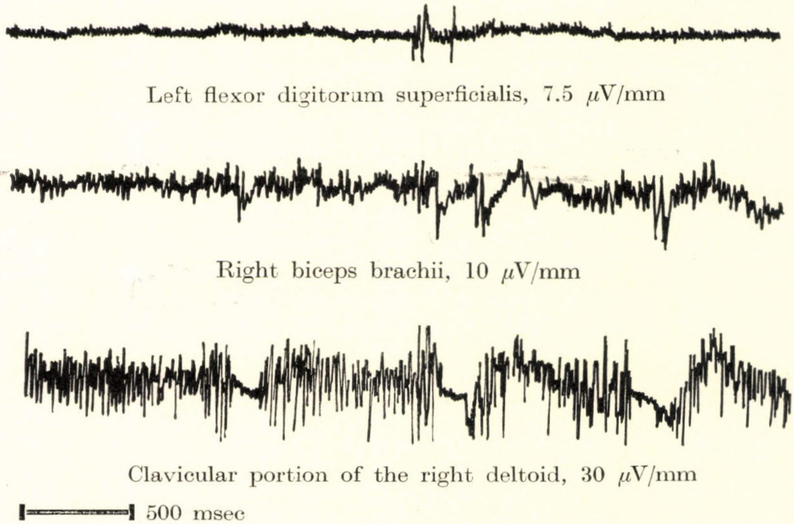


Fig. 68. Muscle activity in martelé; functional order of sequence in left superficial finger flexor, right biceps brachii and deltoid

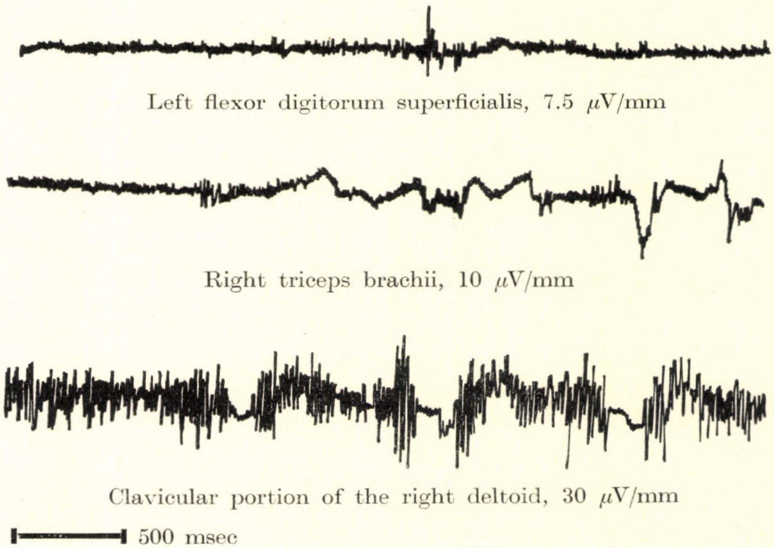


Fig. 69. Muscle activity in martelé; functional order of sequence in left superficial finger flexor, right triceps brachii and deltoid

then relaxes; at the end of the stroke both muscles brake. Co-operating with the deltoid the triceps, which in simple bowing is passive, shows bursts of activity both when the stroke starts and when it stops. By commencing and then braking elbow motion, it affords an opportunity for the deltoid to impart the initial momentum to the arm as a whole (Figs 68–69).

PROBLEM OF CROSSING OVER STRINGS AND OF PREFERENTIAL BOWING DIRECTION

Several attempts are extant of analysing the crossing over of the strings, the change of bow in combination of transition to other strings, and arpeggio. The reason for this interest in the problem lies in the practical experience according to which difficulty or ease in teaching certain tasks in bowing depend on the stroke direction employed. This is how, for example, the common practice began to play unaccentuated commencing notes (upbeats) upbow, so that the accentuated one should arrive at downbow. Trendelenburg (1925) designates downbows as leading or accent strokes, and has opposed Steinhausen's (1918) statement according to which upbows were easier to execute than downbows. Another practical experience proves that in both violin and viola, a downbow arpeggio executed from a lower string towards a higher is easier than the other way round. This is apparent also in certain bowing styles combined with crossing the strings. The reason for this is muscular co-ordination, as confirmed by the cello where strings are arranged in a reverse order in relation to the right arm, and where a downbow arpeggio performed by crossing the strings towards the lower ones is easier.

It follows from what has been said that to handle the bow is a complicated motion even on one string, and still more so if combined with crossing the string planes. In motor analysis several points must be considered: (1) bowing direction in space (upbow or downbow); (2) the arc of bowing related to the bridge; (3) joint movements in respect of the relative directions in which the different arm parts move during the stroke.

The differences noticeable in the motor conditions of the two kinds of arpeggio, in respect of their starting position and direction are as follows. (1) When a downbow arpeggio moves from a lower string to a higher one, the direction of bowing and of the semicircular motion over the bridge coincide during both the upbow and the downbow motions. In reversed arpeggios the direction of the bow motions is opposite. (2) In arpeggios in the usual direction, the whole arm either comes nearer to its lowered resting position close to the body (downbow), or departs from it (upbow). Thus the arm is lowered, and the forearm is stretched outwards from the elbow. In upbow the motion proceeds in the obverse direction, the whole arm is uniformly raised.

With reversed arpeggios the interrelationship of the respective motions of bow, arm and arm parts are considerably more complicated. With a downbow arpeggio passing from higher to lower strings the arm is raised and the forearm is extended from the elbow. The parts of the arm are forced to move in opposite directions in relation to the rest position. With a reversed arpeggio starting upwards, motor conditions are still more intricate. They will also affect the balancing movements of the wrist. The movement directions just described are illustrated by figures containing indications for the characteristic angles (Figs 70–73).

Koeckert (1909), too, has analyzed crossing over strings and arpeggio; in his view crossing over from lower to higher strings by downbow is easier because in moving from left to right the arm, hand, and bow come to the target string from the direction of their own movement. He holds the same to be true for the ease of passing from a higher string to a lower in upbow. His explanation holds good also in regard of arpeggio. Koeckert's justification agrees with the first point of our analysis, but no further. We think, however, that the problem of bowing directions deserves closer investigation, first of all in order to develop suitable styles of bowing.

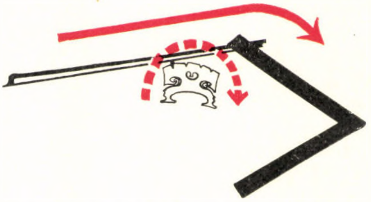


Fig. 70. Downbow arpeggio from lower to higher string (usual direction of arpeggio)

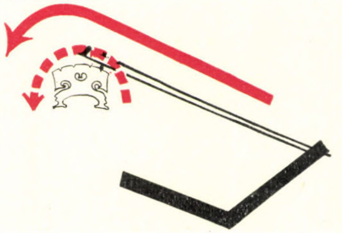


Fig. 71. Upbow arpeggio from higher to lower string (usual direction of arpeggio)

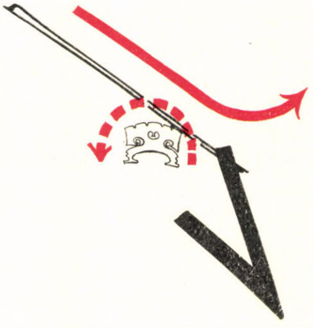


Fig. 72. Downbow arpeggio from higher to lower string (reversed arpeggio)

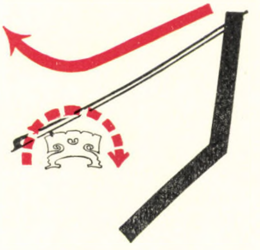


Fig. 73. Upbow arpeggio from lower to higher string (reversed arpeggio)

CONCLUSIONS IN RIGHT-HAND TECHNIQUE

A more detailed discussion of the various tasks of bowing technique and of the muscular functions of bowing styles would exceed the dimensions of this book. The different styles of bowing and their familiar tonal effects arise through the combination of the motions outlined. The following conclusions are reached in respect of the command of bowing styles. (1) The regulation of muscular activity controlling bow movements in continuous strokes involves the whole arm; we must feel the whole arm, whichever part of the bow is used for playing. Even the employment of the upper half of the bow requires forearm motor dominance, and should not be restricted to elbow flexion or extension. (2) Energetic, bold strokes derive from swift alternation of active and passive muscle rows. In such cases training means a suitable habituation of active and passive muscles with reference to the respective motion phases. Thus the essential point in martelé, for example, is a synchronous activity of the deltoid and the biceps (swing from the shoulder, then during the stroke a relaxation of the shoulder). (3) The recurrent elements of bowing styles should be mastered as whole motions. This will secure tonal uniformity too, because in this way entire musical figures and not separate strokes will be heard. A movement of instrumental execution may thus serve as the basis of phrasing. (4) Determining the direction of bowing should start from comparing the forthcoming string transitions with the planned direction of bow progress, so that the following crossing over to another string should coincide with the bowing direction as far as possible.

The economy of bowing directions and styles and so the ease or difficulty of their execution, are influenced also by the respiratory movements (this will be discussed in Chapter Three).

MUSICO-MOTOR PROBLEMS IN TEACHING BOWING STYLES

Endeavouring to obtain a suitable expression of the finest shades of human emotions by music, the performing artist is obliged to regulate not merely the intonation, but also the colour, volume and duration of the tones in unlimited variety. "The performance of a piece means a series of expressive stages that might be compared to the succession of accentual nuances and various gestures that attend the expression of spoken language; a pause here, a questioning rise or voice or accent there, etc.", says Pablo Casals (in Corredor 1955, p. 264). On playing a string instrument the principal means of expression consists in the styles of bowing. Perhaps it may be of interest first to try to define the idea 'styles of bowing'. It denotes bow-strokes, groups, or combination of bow-strokes of different lengths and duration, by the technique of which the intended linking or separation of notes, as well as the difference in duration, tonality and accentuation, are realized; in short, the character of sounds and tone groups on string instruments is shaped. Even this, far from perfect, formulation may make it clear that bowing styles constitute an extraordinarily intricate and far-reaching set of problems. A long series of musical and motor tasks have to be tackled before a style of bowing, in particular if it is a difficult one, sounds true to its character. Again, the fitting application of proper bowing styles represents a special set of questions: when and which of them should be chosen (style of the composer, solo, chamber or orchestral character of the performance). Another point to observe is to select the style of bowing in such a way that its instruction should fit in with the requirements and stage of development of the class, and to decide how far one should go in requiring a terse execution of the respective bowing styles under study.

Since bowing styles are very important means of expression in the case of string instruments, the literature on teaching methods deals with their properties in great detail. All relevant writings stress the function that bowing styles fulfil in the interpretation of mood, rhythm and arrangement of musical conception. "It is the bow by which the notes become living, emotions are kindled, by which the sad will differ from the jolly, the serious from the lively, the sublime from the petty, the humble from the insolent: in one word, this is the means by which musical expression comes into being and by which an idea can be transformed into many of its variations", wrote Quantz two hundred years ago (cit. by Jahn 1951, p. 31). Identical or similar statements are found in other writers. Seling (1952) appears to be right in his view about bowing styles having their precisely defined character of expression; thus to use a particular one makes sense only in so far as it complies with the motivic-melodic features of the piece. Single-note figures, whose expressive power is rather restricted, alone allow variations by bowing styles; the melodies capable of eliciting thoughts (emotions) themselves would almost predetermine, so to say, the choice of the appropriate bowing style. Since close connexion exists between musical context and the style of bowing, it is possible for the latter to exert a modifying influence on the character of a piece, subject to the following facts. (1) Bowing styles—in particular, the combined ones—do not mean simply that a series of notes are tied or detached, but that, moreover, they establish characteristic groups of tones. The various moods they induce do not arise therefore from single or separate notes, but from the co-operative effect of such groups. When it is a matter of alternatives in a characteristic bowing style, e.g. with a sequence of notes in martelé or staccato, the passage is to be considered uniform, till change of bow is required, according to the mood. (2) The majority of combined bowing styles contain perceptible agogic elements. Though the styles of bowing do not alter the tempo (except when employed in training), they possess a certain intrinsic accent of their own. (3) Bowing styles are therefore means of articulation, too, and have a correspondingly important part in the art of violin playing. (According to the interpretation of C. Flesch, 1928, we speak of articulation as stressing the melodically or harmonically important notes within a phrase.)

Fig. 74. Étude No.2 by Mazas

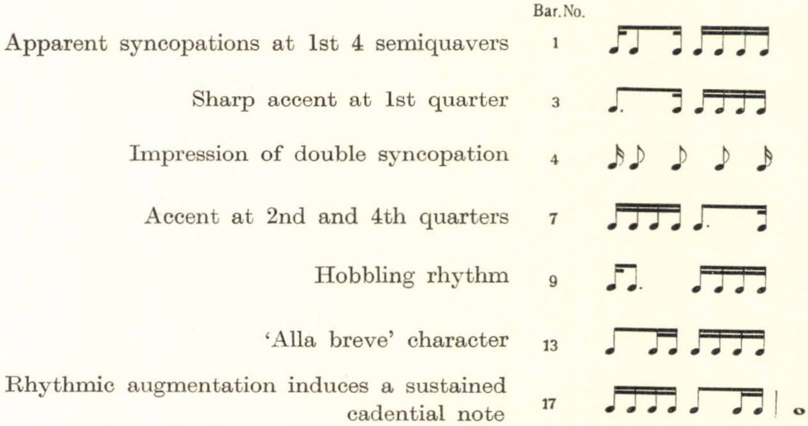


Fig. 75. Rhythmical analysis of Kreutzer's Exercise No. 3

Among études the exercises which promote the skill in performing the bowing styles could be applied best to illustrate what has been said. They consist usually of détaché exercises containing notes of equal length throughout (e.g. semiquavers). Playing them in the same bowing, the mood as a whole is affected; playing them in a combined bowing style, the mood of the separate parts will be affected. How much can be achieved by a simple dotting or slurring of two notes! (To this see Fig. 74 and—which is even more enlightening—an analysis in Fig. 75.) In this exclusively semiquaver exercise of sequential character, bowing styles create the shifts of rhythm as indicated in the figure (for brevity's sake, only the bar number and the rhythmic formula in the first half of the bar are shown since the second half is identical with the first). The analysis of Mazas' 16th exercise is also stimulating; about 16 kinds of internal rhythmic patterns are discovered here in a similar manner.

To realize the implication of colouring possessed by the bowing style, its characteristic agogics must be perceived. This brings the following conclusions. (1) The internal rhythm, which shapes the character of the bowing style, must be consciously emphasized by clear articulation. (2) Within the bowing style formula the short notes must prepare for the long ones. (3) In the choice of bowing styles care must be given to the properties described above lest they 'work against' the original thought of the music.

Since the bowing styles may alter the character of the melodic sequence rendering the musical content, their problem is closely related to phrasing. Essentially, phrasing implies two requirements, viz.: (1) the division of phrases and (2) the arrangement of musical thought within the phrase.

In this respect three bowing styles emerge: (1) phrase bowing to fix the limits of a certain phrase; (2) articulation bowing to form parts within a phrase; (3) technical bowing, i.e. the actual strokes used for articulation or phrasing to distinguish from the previously applied bowing style on grounds of performing technique.

Correct choice in respect of bowing styles (1) and (2) is a crucial matter for the interpretation of the piece. Violinists have to consider certain technical properties of bowing in order to secure logical phrasing: legato bowing, for example, slurs also notes that do not belong to each other; a change of bow (even if it were performed perfectly) divides the notes which are musically connected; crossing over to another string, if arbitrary, would modify tone colour so much that the listener might believe a break had occurred in the melodic line. In relation to the corresponding bowing style (3), its significance derives from its technical execution: it could render the performance easier, but it may make it more difficult. (The connexion between articulation bowing and technical bowing is illustrated in Fig. 76.) We agree with Carl Flesch (1928) in supposing the connexion between articulation and phrasing to be so close that illogical articulation (by articulation we mean the musical logic of the melodic line) would inevitably result in an incorrect phrasing, whereas the suitable bowing style will guarantee the correctness of phrasing as well.

Fig. 76. Étude No. 16 by Mazas
(bars 17–18)

A great number of bowing styles are generally used within a piece. The curriculum should therefore comprise not only the various bowing styles, but their combination as well, i.e. a smooth transition from one to the other. The perception of differences in the mood of the music to be performed is a precondition of the correct execution of necessary motor tasks. The motor intention must be linked to the tonal conception and—after a due course of training—appear concurrently with it. Consequently, the mastery of a bowing style necessarily implies the inducement of an adequate motor intention, whenever the note pattern of the characteristic bowing style or its auditory counterpart is desired.

The employment of bowing styles that were studied in the exercises, to obtain excellence in performance, and its attendant difficulties belong to the domain of transfer problems. Generally we speak of transfer when a violinist in possession of a perfectly worked-out technical approach wishes to apply this skill to the solution of similar tasks under new conditions (Rubinstein 1958). The reason for failing in the attempt of such a transfer is attributable to the solution not being generally valid. Complete success in a transfer is reached by a thorough analysis disclosing essential relationships. This is the intrinsic precondition for transfer. (See Chapter Six.)

What is the essence, the main features of the respective bowing styles that distinguish them from one another? What is the criterion, whose conscious grasp is essential to the proper application of various bowing styles? It is the specific mood already mentioned, which is reflected in bowing-style attributes also discussed previously. In the course of teaching, it is important that, in our explanations, we give a clear analysis of the musical and motor tasks in relation to bowing styles, separated from the secondary conditions of the problem. On the other hand we should not confine ourselves merely to technicalities nor to formal and mechanical memorizing of skills. Our efforts must be directed towards developing creative thinking and resource. This is why the work of musical training is emotionally coloured to a far greater extent than any other type of educational activity. Evolution of emotionality is at least as important as explanations of a logical character.

It is clear from the above that instruction in bowing styles is one of the most important duties for teaching violin playing, since the experience in managing bowing styles endows the artist with an immeasurable facility of expression. To this Pablo Casals says: "The bow constitutes an element of performance; accordingly, one must employ it in agreement with the peculiarities of the music presented. In sustained tones the use of a whole bow is as natural as to use only a part of the bow in the case of shorter ones. The movements of the right hand should emphasize their particular power of expression and therefore that part of bowing should always be applied which corresponds to the musical meaning of the note under discussion" (Corredor 1955, p. 272). It is widely known that the foundation of teaching bowing styles is laid by developing the ability of proportioning and its innervation. New schools of instruction refer to this in the very first steps of teaching; we fully agree with this. It should be noted, however, that the problem is far from being easy: it requires the development of a complex space–time–motion perception. In the dividing of the bow shown in Fig. 77,

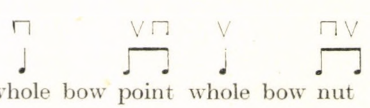


Fig. 77. Dividing the bow

Fig. 78. Uniform character of a phrase

the pupil, if he wants to express the uniform character of the phrase, ought to be correctly aware of the inter-relationships of tempo, bow-length, and the motions necessary for both, within the phrase (Fig. 78).

Faults usually arise from disregarding the stage of instruction mentioned above. A clock-like precision in dividing the bow will be utterly in vain if the pupil can neither comprehend nor feel the uniform character of the expression in the notes executed in the given bowing style. With such deficiencies, the study of bowing styles changes to a dull to-and-fro dragging of the bow; scales appear to the pupil as a vexation, or the teacher's whim to make him repeat always the same notes. It is precisely the sameness which should be avoided (there is one quality of tones which remains the same, and that is their pitch); the words 'staccato' and 'toccatas' consist of the same letters, yet their meaning is quite different. Instruction in bowing styles must take into account the interpretation of music. This has its obvious roots in musical thought. For this reason, its message and value include tune, metre, dynamics, and—in melodic lines of the broken-chord type—the harmonic framework of the piece. This is why, for instance, the necessity of a dynamic pattern may arise within the self-same bowing style, when this is desired to render the message. The staccato notes of the exercise

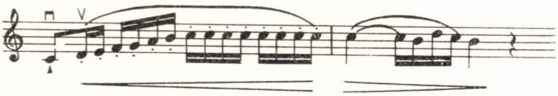


Fig. 79. Étude No. 34 by Mazas (bars 1–2)

Fig. 80. Étude No. 36 by Mazas (bars 5–6)

shown in Fig. 79, if bereft of such dynamics, would sound as a series of uniform, meaningless and partly superfluous repetition of strokes. When the chordal structure of a passage is to be emphasized, it is again with the bowing accent that we can achieve it (Fig. 80).

The examples have been intentionally chosen from the current exercise material. Similar results are obtained in respect of the application of bowing styles by comparing different editions of certain violin pieces, as, for example, the Hubay or Flesch edition of Beethoven's Violin Concerto. To some extent, this naturally involves already the artistic attitude of the performer as well, which is, primarily, a matter of individual taste. That the validity of these observations is not restricted merely to exercises could be confirmed by analyzing the gramophone records of the masterpieces of violin literature. Apart from natural differences in individual performances it is, in this respect, characteristic of any interpretation that the musical conception is in full agreement with the applied bowing style and that bowing, as a means of expression, is subordinated to the emotional content. Several relevant problems of teaching and applying bowing styles could be mentioned. Most concern the faults commonly committed by the pupil in regard to bowing, and the methods of their correction.

FLABBY AND RIGID EXECUTION

Both flabby and rigid executions are physiologically related to the fluency of the motor process. They may be due to a number of circumstances: psychological incidents, muscular and articular factors of constitution, etc. Since the over-all effect will manifest itself in muscular activity and motion, we shall analyse them from this practical point of view.

During the motor action the muscles that produce the motion develop a higher tonus than at rest. In relation to the requirements of a movement to be performed, this tonus increase may be: (1) too intense (hypertension), (2) too weak (hypotension), and (3) adequate (optimum).—Obviously, the first causes rigidity, the second results in flaccidity in the process of motion, and only the third condition secures its object accurately and economically. Both hypertension and hypotension derive from faulty exercise or from adverse mental or somatic conditions. Exercise faults reflect a deficiency in the learning process (bad technique, or insufficient exercise), while performance cramp, for instance, or apathy, manifest the performer's psychosomatic condition prevailing at the time of executing the motion.

As we have seen, our movements arise from a co-ordinated activity of a great number of muscles, and not from the isolated function of single muscles. In the programme of functional co-ordination corresponding to the motor task the innervation and de-innervation of muscles must be interlinked with the precision of a hundredth of a second so that the motor stereotype should be induced fluently by the respective groups (agonist–antagonist–synergist–fixator) and rows of muscles. Were innervation or de-innervation too soon or late in regard to the optimum starting time for the execution of the motor stereotype, the motion becomes rigid or flabby.

There are three regulating mechanisms which are especially capable of securing an optimum performance of the piece, that is, to create the most favourable conditions for muscular tension. (1) Delicate regulation and dividing of muscle tonus corresponding best to the actual task of tone-production. The conditions for tone-production change with every fraction of a second: accordingly, muscular tension is now increasing, now decreasing. A few of the fundamental requirements for a successful performance are an adequately delicate regulation, gradation of muscular tension in every small time unit and the avoidance of hypertension or hypotension. (2) Precise timing of innervation and de-innervation in the co-operating muscles (synchronization) corresponding to the nature of the task presented by the performance. (3) Suitable exploitation of momentum and of gravitation.

Dividing, synchronization and utilization of momentum are the forms of muscular function, whose conscientious acquisition and unhampered execution provide us with the means to perform the movements of the playing mechanism with the economy and accuracy necessary for producing beautiful sounds.

In the course of discussing the various technical elements we have already referred to the ways of performing the motions appropriately and of avoiding an unfavourable co-ordination (relaxed feeling in the nape in maintaining head position; freedom of relaxed shoulder in maintaining arm position; functional differences in muscle rows in stopping, vibrato, and change of position). Instead of repeating them in detail, some complementary remarks would be more appropriate. In determining the amount of relaxation, allowance is to be made for the rate of the respective motion. Movements tend to become less free as the velocity of motion grows, especially so if accurate aiming movements are to be performed. This comes from the intensified control of the antagonists and synergists necessary to regulate these movements, and it makes the joints that partake in the motion more tense. This is the reason why it is impossible to change position accurately during vibrating a note: the elastic maintenance of arm, hand and finger position for vibrato makes the aiming less accurate (cf. p. 70). Similarly, owing to an increasing synchronization of activity in the finger-muscles, execution of swift passages requires stiffening, and a hammer-like action of the fingers. An absence of the necessary stiffness, or an exaggerated rigidity, may equally hinder the development of a swift rolling technique. It is equally essential to distinguish between the respective phases of the technical manoeuvre to be performed. The success of a martelé stroke, for example, will mainly depend: (1) on the necessary stability of the beginning, (2) on the relaxation immediately following to exploit the momentum attained during the stroke (cf. p. 80). When the two phases of the motion are executed by opposing or un-co-ordinated muscular work, neither the martelé bowing, nor the desired tonal effect will result.

Finally, allowance must be made for the stage of refinement to which the technical element to be mastered has reached. The initial phase of motor learning is characterized by superfluous, 'parasitic' movements and exaggerated muscular tension. These problems will be discussed in detail in Chapter Six in connection with exercise. In any case, to value correctly whether a motion is flabby or free, one has to consider the degree of skill, and determine the means of further development accordingly. The faults specified above can be localized by an observation of the arm parts performing the motion, or by controlling, by touch, the tonus of the muscles showing rigidity or flabbiness in activating the joints.

AGE CHARACTERISTICS, SOMATIC DEVELOPMENT, DIFFERENTIATION IN MOTOR SKILL

Human movements evolve and are brought to perfection in the course of development; consequently, they reveal certain characteristic patterns referring to age. Their instruction cannot be effective if these features are unknown or ignored. So to round up this Chapter we wish to elucidate some problems of kinesiology pertinent to the respective age groups. With the exception of wind instruments, the teaching of instrumental execution begins generally at 7–8 years of age, and the pupil will graduate at the age of 22–23. (Here we should not dismiss the fact that the Japanese Suzuki has developed hundreds of players who can play the A Minor Vivaldi Concerto, the Bach D Minor Concerto for Two Violins beautifully and with correct technique at the age of six, starting at four or earlier).—The most complicated period of individual development occurs during the period of adolescence, i.e. when the child becomes an adult. During this time fundamental changes take place in the constitution and motor skills of the body. These changes are brought about by natural development and by the influence of training. The success of the latter will, however, depend mainly on its ability to adapt itself to age characteristics. There is no agreement in the relevant literature in respect of division into age groups. We compiled the characteristics of developmental periods in the child by comparing above all the data of Aryamov (1953), Gorkin (1953), Eiben (1956), Kairov (1956), Meinel (1960), Gandelsman (1961), and also of others. According to this, the period of learning to play a musical instrument may be subdivided into four age phases: (1) the lower period of school age from 7 to 12 years; (2) the mid-period (puberty) of school age from 12 to 15 years; (3) the higher period (adolescence) of school age from 15 to 18 years; (4) youth and early adulthood from 18 to 23 years of age.

According to a somewhat different classification of age groups, e.g., age phases may be between 7 and 10, 11 and 13, 14 and 16/18 years of age, and those above 18. In the characteristics of the age groups discrepancies of 1–2 years may often occur according to subracial types, sex and individual differences. The process itself takes place in everyone during individual development. As regards bodily development and motor skills, the characteristics of the respective age groups can be summarized as given below.

FROM 7 TO 12 YEARS OF AGE

A child's skeleton differs from that of an adult not merely in size and proportions, but also in its morphological and chemical composition. There is more of the organic and less of the mineral substances in a child's bone, therefore, it is more elastic. The physiological curvatures of the spine take shape by the age of 7, though during the years to follow further changes will occur. For this reason one must take great care about postural questions between 7 and 22. Muscular activity, static and dynamic effort, the frequency, extent and type of exertion have a significant impact upon the modification of the skeleton. Thus, physical education plays a part of considerable importance in the development of favourable skeletal and constitutional proportions. Infantile muscles contain usually less of myoglobin, protein and organic salts. Weakness of a child and strength of an adult find their reason not merely in a difference of muscle mass but also in one of composition. Muscles are developing intensively during this period. Though the proportions of muscle mass in relation to body weight differ from the newborn state by only some small percentage, in chemical and morphological composition significant modifications take place. At 7·5 years of age the child is able to lift a weight of 11·5 kg, while at 11·5 years he pulls up 16–19 kg using his right hand only. Muscular power does not grow proportionally. First the great trunk and limb muscles grow stronger, because these are continuously exerted by the walking and other movements of everyday life. The muscles of the hand begin to grow rapidly between 6 and 7 years of age.

With respect to motor skills Aryamov (1953) discerns two phases in this period: the age group of 8–10 and that of 10–12.

(1) Motor functions develop intensely in the first phase already. Pupils of the lower grades are almost incessantly on the move. Certain movement combinations (like repeated throwing and catching of the ball) are formed and stabilized at this time. The speed of motions in the shoulder girdle, in particular, will grow; though these movements are yet rather inaccurate. Synkineses (concurrent movements) and superfluous (parasitic) motions abound.

According to Meinel's (1960) analysis, in the first three years at school the characteristic traits are the following: (a) In the first form the movements become square and awkward because of the painstaking endeavour to be accurate. The crucial difference between the child attending a kindergarten or the one attending a lower grade of school is that the latter wants to attain some concrete goal by his movements. Consequently he also cares for the result (whether the throw hits the target, etc.). (b) In the second form the speed of motions also increases. (c) The third school year is the period when movements become more harmonic and well-balanced. The reason for this is the equilibrium of stimulatory and inhibitory processes that takes shape in this period. This pattern of nervous equilibrium will remain characteristic of the individual's motor apparatus.—In the lower form of school sustained attention is hindered by the profusion of movements, by the immediate responsiveness to any stimulus. Subtle motions often encounter difficulties in children of the lower forms; they become exhausted sooner by movements like writing, drawing and using the needle than do those above 12 years.

(2) In the second phase of Aryamov's (1953) classification the precision of co-ordination will abruptly increase. This is why Meinel (1960) takes the period between 10 and 13 to be the best for the learning of movements during childhood. The features of this motor peak are: (a) new motor patterns are acquired very speedily; (b) the remarkable adaptivity of the motor system to new conditions. —Several branches of sport can be mastered almost without any previous practice. Children between 10 and 13 years imitate the motion observed in its entirety, often skipping several intermediary steps of learning. This age is therefore very favourable for the initiation into several types of motion. Even specialization has some opportunity. Instrumental motor skills, too, are most likely to achieve higher development in this period; perhaps even the first indications of choosing a musical career might appear.

For learning to play the violin an accelerated motor development is necessary. As regards the initial period of learning to play a string instrument certain points have to be emphasized: (1) the main difficulty lies in the precision of co-ordination and in the acquisition of suitable fingering, (2) in the curriculum the two phases of motor skill development outlined above must be taken into account.

FROM 12 TO 15 YEARS OF AGE

Puberty is a stormy period of human development. Unnecessary exaggeration of its influence would be as mistaken as to disregard it, to which attitude music teaching has appeared to incline recently. Children of this age grow on the average 6 cm per annum. The greatest part of this growth concerns the elongation of the limbs. Ossification of the trunk and limbs is not complete as yet. The spine is particularly prone to get scoliotic. The development of the solid framework is disproportionate: that of the chest lags behind the skeleton as a whole, and that of the trunk falls behind the growth of the limbs. Particularly the lower limbs grow very quickly. Muscular development does not keep abreast with the longitudinal growth of tubular bones; this lagging behind disturbs the relationship of weight and power. In comparison with body weight the muscle mass represents 33 per cent. The remarkable increase in muscular volume and power, the superior perfection of accuracy in, and co-ordination of, movements arrive by the time of sexual maturity. In consequence of the non-proportionate development of muscles and solid framework, in puberty gait and action become clumsy. There are conspicuous sexual differences in motor development. Not only are motions requiring an effort affected, but also those requiring speed. Corresponding to the change in constitution girls move smoother and more flexibly, though their movements lack power. Boys move more squarely, yet swifter, and more powerfully.

As to the extent of motor disorders at the age of puberty opinions differ. Some investigators presume that considerable motor disorder is bound to occur in the majority of adolescents. Others believe that, particularly in the case of well-trained movements, such disorders will not develop. According to Gorkin (1953) the disorder of motions is manifested by the following: (1) rhythm and fluency of the movements deteriorate; (2) skill and accuracy of aiming diminish; (3) hypermotility appears again; (4) the disturbed dynamism causes excessive tension; (5) ability to learn is found to decrease (though its source might be a progressive consciousness; the learning of a movement takes longer because of it); (6) extreme states of motility: some get restless, others become lazy.

The correct manner to handle these symptoms is to strive to maintain the level of motion forms already possessed by cultivating them and, on the other hand, to delay the initiation of new and intricate forms of motion. Another helpful means is to appeal to the pupil's understanding, since at the age of puberty he is already interested in the reason why movements should be performed in a specified manner.

The rapid but unbalanced progress of bodily constitution may embarrass the flow of instrumental movements. Longitudinal growth tends to bring the body's centre of gravity higher, thus standing will become more labile and impede the equilibration of movements performed by the arms and upper half of the body. This worries violinists above all. Up to this period somatic growth could be compensated for by changing the instrument. From this time on, till the end of somatic growth, however, one has to adapt one's continuously changing size of limbs to an instrument of identical size. The rapidly growing hand tends to clutch, the elongation of the fingers brings about an uncertainty of intonation, and also moving in positions becomes less reliable. Bowing and dividing the bow become inaccurate. For the technical faults that appear in this period without apparent cause, the reason is to be sought mainly in the somatic development and in the deterioration of motor skills. With some pupils the rate of progress in playing the violin slows down, and stagnation, sometimes even retrogression, may be encountered. This is due mainly, in addition to factors already mentioned, to the hormonal changes of puberty.

FROM 15 TO 18 YEARS OF AGE

Height is increasing by merely 1·5–2·5 cm per annum in these years. The weight increase is 2–4 kg yearly on the average. Chest volume becomes adjusted to body proportions. On the other hand, the rate of growth of the long tubular bones and their compact substance is decreasing. The progress in muscular working capacity and strength development continue. The unbalance between the growth of the solid framework and the muscles also disappears. Muscles represent on the average 44 per cent of body weight. As the skeleton and the muscles become proportionate to each other, motor co-ordination also improves and gradually approaches that of adults. The relative quietening of the tempestuous growth exerts a beneficial influence on the progress in instrumental skills. As a matter of fact, this is the period when a virtual stabilization of the mechanism engaged in playing may begin.

FROM 18 TO 23 YEARS OF AGE

Skeletal and muscular developments of the adolescent come to an end. Further progress will depend on the profession or sports-activity chosen. General development is replaced by the specific direction determined by the new circumstances of life. From the 18th year of age onwards individual motor peculiarities become settled. The ability to check and direct endows the hand and fingers with full certainty. In the course of learning instrumental performance this is the period of training at an advanced level. Whether the student chooses to be an artist or a teacher, his efforts will be directed towards a culmination of the results attained up to that time. The principal duty is to further the evolution of individual technique and to promote the development of personality within which the factors of bodily constitution have a minor role. In striving to optimally evolve his skills either as a performing artist or as a teacher, he must take account, first of all, of the psychic properties of his personality. But these are outside the limits of this Chapter.

Chapter Three

CHANGES IN VITAL FUNCTIONS IN VIOLIN PLAYING

GENERAL PROPERTIES OF RESPIRATION

Among the processes taking place in our body during instrumental playing the domain of autonomous responses is perhaps least known. The investigations into stage-fright give us no clue about the functional capability of the organs guaranteeing the unimpeded flow of such a high-order activity as the art of instrumental performance.

One of the most characteristic autonomous or vital functions in man is respiration. Its modification often predicts the switch-over of the organism for tackling a new task. Respiratory air exchange, respiratory rate and rhythm, the depth of breathing reflect faithfully the physical condition and degree of exertion, as also the variations in metabolism. By studying these indications it can be shown to what extent and in which manner the organism is charged by the respective action. The relationship between violin playing and respiration has been examined in some detail by O. Szende and E. Stadler, in the Research Department of the National Institute for Medicine of Physical Education and Sports, Budapest (Hungary).

By making 16 respirations per minute, about 8 l. of air are exchanged by pulmonary ventilation. In the period between 6 and 16 years of age respiratory rate decreases from 23 to 16 respirations per minute. The mean tidal volume of air is around 0·5 l. At rest, inspiration is active, while expiration is partly passive, partly active. Under normal conditions respiration proceeds automatically, but it can be regulated and controlled also voluntarily. Certain activities (such as sports, singing, playing wind instruments, etc.) have definite rules for respiration. These rules have a decisive effect on the activity itself, and their habituation constitutes an organic part of acquiring skill in the given activity.

MECHANISM OF RESPIRATORY MOVEMENTS

Breathing is a result of the rhythmical contraction and relaxation of respiratory muscles. As a motor function, respiration is a rhythmical, symmetrical and cyclical activity which, however, involves certain physiological arrhythmia.

During respiratory movements the chest rises and sinks rhythmically. This motion consists of several factors. The ribs rotate in the two joints connecting them to the vertebrae. The costal cartilage expands and shrinks elastically; the breastbone is shifted forwards and upwards, to return to its former place in the next phase. When the technique of respiration is correct, the abdominal muscles relax during inspiration and contract during expiration. The movement of the ribs in the combined costovertebral joint, the elastic configuration of the cartilage, the motion of the breastbone, and the activity of the abdominal muscles combine to produce the chest's expansion during inspiration and its contraction after expiration. Chest movements are passively followed by the lungs. The lungs are not able to move so actively as is the heart with its strong cardiac muscle, or the bowels which are lined by unstriped muscles. The lungs follow the moving chest by expanding and recoiling elastically.

Respiratory movements may be resolved into the components, viz. muscular activity, force of gravity and elastic force.

Inspiration is attributed firstly to muscular activity while expiration is mainly due to the force of gravity and elastic forces.

The position of the chest at the end of a normal expiration may be regarded as being at rest. It is the position assumed when all the respiratory muscles are at rest. Starting from that position respiration takes place in two phases, viz. inspiration and expiration.

INSPIRATION

Air is drawn into the lungs by virtue of the suction effect of the negative intrathoracic pressure arising from the volume expansion of the chest. An increase in the volume of the thorax can be brought about in two ways: (1) the diaphragm which separates the thoracic from the abdominal cavity contracts and displaces the internal abdominal organs; in this way the capacity of the chest is augmented. Concurrently, the muscles of the abdominal wall become relaxed, thus giving way to the abdominal organs: the abdominal wall will protrude. This kind of respiration is called abdominal respiration. (2) Contraction of the intercostal muscles elevates the ribs, in this way the cross-sectional area of the chest will circularly increase; this method of breathing is called costal respiration. Its prerequisite is a downward slant of the ribs, for only in this way will chest capacity increase by their elevation.

Either method is adequate to meet the demands of resting body position and mild exercise, and as Nims stated (Fulton 1955, p. 808), normally both methods are operative at all times; they are effectively co-ordinated to meet the increased respiratory demands of strenuous exercises. In addition to the intercostal muscles, respiration is supported by several other mus-

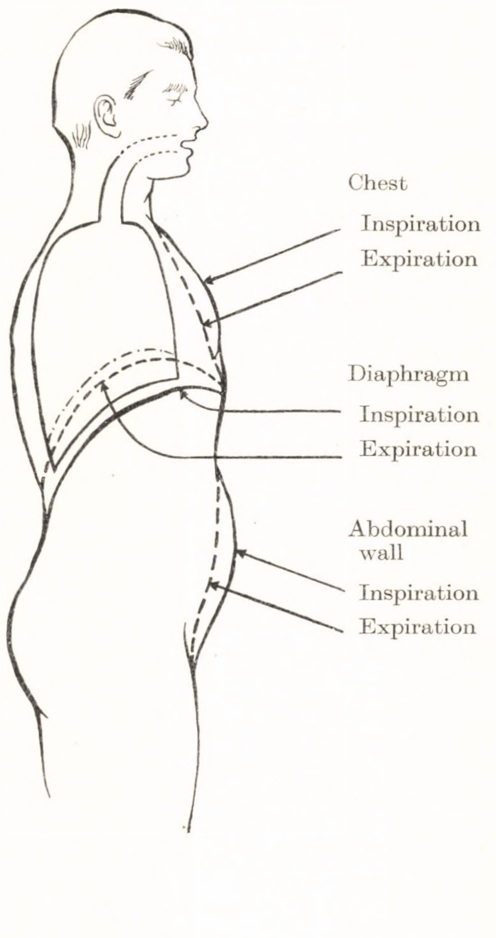


Fig. 81. Activity of respiratory muscles, side view; full line: inspiratory end-position; dashed line: expiratory end-position (diagram after Nims 1955)

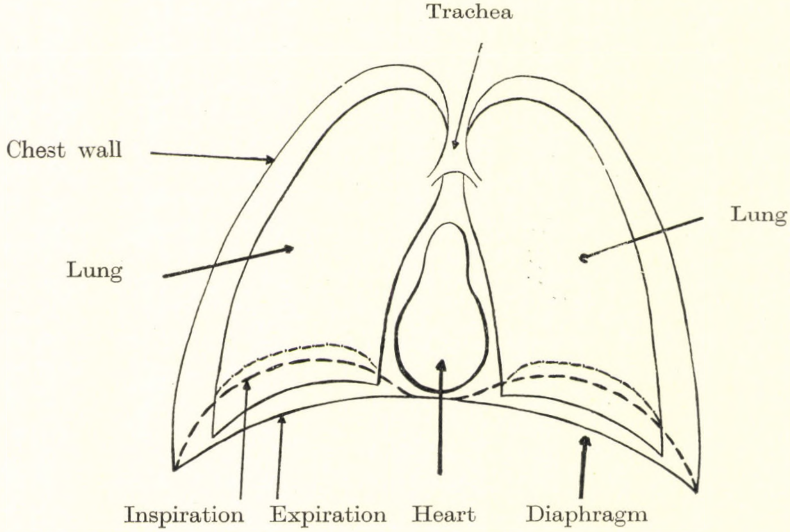


Fig. 82. Function of the diaphragm, front view (diagram after Nims 1955)

cles which are also charged with other duties. These are the accessory muscles of respiration. Inspiration requires active muscular function at all times. (Figures 81 and 82 illustrate the entire mechanism of respiratory function, the activities of the diaphragm, the intercostal and abdominal wall muscles.)

Infants make use mainly of the diaphragmatic, i.e. abdominal method of respiration. The cause of this is that their ribs are nearly at right angles to the spine, and a movement of the ribs in either direction would decrease the volume of the thorax instead of increasing it (Fulton 1955, p. 810). As soon as the infant assumes an upright posture, both the force of gravity and the rhythmic contractions of the diaphragm assist in giving the ribs a downward slope, and thus costal respiration will also develop. Combined breathing is therefore a result of upright posture and in adults it may be taken as normal. Within the scope of combined breathing one of the two methods will dominate, the extent of which will differ individually (Nemessuri 1963). In females costal respiration is usually more conspicuous while in males abdominal respiration is more forceful.

EXPIRATION

As mentioned, expiration in rest is mostly a passive process: the inspiratory muscles having relaxed, an elastic recoil of the thoracic wall and lungs, assisted by the upward pressure of the abdominal organs, force the air out of the lungs, then a short pause ensues in respiration. The main expiratory muscles are the internal intercostals and the muscles of the abdominal wall. When the latter contract, the pressure in the abdominal cavity is raised and air is effectively expelled from the lungs. In vigorous breathing the expiratory pause may considerably shorten or even cease. Any un-co-ordination will result in ventilatory disturbance. According to Kereszty (1961), such are the following faults. (1) Paradoxical respiration, when the volume increase in the thoracic cavity attained by virtue of the intercostal muscle contraction is handicapped by a concurrent relaxation of the diaphragm assisted by a co-contraction of abdominal muscles. Thus the contents of the abdominal cavity cannot be accommodated. It is found mostly with asthenic body constitution. (2) Upper costal respiration, when the contraction of the muscles of the abdominal wall forces the diaphragm and, with it, certain internal organs upwards, and thus impedes adequate expansion of the thoracic cavity. It is observed in those having a pycnic constitution. (3) Respiration by straining the thoracic muscles; this is seen in athletes.

These faults are noted, in respect of types of bodily constitution, in observing the respiratory movements of the abdominal and thoracic muscles. Such observations may be utilized also in teaching the correct technique of respiration. Respiratory exercises will help the pupil correcting possible faults in respiration. These could be executed during breaks from practising on the instrument. Corrective measures for respiratory rate and capacity during violin playing will be discussed later.

RELATIONSHIP OF RESPIRATION AND CIRCULATION

The central regulation of breathing is closely associated with the circulation and its central nervous organization. With more vigorous circulation of blood respiratory movements also increase. The activity of circulatory and respiratory organs will increase as soon as we sit or stand up from a supine or resting position. Pulse rate will slightly rise, systolic and diastolic blood pressure becomes a little higher, and owing to a similar modification in breathing respiratory gas exchange will also increase. In the course of performing further movements these vital changes become even more marked. A more forceful activity of the respiratory muscles, in the first place of the diaphragm, in its turn exerts a favourable influence on the circulation. The suction effect of inspiratory chest expansion promotes the blood flow towards the right auricle of the heart. In passing through the diaphragm the inferior vena cava constricts slightly by the action of the contracting muscles during inspiration, so that some resistance is interposed to the upward flow of venous blood. In the expiratory phase the cross-sectional area of the vein becomes full again and blood flow resumes its former speed. Immediately before expiration the positive intrathoracic pressure assists in the work of the heart.

The respiratory muscles are effectively promoting the pump-like activity of the heart by changing rhythmically the pressure in the thoracic cavity. While circulatory and cardiac function are independent of will-power, respiration may be influenced by volition. This fact stresses the importance of respiration for the efficient function of our whole circulatory system.

CONTROL OF BREATHING

Respiration in general is not under conscious control. Its flow is regulated by the respiratory centres of the central nervous system, primarily by those located in the brain stem. The group of nerve cells which discharge the impulses stimulating inspiration and expiration are allocated over a rather broad area of bulbar, pontine, mid-brain and hypothalamic structures. This is the reason for the vigorous increase in pulmonary ventilation, accompanying circulatory response at the onset of muscular work, or often even preceding it. The voluntary control of breathing is, however, of cortical origin, and takes place in the frontal and limbic areas of the cerebral cortex. This is the neuro-physiological basis for a volitional control of breathing. Conscious control or adaptation to certain rules for breathing may be necessary during sports and musical activities. However, observance of these rules in singing or in playing wind instruments will elicit arrhythmic respiration, and in consequence, breath-retention and a temporary lack of oxygenation. Sustained positive-pressure exhalation imposes a considerable load on the heart and lungs of those playing wind instruments, which may cause complaints of pulmonary and cardiac disturbances.

There is a close interrelationship between respiration and movement. Bodily movements involve an increased demand for oxygen, modifying the rate and depth of inspiration. The rules of breathing for singing, and for playing wind instruments, depend on musical articulation and technical execution. The manner of respiration for strings is, however, different in principle from that of singers or wind-players, since the tone-production of the latter is established exclusively by making use of expired air, whereas in the case of string instruments the respiratory cycle is apparently independent of tone-production: musical tone-production continues during inspiration as well. That is why the same melody is different according to whether it is being sung or being played on the violin.

We have to turn now to the question of the connexions that may exist between musical articulation, the movements of violin playing and respiration, as well as the particular properties that can be noticed in them.

RESPIRATORY RHYTHM IN VIOLIN PLAYING

It is a generally recognized fact that in violin playing respiration is closely correlated to the musical message of the piece. Yet the literature of experimental studies which would render an acceptable solution to the problem is scarce. This was the reason for our efforts in elucidating the relationship respectively of breathing, motor activity and musical message by experimental means.

Physiologically, the playing of a musical instrument is a complex senso-motor activity subject to various interrelationships. Accordingly, not only music pedagogues, but also certain physiologists and psychologists have become interested in the process that takes place during a musical performance. Steinhausen (1918), Trendelenburg (1925), Dolder (1932), Basler and Kawaletz (1943) and others investigated the motor process and the equilibrium conditions of instrumental playing mostly by experimental methods. On the other hand, Kovács (1916), Teplov (1947) and Yakobson (1958) studied the psychological problems of instrumental performance. In the teaching of the violin hardly any attention has hitherto been given to respiration. Nevertheless, violin teachers have sometimes observed certain signs of exhaustion during violin performance, for which there was no apparent reason. In several such conditions a comprehensive study of the respiratory mechanism could disclose instances of circulatory collapse or dyspnoea elicited by orthostasis. Our experiments were performed with the intention of investigating the time sequence, rhythm and pattern of respiration.

We constructed a face mask with inspiratory and expiratory valves that permitted the registration of the phase of breathing. The valves had an identical diameter with the upper air-tracts. They were made of thin sheet rubber so that during inspiration and expiration the air could flow unhindered. The mask covered only the nose and the mouth, viz. it was a half-mask having a thin aluminium framework whose rubber edges fitted airtight to the face; violin holding was not handicapped by it. The subjects put on the mask a few minutes before they started to play in order to get accustomed to breathing through the mask. The composition played by the violinist was tape-recorded, and the respiration was observed during the recital. The beginning of each inspiration was marked on the tape by knocking at a microphone at the corresponding instant.

There were ten subjects, all active violinists who played the selected piece of music (the First Minuet of Bach's Solo Sonata for Violin No. 6) 31 times in all (nine subjects played it three times each and one subject played it four times). As subjects, we deliberately chose persons of different qualification and preliminary training. (Qualification and sex distribution of the subjects are listed in Table V.) The experiment took about an hour for each subject. During the test period a total of 822 respiratory movements were registered.

Table V

Qualification and sex distribution of subjects

	♂	♀
Teacher and performing artist	1	2
Violin teacher	2	—
Violinist in orchestra	3	—
Student	2	—
Number of subjects	8	2

The above piece of music has been selected because it represents a composition included in the syllabus as well as one of artistic performance, further, because it constitutes a self-contained work, and not just part of a composition like a concert piece which demands an accompaniment. In this way the player assumes the character of an interpreter and not merely of a practising individual, and he is able to render an expressive performance. In this respect also the conditions of the experiment resemble those of a concert recital.

The specific bowing styles required (détaché, slurring, upbow and downbow) were indicated in the subject's score before the performance. Thus every motor phase of the right arm could be identified subsequently. From the position of the bow we were able to infer the actual place of the right arm. Accordingly: the bow is close to the nut = arm and forearm are raised to the level of the shoulder, the forearm is flexed, the wrist is in the frontal plane, forearm and arm form an angle of 45–60 degrees; the bow is close to the point = arm is extended and abducted forwards and downwards to the right, forearm and arm are at a straight angle (180°); the bow is in the middle = intermediary condition (the angle of the elbow joint corresponds to 90–130 degrees in this half flexion). When the performance was played back, the time-points of inspirations and expirations, as well as bow positions at the moment when inspiration began, were marked in the score.

In analyzing the results we classified as upbow all the inspirations which either had begun during an upbow, i.e. while raising the right arm, or took place immediately before a downbow stroke. Inspirations that had begun downbow, i.e. during the descent of the right arm, were classified as downbow. In Fig. 83 we plotted the frequency of inspirations against the duration of the performance. Each point represents one performance, i.e. there are 31 points for the 31 recitals. As it can be seen, the time taken by a recital varied between 65 and 86 sec, and the respiratory frequency between 15 and 38 per minute. The mean duration of the recitals was 74 sec for which the mean respiratory rate was 26. That means 21·5 inspirations per min; 80·6 per cent of the inspirations occurred during or immediately before an upbow and only 19·4 during a downbow stroke. These findings show the tendency to inspire concurrently with raising the right arm, and to expire with lowering it. The fact that inspiratory rate was significantly higher when chords were played or before changing over to lower strings, further corroborated the above statement, i.e. these motions coincided with right arm raising; 78·6 per cent of the inspirations took place around changes of the bow, and only 21·4 during a continuous stroke (Fig. 84). As appears from Table VI which includes also the findings of later investigations, further difficulties of technical nature cause even more divergent changes in the above rates. This indicates that inspiration bears a close relationship to changes in the direction of right arm motion.

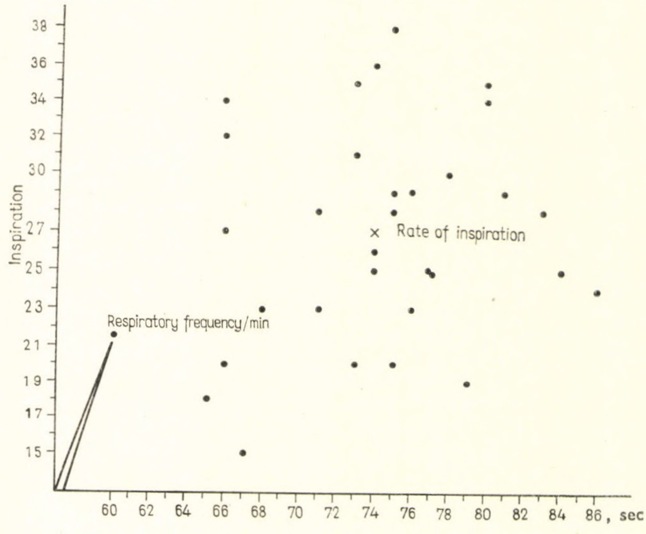


Fig. 83. Relationship of inspiratory rate and playing times

On Trendelenburg's (1925) initiation, Dolder (1932) investigated the peculiarities of drawing the bow on a cello during quiet whole-bow strokes, and confirmed that the maximum level of bow-pressure was lower in upbows than in downbows. Bow-pressure was lowest during transition to another string, and was less at the nut than at the point. Finally, he reported that a decrease in bow-pressure proceeded more rapidly than its increase. His observations cannot be applied to violin playing without reservation; nevertheless they confirm our results. The effect of inspiration which is tending to elevate the bow from the strings, has to be

Fig. 84. Correlation between respiratory rhythm and change of strings during the recital of the First Minuet of Bach's Solo Sonata for Violin No. 6

Table VI

Respiratory rhythm and bowing

Title of composition	Number of recitals	Number of breaths	Inspiration during				Inspiration with respect of bow position				Nut and point total		Near half bow	
			downbow		upbow		near the nut		near the point					
			number	%	number	%	number	%	number	%	number	%	number	%
First Minuet of Bach's Solo Sonata for Violin No. 6	31	822	159	19·4	663	80·6	302	36·8	344	41·8	646	78·6	176	21·4
Paganini Capriccio No. 13	6	319	22	6·9	297	93·1	118	36·9	172	53·9	290	90·8	29	9·2
Paganini Capriccio No. 17	6	260	16	6·1	244	93·9	146	56·2	70	26·9	216	83·1	44	16·9
Veracini Largo	3	185	36	19·4	149	80·6	67	36·2	75	40·5	142	76·7	43	23·3
Total	46	1586	233	14·7	1353	85·3	633	39·9	661	41·7	1294	81·6	292	18·4

cancelled by muscular work producing increased pressure. Naturally, his subjects could not regulate this pressure with an absolute accuracy, thus the downbows reflecting the active muscular work of downward direction brought about a bow-pressure of a few grams more. Since inspirations occur in the proximity of transitions, prior to a large number of them bow-pressure is reduced. The fact that a reduction in bow-pressure is quicker, seems to correspond to the attribute of normal breathing, viz. that inspiration is generally a more rapid process than expiration.

The literature and the practice of violin teaching agree in believing upward strokes to have less weight than downward ones. The explanation given refers to the weight of the arm, i.e. to gravitational effects. According to our experimental results the weightlessness of upbows is accentuated by a coincidence with inspiration. The opinions which in the literature of violin teaching assert that a downbow is more heavy 'by its nature', are confirmed in this regard. Consequently, we disbelieve the assumption of certain teachers of methodology, that bow-strokes of either direction were equal in this respect.

The quality of tone-production is well known to be considerably affected by the manner the bow attacks the strings. This attack has therefore an influence upon the interpretation of the musical message.

Inspiration is a motion that raises the shoulder-girdle from which fact we deduce that to raise the right arm and to inspire are complementary activities. According to our investigation no direct relationship can be verified between respiratory rhythm and musical articulation or phrasing. The results indicate that a greater density of certain values for respiratory rate around particular points is first of all attributable to motor acts. A break in the motion brings about naturally a pause in tone-production and leads thus indirectly to musical articulation. The pause is usually followed by a change in movement direction so that inspiration begins either during the pause, or during the stroke if the following motion requires an upbow.

In the majority of cases it may be inferred that musically accentuated notes and cadences (such as the ones at the end of musical phrases or sentences) are accompanied by an expiration. The primary reason for this does not appear to lie in the musical conception itself signifying a conscious expiration at these musically important points, but in the fact that these passages are usually played downbow. A further support for our assumption is that in the selected pieces most of these cadences were chords and were played by the subjects mainly downbow owing to reasons mentioned previously. Thus it is the motor activity, and the respiratory pattern associated with it, in which the musical conception is expressed during the performance. It is in this sense that the connexion between respiratory rhythm and phrasing can be seen in Fig. 85. The close dependence of realised musical conception on the senso-motor process that executes it is still more evident here. The effort of the performers to avoid an accentuation of the first crotchet in bars 2, 10 and 28 as well as an accent on notes of the first beat of the bar in the legato part between the 19th and 26th bars are shown by the ratio of the respective upbows and downbows applied to these notes.

To exert a deliberate, direct influence on respiratory rhythm while playing the violin is impossible; this rhythm is subject first to the oxygen requirement of the motions in interpreting the musical message, and second, to the opportunity available to respiration allowed by the motor sequence (given suitable time, etc.). The results may be considered further evidence of the significance of bowing

Fig. 85. Correlation between respiratory rhythm and musical phrasing during the recital of the First Minuet of Bach's Solo Sonata for Violin No. 6; E = expiration, ⊓ = phrases

styles, musical means to control right arm movements in musical articulation on the violin. Tone-production, and with it the expression of a musical message, is made easier if decision is made in respect of the applicable bowing styles, taking the expected pattern of respiration into consideration, or if the respiratory pattern is adjusted to the musical phrasing. When a physiologically conditioned inspiration contradicts a musically motivated accent, the result may be an incorrect musical accentuation. Of course, it is not always manifested in an audible form. In the course of auditively controlled practice the pupil is capable of adjusting the pressure, and of habituating it together with the correction. An inspiration contradicting musical accentuation is likely to interfere with motor efficiency. When inspiration takes place during downbow, it will raise the right shoulder and embarrass a smooth downward gliding of the right arm. This seems to be one of the reasons for the type of downbow so well known in practice, in which the right shoulder becomes stiff during elbow extension, i.e. while the bow approaches the point. Immediately after the last notes have been played a deeper breath is usually registered. One of its causes is certainly of psychic origin: the sigh of relief. It may also be of help in taking the bow smoothly off the strings.

Our investigation, comparing the rhythm and the time of inspiratory events with the direction of the strokes, mostly confirms the practice applied hitherto in teaching, and offers factual didactic means for certain cases. Our data permit the following suggestions. (1) It is advisable to begin the unaccented parts of a bar as well as a rising tune (i.e. proceeding to higher strings) by an upward bow.

(2) According to the accepted practice, upbeats should be executed upbow. Those upbeats, however, which consist of two parts should begin downbow so that the main accent falls on a downward stroke (Fig. 86). (3) Changes of bow that leap over more than one string should be prepared according to the analysis of right-

Fig. 86. Advantageous movement direction on special upbeats

hand motion presented in Chapter Two, so that they proceed in the direction of the movement (Fig. 87).

There are interesting comparisons to be made in this respect. Three versions are given below for the first line in the Andante movement of Paganini's Capriccio No. 17 investigated by us: (1) Hubay's edition, (2) Flesch's edition and (3) the bowing styles applied by subject DK who has been taught by G. Garay (Fig. 88).

Fig. 87. Advantageous changes of bow by leaping over more than one string

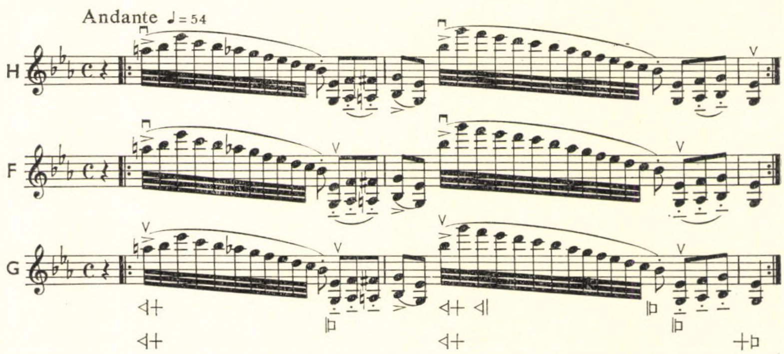


Fig. 88. Variants of bowing styles in Paganini's Capriccio No. 17

In the third version that was actually analyzed by us we have indicated the points in time where inspirations began (| first occasion, + repeats), and the part of the bow used (⌷ at the nut, <| at the point). The symbols indicate that inspirations took place corresponding both to the direction of arm motion and to the change of bow, i.e. according to the rule valid for the respiratory rhythm (cf. p. 101). The legato passages proceed from the E-string to the A-string; approaching their conclusion they require the raising of the arm, with an increase for the transition to the G-string section. If one wishes to make respiration co-operate with the motion, one must be prepared to employ all possible means for their synchronized action. In this respect Hubay's edition is the least expedient:

(a) during the legato passages the inspirations—bound to occur, as shown by our experiments—will coincide with a lowering of the arm; (b) the first two quavers bearing a musical accent in the 2nd and 4th bars, respectively, will fall on an upward stroke. (The preceding three quavers are similarly inexpedient when played at the point.) Flesch's edition allows for slightly more economic breathing: (a) the three quavers are taken on one upbow stroke rendering inspiration comfortable; (b) the first two accented quavers in the 2nd and 4th bars, respectively, fall on a downbow stroke, i.e., for a possible expiration. (The preceding three quavers are played near the nut.) The version taught by Garay is an economic one: (a) the legato passage is taken on an upbow (a comfortable period for inspiration); (b) the right arm is allowed to rise to the G-string in an unbroken arc of motion and return to the E-string likewise; (c) the first two quavers in the 2nd and 4th bars, respectively, will be taken downbow (during an expiratory period).

The 'breaking' in the first two versions will render the performance more difficult without having any musical advantage, while the third version has the greatest efficiency both musically and technically. The analysis outlined here shows that the acceptance of physiological points of view facilitates violin playing, a point of importance in the case of compositions which require a thorough technical preparation and endurance. An abrupt breakdown, or unexpected deconcentration, may find its cause in a defective co-ordination of respiration with artistic motions.

CHANGES IN THE RESPIRATORY RATE, TIDAL VOLUME AND PULMONARY VENTILATION IN VIOLIN PLAYING

The physical and mental conditions necessary for violin playing are fulfilled more easily if the technique of respiration is adapted to the particular static and dynamic demands of violin playing. Economy would become an important factor, owing to the considerable load imposed on a performing artist by his daily exercise taking several hours, as well as by the concert recitals usually of about 2 hours' duration and interrupted by one interval only. In this section we wish to describe the changes in respiratory tidal volume, breathing rate and pulmonary ventilation per minute observed during violin playing. (In some of our experiments cardiac activity, too, was recorded.) There are three recognized ways of increasing ventilation: (1) to increase the number of breaths taken per minute while maintaining a constant tidal volume; (2) to increase the tidal volume at a constant rate of breathing; (3) to employ both of these means.

In our series of experiments we had to answer the following questions: (a) Do or do not the different respiratory parameters maintain their respective levels of rest? (b) If they do not, to what extent will the above-mentioned factors of ventilation tend to increase? (c) What conclusions could be drawn on an experimental basis for the sake of economy in violin playing?

The aluminium half-mask used in the previously described experiments was connected by a corrugated rubber tube to a spirograph to record respiratory gas exchange. Total length of the rubber tube and the internal tubing of the spirograph did not exceed 2·5 m. In this way respiration took place in a closed system. The necessary positive pressure required to the working of the apparatus was measured to be 6 mm Hg, thus respiration had a negligible resistance. The

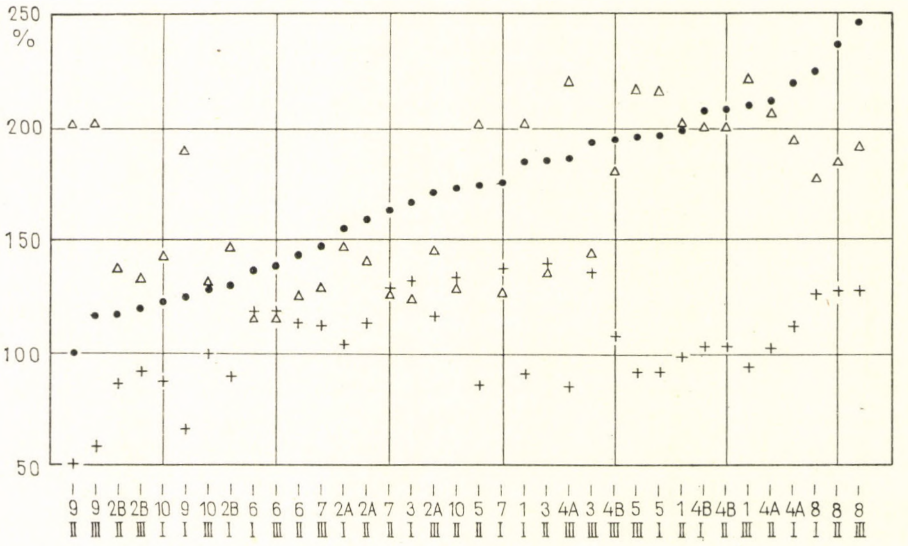


Fig. 89. Results in 36 recitals of Bach's composition arranged in increasing order of pulmonary ventilation; (△) respiratory rate, (+) tidal volume, (●) pulmonary ventilation

rubber tube ran towards the back of the subject so as to avoid any interference with his holding and manipulating the violin. The subject played standing upright. The studies were performed in the morning. The basal metabolic rate was estimated with the subjects fasting and lying supine. Then a determination of oxygen consumption followed while playing. The study took one and a half hours for each subject. The subjects were ten practising violinists of 18–42 years of age, 9 males and 1 female, of whom 7 were subjects participating in the previous series of tests, too.

In order to secure a basis for comparison with former results, the piece, played by each subject three times immediately succeeding, was again the Minuet movement of Bach's Solo Sonata No. 6. Besides this, one of the subjects played Paganini's Capriccio No. 13, and another played No. 17, which they repeated immediately three times on two different days, and four of the subjects played Veracini's Largo, likewise three times consecutively. We could thus compare compositions that differed in style, tempo, mood and technical difficulty. The pieces were played altogether 60 times by the ten subjects. As on previous occasions, the performances were recorded on tape. The pen of the spirograph indicated the start of inspirations, and these time points were marked by knocking at the microphone of the tape-recorder. As in the previous series, the particular bowing styles were indicated this time again in the subjects' score of the respective piece, together with the time the subjects inspired.

Evaluation was based on a comparison of the tape, spirogram and the score. The knocks on the tape indicating the inspirations were counted, marked in the score and compared to the number of inspirations found in the spirogram, recorded during the recital. In this way we could determine accurately the respiratory rate, tidal volume and the time-points of breathing for each note in the score.

The data observed during violin playing were compared to the values of respiration during rest. The results are shown in Figs 89–91. The 100 per cent mark on the vertical axis indicates resting conditions in order to allow a comparison of individual percentages. The consecutive recitals supply another type of internal comparison. The subjects are designated by Arabic numerals, the serial numbers of the repetitions by Roman numerals. The letters A and B indicate the respective recitals performed by Subjects 2 and 4 on different days.

As is noted in the graphs, violin playing caused an increase in pulmonary ventilation, if one disregards Subject 9's second recital of Bach's Minuet. The changes varied between 100 and 385 per cent, representing volumes of ventilation between 12 and 30 l. per minute. The upper limit of pulmonary ventilation was reached by Subject 4 in his 'A II' (333·5 per cent) and 'A III' (385 per cent) reprises of the Paganini composition only; the respiratory minute volume did not rise above 249 per cent of the resting level in the other subjects. Out of the 60 recitals 58 (96·6 per cent) required an increase in pulmonary ventilation, the maximum level of which was 249 per cent of the resting value. As shown in the diagrams, respiratory rate rises without exception in violin playing; it was by 112–287 per cent higher than at rest.

The depth of breathing (tidal volume) varied between 49–157 per cent, and in 15 recitals of the Bach piece, in 2 Paganinis and in 3 Veracinis it was less than at rest. It is noted, further, that the main factor in the increase in ventilation was a rise of respiratory rate. There were 49 'disproportionate' recitals (81·7 per cent). The recitals in which the increases in tidal volume and respiratory rate in percentages did not deviate more than by 15 per cent we classified in the category of 'proportionate increase'. In these cases the deviation amounted to 1–14 per cent. Ventilatory increase was found to be due to a

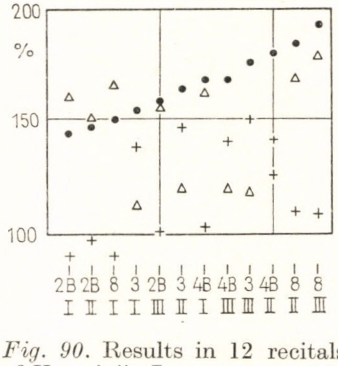


Fig. 90. Results in 12 recitals of Veracini's Largo arranged in increasing order of pulmonary ventilation; (△) respiratory rate, (+) tidal volume, (●) pulmonary ventilation

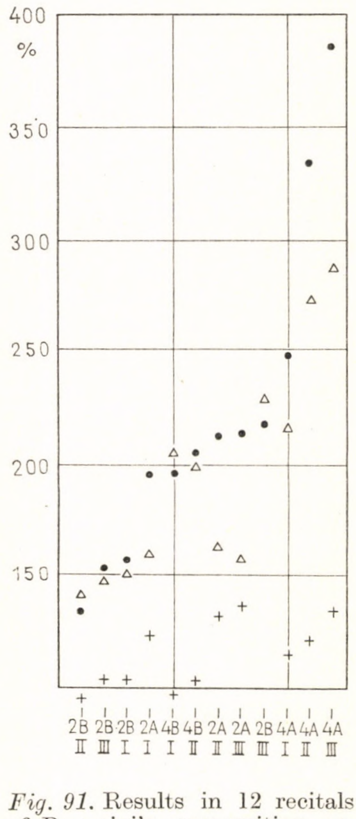


Fig. 91. Results in 12 recitals of Paganini's composition arranged in an increasing order of pulmonary ventilation; (△) respiratory rate, (+) tidal volume, (●) pulmonary ventilation

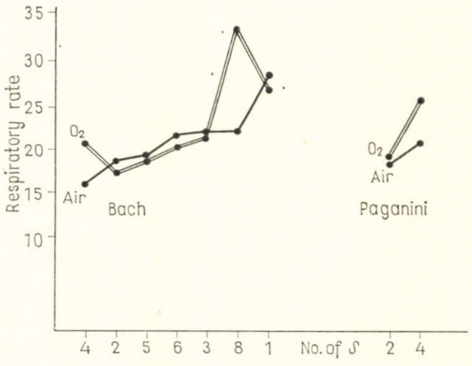


Fig. 92. Respiratory rate in breathing ambient air and oxygen, respectively

greater tidal volume in the three recitals of Subject 3 and in the last recital of Subject 4 only.

First of all, we have to consider whether the obtained results are valid also for breathing atmospheric air. In this respect we refer to two facts: (1) According to the literature on respiration (Böhlau 1955, Müller and Karrasch 1955, Arnold 1960, Anthony and Venrath 1962), at relatively moderate exercise loads, the curve of ventilation for breathing oxygen differs scarcely or not at all from that of breathing air. (2) In our previous series of respiratory rhythm study atmospheric air was breathed and we recorded the respiratory rate. In Fig. 92 we compared the respective rates of breaths in the seven subjects who participated in both series of tests. Each point represents the mean value of three recitals. It will be observed that the respective curves of respiratory rate run almost parallel for breathing oxygen and air. The rise in the respiratory rate is therefore not due to oxygen inhalation but a pattern of breathing peculiar to violin playing.

The results show that in 81·7 per cent of the performances the necessary excess ventilation was not matched by a proportionate change in respiratory rate and tidal volume respectively. The explanation may be found in the way the violin is held. The violin rests upon the left clavicle on which the regulated tonus of the trapezius and neck muscles as well as the weight of the head press down by way of the left mandible. This reduces systematic active participation of the left shoulder girdle in the respiratory movements, i.e. inspirations are confined to narrow limits in violin playing. This limitation is further aggravated, firstly, by left arm motions becoming fixed to the fingerboard as if secured by a splint, i.e. they have smaller area of movement compared to the right arm, and secondly, they occur in close proximity to the body in a plane unfavourable for respiration. This is the explanation for the fact observed in our previous series, viz., that respiratory rhythm is related to the motions of the right, and not to those of the left arm. The movements of the right arm also have a decisive influence on respiratory rhythm when the left arm and hand have to execute complicated and rapid movements over the whole fingerboard, as e.g. in playing the Paganini capriccios. A stiff and cramped holding of the violin apparently increases the impeding effect on respiration. It is likely to interfere with a fluent activity of the whole motor mechanism so that in some cases even audible faults of tone-production may occur, whereas a relatively well-balanced ratio of tidal volume and respiratory rate may relax a stiff holding of the violin and secure its elastic stability.

In some cases the rigidity of holding the violin is caused by psychic factors, such as stage-fright, deficient preparation, or unfavourable extraneous circumstances. Stage-fright might arise also from causes related to bodily constitution. Many artists struggle against stage-fright all their lives. Deeper respiration is a recognized means for calming down. Stage-fright may have to be overcome not merely during the first phase of the performance; it might arise again at unexpected mistakes or obstacles. Consequently one has to discover the method of using the respiratory control to defeat stage-fright. To take account of peculiarities of breathing may help.

We have observed far deeper than average respiration during the musical pauses (interrupted motion) of the Bach composition. The records show that in fact there are deeper inspirations at pauses required by musical articulation (called caesurae, breaks or hiatus by musicians). These pauses have the same role in music as those of speech between parts of a sentence or at punctuation marks. When the technical task demanded change of bow or string or multiple stopping for chords, similar events regularly occurred (Fig. 93). These deeper inspirations compensate to a certain extent for the hypoxic condition brought about by taking rapid and shallow breaths. Musical pauses depend on the content and form of the composition as well as on the musical conception of the artist interpreting it. The indirect influence of musical content and form exerted on respiration during violin playing is manifested by the pauses required in artistic musical interpretation and the opportunity to equalize oxygen debt. The timing of such deeper inspirations in order to obtain fluency in performing musical and motor tasks is by no means of minor importance. Deep inspirations will move the left shoulder girdle and so impair holding of the violin and the stability of violin playing. These in turn interfere with the security of the technical manipulation to come. These deep inspirations should not coincide mechanically with the musical pauses. In a composition which consists for example of smaller units (short phrases), this would result in hyperventilation and lead to disturbing effects. In regard to the method and technique of teaching the violin, it is advisable to outline in advance not merely the artistic points of the performance (articulation, phrasing, dynamics, etc.), but the suitable time for these compensatory inspirations as well, and engrave them by exercising them as dynamic stereotypes. By adopting this method, violin performances would interfere less with the vital demands of the organism. Oxygen debt would be reduced, and musical articulation would be supported by a physiological function. Without affecting the stability of the performance an ingrained respiratory pattern might be of help also in overcoming stage-fright.

An excess of technical difficulties in a composition is clearly revealed by the increase in respiratory rate and by breaths becoming shallow. Paganini's Capriccio No. 17 has a formal pattern of A—B—A. In comparison to the left one, the right arm moves slower and broader in Part A; in Part B, however, both arms have to perform extraordinarily swift and precise movements (octave passage to a short bow). The respiratory pattern recorded by the spirograph (Fig. 94) almost corresponds to a musical form analysis owing to the basic difference in the motion patterns of executing Parts A and B respectively.

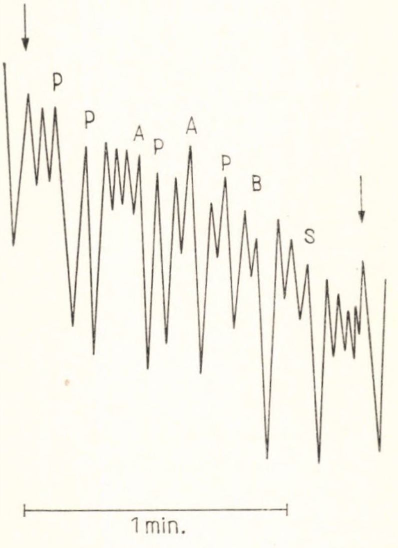


Fig. 93. Respiratory diagram of Subject 4 during the 3rd recital of the Bach composition, observation A; *A* chord, *B* change of bow, *P* end of phrase, *S* change of string

The manner in which pulmonary ventilation had changed during the consecutive performances appeared to be characteristic. Out of the 60 performances, the respiratory pattern was observed to be modified by Subject 4 alone, in connexion with the three Veracini recitals, and by Subject 10 on the second performance of the Bach piece. In all other performances the respiratory pattern of the first was retained. In two of the subjects, who had played the Bach and Paganini pieces in another test series as well, the dominant rate of respiration was the same as previously.

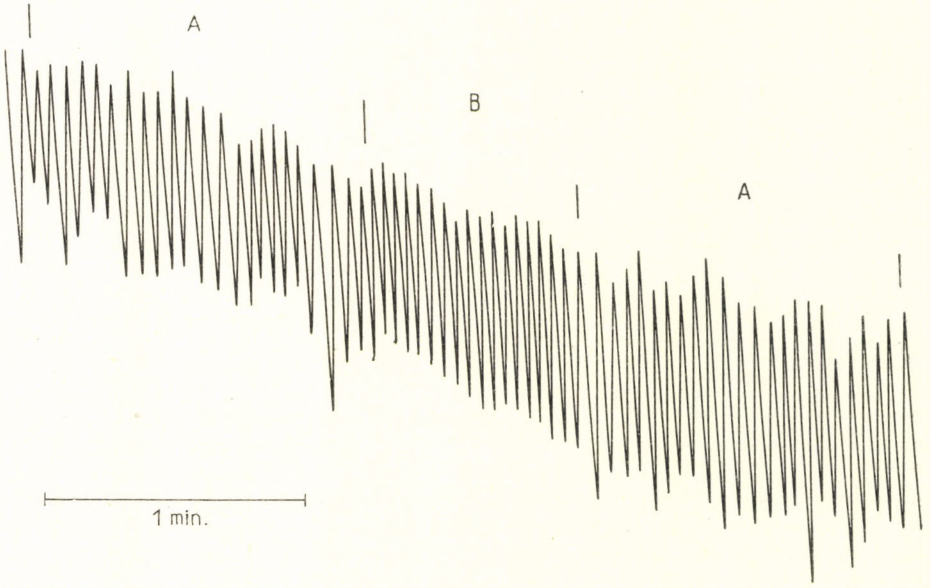


Fig. 94. Respiratory diagram of Subject 2 during the 1st recital of the Paganini composition; observation A

In respect of age and technical proficiency, the ten subjects differed greatly from one another. Nevertheless, the general principles of breathing did not change, either in the same or in another kind of music, i.e. they were apparently independent of the individual habits of the subjects. Respiration was modified only to the extent that the motion in the different types of music required it. We came to the conclusion that in playing the violin, that is, being engaged in a trained process of motion, the subjects developed a respiratory pattern that matched this process, the tendency of which was perhaps modified but not altered by the compositions. We have already mentioned that with the majority of our subjects the ventilation requirements incurred by violin playing were satisfied by a disproportionate increase in respiratory rate and tidal volume respectively. Breath frequency and volume of respiration grew proportionately only in 18·3 per cent of the cases. As a matter of fact, this proportionate increase was observed only during the performance of the Bach piece, requiring relatively slow arm and hand movements, and in Veracini's Largo, which had to be played with pronouncedly slow motions. So, holding the violin has a direct influence upon the rate of motion and of increase in ventilation.

On the other hand, the 10 recitals of Bach's Minuet that were accompanied by a proportionate rise in respiratory rate and tidal volume, have shown that up to a certain limit of technical difficulty it was possible to attain proportionality between the respiratory factors mentioned. With regard to economy, we have to consider this type of breathing to be the more favourable, since frequent and superficial respiration requires superfluous muscular work. According to Müller and Karrasch (1955) the expense of oxygen to maintain respiration amounts to 4–5 per cent of total oxygen consumption. An excessive increase in respiratory rate will therefore interfere with the economy of violin playing, and result in premature exhaustion. By prior planning of respiratory functions the performance on the violin of a piece may become easier both in respect of physiology and pedagogy. In those cases where indications of stiffness in holding the violin are discovered or an obstruction in the process of motion is shown by professional violinists or with pupils, it would be advisable to carry out similar studies on respiratory function to those attempted by us. The results of such studies (on rhythm, pulmonary ventilation, rate and depth of breathing, etc.) may facilitate the localization and correction of faults.

OXYGEN CONSUMPTION AND RESPIRATORY FUNCTION IN VIOLIN PLAYING

Oxygen consumption and energy production in playing music had already been studied by Loewy and Schroetter in 1926 on 15 subjects, one of whom was a violinist. It was, however, rather a matter of exploratory observation from which no conclusions for the practice and education of violin playing could be deduced. From the aspect of teaching methods the investigations are considered useful only if, in attempting to clarify the mutual relationship, they concurrently register the relevant motions and the performance as a whole or at least the characteristic features, and do not content themselves with the physiological parameters of the activity alone. This was why violin teaching could not use these pioneer studies to which we would return later. In 1928 similar investigations were carried out by Farkas and Geldrich in the field of organ playing. Though they had considered the effect of technique and difficulties encountered in playing the composition, the limited scope of their study (2 subjects, 6 performances each) permitted neither physiological nor pedagogical conclusions. This made it necessary to launch an experiment which would yield an opportunity to study the various phases of musical activity (e.g. the level of proficiency) over a longer period. In agreement with the pedagogical motive, efforts were made to elucidate the relationships between the respective factors of respiration and the technical–musical tasks of violin playing. Starting with the intention of making the performance correspond to concert conditions, we registered the movements of violin playing as well as of tone-production. In order to retain the specifically musical factors, the recording period was matched to the performing time of the piece. A further intention was to investigate various pieces of music, and to stress the specific factors in the rendering of compositions of varying technical difficulty and musical message. Accordingly the following questions were proposed: (a) Does oxygen consumption reflect the grade of skill, psychic condition or exhaustion? (b) Does oxygen consumption possess a pattern from which physiological and pedagogical conclusions can be drawn? The methods used have previously been described. The following supplementary notes are recommended.

(1) The 60 performances allowed the analysis of music of two hours' duration; this period would correspond to an evening of a violin recital. The shortest net time of playing was 3 min 26 sec (in the case of Subject 5), the longest playing period amounted to 23 min 34 sec (with Subject 2B). The latter subject played three different pieces of music, three times each, consecutively (for the various playing times see Table VII).

Table VII

Mean playing times in seconds

Composition	Recitals			Difference		Total
	I	II	III	I—II	II—III	
Bach	76·7	76·2	75·7	−0·5	−0·5	−1·0
Paganini No. 13	132·5	129·5	123·0	−3·0	−6·5	−9·5
Paganini No. 17	204·0	203·0	201·0	−1·0	−2·0	−3·0
Veracini	202·5	208·5	206·7	+6·0	−1·8	+4·2

(2) The consecutive performances were interrupted by breaks of 1·5–2 min. The Minuet of Bach was, however, played also without interruption.

(3) Pulmonary ventilation and oxygen consumption are presented in the respective figures and tables as percentages of the resting volumes per minute, partly because the changes in ventilation and oxygen consumption are better compared when using this dimension and partly because individual values at rest represent starting levels of equal magnitude.

(4) In comparing the oxygen expense of the respective performances (I, II, III) those values which have no greater deviation than ± 25 per cent are considered equal, whereas such values that have changed by more than 25 per cent are classified as increased ($<$) and decreased ($>$), respectively. This constitutes a variation range of ± 10 per cent in absolute data (ml). When allowance is made for the fact that Lehmann (1934) reported respiratory studies to have a variability of ± 5 per cent, our arbitrary limits may be calculated as constituting a realistic representation of the factual change. Deviations of less than ± 10 per cent fall in the range of physiological variability. Values beyond these limits are very likely to indicate changes in physical performance. In the 60 (20×3) performances 28 out of the 40 differences (70 per cent) were beyond these limits (Table VIII).

Table VIII

Rate of recital differences beyond $\pm$ 10% deviations

Bach	19 out	of 24	79·2%
Paganini	6	8	75·0%
Veracini	3	8	37·5%
	28	40	

(5) The changes in pulmonary ventilation and oxygen consumption are considered to be proportionate to each other only when the values, expressed as the percentage deviation from the resting level, do not differ by more than ± 25 per cent for the

relative data and one of ± 15 per cent if expressed in absolute numbers (litres). Accordingly, in comparing the sums of the absolute values we consider the changes of less than ± 25 per cent (for pulmonary ventilation ± 15 per cent, for oxygen consumption ± 10 per cent) proportionate. The results are shown in Figs 95–97, and in Tables IX–XI. Figures 95 and 96 illustrate the observations made in the 36 performances of Bach's Minuet, while Fig. 97 shows the Paganini Capriccios Nos 13 and 17, six performances each and the 12 performances of Veracini's Largo. The individual volumes of rest are indicated as 100 per cent on the horizontal-vertical co-ordinate. The respective subjects are indicated in Arabic, the three consecutive performances by Roman numerals; the three performances of subjects 2 and 4, which were repeated later, are indicated by letters A and B. In Figs 95, 96 and 97 the volumes of oxygen consumption per minute can be seen plotted in the percentage of the resting level. Figure 95 shows the unbroken sequence of the Bach performances, while Fig. 96 those interrupted by pauses (cf. Point 2 among the notes above). Let us now have an analysis of the results obtained.

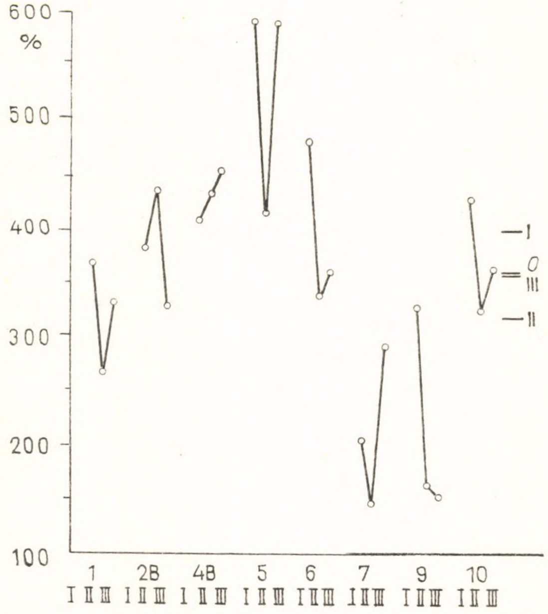


Fig. 95. Bach recitals. Increase in oxygen consumption in comparison with rest; I, II, III: mean values of respective recitals; *O*: over-all mean of recitals

(1) During playing oxygen consumption rose in all instances. The rise varied between 135 and 590 per cent of the resting level (180–1340 ml/min, the mean being at 261·7 ml/min). As shown by the totals of Table IX and by Figs 95, 96 and 97, the mean increase in oxygen consumption was 283·76 per cent in the 60 performances, in comparison with the level at rest.

The order of sequence of the pieces for the subjects who played pieces by different authors has always been: 3 Bach, 3 Paganini, 3 Vera-

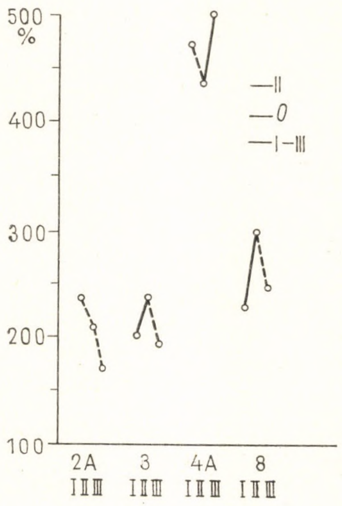


Fig. 96. Bach recitals. Increase in oxygen consumption in comparison with rest; full line: recitals with interposed breaks; dashed line: recitals without interposed breaks; other symbols as before

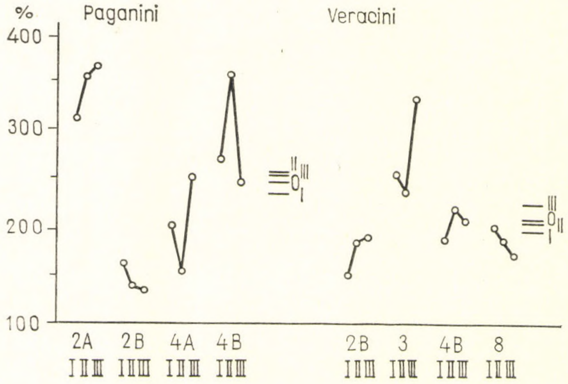


Fig. 97. Increase in oxygen consumption during the Paganini and Veracini recitals in comparison with rest; symbols as before

cini; for those who did not play Paganini it was: 3 Bach, 3 Veracini. The first piece played was Bach I in each instance; it required the greatest volume of oxygen, as shown. When the uninterrupted performances of the Bach piece are included, this level is not exceeded either by the mean value of the Paganini, or by the Veracini recitals.

(2a) As indicated in Table IX, and by the broken line in Fig. 96, continuous performance was always achieved with a lower oxygen consumption, even when pulmonary ventilation exceeded the upper limit of the optimal 249 per cent. In all subject groups tested the repeating of performance started from a higher level of oxygen consumption than an uninterrupted performance.

(2b) With regard to the oxygen consumption of the three consecutive performances six versions were found in the 48 performances that were played with interruptions (Figs 95 and 96).

(3) The mean playing time of performances I–III showed a remarkably small variation; they all decreased except for the Veracini piece.

(4a) In 58 of 60 performances (96·6 per cent) pulmonary ventilation rose at most up to 249 per cent of resting level. This level was surpassed only by Subject 4 during the performances indicated as Paganini AII and III (cf. the preceding section). In the 60 performances which were investigated the increases shown in Table X were noted (calculated from the initial values of ml per min). Thus on the average, violin playing brought about a 169·1 per cent increase in pulmonary ventilation in comparison with the level of rest.

Table IX

Oxygen consumption

Recital	Bach		Paganini	Veracini	Total
	with pause	no pause			
	percentages per min. calculated from absolute ml data				
I	382·23	284·71	222·44	192·97	294·61
II	307·68	301·58	235·96	203·99	270·85
III	344·76	284·72	232·98	217·00	285·83
Number of performances	24	12	12	12	60
Mean	344·89	290·32	230·46	204·41	283·76

Table X

Means of pulmonary ventilation

Piece	%
Bach	167·9
Paganini	215·1
Veracini	165·1

(4b) Considering the ratio of the respective increases in oxygen consumption and pulmonary ventilation we found even rates with all the three compositions of different difficulty and varying musical contents, during performances where pulmonary ventilation did not exceed the optimum increase of 249 per cent. In 24 of the 28 performances falling below this limit the increases in oxygen consumption and ventilation were within ± 50 per cent; in the 32 performances which were in excess of this level oxygen consumption and pulmonary ventilation did not rise proportionately (Table XI).

Oxygen consumption varies between broad limits (135–590 per cent of the rest level), both as regards individuals, and different recitals. Variation is independent of the musical content and technical difficulty of the pieces performed. In the violinist investigated, Loewy and Schroetter (1926) observed oxygen consumptions between 163 and 165 per cent compared to resting level. They noted, however, that in Vienna Schroetter (1922) also found levels between 185 and 225 per cent. These values are mostly lower than those found by us, although we, too, have observed individual data of this measure (see Figs 95, 96 and 97). The discrepancy may arise from the following facts. (a) The authors cited measured the resting levels in a standing position, whereas we recorded them in a supine position. According to Loewy (1926) and Müller and Karrasch (1955), in standing upright oxygen consumption is by 10 per cent higher than in lying, or even by 30 per cent, according to Rein and Schneider (1956) and Bykov (1947). On the other hand, in investigating organ playing, Farkas and Geldrich (1928) took the position occupied on an organ bench without a back-support as that yielding values in rest. (b) The discrepancy may arise also from the variation in proficiency, of which we will speak later on. The subject investigated by Loewy and Schroetter (1926) rendered Sarasate's Tzigane at an individual level of practising, so that in the absence of repeated performances and of other subjects this study offers no possibility to decide by comparison what oxygen consumption would have been if the piece had been played repeatedly by the same or

Table XI

Rate of ventilation and oxygen consumption

Piece	No. of performances	Ventilation < 249%				No. of performances	Ventilation > 249%				No. of performances by pieces
		Proportional		Disproportional			Proportional		Disproportional		
		perf.	%	perf.	%		perf.	%	perf.	%	
Bach	12	10	83·4	2	16·6	24	—	—	24	100	36
Paganini	6	5	83·4	1	16·6	6	—	—	6	100	12
Veracini	10	9	90·0	1	10·0	2	—	—	2	100	12
Total	28	24	—	4	—	32	—	—	32	—	60
Mean	—	—	85·7	—	14·4	—	—	—	—	100	—

other subjects. This seems to be the reason why the authors referred to their observation as being the lower limit of values obtained in practice.

By analyzing the effect of uninterrupted performance a better insight may be gained into the adaptive mechanism of autonomous regulation. Each of the uninterrupted recitals caused a marked decrease in oxygen consumption, irrespective of which two recitals were thus played. The initial excitement tends to decrease very likely owing to the warming-up effect. The state thus generated in the autonomous nervous system is helpful to the artist in overcoming technical problems in the piece.

We also had to provide an answer to the question of whether the degree of difficulty in each piece had an influence on oxygen consumption and ventilation increase. Among the compositions investigated the Paganini Capriccios are by far the most difficult from the point of view of violin technique. Bach's Minuet is technically more difficult but shorter than the song-like Largo of Veracini which, by having no chords or swift passages, needed slower and more uniform movements. Our results are at variance with the finding of Farkas and Geldrich (1928) in that they show oxygen consumption to depend only slightly on the grade of difficulty of the composition. It was Subject 2 who, playing Bach's Minuet IIB, showed the highest volume of oxygen consumption by consuming 1443 ml per min (during Performance IIIB, his consumption was 1085 ml per min). After a few minutes of rest the same subject played Paganini's Capriccio No. 17, a piece three times longer and incomparably more difficult, and consumed but 539 ml oxygen per minute. (In Figs 95, 96 and 97 one may find further similar instances.)

Oxygen consumption may rise also owing to an unexpected embarrassment encountered in the course of the performance. During the Paganini performance IIA, Subject 2 made a technical mistake, which he corrected without interrupting his performance. The faulty fingering recorded on the tape was accompanied by an immediate rise in oxygen consumption (Table XII). Although the young artist kept his presence of mind and did not apply for a rest before the third performance, the embarrassment caused by the blunder elicited a rise in oxygen consumption during the third performance. The third performance was flawless musically as well as in violin technique.

The marked oscillation of oxygen consumption should not be explained mechanically by an absolute grade of difficulty in the piece of music; not even the same composition is found invariably difficult. Several features characteristic of the personality of the artist combine to establish the subjective grade of difficulty:

Table XII

Effect of a faulty fingering on oxygen consumption

Recital	Intake of O_2		Increase	Total intake of O_2	Performance time	Intake of O_2 between 90th and 120th sec
	before fault	after fault				
	ml		%	ml	sec	
I	860	1020	—	1880	201	360
II	900	1300	44	2200	201	550*
III	900	1370	52	2270	201	520

* Mistake and consecutive correction at the 90th sec.

(a) the level of general skill and of physical fitness (proficiency in mastering the instrument as well as fitness in general and in particular); (b) the quality of specific practice in respect of the composition in question (to what extent is the piece mastered by the player); (c) the extent of physical and mental excitement resulting from, and related to, the performance, and the ability to overcome this excitement.

Any effort to determine objectively these three factors is faced by fairly great difficulties. At present, judgement relies merely on the tune produced, i.e. on a musical basis, a fact that has often regrettable and surprising consequences at examinations as well as in concert recitals: pupils or performing artists who may seem to have been well prepared from a musical point of view, sometimes display an incomprehensibly and unexpectedly poor performance. In our opinion this can be put down first of all to a lack of physiological economy in the motor process of the performance. The performances of a composition for which oxygen consumptions differ by three and a half times from each other can obviously not be considered equally economic. Though an artistic performance is not judged by its economy but by its aesthetic effect, the energetic demands of a performance lasting about two hours are evidently affected by the oxygen requirements of the respective recitals. At a concert performance it is possible that before or after the pieces like the ones investigated, other compositions may have also to be presented. Thus, the concert performance may be taken as an endurance test, perhaps to a much greater extent than practising for it, since in the latter case the player himself can decide the duration of rest periods. Premature exhaustion during a concert performance has its due consequences: one, if not more, of the pieces performed will not attain the required standard. Thus, economy (even if this category were thoroughly 'unmusical') may be decisive for the success or failure of an artistic recital. By analyzing the deviations found in the three consecutive recitals, some conclusions may be drawn from our results in respect of the efficiency of a performance. Müller and Karrasch (1955) pointed out that a brief, uninterrupted exertion is more fatiguing than a longer work that is interrupted by short pauses, even if the latter added up to a greater total. Our results confirm this assertion. During the Veracini Largo the oxygen consumption exceeded the ± 10 per cent deviation range in only 3 cases, whereas it did so in 19 of the shorter Bach recitals and in 6 of the far more difficult Paganini Capriccios (cf. p. 112). A closer scrutiny on analyzing Table IX showed that (as is usual in sports performances) objective and registrable signs of 'start-fright' were manifested in the starting phase. The recital of Bach I, which was played always at first, revealed invariably a higher mean level of oxygen consumption; 6 of the 8 non-consecutive renderings of Bach I had a higher oxygen consumption than those of Bach II. In 5 instances oxygen consumption was higher than even in Bach III (cf. Fig. 95). The types of oxygen consumption observed during the three performances and described under point 2b of the results may be characterized as follows.

(1) I $>$ II $<$ III. The higher level of Performances I indicate the existence of start-fright. By the lower level of Rendering II the subject reveals his ability to adapt swiftly. On the other hand, Rendering III is indicative of a lability in adaptation and of an early exhaustion. This is a type of labile performance.

(2) I $>$ II $=$ III. Adaptation develops rapidly and becomes stabilized at a favourable level; a type of stable performance.

(3) I $<$ II $=$ III. The relatively marked state of excitation at the beginning continues, adaptation is poor, oxygen consumption remains at an unfavourably high level. Another type of stable performance.

(4) I $<$ II $>$ III. The initial state of excitation tends to increase and, due to the sluggishness of the adaptive mechanism, adaptation is induced to move only at Performance III. That we may still speak of an adaptation is shown by the I $>$ III pattern encountered in both cases. Another type of labile performance.

(5) I $=$ II $=$ III. The autonomous nervous tonus observed during the first Renderings I, II and III is maintained relatively evenly (the respective performances deviate from each other by less than $\pm$ 10 per cent). Evaluation can rely only on a comparison of the levels found in Performances I and III. The two instances encountered lack the tendency for stabilization. The values for both Performances III are already in excess of the $\pm$ 10 per cent deviation limit and display a definite trend. For the latter, a decreasing tendency—which leads to a continuous performance (Type 7 below)—is preferable, whereas an increasing one (Type 6) is unfavourable. Principally a type of stable performance.

(6) I $=$ II $<$ III. The initial excited state is maintained, but it is labile, because Performance III brings about a further elevation in oxygen consumption. As the equilibrium of Rendering II is not retained, we are confronted with a type of labile performance.

(7) I $>$ II $>$ III. This type was most conspicuous in the uninterrupted performances. (Within the range of physiological extension, the same could be discovered also in the Bach recitals of Subject 9, in the B recitals of Paganini's piece of Subject 2, and in the Veracini performance of Subject 8.) The gradually improving adaptation tends to stabilize at a preferable level; in this case we have to do with a performance of the stable type.

From the seven varieties we conclude that the recorded series of respiratory gas exchange were either stable or labile. The dynamics of the gas metabolism corresponded also to the aesthetic evaluation of the musical performance recorded on the tape. In this way the purely subjective judgement of artistic performance was given certain objective support. Though they did not occur in our test series, out of the theoretically possible other varieties a Type I $<$ II $<$ III (let us call it Type 8) may be considered stable but poor, a Type I $=$ II $>$ III (let us call it Type 9) favourably labile. Although we have seen indications for a trend of Type I $<$ II $<$ III, none of the performance series was quantitatively classifiable as such (so, for example, Performances Bach 4B, Paganini 2A and Veracini 2B). From the absence of Type I $<$ II $<$ III it may be inferred that the performers were of a higher standard in technical skill and actual fitness than expected in this type. Type I $=$ II $>$ III is, as a matter of fact, a variety of Types 4, 5 and 7; in respect of the quantitative factors, it should be evaluated in a similar manner as these.

In spite of the relationships noted it must be emphasized that we are still up against considerable difficulties in an exact determination of the physiological basis of power output, and so also in assessment of economy and reliability of the performance. This is in contrast with the field of work and sport performance, since we generally lack adequate functional tests by which a performer's activity might be effectively judged. Our results nevertheless justify certain considerations. In addition to oxygen consumption, the economy in breathing is known to be influenced also by the respiratory work and its indices such as respiratory rate, tidal volume and pulmonary ventilation, all of which are necessary for the supply of oxygen. For instance, excessive hyperventilation cannot be taken as economic, particularly not if we note that in violin playing ventilation increases are brought about by a rise in respiratory rate which demands muscular work (cf. the preceding section). Economy (also in a 'recital-ripe' performance) is characterized by the co-existence of several conditions in connexion with ventilation and oxygen consumption. Among these the oxygen consumption of Recital I is fundamental, since it affects the magnitude of further changes to a certain extent. Some of the distinctive features of an economic performance are as follows.

(a) The oxygen demand of Recital I does not exceed 250 per cent of the consumption at rest. In this case we may expect a well-balanced respiratory activity. A higher value indicates an intensive initial excitement in addition to those mentioned earlier; in subsequent recitals, particularly in the case of impending exhaustion, it is relatively seldom that it decreases to a continuously preferable level. There is no instance of it.

(b) A I $>$ II change in oxygen consumption suggests an ability to adapt rapidly. This is to be preferred in any case, even when oxygen consumption in Recital I has been unfavourably high in comparison with the level at rest.

(c) A performance of Type 3 or 4 indicates a sluggishness of adaptivity and is a disadvantage for the recital, even when Recital I started at a favourably low level, and particularly so if an already high initial level rises further, as e.g. in the case of Recitals Bach 2B and Paganini 2A. (The critics will describe the former case as "overcoming the discomposure of the first minutes, the artist could . . . ")

(d) By relating Recital II to III, further information may be gained on the adaptive process, but also on the signs foreshadowing exhaustion. When oxygen consumption was as high during Recital III as it was during Recital II, it pointed to the fact that adaptation did not improve; had it risen, we should have to suspect exhaustion. It is especially suggestive of exhaustion if the oxygen consumption of Recital III exceeds that of Recital I as for instance in the case of the Veracini rendering of Subject 3: adaptation did not improve (I = II), on the contrary, oxygen consumption rose even above the level of the first recital (I $<$ III, II $<$ III). We must note, however, that exhaustion in this sense cannot be identified with the signs of fatigue in everyday life. Following the symptoms of initial tiredness as observed by us, physiological mechanisms are set in motion and make these signs of fatigue disappear, so that the artist may continue his recital in an adequate physical condition.

A 'reliable' performance requires certain autonomous stability, the extent of which may be judged by the findings of the three consecutive performances. The types of performance which we consider favourable take a decreasing, or at least an even, course of consumption of oxygen, and attain it at not more than 250–260 per cent of the level at rest. A rendering of Performances I, II and III in this manner suggests that the performer could overcome his initial excitement and has obtained control over the composition. Slightly less preferable are the types of performance in which the level of consumption is higher in comparison with Performance I, but at least remains constant on later repeats. These categories represent performance types of favourable and of developing stabilities. The performance types which show continuous or gradual increase in oxygen consumption as well as the labile, oscillating, type are unfavourable. The latter is not favourable, even though the oxygen consumption of Performance

II was lower than that of Performance I, if during III a further increase is noted, since it indicates an early exhaustion.

On summing up it may be said that Performance Types 2, 5 and 7 and Type 9 are favourable; Type 4 is less favourable, while Types 1, 3 and 6 as well as Type 8 are unfavourable.

As to playing times, only very slight deviations were noted in the values observed (cf. Point 1 among the notes on results and Table VII). This is considered indicative of the stability of the senso-motor stereotypes of violin playing and may be explained by a high degree of proficiency. From the almost uniform duration of the performances, observed in 8 of the 10 subjects, one may draw conclusions about the actual proficiency in relation to the composition. The performer's effort to render the composition in the musically prescribed tempo may be revealed by his striving to secure oxygen requirement even at the cost of a higher energy expense. One is led to believe this fact to be the reason for the lack of correlation between playing times and oxygen consumption, and the changes in pulmonary ventilation respectively; so, for example, in Subjects 1 and 6, who took the same time to play the Bach movement in all three instances, as well as in Subject 2 during the Paganini recital, where we noted consistently divergent values of respective oxygen consumptions.

We have already pointed out in the preceding chapter that respiration during violin playing is limited. The hindered participation of the left shoulder girdle in respiratory movements is the reason why a rise in pulmonary ventilation comes about mainly by an increase in respiratory rate. Another finding, namely that except for two extreme cases pulmonary ventilation rose to only 249 per cent of the resting volume, irrespective of either the musical content or the technical difficulty of the composition, is possibly also explained by that fact. In the two extreme cases, too, the rise in pulmonary ventilation was brought about by a disproportionate increase in respiratory rate.

In evaluating the increase in pulmonary ventilation it will be seen that the values observed by us (165·1–215·1 per cent) are closely comparable with those found by Loewy and Schroetter in 1926 (157·7–184·2 per cent). Since these authors did not perform their examinations serially, they could not estimate the dispersion of ventilation data. According to the literature on the subject (Lehmann 1934; Böhlau 1955; Arnold 1960), pulmonary ventilation rises proportionately to oxygen consumption, to a certain upper limit. As seen in Table XI, this happened in the 28 recitals during which ventilatory increase did not exceed 249 per cent. On the other hand, in the 32 performances during which this level was exceeded, the respective rises in oxygen consumption and pulmonary ventilation were no longer proportionate.

As to the limitation of respiration during violin playing, the limit seems to be set at 250–260 per cent of the resting value. If the performance of a piece requires a considerably higher oxygen consumption than this limit, be it for psychic or motor causes, supply deficiencies are bound to occur, and a sustained performance is likely to fail. Thus the expectancies of a performance can be outlined fairly well: when the performer is unable to play the selected composition below this limit of oxygen consumption, he does not possess the physical fitness (in a broader sense) for a secure rendering of the piece. Accordingly, it is during practice that the oxygen consumption level has to be adjusted to performing of longer compositions, such as those investigated by us, in order to allow a performance of duration even in case of unexpected obstacles.

High technical requirements in the composition are supposed to influence the mutual rate of respiratory functions and oxygen consumption. Hyperventilatory phenomena were observed by us in one of the 12 performances of Veracini's Largo, in two of the 36 performances of Bach's Minuet and in four of the 12 performances of Paganini's Capriccios. The extent of hyperventilation was relatively small in the two pieces mentioned first, and fairly large in two of the four Paganini performances. This corresponds to a mean increase in ventilation of 168 per cent in Bach's Minuet, of 165 per cent in Veracini's Largo, and to 215 per cent in the Paganini Capriccios (cf. Point 4a among the notes on the results). Technical problems require a greater stability (fixation) in holding the violin and restrict respiration still more. In relation to the extent by which the degree of proficiency can counterbalance the difference in problems as to the respective compositions, it may be stated that among the least practised Bach performances only 27·8 per cent showed a proportionate rise in oxygen and ventilation, while in the Paganini pieces the same amounted to 41·7 per cent. Veracini's Largo required no actual practice; if the performer had played it once previously, he could execute it adequately after one more repetition.

VIOLIN PLAYING AND CARDIAC FUNCTION

By means of a complex method (see Stadler and Szende 1968), the dynamic variations of the cardiac function were continuously recorded during violin playing in the preliminary experiments; when only scales and common chords had to be sounded, nothing but the heart function was registered, whereas in the main test, while playing Bach, Paganini and Veracini compositions, the respiratory functions and the gas metabolism were also studied.

Individual examinations were emphasized as the analysis of the solo play was considered most important, owing to its educational adaptability. Connections between the physiological indices and the music played were studied. Among the respiratory functions, the relation between respiration frequency and pulse frequency variations seemed much more intensive than that between oxygen consumption and pulse frequency variations; in 8 cases out of 12, a parallel increase in variation could be recorded. There was a correlation between the variation of the pulse frequency and the physical as well as psychic stress during performance. It can be inferred that (a) the average extent of the pulse frequency increase can be closely related to the physical loading; (b) the emotional fluctuation of the psychic stress was reflected by the dynamic variation of the pulse frequency.

During the preliminary test gamut and common chord sounding hardly gave rise to any emotions in the player; still, there was a correlation between the melodic line of the common chord play and the increase in the pulse frequency variation, which appeared rather significant. This correlation was found even more significant between the melody of the music played, its variation, and the variations of the pulse frequency, during the main test.

CONCLUSIONS

On the basis of our investigations we have arrived at certain conclusions concerning the effects of all the above factors on both teaching and performance.

(a) It is not advisable to disturb or stop the pupil by interjections (such as "Wrong! Careful about that bow?!" etc.). Instead, the teacher should make a note of his remarks, and discuss it with the pupil after the latter has finished his performance; if necessary he can request him to repeat it.

(b) The pupil should be encouraged to continue and not to stop his playing even though he has mistaken a fingering. He must acquire the habit of finishing his performance of a piece of music already during the lessons; this will cause less embarrassment when making a mistake even on the concert platform.

(c) Sight-reading performance (prima vista) demands rapid concentration and adaptability; during instrumental lessons this skill ought to be encouraged more systematically than is customary nowadays.

(d) In regard to artistic performance, our inquiries registering the course of oxygen consumption, respiratory functions, motion and tone-production at the same time, have given the opportunity for a more accurate determination of physiological changes and causes than attainable otherwise by customary methods.

On the basis of physiological indices certain inferences may be brought to light which would contribute to greater efficiency, not only in violin teaching, but also in instrumental pedagogy as a whole. The methods evolved apply to estimate physiological exertion not merely in playing musical instruments, but also generally in skills that are to be acquired through a senso-motor process of learning. The task of making methods of measurement and evaluation more accurate is left for further research.

Chapter Four

NERVOUS CONTROL OF INSTRUMENTAL PERFORMANCE

CENTRAL NERVOUS SYSTEM AS A CONTROLLER

A living organism must constantly adapt itself to the continuous change in environmental conditions in order to survive. The ability to do so requires excitability. In living structures this is manifested by the functional, morphological and chemical responses to commensurate stimuli, i.e. a living organism responds to stimuli. This fundamental process is the essence of adaptation that man, an organism of the highest order, has developed. The most sensitive, responsive and specially differentiated organic system among all others, i.e. the nervous system, is given the principal part in such adaptation. The nervous system is therefore the most important organ to control the intricate and complex mechanism of the adaptation that is indispensable for survival. The reception of the stimuli of the environment, of their processing to give adequate responses, is the duty of the sensory system. Sensory functions analyse the stimuli coming from the environment and integrate them. This analytical integration is followed by giving corresponding, economic responses, i.e. responses that secure survival at a relatively moderate expense of energy. Most frequently the response consists of a movement, of the activity of the motor apparatus. Only as a whole is the organism capable of responses, viz. avoiding danger and securing the supply of factors required for its functioning, i.e. nourishment; hence senso-motor activity is manifested as a uniform whole.

Among living creatures it is man who is in possession of the most developed and intricate nervous system. Characteristic of the latter is the ability to select from among the flood of sensory stimulation of the environment those that are most important for the individual, and to respond them in a suitable manner. First in order of importance comes filtering appropriately and arranging stimuli, then preparing the right response, and finally, carrying out this response. The nervous system of man is, however, capable of doing more than merely adapt. After becoming acquainted with the environment through his highly developed receptive and analyzer system he is able to transform this external world actively. The operation of this high-grade organization and function, which surpasses out of all proportions the capacity of the best developed animal, is not bound to the peripheral structures of the nervous system. The receptors, the sensory endings screening the external stimuli, scarcely differ from those in higher animals. Roughly the same is valid for the spinal motor structures. The main difference lies in the higher sections of the central nervous system, above all in the brain, which has developed in the human nervous system the highest structural and functional perfection existing in the realm of life.

NEURO-ENDOCRINE REGULATION

The system of endocrine (hormone producing) glands is of paramount importance for the adaptive functions of living organisms. These glands participate in the vital processes by producing hormones, and discharging the glandular secretion into the blood stream. In other words the hormones affect our vital functions by a chemical route.

There is a close interconnexion between the two mechanisms of control, the central nervous system and the endocrine organs. The central nervous system exerts an influence on the endocrine glands, enhances or inhibits their activity; in their turn the hormones re-affect the nervous activity. The main duty for both systems of control is the maintenance of the constancy of the internal environment (*le milieu interne,* Claude Bernard 1856), in spite of the constant change in the external world. The neuro-endocrine regulation is, therefore, of the highest importance to the adaptivity of the organism. Behavioural responses are not governed by the influence on the actual state of the nervous system alone of the external conditions, but through the hormonal effects exerted on the nervous system as well. The endocrine factors have a complex influence on the nervous system in that they elicit both quantitative and qualitative changes in it (specific adaptation). Together with other complementary mechanisms, neuro-endocrine regulation maintains the relative constancy of the internal milieu while resting. During the variable periods of the senso-motor and autonomous activation it strives to re-establish the state of resting (homeostasis) of the internal milieu.

The conditioned reflexes (see later) are involved to a greater extent in the hormonally elicited enhancement of activity than unconditioned ones are. In this connexion the research work of Lissák and his associates is of importance (Lissák and Endrőczi 1960). They have shown that environmental conditions, the succession of reflexes, have a significant part in the aforementioned process. Their investigations suggest that among the hormones affecting higher nervous activity, the hormones of pituitary gland and of the adrenal cortex possess an important function, and that corticoids play a principal part in the initiation of conditioned reflexes.

Hormonal regulation has a significant influence also upon the emotional side of behaviour. Lissák and Endrőczi (1960) have shown that the adrenohypophyseal system as well as the gonadal glands can produce aggressive behaviour, for example, or in another combination they can abolish it. The authors have demonstrated further the existence of a connexion between adrenal function and Pavlovian internal inhibition, to which we shall return later. The excitatory and inhibitory processes of the central nervous system are thus in relationship with the adreno-pituitary system. According to their data, conditioned reflexes depend on the type of higher nervous pattern, provided that the hormonal influence is identical. They obtained responses of greatest intensity in sanguine and choleric types (for details see Chapter Five).

The analysis of biological processes has increasingly led to the conclusion that the activity of endocrine organs is maintained by environmental stimuli, and that these stimuli are mediated by the central nervous system. A great number of data confirm the leading part of the central nervous system under the control of endocrine organs. Summarizing the above it may be stated that simpler autonomous functions and intricate psychic events are based alike on the principle of neuro-endocrine adaptive processes.

During violin playing the autonomous organs also become excited; they display a more intense activity, the beginning of intensified functions precedes the performance (e.g. stage-fright), which continue being intensified for a while even after the end of performance. The data reported in Chapter Three on the experiments designed to investigate the relationship between violin playing and respiration have confirmed the same fact.

The nervous system includes mechanisms that do not merely elicit the higher level of activity, but also secure the restoration of original resting conditions. Various feedback systems serve this end. The function of the hormone-producing glands plays an important part both in the increase in autonomic activity and in the restoration of repose. Neuro-endocrine regulation, as stated above, is closely connected to senso-motor activity. We must emphasize this since, according to our present purpose, we shall deal with the latter in greater detail on subsequent pages. Nevertheless, in analyzing nervous functions its linkage to endocrine functions of the organism must always be kept in mind.

SOME BASIC PROPERTIES OF NERVOUS FUNCTION

Higher nervous activity rests on elementary nervous functions. A typical elementary process is the reflex already mentioned, in which sensory (receptor) excitation is connected to the effector functions of the execution. In view of our subject we are, first, interested in those reflexes that connect simpler or more complicated receptors to the musculature directly or through transmissions. These are the motor reflexes. Some are inherited: without previous learning these become operative whenever the respective receptor of the reflex arc is excited by the stimulus necessary for its operation. These reflexes are called unconditioned, since their function does not depend on previous conditioning. The reflex is materialized through the reflex arc consisting of nervous tissue. The stimulus excites the receptor, the sensory ending evolved for its reception; next, the excitatory discharge is conducted by the nerve fibres (the afferent pathway of the reflex arc) to the central nervous system. Here excitation propagates either directly or through transmissions to the nerve fibres leaving the central nervous system (the efferent pathway of the reflex arc), which activate the specific nerve endings, the effector. The latter transmits its excitation to the muscle fibres. The parts of the reflex arc are receptor, afferent pathway, central nervous part, efferent pathway and effector. The reflex mechanism is an elementary form of the nervous activity. In the pattern of motions two simple reflex types have an important part: the stretch reflex and the flexor reflex. The stretch reflex is thrown into action when a muscle is exposed to a rapid stretching effect. This makes the tension in the muscle increase: the muscle resists its extension. The mechanism of the reflex is the following: the receptors in the muscle (muscle spindles; see later) are excited by the stretch stimulus and forward their charge through the afferent (centripetal) nerve fibres towards the spinal cord. At this point excitation is directly transmitted to the motor neuron of the same muscle which elicits muscle contraction by its effector. In other words, the muscle behaves as if it were exciting itself; accordingly, we call this elementary motor reflex also myotatic. Myotatic reflexes have a fundamental physiological significance. Owing to these reflexes the joints are firmly fixed and body posture maintained against accidental effects. They participate in restoring body posture. Basic tonus, the tension persistent in normal muscle, is also attributed to the myotatic reflex. The stretch reflex is therefore a mechanism to assist the fixation of limb joints. Its inverse, according to its name, the flexor reflex induces a flexion in the joints of the extremity. By tickling the sole slightly a flexion of the plantar arch occurs; in case of a more vigorous stimulation the synchronous flexion of ankle, knee, and hip draws the limb away from the disagreeable source of stimulus. According to its elementary form the stretch reflex is the primitive motor mechanism of limb stabilization, the flexor reflex is that of limb motion. By acting in close mutual relationship these reflexes constitute reflex combinations, and exert their influence accordingly (Fig. 98).

In a healthy organism reflexes do not act in an isolated manner, but they pass on to, spread over, other reflex arcs. Spreading of excitation is made possible by the large number of terminations connecting the neurons. In the ventral horn of the spinal cord, for instance, each nerve cell (motor neuron) is exposed to the effect of about 1000 nerve terminations arising from other neurons; in its turn the motor neuron affects a great number of other neurons by its impulses (Fig. 99). Thus, for instance, it can be demonstrated that not merely the muscles of fingers and arm are thrown into action in violin playing, but owing to the diffusion of excitation distant muscles also increase their tension. The irradiation of excitation just outlined may become, however, increasingly restricted by training and by increasing perfection of muscular function in general. Less and less of such muscle fibres that have no direct part in the execution of the specified movement are excited and excitation concentrates on the muscles participating in the motor act itself.

Motor activity is thus endowed by economy, consequently the symptoms of fatigue occur later. In the background of the phenomenon we find another funda-

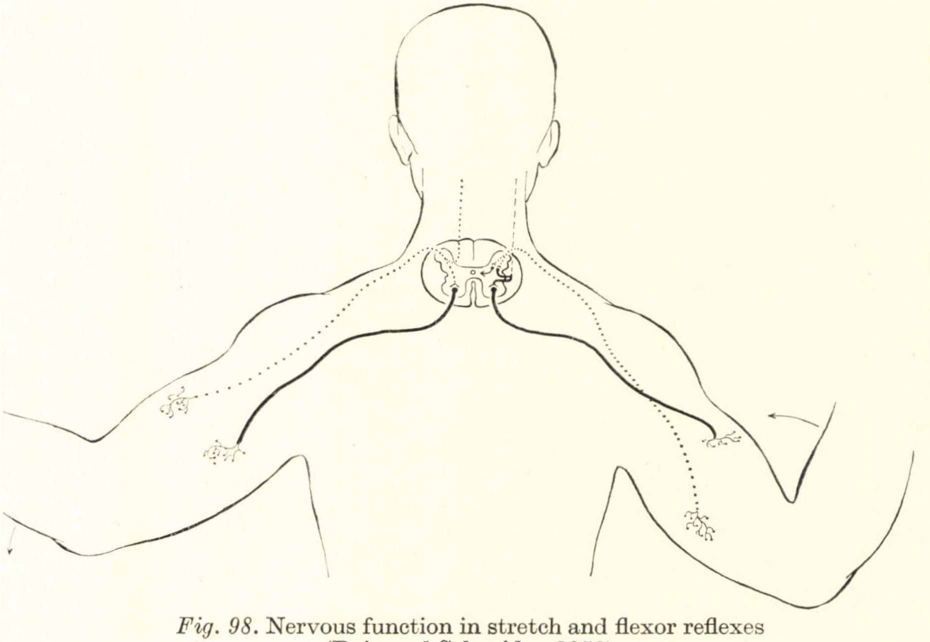
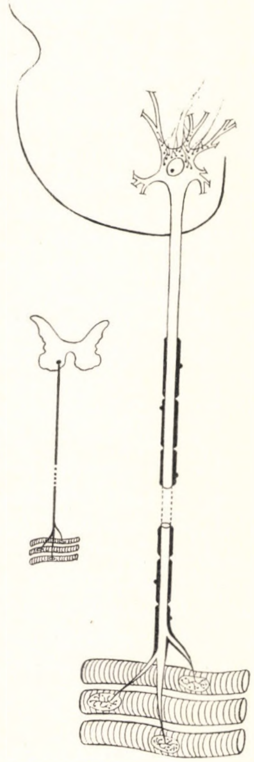


Fig. 98. Nervous function in stretch and flexor reflexes (Rein and Schneider 1956)

Fig. 99. Motor neuron. Motor cell, some adherent free endings, own short dendrites and the long axon connected to the motor end-plates in the muscles (Rein and Schneider 1956)



mental physiological process, that of inhibition. Undue diffusion of excitation is limited by it. Inhibition is indispensable with the motor act and with the efficiency of nervous processes in general. Were it absent, the incessant barrage of stimuli would cause chaotic responses by the unrestrained diffusion of excitation in the nervous system. This is why a concurrent existence of several excitatory and inhibitory processes is observed in the central nervous system. A state of central excitation is disclosed by the fact that the charges travelling through the synapses (the terminal knobs of nerves) interconnecting the respective neurons (which as said above are the elementary functional units of the nervous system)bring about a change which enhances synaptic excitability and facilitates the transmission of subsequent impulses. This may take the form in which weak stimuli, which would be otherwise insufficient to cause excitation, become effective by occurring successively or concurrently or enhance the excitatory state already in existence. This higher level of sensitivity is called facilitation, and is an important means of activating the nervous system. The opposite process of excitation, namely inhibition, also present in the central nervous system, is called central inhibition. Weak inhibitory impulses may be inefficient when arriving alone, but as with facilitation, when they support one another, they elicit manifest inhibition. In the central nervous system the excitatory and inhibitory processes are constantly at work; they combine, and even condition one another.

PROPAGATION OF EXCITATION, NEURON CIRCUITS

Excitation is propagated in the nervous system by transmission: one elementary unit of function, neuron, transmits its excitation to another. The sensory impulse is transmitted to the motor neuron by the sensory neuron; the transmission is, however, rarely direct (stretch reflex). Excitation mostly passes through a long chain of interposed neurons, called internuncial. The discharge may take its way along several possible routes: various pathways constituted by neuron chains of different length may convey it. Thus the impulses discharged by one neuron may arrive at the motor cell at different times. Since the neuron chains have cross-links to one another, excitation is conducted not necessarily along the shortest direct route, but may reverberate in the neuron circuits of this network. This results in a process in which the charges reverberating in the neuron circuits impinge several times consecutively upon the motor neuron, and subject it to a barrage by repeated excitation. There are various mechanisms to prevent the risk of one impulse eliciting sustained activity, perhaps even cramp-like contraction. The transmission of a single discharge that fails to activate the motor neuron, and so the contraction of the muscle does not occur, belongs to the same phenomenon. Finely graded movements, too, are generated in a similar manner; viz. the motor impulses arriving from higher levels of the nervous system cannot excite the motor neuron until the feedback signals return to the alpha cells (motor cells).

Another means to restrict an excessive diffusion is what has been outlined before, viz. central inhibition which excludes certain nervous pathways from the propagation of impulses. In the ventral horn of the spinal cord certain small nerve cells are found which emit directly inhibitory impulses. In the cerebral cortex there are whole areas whose discharge has a directly inhibiting influence.

Impulse propagation and neuron circuits are illustrated by schematic drawings. Figure 100 shows how the impulse of one neuron may be transmitted to three others as well as the propagation along neuron chains. We owe this conception as well as that of neuron circuits to Lorento de No (1938). In Fig. 101 the released charge returns to the emitter neuron after having passed two others, and excites the former once again. On the other hand, instead of being boosted to increase like an avalanche, the discharge may become extinguished along the way, as is seen in Fig. 102. Of the four chains depicted only that one may propagate excitation along which two impulses were received by each neuron, while in others propagation is extinguished. Of the innumerable input impulses only those which encounter suitable excitatory conditions will be selected for propagation. In regard to the vast number of input impulses flowing incessantly towards the central nervous system, it is said that firstly the neurons are subjected to inhibition, excitation being restricted to a small fraction of them.

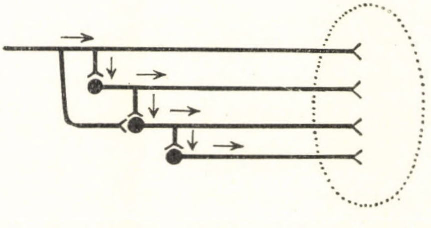


Fig. 100. Scatter-type neuron circuit; each neuron transmits excitation to several others through the branches

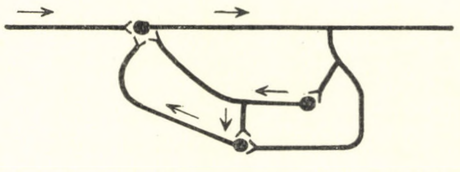


Fig. 101. Closed neuron circuit; excitation returns across internuncial synapses to the neuron originally excited and modifies its excitatory state

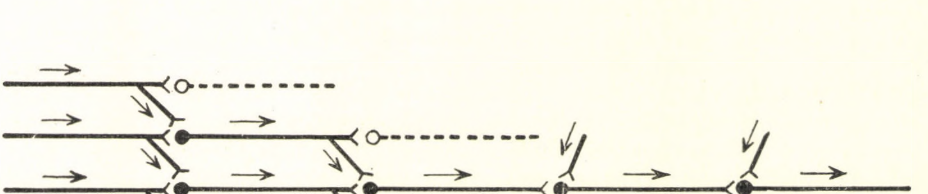


Fig. 102. Occlusion-type neuron circuit; excitation is propagated only by neurons twice excited, thus the excitation propagated by several neurons converges to one pathway

NEURAL ORGANIZATION OF SENSORY FUNCTION

The task of sensing and processing the stimuli coming from the environment, of elaborating an adequate response, and finally, of executing this response constitute an intricate problem. It is tackled by the sensory and motor part of the central nervous system, and this requires complex action.

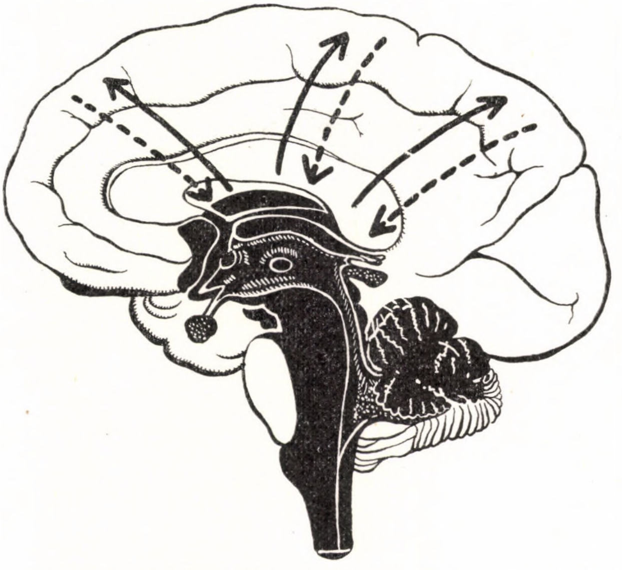


Fig. 103. Relationship of the hemispheres and the brain-stem (Max Clara 1959)

The first stage in the process of recognition consists in the reception of environmental stimuli which is succeeded by central processing. The receptor impulses corresponding to the effects of the external world are forwarded by two systems. (1) The vague, poorly defined and localized sensations are conducted to certain structures of the brain-stem (reticular formation). From here they are diffused along the complicated connexions of the diencephalon upon almost the whole cerebral cortex. The maintenance of cortical activity is due to this system. It sustains attention, the function of sense organs, the perception of signals coming from visceral organs, and provides also for cortical excitatory state required for the execution of movements (Fig. 103). Concentration, however, needs inhibitory processes as well. In addition to the afore-mentioned effects brain areas that are momentarily not involved must be inhibited in order to concentrate attention. Some part may be attributed to the recently demonstrated centrifugal fibres which run along the sensory pathways, and adjust the sensitivity of receptors. (2) Visual, auditory and other sensations, which are exactly defined, proceed along direct afferent pathways. These sensations arrive at the respective cortical sensory areas through the largest group of grey nuclei in the brain, i.e. through the thalamus.

Secondary sensory fields have also been identified besides the primary cortical sensory areas. The impulses to these are supplied by the primary sensory areas and by the subcortical thalamic grey matter. We know little about these areas. They are presumed to participate in aligning the visual, auditory, tactile and other signals with the various cortical processes. In addition, they are involved in the reflex movement of turning the respective body part or even the whole body into a favourable stimulus reception position. The significance of primary sensory areas is shown by the fact that injuries extinguish the sensation pertaining to the injured part of the brain.

The character of a sensation is influenced by several factors. First, it indisputably depends on the intensity and quality of the environmental stimulus. Apart from that, however, it is modified by the receptivity of the sensor itself, by the afferent impulses reaching the cortical sensory area, and even by efferent impulses, because the latter re-affect, i.e. facilitate or inhibit, the afferent excitatory events. Sensory processes provide the chief means of gathering information. Nevertheless, motor activity is no less important in the recognition of the environment; indeed it proceeds hand in hand with perception. Most phenomena are made known to us by vision and palpation concurrently. In palpation the sensation of muscular work, the extent of muscle tension exerted against the solidity of objects has an important part to play.

In the course of violin learning, manual work of the fingers and score reading supply various muscle, joint and positional sensations in addition to those supplied by auditory impulses, to structures of the highest order in the central nervous system; together with this, diverse motor activities also take place. The conquest of a composition is evidently not restricted to a perception and processing of complicated sensory signals, but also involves a synchronized execution of motor acts.

NEURAL ORGANIZATION OF MOTOR FUNCTION

Every motor act arises from and proceeds by sensory stimuli and depends on impulses derived from the memory. In the course of motor learning, complicated sensory-motor reflex connexions develop which grow to be the substituents for direct motor stimuli after having become inculcated and consolidated. They are the basis of motor memory: we shall return to their detailed discussion in Chapter Six in connexion with the subject of practice drill. A relatively moderate part is brought to consciousness of the vast number of postural and motor impulses processed by the alert organism, i.e. only a small fraction of them is 'voluntary' despite the involvement of cross-striated muscular function. Motor activity is directly due to the motor part of the nervous system which exerts its action at several levels. Not only voluntary motor effects arise in the cerebral cortex (and first of all in the motor area of it) but also those which never reach our consciousness. Several authors are of the opinion that as in the corresponding case of sensory areas, there is also a secondary motor field where the motor engrams are stored. This is the place also where the motor patterns of intricate motions develop. The motor impulses arising in the cortex proceed to the lower-level motor structures of the brain; from there to the various neuron circuits through intricate pathways and synapses in order to arrive at the internuncial cells of the spinal cord. From this place the motor impulse is passed on to the ventral-horn motor neurons. Here motor fibres arise which run directly to the respective muscle fibres and innervate them.

The motor charges are conducted along two pathway systems. The pyramidal tract arising in the cerebral cortex is a typical structure in the human nervous system. It is found also in higher mammals, but in man it attains an extraordinarily high degree of sophistication. The origins of the pyramidal tract involving about a million fibres are partially known as yet. Such fibres arise also from the sensory and other areas of the cortex in addition to the cortical motor areas. Where the medulla oblongata and spinal cord divide, the majority of the fibres cross over, and after arrival in the white-matter of the spinal cord each fibre terminates on the ventral-horn cells of the spinal cord, at a level where the respective spinal motor neurons of the muscle innervated by it are found. In its brain section the pyramidal tract contributes fibres to the oculo-motor and face muscles: these also belong to its area of innervation.

The fact that the pyramidal tract conveys the impulses of the voluntary motions has been known for a long time. Finely differentiated and accurate movements are associated with the function of the pyramidal tract; in addition this stimulates the activity of spinal motor neurons. Recent experiments suggest that we shall have to correct our conception hitherto held. Processes connected with the organization of subtler motions are far more complicated and intricate than it was previously thought, and even the notion of the pyramidal tract would need revision. The new experiments, however, have not yet provided sufficient information on what our conception should be in respect of the main pathway of volitional movements, and the hypotheses forwarded in recent literature have not yet been generally adopted. In addition to the pyramidal system another motor pathway arises in the motor cortex which also influences the cranial motor nerves, and through them the muscles of the head, as well as the ventral-horn neurons of the spinal cord, and further, the cross-striated muscles of the body. Unlike that in the pyramidal tract, in this second motor system excitation is to be relayed several times; this takes place in the junctions of the subcortical grey nuclei. This rather complicated fibre system is called the extrapyramidal system. It develops at an earlier stage of biological evolution than the pyramidal tract. Functionally it is closely correlated with the activity of the pyramidal tract so that it is difficult to distinguish between them. The postural reflex actions and the rough, less delicate movements are presumed to be attached mainly to an extrapyramidal activity.

The motor impulses conducted through the neuron associations of the higher and lower strata of the central nervous system are exposed to numerous modulating effects. In general, transmission does not take the shortest possible way, but, as has been mentioned, the motor impulses reverberate in various neuron circuits where their further propagation is made possible by certain accessory excitation. In this procedure the various sensory stimuli have a very important part to play.

The motor charges processed by the central nervous system arrive eventually at the final common effectors, the great alpha motor neurons in the ventral horn of the spinal cord. At this place tiny gamma neurons are also found; they supply the most important sensory organ of the muscle, i.e. the muscle spindle (Fig. 104).

Finally, we must mention a third kind of small neurons which are believed to have direct inhibitory influence. The three sorts of motor neurons referred to constitute a very intricate, but finely adjustable and regulable mechanism of motion. The impulses which elicit the contraction of the muscle fibres are discharged by about half a million spinal alpha motor neurons. When the motor fibre of an alpha cell approaches the muscle, it branches out and innervates a great number of muscle fibres. In the case of rough muscles the discharge of one neuron activates about 100–150 muscle fibres synchronously. In this sense the alpha motor neuron, the axon (motor fibre) and the muscle fibres innervated by its ramifications constitute a functional entity, the motor unit (cf. Fig. 99). More delicate muscles like those tiny ones of the hand have a more dense innervation.

Accordingly, in contrast to rough muscles, one alpha neuron innervates much less, only 20–50 muscle fibres. Motion can be regulated much more delicately this way.

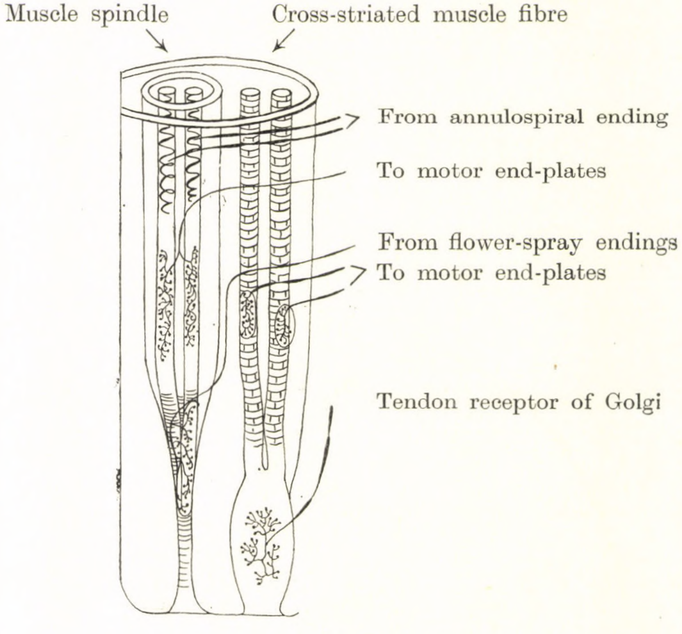


Fig. 104. Muscle spindle (Rein and Schneider 1956)

The smaller gamma cells located next to the alpha neurons are parts of a complicated neuronal network called the gamma system. In comparison with the multitude of muscle fibres, spinal alpha neurons are relatively few in number. Their activity could not guarantee the refinement of our movements. The delicate control is due to the gamma system which regulates the movements in a secondary, reflex way, by adjusting the muscle spindles. Contrary to the discharge of an alpha neuron, the excitation produced by gamma motor neurons does not directly elicit muscular activity. It is the muscle spindle that they activate. In the modified muscle fibre two kinds of receptors are found: the muscle spindle resembling a cork-screw, and the flower-spray ending. Within the tendon another kind of spindle, the Golgi organ, is found. The muscle spindle becomes excited when the muscle is stretched, and its excitation is a feed-back signal sent to the central nervous system. On the other hand, the tendon organ of Golgi, though of lower sensitivity, is excited both by a stretching and a contraction of the muscle (Fig. 105). The gamma neurons are more sensitive than the alpha neurons, that is, they respond sooner to the motor impulses coming from the higher parts of the central nervous system, and induce the muscle spindles to action. The tension developed in the muscle spindle is a feed-back signal for the spinal alpha cells, and due to the branching out of the ascending nerve, it also reaches higher nervous structures. The feed-back signals and the charges bombarding the alpha neurons work additively. This double excitation will then activate the alpha neuron, and the motor impulse discharged by it will now contract the muscles.

Muscular activity having started, the above process is continually sustained. The alpha motor neurons discharge impulse trains towards the muscle fibres and maintain activity in them. The muscle spindles, tendon spindles and other

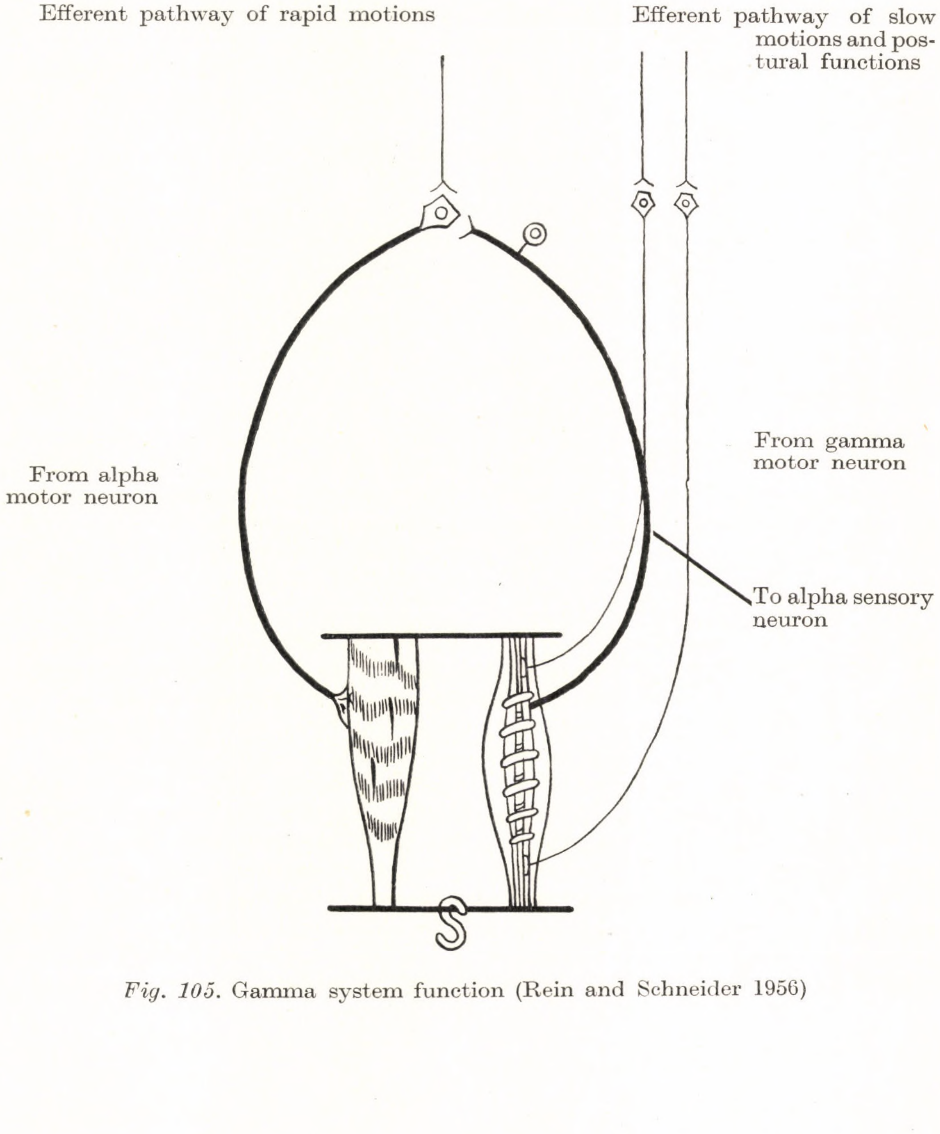


Fig. 105. Gamma system function (Rein and Schneider 1956)

sensory endings of the muscles provide in turn the spinal and higher nervous structures with continuous feed-back information. During activity this effect modifies and grades muscular action more delicately. In case of swift movements, however, alpha motor neurons may be also directly activated, without reliance on the feed-back system. The system which senses, signals and feeds back the events of body posture and movement is rather complicated and many-sided, and it presumes the function of several organs. Sensory bodies are found in the muscle, in the tendon, in the fasciae as well as in the articular stabilizing structure (joint capsule and ligaments). Moreover, special postural and equilibrium sensations develop also in the semicircular canals of the inner ear. However, the sense of muscular position and movement is not merely a product of these organs. A tension change in the skin in connexion with posture and positional change as well as blood-pressure changes within the respective vessels elicit further signals which are transmitted by cutaneous and vascular receptors towards the central nervous areas specialized for the sense of movement.

The motor impulses whose principal structures are cortical motor areas involving also several subcortical formations activate two types of neurons in the spinal cord. The discharge of the great alpha motor neurons activates the subordinated muscle fibres directly, while the gamma neurons adjust them accurately by means of the muscle spindles.

The higher structures of the gamma system are found in the brain-stem. They are closely correlated with cerebellar activity; in fact, certain authors (Granit 1950a) claim that even the sensitivity of the muscle spindles is adjusted by localized cortical control. What we know of the gamma system explains also the significance of primitive reflexes, and incorporates them into the whole of the motor mechanism. In order to maintain body posture certain joints must obviously be stabilized in a definite position. This muscular tension is secured by the gamma system through innervation of muscle spindles. With the mediation of the gamma system alternate parts of the fixator muscles are activated, and these make the given muscle capable of sustained action without exhaustion.

The above mechanism is the means for maintaining erect posture, and it underlies also movements which are initiated in the respective posture. That is to say, the gamma system controls, in addition to the precise regulation of movements, also the fundamental tonus of the musculature involved in the various postures. The basis for the events described is the stretch reflex. The principal part in maintaining erect body posture is played by the continuously active and practically inexhaustible stretch reflex which, by muscular contraction, restores the articular fixation endangered by elongation of the muscle. The function of stretch reflexes is associated with flexor reflexes, as well as with other more intricate postural, righting, etc. reflexes. Their multiple co-ordination, together with the feed-back system, ensures that our motions proceed in an efficient manner.

Thus the gamma feed-back system participates in the regulation of our whole motor mechanism and it represents an effector organ of motor management by distributing the extent of muscular tension. In accordance with the prevailing motor 'mood', it adjusts play of features, body posture, and regulates the force to be exerted by the respective muscle rows according to the requirement of the motor situation. In addition to this delicate regulation the previously described coarser one is also operative in our motor actions. Liddell and Sherrington (1924) showed that its elementary mechanism is a reflex inhibition of antagonists. As a result of its spinal innervation the muscle antagonistically related to the active one will relax. In addition to the agonist muscles and muscle rows which effectuate motion, the antagonistic muscles also become activated to some extent in most of our movements, particularly in those which require a more delicate control of muscular activity. They function as modulators in performing movements, and in this way promote the accuracy of motor activity.

HIGHER ORGANIZATION OF NERVOUS FUNCTION

What we have said so far may seem to suggest that the neural structure operates like reflex machines. This is indeed the case, up to certain limits, in primitive organisms. In the course of biological evolution, however, neural processes have grown more and more intricate. The lower structures of the nervous system have gradually become deprived of self-dependence. The nervous functions, as inherited, are rather primitive: they concentrate in the brain-stem, while the more complicated and compound activities, and the acquired patterns of behaviour, are manifested mainly as cortical events. However, this statement applies only with certain restrictions, since the intimate connexions and interrelationships which exist between lower-order nervous structures tend to obliterate any sharp boundaries. That the hemispheres have an influence on, and a control over, the lower formations of the nervous system is indisputable, but no less does the cortex depend on the latter, in particular on the diencephalon.

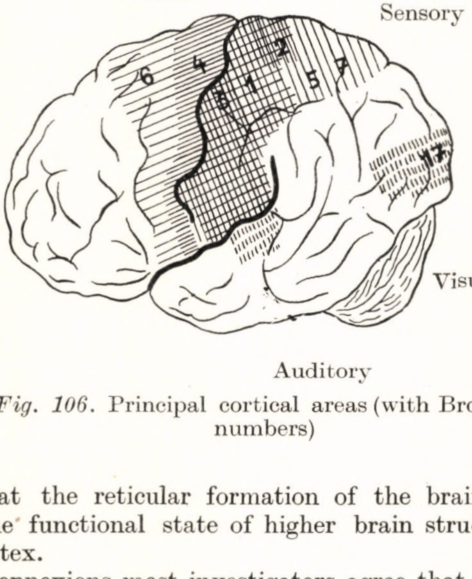


Fig. 106. Principal cortical areas (with Brodman numbers)

In 1911 Pavlov and his associates pointed out the dominant function of the cerebral cortex. On the other hand, Moruzzi (1954) and Magoun (1958) have shown that the reticular formation of the brain-stem exerts a marked influence on the functional state of higher brain structures, even on that of the cerebral cortex.

In spite of the complex interconnexions most investigators agree that higher grade nervous function, or mental activity, is related, first, to the predominance of cortical processes. Penfield and Rasmussen (1950) claimed a dominance for lower-order brain parts, but since they have as yet been unable to substantiate their theory by experimental proofs, it has not found general acceptance. We have already described the primary cortical sensory and motor areas in which a topographical representation was found for the respective organs. It was further maintained that these fields exert activity only if their excitatory state is continuously maintained by the afferent impulses coming from certain brain-stem structures (reticular formation), and from the thalamus. However, it is also required that excitation should reach further cortical and subcortical areas. After having arrived at the sensory area of the thalamus, from where they stream back to the cortical fields adjacent to the sensory ones, they diffuse eventually over the entire hemisphere. These fields provide the primary cortical sensory areas with feed-back information. The impulses coming from the periphery may enter consciousness only after they have run through the neuron circuits outlined above or some even more complicated paths. Cerebral function of the highest order is thus not based on brain parts working in isolation; it is exercised in an intimate relationship with the functions of lower-order structures (Fig. 106).

The hemispheres of a newborn baby are like empty pages that are to be inscribed by life itself, or, to come nearer our subject, by the notes of singing and instrumental playing. Naturally, the quality of the 'text' is influenced also by the inherited factors of higher nervous function. Their more exact physiological characteristics and structural topography are as yet unclear. In the brain the hosts of perceptual components combine to form various excitatory patterns which are linked to one another and are stored. These excitatory patterns are coupled in some definite system; the condition of their storage, as well as their impregnation and retrieval depend on certain circumstances. Practice (the number and quality of repetitions) as well as the emotional attitude associated with these patterns (interest) are classified as such circumstances.

CONDITIONED REFLEXES

Through the complicated network of sense organs the environmental signals stream towards the alert central nervous system in an endless flow. However varied these external stimuli might be, part of them will recur from time to time; to these inputs the motor response, which takes place after the corresponding relay activity, will be similar or identical. Thus in answer to recurrent identical sensory inputs the motor impulse propagated towards the muscles by the intricate network of neurons will be the same. Essentially, this is the physiological basis of practice.

The reflex events described above (stretch reflex, flexor reflex, etc.) are congenital and occur unconditionally whenever the corresponding stimulus excites the organism. This provides us with a mechanism that ensures an adequate response to environmental stimuli. An organism of higher developmental order however requires also another, far more delicately differentiated mechanism capable of infinite improvement. This is represented by the system of conditioned reflexes, acquired during individual life only, i.e. it does not constitute an unconditioned, inborn system of reflexes. The development of conditioned reflexes begins instantly at birth, and constitutes the prerequisite of survival by the flexible adaptation of the organism to environmental changes. Among the conditioned reflexes some are natural, these affecting mainly nutrition and avoidance of harmful effects. Though artificially conditioned responses are not directly related to individual survival, yet they are of fundamental importance in the physiological and psychological processes of evolution in man, and also to further human development. Such manifestations of intellectual and emotional life as instrumental playing are ranked with the latter.

In the elaboration of the extremely complicated and many-sided procedures of conditioned response arising in instrumental performance, the principal part is played by those auditory and visual sensations that leave imprints in the respective structures of the brain. In the process of learning, sensory and motor activities are inseparable from one another: the neuron chains establish contact between the impulse coming from the organs of vision and hearing and the motor neurons respectively; when the notes produced by muscular movements are heard and when these movements are subjected to visual control, they provide feed-back signals for defined parts of the brain. The latter in turn will re-affect the motions by correcting and refining them. In violin playing, the effects are not brought about by isolated conditioned stimuli, but by stimulus complexes. Nor is the response given to them isolated, but consists of a complicated chain of reflexes.

There is practically no limit to the acquisition of conditioned reflex procedures. The instrumental movement forms described in Chapter Two develop also on the basis of central nervous excitatory patterns. As regards motor innervation, the vibrato relies for instance, on the generation and processing of discharges (called reciprocal innervation) directed alternatively towards agonist and antagonist muscles. Swift stopping is due to charge whose synchronization is proportionate to the increasing speed. A change of position is similarly attributable to excitatory patterns which establish certain simultaneous activity in arm and finger muscles. These examples make it obvious that all movement forms occurring during violin playing depend on the specific conditioned reflex activity associated with violin playing and belonging to the central nervous system as a whole. Their acquisition constitutes, neuro-physiologically, learning to play the violin.

THE SENSE OF TOUCH

Methodologies show relatively slight interest in the part the sense of touch has in playing the violin, though the point is important, first of all, in respect of left-hand technique.

CUTANEOUS SENSATION

The skin mediates four sense modalities: touch, warmth, cold and pain. Cutaneous sensation is the outcome of a complex function. The areas of cutaneous sensation, viz. innervation, overlap; the sensory fibres of certain skin parts derive from several nerves. Their endings vary according to the layers of the skin, e.g. in the corium the endings are either terminal corpuscles or end-bulbs. In one square centimetre of our skin an average of about 2 endings are found for warmth, 13 for cold, 25 for touch and 200 for pain. Tactile corpuscles are most frequent on the fingertips (100 per sq.mm, i.e. at a distance of 0·1 mm apart from one another), in the palm and on the sole. There are glands also on the skin. The greatest density of sweat glands was observed on the fingers, palm and sole. Their function is subjected to autonomous nervous control. The important part allotted to the skin in the sensation of the limbs' spatial position and body posture has already been mentioned.

FACTORS OF TOUCHING

The quality of touching is subjected to several conditions. Some of these are: (1) skin temperature (in cold, sensitivity is lower), (2) cutaneous moisture (the moist skin is more adhesive, its sensation of touch is more delicate than that of dry skin), (3) the oiliness of the skin (an oily skin is more slippery, its grip is less resolute). The most important factor is, however, the developmental grade of tactile sensation which depends above all on the subtlety of the respective cortical sensory area. It depends, to a significant extent, on the momentary state of the central nervous system (concentration, tiredness, etc.).

The skin is very responsive to emotions, as is demonstrated by psycho-galvanic skin response research. Certain emotional states, or even recall of the words representing them, will modify electrical skin resistance, which is consequent upon the changed volume of cutaneous glandular secretion, and the blood supply flowing through the small vessels. When perspiration is more profuse, and the subcutaneous connective tissue becomes perfused by more blood owing to the distension of the small vessels, skin resistance will decrease. It is possible to measure exactly the intensity of the psycho-galvanic skin response by a suitable device, thus a continuous record is obtained, revealing the dynamics of emotional factors. Similar observations may be made during the period of preparation for activity: the skin grows moister, its electrical resistance decreases. Mental concentration on violin performance is accompanied by a moderate increase in perspiration of the hand even under normal conditions, while in pathological cases it may elicit profuse sweating or else dry up the hand completely. Violin playing is impeded by any of these situations. A normal moistness of the hand may be considered a protective means by which the organism prepares, with a minimum disturbance and impediment, for the task. (The hands of the wood-cutter would get hurt by the moving axe-shaft if it did not adhere to them; this is why he moistens his palm.)

It is clear, from what has been said in the preceding, that violin playing consists not merely of complex motion patterns but also of no less complex series of tactile sensations. Of these the direct tone-productive action of the left fingers is the most essential. This involves touch-pressure sensations as follows: (1) stopping of strings of varying diameters, (2) gliding of the finger-tip, (3) vibrato, (4) production of harmonic tones; each of which, taken separately and together, converges on the question of precision in violin playing and justness of instrumental intonation. Problems concerning the sense of touch in violin playing have received little attention. The question is rarely raised by didactics, even though it represents a specifically string instrument problem, because with the exception of certain wind and percussion instruments, no other instrument requires tone-production by direct application of finger-tips.

TOUCHING AS A COMPLEX SENSATION

Touching of objects and change in temperature elicit an excitation in the sensory nerves. Active palpation is, however, not a sensory process only; in addition to the activation of cutaneous nerve endings the change in muscular tension has also a prominent part in it. In the psychological literature distinction is made therefore between tactile and haptic sensations. While tactile sensation reflects merely the superficial properties of objects, by haptic perception we can recognize also the state and solidity of matters. In haptic perception certain pressure has to be exerted on the object (we call it therefore active palpation), i.e., in haptic sensation muscular function also associates with this pressing. Thus, haptic perception provides a kind of spatial orientation; it signalizes even our distance from the objects palpated. A haptic space is thus generated by means of the tactile sensations concerning space.

Touching the objects surrounding us is a means of cognition. The working and recognizing hand becomes thus a special organ of sense, and is thus associated with the direct effect exerted on the objects of the external world: 'touching' is transformed into a conscious and convenient handling of objects, into active cognition. The purposeful manipulation of objects is directed by the sensory signals of palpation, interwoven, of course, with other sensory modalities (Kardos 1964). When palpating, cognition is therefore effected by the very process of motion; it involves tactile, pressure and kinesthetic (muscle-joint) sensations; it represents both exteroceptive and proprioceptive sensibility by interrelating and uniting them.

PROPERTIES OF TOUCHING

In palpation the sensations of touch and pressure combine. Pressure is realized as intensive touch. It is characterized by rapid adaptation of pressure receptors and therefore what we perceive is essentially a change in pressure. The minimal sensible distance at the tip of the fingers is 0·1 mm. The difference between hard and soft contact depends on the degree of compression that arises between articular surfaces. The muscular tension which develops when the fingers are placed on an object is an important contribution to the sense of touch. The rough and smooth characters of surfaces are recognized by the vibration which is caused by making our hand, or usually the fingers, glide, as well as by the excitation of receptors signalizing the pressure difference between the skin areas contacting the object and those not directly engaged in it, viz., the adjacent ones. If palpation is isolated from other sensory modalities such as vision, for example, it is weakest in recognizing spatial dimensions. On the other hand, it is most efficient in the reflection of dynamics, movement, activity.

EFFECTS OF TOUCHING IN LEFT-HAND TECHNIQUE

It is generally recognized that the manner of stopping has a paramount influence on tone-production. This makes the intended tone-quality differ from what is actually produced. 'Hard' and 'liquescent' stopping, false intonation, uneven vibrato, insecure change of position, etc. are in part all due to a poorly developed touching that is incapable of adaptation. Our violin teaching does not use enough of the opportunities residing in an improvement of tactile faculties; it fails to approach violin performance from this aspect. Yet, as a matter of fact, the purpose of every finger movement, arm and hand motion serve but one aim: the depression of the strings in a finely differentiated manner of touch by the fingertips. Motor and sensory elements become integrated, and together represent the activity of tone-production; this complex function is the final result. The pupil's attention must be focussed therefore upon developing a differentiated tactile sensation: he should feel the intended note at his fingertips. Every note of the performance must be linked to a corresponding tactile conception. Delicacy of touch can be improved by means of kinetic and visual sensations, since it is in specific connexion with them. The role of auditory control is secondary here, because it becomes operative only after audition of the sound.

The proper means of improving the faculty of touch are fast finger drills, alternations of harmonics and normal playing, the teaching of vibrato, according to the degree of advance and technical experience of the pupil. The playing of sustained non-vibrato notes, because of the already mentioned adaptation, is not suitable here. In fact, even a possible inadequacy of habituation may be retained. In verbal instruction, too, it is advisable to use words that imply tactile notions: "Let the finger-board feel soft and smooth", "In changing position the finger should glide along as if caressing the fingerboard", and so on.

TOUCH AND INTONATION

As for pure intonation, and its physical relationship with touch, Flesch (1923) comes to the conclusion that pure playing is physically impossible. He quotes the upper ledger-line notes A and B flat (880, and 940 c/s, respectively) played on the A string as an example. According to him, these would be at a distance of 2 mm on the string, and their frequency differed by 60 c/s.* One cycle would engage thus 2/60 mm = 0·033 mm of the string, a point which should be touched by about a 10 mm wide finger-pad with an accuracy of more than one cycle per second; this is certainly impossible. According to him a 'pure' intonation is actually an extraordinarily swift and skilful readjustment of an originally inaccurate note.

Flesch's (1923) reasoning is obviously meant to serve teaching purposes. He wants to make violinists realize that (1) they have to continue improving the acuteness of their sense of pitch, (2) to refine their motor mechanism so as to be able, at any time, to adjust with the speed of lightning and inaudibly to the audience; (3) he urges teachers never to put up with the pupil's faulty intonation, but to insist on correction under the same bow (without change!).

The problem of pure violin intonation cannot be examined by restricting ourselves to this single aspect; it is far more complex than that. First, two questions emerge: (1) Is such a high degree of accuracy necessary at all? (2) What means do we need in obtaining pure intonation with our natural faculties?

The first point concerns the physiology of hearing. According to recent investigations, an average human ear is capable of perceiving vibrations between 16 and 18,000 c/s. As to its sensitiveness, it distinguishes between 1000 and 1003 c/s, a difference corresponding to 5·2 Cents (one Cent difference in pitch equals one hundredth of a semitone in the scale of equal temperament). The physiological basis of it according to present day theory is the average of 20 nerve terminations that are involved in the perception of one note. In the pitch range between 1000 and 2000 c/s other investigations found some 231 different pitches, which corresponds to a sensitivity of about 5·2 Cents per sound. The threshold of sense of purity lies between 17 and 25 Cents, depending on the pitch range. (For higher

* The premises of his argument are incorrect in themselves, because on a full-size violin having a string-length of 325 mm the distance quoted should be 10·1 mm instead of 2 mm.

audio frequencies it is about 17 Cents, towards the lower range it increases to 25 Cents.) Below that threshold the average human ear cannot distinguish between differences in pitch. Thus to obtain more accurate pitches would be practically unnecessary. According to the experiments of Blagonadyozhina (1940) the threshold of pitch-sensation in children of exceptional musical talent varies between 6 and 21 Cents. Even an extraordinarily sensitive ear is therefore limited to about 6 Cents in discerning sound pitch. Flesch (1923), however, demands an accuracy within 1 c/s in pureness of intonation. This has no practical value, since it cannot be verified by the ear, and we do not play music to electronic measuring instruments. So far as hearing is concerned, the question of pureness in music is further complicated by two sets of problems: (1) non-diatonic intonation; and (2) the zonal nature of hearing.

The first is a well-known point: C sharp and D flat, F sharp and G flat, etc. are not enharmonic; sharp tones sound higher, flat ones lower, according to their direction, and we have to produce them on the violin accordingly. The perception of accuracy of a given note is likewise modified by the place it occupies in the context of a chord.

The second point was elaborated by Garbuzov (1948). He found experimental evidence for his observation that the musical ear is sensitive to pitch zones around the given sound and not tones of a definite frequency. In respect of physiology, our present system of music is arranged into 12 zones instead of 12 semitones. Garbuzov made an analysis of gramophone records (by Zimbalist, Oistrak and Misha Elman) and in this respect could show the tendency to avoid neutrality of adjacent intervals in intonation, i.e. to make precise distinction between the respective pitch-relationships. Between the recitals of the three artists the difference in intonation was so great that it was impossible to include them into a common system, so that only "the respective order of intonation used in the recital" could be assessed. We do not intend now to enter upon details; we confine ourselves to touch upon some of the practical inferences necessitated by the data obtained.

(1) The problem of accuracy in violin playing is by no means so simple as the example quoted by Flesch (1923) seems to make it; there are other criteria by which to assess the accuracy by the ear, which are not 'tied down to frequencies', but defined by several conditions. One of these represents the place of the given note in the context of melody and harmony as well as the function it occupies in this place. Another condition is the particular zonal nature of the performer's hearing. As regards the extent of the deviation, this does not invalidate the rather rough conception about the accuracy or otherwise of a note, and serves merely to illustrate the possibility that the same note may be accurate in various senses.

(2) The practice that is common nowadays, viz. to educate the ear for music, is correct in emphasizing that both the image and production of notes should be accommodated into the melodic line and harmonic pattern.

In respect of the other question, viz. the accuracy of our hand and nervous system: the tactile corpuscles in the fingertips have a distance of 0·1 mm, that is, about 100 sensory corpuscles are allocated along a line of 10 mm length. Considering that palpation occurs over an area, about 200 touch corpuscles stand at our disposal to hit at the suitable point over the respective half of the 10 mm long surface of the E string in contact with the finger. Along the fibre deriving from the nerve endings for touch-pressure, the speed of impulse condition is about 60 m/s, while along motor fibres it is 80–120 m/s. Yet another important factor: the smallest recognizable interval of time for a human is 1/18 (0·056) second. We cannot distinguish between events occurring within that period; thus notes which succeed one another within 0·056 sec will merge into a glissando. This is the reason why a slower but precisely played passage impresses one as a sign of greater virtuosity in comparison to a faster one being already 'below threshold level'.

What is the general speed in succession for notes in the violin literature? According to an analysis of 20 compositions, the shortest time for having a note sounded varies between 0·100 and 0·049 seconds, in respect of the indicated metronome beat. This corresponds eventually to the necessary speed of stopping. It is obvious that such speed precludes any possibility of a 'fine, unobservable' correction. The notes produced are just audible, thus they must be stopped with a pre-defined precision and purity. The question is whether it is possible to secure prior accuracy of note?

Considering physiological data the answer is positive, since (1) we possess a multitude of nerve endings located in the skin, muscle, tendons, and above all, in the finger-tips, directly involved in tone-production. Thus the site of a note is obviously found within the limits of pitch-sensation (subjective accuracy). The vast number of nerve endings as well as the broad cortical area of tactile representation endow us with the necessary delicacy of sensory-motor co-ordination to achieve accurate intonation. (2) The time of response for the nervous system allows (after the formation and exercise-fixation of reflex arcs) accurate intonation of even the shortest notes occurring in music.

From the point of view of teaching, these are not as important as the question of accuracy, i.e., whether we accept or refuse that clear intonation is possible. The reply given to the question implies didactic principles, viz. whether we seek to tune the motor mechanism for a 'clear-from-the-outset' manner of playing or whether we make allowance for using evasions such as continuous readjustment. In spite of all his pedagogical goodwill Flesch's arguments will lead to the latter, whereas the experimental data of physiological research emphasize the former. What remains to be settled is the problem of finding practical methods of 'preconditioning'; this, however, concerns training methods in the strict sense

CO-ORDINATION OF HOMOLATERAL AND BILATERAL MUSCULAR FUNCTIONS

The tendency to symmetrical motions is a consequence of the symmetrical build of our body, as has been pointed out in Chapter One. With certain movements the displacement of a limb induces the contralateral limb to move in the same or in the opposite direction. In certain movements the underlying objective is the maintenance of equilibrium or the gathering of momentum (as e.g. the co-motion of arms and legs in walking). In the domain of music the typical examples of the trend of bilateral co-ordination are those conductors who very often conduct with both arms like a mirror image, though in theory they are aware of the functionally different role in conducting of the two arms and have even practised to achieve it.

The trend for bilateral symmetry in motor co-ordination constitutes one of the basic difficulties of instrumental playing. This applies above all to string instruments. In the course of teaching, children are often observed to extend the little finger of the right hand on the bow at the same time as the little finger of the left hand is extended. Or, in legato playing, the bow jerks in the rhythm of left hand fingering, etc.

In the literature of teaching methods several authors have dealt with this problem (Koeckert 1909; Klingler 1921; Eberhardt 1922; Trendelenburg 1925; Mostras 1947) and referred to the following cases as being disorders of bilateral co-ordination: (1) increasing bow pressure induces a rise in the fingering pressure of the left hand, and vice versa; (2) during change of position the movement of the right hand is also accelerated because of the rapidity of left-arm movement; (3) increased left-hand activity in performing fast passages includes increased tension in the joints and muscles of the right hand.

Faults of various degrees develop in tone-production since effective co-ordination in violin playing requires a certain degree of bilateral isolation and a definite sequence of movements. The basic direction of the motion sequence for stopping is: (1) left hand, (2) right hand. Mistakes committed in bow or string changes are often due to the condition in which the forthcoming left finger has not yet produced the tone, but the bow had already been changed. This is the case when an open string is sounded between two notes, etc. The periods of left and right hand movements need not coincide; an asynchronism is necessary. This is confirmed by the bilateral EMG investigations we have performed during playing short martelé tones. The current required for the stopping actions by the superficial finger flexor preceded regularly the absence of activity in the clavicular part of the right deltoid during the sudden swing (cf. Figs 68–69, martelé).

The regulating function of the appropriate bilateral co-ordination is apparent when whole notes are played vibrato. In the EMG records of such instances tonus changes have been observed in the biceps of the bowing right hand, together with the alternating rhythm of left superficial finger flexor activity. These findings suggest three conclusions: (1) it is advisable to make the pupil conscious of the movement sequence at an early stage in study; (2) the source of noisy bow changes are usually traced to the neglect of movement sequence to which beginners, but often also advanced players, are equally prone; (3) the physiological basis underlying the well-known inclination of the left hand to being fast is traced to a regulating mechanism which is acquired during violin learning, and has been described by ourselves as the order of sequence in the bilateral co-ordination of movements.

The method of correction, proposed by Flesch (1928), viz. practising of passages by separate bow, may be recorded as physiologically well-founded. The tendency to symmetry of movement in bilateral co-ordination agrees with our proposal described in Chapter One, viz. that it is expedient to begin work by the two hands being coupled to one another by symmetric cyclical movements. Later the extent of acyclicity should be gradually increased. In our opinion the faults in tone-production, as reported in the literature for the violin, are due to disregarding the rules concerning gradual progress and correct order of movements.

CONCENTRATION

In the neurophysiological process of concentration a significant role is attributed to two general principles of higher nervous functions, i.e. to negative induction and to the principle of dominance.

Having arrived at the cerebral cortex, the excitatory and inhibitory processes tend at first to diffuse, only to converge (concentrate) again to definite areas. When at some point of the hemispheres an excitatory focus is formed, it will induce inhibition in the adjacent parts. This is called negative induction. Owing to the continuous inflow of afferent impulses, some centres of optimum excitation are always found in the cortex. If these excitatory foci become dominant, to use Ukhtomsky's expression (1923; re-issued 1950), they exercise an attraction on the effects of all other stimuli. By means of suitable pathways the cortex communicates also with other parts of the central nervous system. Thus the dominance is not restricted to cortical areas. Over the whole central nervous system several points of excitatory dominance develop which, instead of being a topographically (locally) uniform domain, represent rather a determined constellation of areas with increased sensitivity within the different strata of the brain.

The neural organization of attention is believed to imply the function of the relatively little known centrifugal fibres which lead to the periphery of the nervous system. It is possible that with its impulses or through these fibres the central nervous system regulates the receptor's sensitivity so that these accept stimuli only corresponding to the quantity and quality of the existing state of affairs, that is, it modifies the specific threshold of excitation in the respective sense organs. From the various subcortical structures, primarily from the reticular formation, the inhibitory impulses necessary for attentiveness run through efferent pathways to the peripheral neuron junctions. There they reduce the transmissibility of such environmental stimuli that do not affect the organism. This functional state arouses an emotional complex which, owing to its high intensity, may cross the threshold of consciousness and become, in the form of concentrated attention, a psychic phenomenon.

Concentration is thus not a particular psychic phenomenon, but an organic part of any activity. In accordance with Rubinstein's (1958, p. 557) definition, the attention concentrated on something constitutes a specific feature of processing, and is governed by the activity itself in which it becomes involved.

PRINCIPAL FORMS OF ATTENTION

Attention has two main forms, viz.(1) spontaneous alertness, which is involuntarily drawn upon stimulus complexes that exceed certain intensity, or become suddenly actual; (2) deliberate consideration manifested by a conscious selection of object and concentrating on it.

In everyday life the two forms work equitably and merge into one another. The transition occurs frequently in such a way that we become spontaneously aware of something which then is followed by conscious attention. Sustained attention depends on how far we are interested in the object our attention has been drawn to. Concentration is thus largely a function of being interested. Consequently, and in particular in the case of apparently dreary technical tasks, such as scales or finger drills, it is a point of importance that active concentration should be evoked by suitable methods. Concentration depends on the individual's choice of direction, personal wishes and aspirations, and on the aims he sets for himself. Anything that 'falls in' with these, will attract our conscious attention, anything inconsistent with them will be left 'unattended'. Consequently, the advance from taking notice of a thing inadvertently, to concentrating conscious attention on it, is determined by man's ability to set tasks for himself. Concentration of attention in its particular human manifestation is a conscious process.

Nor can concentration be reduced merely to a structural pattern of perception. To consider something means first to analyze it, and second, to abstract it, to treat it apart from the concrete. Concentration offers a way to departmentalize the structure of perception, to proceed to abstraction, and as a result, to guide observation in a deliberately chosen direction. This feature links concentration directly to higher thinking operations. The particulars of attention outlined above also influence its other characteristics, such as intensity and range: they are mostly inversely proportionate to one another (the more intensive the concentration, the smaller its scope), but hard and fast rules cannot be laid down. Indeed, range is strongly dependent on the contents of attention, on the ability to work out associations in an intelligent manner and so on, viz. of several specific individual traits that merely appear to be 'irrelevant to concentration'. Thus, for example, an expansion of the attentive range may sometimes intensify the degree of concentration.

Two factors contribute in particular to the divisibility of attention. These are: (1) the interconnexion between objects or events on which concentration is focussed, and (2) the grade of habituation reached in dealing with them. — The closer the interconnexion of objects or relationships under observation, and the more automated actions have to be undertaken, the easier will it be to divide attention among more things or activities. This implies, after all, the problem of experience in the necessary actions.

To ensure alertness of attention is not easy, either in keeping attention upon an activity of unchanged nature or when several activities have to be monitored simultaneously. To be able to transfer attention rapidly is not an easy task either. In the maintenance of constant concentration the effects of several factors combine: structural and content particulars, the degree of difficulty of and interest in the subject, and finally also individual factors. Teplov (1947) emphasizes that in the psychological analysis of a musician's personality explicit attention must be paid to the characteristics of attention. He employs this method in his study about the activity of composers. The quality of concentration is no less important in instrumental artists and their creative activity.

The very first steps of learning a musical instrument demand conscious concentration. The particulars of devoting attention to instrumental training will be entered upon in the chapter dealing with practising. Here we merely wish to point out that the manipulation of a string instrument requires a continuous and reliable co-ordination of functions of the diverse types of motor elements, complicated acyclical motion sequences, and their employment in the service of music. It is evident that a successful instrumental performance is impossible without the ability of high-grade concentration in full possession of the properties described. There are a number of pupils who are unfit for a professional career precisely because of the lack of this wholly 'non-musical' talent and who hardly attain the level of a good amateur.

AUTOMATION

It would be an obviously insurmountable task to execute motions of extraordinary precision for the sake of expressing a high-grade intellectual message, if higher nervous functions were deprived of the mechanism of automation. The majority of our everyday actions do not require continuous concentration. We listen to music while shaving, smoke during conversation, or, though it cannot be approved, we read the news while eating, etc. We can do all that because these actions are performed mechanically, automatically. The possibility to automatize is provided by a functional property of our central nervous system. It was Pavlov (1911) who pointed out that successive reflexes become arranged into sequences owing to the systematizer function of the cerebral cortex, and after the necessary number of repetitions they become stabilized.

If excitatory and inhibitory events recur several times under identical conditions, the cortical arrangement and distribution of the stimulative impulses will grow gradually more fixed. In this way, an interlocking and well-balanced system of processing builds up in the cortex, the maintenance of which will require less energy, and release become easier. This functional state of the hemispheres, which operates in an organized manner in order to match the actual state of affairs, is called dynamic stereotype. The characteristic feature of an established dynamic stereotype is that, following the first stimulus, the whole response or action series follows in a smooth succession. According to Krestovnikov (1953), in the first phase of learning movement patterns the pupil learns separate movement elements and then links them into a uniform action. In the second phase superfluous muscular tension and activity are eliminated. In the final phase of motor learning the movements become gradually more perfect thanks to the increasing precision of afferent impulses. During the course of learning the phases may vary with the intricacy of the motion. Dynamic stereotypes as functional states display considerable inertness; to change them is rather difficult even by the employment of new methods of stimulation and innervation. Dynamic stereotypes underlie the operation of functional entities called automatisms. Interference with any member of the functional system will interfere with the whole system. By studying the experimental transformability of dynamic stereotypes in animals and in humans Molnár (1958 and 1962) has found that the extent of fixation differed according to the respective members of an automatical action sequence. The members which arrive later in the action sequence are less easily transformed than those at the beginning. This was manifested by the characteristic number of errors.

The situation described is of considerable interest to instrumental teaching methods in the teaching of new material. The introduction of technical novelties, e.g. fingering or bowing styles, etc. require a transformation of certain dynamic stereotypes. In planning exercise material it is advisable to take note of it.

Chapter Five

THE ROLE OF HIGHER NERVOUS FUNCTIONS IN VIOLIN PLAYING

TYPES OF HIGHER NERVOUS FUNCTION

Man adapts himself to the endless change in his environment by action. Action and consciousness constitute an organic entity. Man not only senses and desires, but also knows what he sees, hears, wishes, and also evaluates what he does on a high level. Consciousness is the reflection of independent objective reality. Consciousness is characterized by a degree of stability formed by the situations and experiences encountered, and by memory. Personality develops in subjection partly to biological elements (hereditary factors), partly to social conditions (family-affairs, education, cultural level, etc.). The category of personality comprises both factors: with the expression personality we refer to man living in a definite social structure (Büchler 1960). From a physiological point of view personality is characterized by the constitutional traits in the nervous system. This is the topic we have to deal with first. According to Pavlov's definition, constitution is understood as the partly inborn, partly acquired functional specificity of the organism that is manifested by typically personal responses to the stimuli of the outer world. Constitution has thus both constant and changing components which combine in establishing the variability of constitution as a whole. Educational influence derives from the direction of the changing components; adverse hereditary trends may be suppressed and the development of good dispositions may be promoted, i.e. good for the individual and good for the life of society.

The functional pattern of the nervous system is the basic hereditary component of constitution. The two main forms of nervous function, excitation and inhibition, are characterized by three factors: (1) intensity, (2) mobility, and (3) balance. These features vary from individual to individual; nevertheless we classify people into the following categories according to central nervous responsiveness (according to Hippocrates and Pavlov, respectively): (1) vigorous (sanguine), (2) calm (placid, phlegmatic), (3) short-tempered (choleric), and (4) inhibited (melancholic).

The difference between the types lies in the fact that nerve cells are of varying strength, and their working capacity is different. This is manifest in the manner of acting, in temperament. In life the above types occur in mixtures of varying degree: pure versions are rare. In the choleric type the dominant feature is excitation, in the melancholic, inhibition. In phlegmatic and sanguine individuals the two contrasting nervous processes are more or less balanced.

From the viewpoint of instrumental music it is of importance that Pavlov (1932, re-issued 1951) brought evidence on two further human categories, viz. the types of artistic and intellectual inclination respectively. The difference between the two groups lies in the relationship to the world. Those having an artistic disposition grasp reality in an immediate, undivided whole, eidetically, while 'thinkers' first dissect and analyze it, then re-construct and synthetize by reasoning. According to Pavlov, perceptions of reality are elaborated by the whole brain substance in the artistically inclined individuals, but with a relatively less active participation of the frontal lobes, whereas in those inclined to reasoning this occurs by concentrating primarily on the frontal lobes of the hemispheres. This conception has received further support from recent researches concerning the nervous functions involved in emotional and intellectual activities. The two kinds of function appear usually in combination; but with those showing vocational excellence certain polarization is more or less apparent. In respect of learning music and choosing it as a vocation, Jung (1921) has made significant observations concerning individual attitudes and relationships to the external world and internal self. With respect to Jung's theory of constitution people are classified in two main categories: (1) extrovert, and (2) introvert ones. Extrovert people maintain close relations with their environment, while the psychic functions of the introvert man concentrate upon his own internal world. In addition to these two main tendencies, Jung indicates several sub-divisions as well. It is hardly doubted that the aptitude of people for certain professions depends considerably on the relationship to themselves and to the outer world. On the basis of several studies carried out during the last decade, Sheldon (1940), the American scientist, published a new typology of his own. He made use of the statistical correlation of 650 typical traits to distinguish three main characteristics of the individual investigated. He elaborated 20 specifications for each of these.

AGE CHARACTERISTICS IN THE DEVELOPMENT OF HIGHER NERVOUS FUNCTIONS

Constitution is shaped by the developmental and growth process of man. From an educational point of view a knowledge of the course taken by individual development in respect of age periods is essential. Investigating the chronology of psychic development begins with the characteristic structural and functional state of the central nervous system of the age concerned. In analyzing skeletal and muscular development we have already indicated that in respect of mean level development deviations of 1–2 years are allowed. In connexion with nervous functions the point attains even greater importance. Krasnogorsky (1952) in his experiment with children has found that thinking and speech development are not a linear function of chronological age.

The chronological change in emotional awareness is due to physical and intellectual maturation of the growing child, who modifies his relationship to the environment simultaneously and incessantly. As bodily growth proceeds the child's behaviour usually shows a gradual loss in impulsiveness and an increasing tendency to take a definite direction. This is induced primarily by educational influences (Yakobson 1958). In developmental analysis of higher nervous functions a chronological classification, much more so than in skeletal or muscular, growth, offers but an approximate orientation for the evaluation of individual development. Age characteristics essentially rely on averages.

FROM 7 TO 12 YEARS OF AGE

The brain develops at an increased rate in the lower school-years, as revealed by both the change in brain weight and brain structure. The brain which weighs in the newborn about 370 g, attains a weight of 1350 g by the seventh year

(Gundobin 1912, pp. 462–5). This approximates the brain weight of the adult. At the same time brain structure also becomes more refined. At the age of 7 growth involves the frontal lobes in particular and the 4 or 5 previous strata of the cortex transform relatively quickly into the structure of 6 layers characteristic of adults. The structural evolution of the cerebral cortex has great influence upon the whole central nervous system and constitutes the morphological basis for speedy development of mental activities. The latter prepares the ground for regular school education.

At 7 years of age skill in spatial differentiation is usually still meagre. This is why elementary school children alter arbitrarily the position of objects or letters, etc. It may occur even in the 3rd or 4th year at school that some pupils read nonsense words and do not correct it. The cause is found in the inaccuracy of the faculty of observation. Improving this faculty must be aimed at from the very first minute of teaching, the more so since its deficiency will interfere with the acquisition of other skills. Every learning demands concentrated attention. We cannot content ourselves with a spontaneous kind of attention; the pupil must get accustomed to consciously concentrate his attention. The best means to this end is regular daily work.

The training of the faculty of conscious attention at the quickest possible rate is an important task. Another matter needed for the impregnation and reproduction of the subject-matter is that the pupil should learn the material whether he is directly interested in it or not. Conscious attention and intentional remembering are essential elements in instrumental education. In practice we often come across mistakes as, for example, inaccurately learned melodies, negligence in noting accidentals of bowing direction or slurs, etc. The 'finest' and most interesting example of arbitrary picking and choosing happens when the pupil does not learn the scales or preparatory drills for changes of position, or bowing direction, or bowing style prior to the assigned exercise or piece, but nevertheless he does learn the exercise or piece. Once or twice this may not interfere with the performance level of the respective exercise or piece; if however this procedure of learning becomes a regular habit, a technical decline is bound to happen. The pupil's level of ambition will fall, he becomes accustomed to tolerate technical insufficiency in violin playing. Its remedy later on might cost more trouble.

However, we cannot expect 7–12 year-old children to realize clearly the technique of learning. Their faculty of abstract thinking is yet underdeveloped; it becomes typical only from about the age of 12; they are not capable yet of the necessary generalization in order to understand the rules for exercising. Nor can they control themselves yet in this respect: they appreciate the efficiency of learning on the basis of repeated reading or playing the assigned material, and not by the degree of mastery. Accordingly, we must also give full information on the manner of the exercise to be practised. The characteristic level of concept formation and logical deduction in the lower forms of school consist in vivid descriptions and concrete terms which are grasped and used by the pupils. They are already able to classify things and events in some respect, they can make inferences by utilizing the relationship between the whole and its parts.

The mood of a child of 7–8 years is likely to undergo swift changes owing to accidental impressions. Each following year will reduce this instability of emotions, gradually increasing perseverance is noted: friendship, preference to some curricular subject, etc., at least for periods. By fulfilling school requirements the emotional side of life is enriched with new impressions. The pupil becomes acquainted with approval and disapproval, which will constitute the assessment of his performance: these will become emotionally shaded motivation for action. Changing moods affect also instrumental learning, especially in regard of willingness to practise. The emotional stability that is needed for regular work first develops by the age of 10–12. The performance of younger children is therefore fluctuating. Obviously, this lability is among the causative factors in a pupil whose excellence in one term changes to less efficient in the next one, without any apparent reason.

At the age of 11–13 certain emotional seclusion may be expected. Lénárd and Mrs Forrai (see Lénárd and Bánlaki 1961, pp. 268–82) performed a series of experiments in which pictures were used to identify emotions, and have found a peculiar emotional blindness in this age group. Among the groups of 7–17 years, 11–13-year-old ones tended to recognize the least number of emotional cues in the pictures. This of course will bear upon their instrumental performance. They feel no urge to express finer emotional fluctuations, and when they yield, it is rather in obedience to the instructor's insistence.

FROM 12 TO 15 YEARS OF AGE

The development of cortical motor structures is complete at about 12 years of age. The work of the brain hemispheres becomes more complicated, and functionally it is brought nearer to perfection. Several new dynamic stereotypes evolve by learning, and the old ones decline. This makes great demands on the nervous system of the adolescent which accordingly needs tender treatment. The growth of the body's mass is not paralleled by the development of the heart and vascular system; in consequence discrepancies arise in the blood supply of certain organs. This will affect physical working capacity and mental activity in adolescent youth who develop fatigue sooner. At this age sexual maturity is another burden on the whole neuro-endocrine system. During puberty sex hormones alter the function and degree of response of the central nervous system. It is associated with functional instability found in some areas of nervous activity (frequent and swift changes in mood, etc.).

The level of the cortical analytic-synthetic activity in the adolescent brain has already been mentioned to be considerably more developed; accordingly it is possible to concentrate attention for longer periods of time. Students are more efficient also in dividing attention, and thus have a better command over the parts of an object or an action sequence. They are already able to break up the material to be learned. Their cogitation grasps and applies more and more abstract conceptions. However, they are still weak in discerning essential from non-essential, obligatory from accidental, particularly when a customary situation or action is replaced by an unusual incident. Students of the higher forms comprehend abstract conceptions as well, and they employ them in their way of thinking. They can make use of comprehensive systems of ideas, realize the obligatory character of simple basic rules and principles, and may reach to inherent conclusions.

Reproductive imagination shows increasing expansion, and consequently they are more and more efficient in conceiving and understanding phenomena which are beyond simple and direct empirical perception. Again this is the period in which mere self-conscious application of previously acquired practising methods will develop. A real understanding of musical forms and functions makes rapid advances in this period. The means of musical phrasing, too, are beginning to find a self-reliant and conscious application at this age. Behavioural impulsiveness persists during adolescence, with the difference that the adolescents are fully aware of it, and endeavour to overcome it. They begin to appreciate their own behaviour with a more critical eye. Impressions and relevant emotions are persisting longer. Positive or negative emotions concerning certain subject-matters grow more constant. This constitutes the preparatory phase within the sphere of motives for a concrete trend in respect of choosing a profession.

This is mostly the age when those who learn music realize the intention of choosing a musical profession. By this time the student has already had a taste of the delight and exertion involved in instrumental performance, and the requisite, more persistent praxic emotions (cf. p. 157) have been developed by prior training. If these are sufficiently intense, performance will considerably improve. In making a contrary choice, the reverse will be observed.

FROM 15 TO 18 YEARS OF AGE

The growth of internal organs is nearly complete. Respiratory rate falls to 16 from the previous 20 per minute. The pulse rate decreases to about 72. Systolic blood pressure rises from the preceding mean level of 114–116 mm Hg and vital capacity grows from 3200 to 4000 ml. Functional perfection of the central nervous system and of the whole organism continues. Active concentration is considerably developed in youths of this age. This is most marked in the favourite curricular subjects, and is also related to an advancing trend towards choosing a career. In its turn, active concentration makes learning easier, the requisite willpower being needed only at the beginning of study. Learning itself shows a dominance of intellectual understanding. This is the reason why youths of this age enjoy, and insist on, logical arguments when changes are introduced in fingering, style of bowing, and interpretation. On the basis of having understood the events they attempt to put forward hypotheses. This derives from their vivid imagination. Their skill of expression is also gradually improving. As they proceed in shaking off the internal seclusion of adolescence, so do accuracy and clarity improve in intellectual and emotional expressions. The unfolding of imagination and expressive force stimulates the self-appointed, exacting standards of musical interpretation. Self-conscious conception and an effort to realize it begin at this age. It is the time when teacher and pupil will become engaged in discussions concerning style and interpretation. It is advisable to treat the pupil as an equal in these discussions. The pupils will never yield to an opinion proffered on an authoritative basis; they expect to be convinced.

During this period their capacity for work increases. However, the pupil is liable to fail in appreciating it correctly, and overestimates his powers and his factual knowledge. In such cases he comes forward with a wish to perform the violin concertos of Paganini just heard at a concert. Nevertheless, the processes of volition are no longer so impulsive; not that they were irresolute, but they postpone their wishes after having given careful consideration to pros and cons.

FROM 18 TO 23 YEARS OF AGE

This is the period during which the individual character of the young teacher or artist is fully shaped. In general by this age only those will continue to learn who chose violin playing as their career. The would-be artists, teachers, or those who wish to attain a higher standard of amateurism, are absorbed in studying with a sense of vocation, and are able to solve high-grade technical and musical problems. They already dispose of the necessary emotional factors and will-power. As regards artists and teachers, development of neither personality nor mastery could be expressed by periods of age; nor can it be guaranteed by graduation. Where studies end, self-dependent work begins. Artists and teachers develop throughout life.

PROBLEMS OF DISPOSITION AND TALENT

As far as results or performance of human activity are concerned, that part of psychological dispositions which is generally called talent or aptitude deserves special attention. According to Teplov (1947), talent is understood as a qualified combination of aptitudes on which some extent of success depends in a definite field of activity. However, the influence of hereditary factors should not be disregarded in this respect according to the Pavlovian sense of constitution. Man inherits from his ancestors not merely certain physical marks (constitutional elements, figure of head, colour of hairs and eyes, etc.) and certain definite reflex mechanisms (feeding, avoidance, walking reflexes, etc.), but temperament, a type of nervous system as well. The latter obviously leaves its stamp on some of the mental events, though several details of the interrelationship are so far unknown. We can but regret that the impact and extent of hereditary factors affecting aptitudes cannot yet be shown by objective methods, and that thus we have to content ourselves by appraising aptitudes merely by the progress made during evolution and developmental course.

In analyzing musical talent hereditary factors cannot be left out of account, though due attention should be paid also to the important influence of musical education. The way Teplov looks at it seems to be right, in that it is not the musical talent, but the disposition for it which is inborn, and is the basis on which a talent may build (this may also be spontaneous at first). A talent for music is far from being a sum total of isolated musical faculties in any case: it is an interlinking of aptitudes characteristic of the entire personality. This interpenetration of abilities involves not only explicit musical ones, but also such 'extramusical' qualities of the individual as concentration and will-power, etc. The latter is of great consequence, because learning music, instrumental performance, belong, from a psychological point of view, to voluntary actions.

Musical talent is therefore a compound of inherited and acquired qualities in as yet unknown proportions, but it constitutes an intimate dialectical unity. Age characteristics and the first manifestation of a musical talent may not be directly related to one another. According to Teplov (1947) and Michel (1960), an exquisite musical ear is characterized mostly by the very fact that it reveals itself very soon, without having been taught, so that even the parents come to realize it at a well-developed stage and form (as regards its elements). Thus, a child of 3 or 4 may display auditory conceptions or even motor faculties that would otherwise correspond to a considerably older age.

The above description usually applies to the majority of great artists if their biography is considered; it often happens, however, that the faculties of an excellent artist develop later, in the course of intensive musical education, though in double-quick pace than in persons of average potentials. In some other instances the children in question show a rate of general development that corresponds to the chronological age in spite of the fact that their auditory conceptions were manifested before time.

Several writers have investigated the relationship of musical talent to other kinds of capabilities. According to Michel's report (1960) only 12 of the 76 students who displayed an excellent aptitude for music showed less favourable progress in other, non-instrumental subjects. In over-all performance the mean level was 27 per cent higher in comparison with less talented ones. Schüssler (1916) investigated 200 children whose faculties for music were poor, and found that only one per cent of them performed better in other subjects. Bartsch (1920), however, did not find a difference of significance between the performance levels of pupils who were very good and those who where rather weak in music. The picture is thus not uniform. In our opinion, further studies will be required to elucidate the connexion between musical and non-musical faculties. In the initial period of learning music musical aptitudes are usually displayed collectively and they represent collectively the reference level characteristic of a child's musical faculties. Subsequent development mostly shows, however, that one of these faculties comes into prominence. The individual qualities of a child's musical talent evolve in the course of learning music. This fact explains several others, first of all the cause of certain phases of stagnation. In practice it is a common observation that pupils who were considered talented as beginners, fail the requirements at a later stage (e.g. at a higher grade of school or technique). Such educational 'disappointment' is due to the unequal development of musical skills. If this refers to one of the principal aptitudes, and fails in spite of intensive training to attain the level required by curricular material, we have to renounce the project of teaching him instrumental playing at a professional level. The most important musical aptitudes which, in Teplov's (1947) words, "constitute the nucleus of musical mind", concern the perception and production of motion of pitch and rhythm. Speaking of a performing art, sense of movement and the skill in executing movements are in a fundamental relationship with musical mind. Accordingly, the level of instrumental skill may set limits to further development and also settle its further issue.

WILFUL ACTION, COGITATION

In Chapter One we referred to the four categories into which human movements may be classified in respect of functional principles. Wilful actions constitute the highest class. Voluntary motion consists of complicated reflex chains. The execution of movements involves large areas of the brain hemispheres in these instances. Cortical motor neurons may establish contact with any of the cells supporting other purposes in the cerebral cortex and this, too, obliges motions to depend on the hemispheres as a whole. Intelligent, purposeful action, i.e. the best developed form of psychological adaptation, is built upon the foundation of voluntary motion mechanism. In the course of intentional actions internal obstacles (e.g. habits) or even external ones have to be overcome. This requires will. Thus, purposeful activity means also an act of will-power. Accordingly, wilful action is the name for a conscious activity towards an aim, provided also that obstacles have to be overcome. Wilful action in man is determined, and also distinguished from that of animals, by two facts: (1) consciousness, that is, the existence and function of the second signal system, and (2) a higher level of memory functions and imagination consequent upon it. The latter is apparent in the case of new actions; man projects the outcome of work done previously into the future (anticipative engram) and by using it may assess both the action and its expected result. Imaginative function, on the other hand, generates new versions according to the model of engrams already acquired. The essence of the problem lies in the fact that man acts consciously, on decisions resulting from the struggle of motives (potential actions). Between motive (even if it were instinctual, i.e. unconditioned reflex connexions of great intensity) and action itself, a cogitative process is interposed. Sechenov put it aptly (1866, re-issued 1961; p. 76): "thinking is an uncompleted reflex". Human cogitation, the most intricate function of the cerebral cortex, has evolved in close relation with speech.

The forms of central nervous function described so far represent a whole system of signals. They occur both concurrently and successively. In beings with a highly developed cerebral cortex they are able to conform within broad limits to changing external conditions, and thus to maintain the stability of internal environment (body temperature, blood sugar concentration, blood pressure, etc.), which is indispensable with the vital functions. The complexity of functions which establishes contact with the environment by perception is the first signal system. As it happens, this is also the highest level at which the system is capable of attainment: it is incapable of doing more. Perception is a particular reflection of reality, because nervous excitation and the response elicited by it are experienced emotionally; as such, perception represents the first stage of psychic events.

Among the incoming environmental stimuli the complex ones which constitute words and speech are of paramount importance in man's life. The indirect signals of those referring to the changes of the surrounding world constitute together a qualitatively new, second system of signals. The connexions established by the motor acts of speech and writing constitute the chains of conditioned reflex elements making up the second signal system. By these connexions human adaptation to the environment improves, until man develops abstract thinking. Pavlov thought the qualitative difference between the behaviour of man and animal to be rooted in the 'excess' provided by speech and language. He said in 1932 that "this excess consists in the function of speaking by which a new principle has entered the activity of the hemispheres. Whenever our perceptions and impressions refer to the world surrounding us, we are made aware of the first order, i.e. concrete, signals of reality, whereas speech, and particularly the kinesthetic sensations travelling from the organs of speech to the cerebral cortex, represent signals of the second order, i.e. signals of signals. This means an alienation from reality, and provides the possibility of generalization. It is performed by our peculiar, human, high-grade thinking which first brought about general human empiricism, then science itself, to possess a human means of high-grade orientation in the world around and in us. . ." (Pavlov 1951, Vol. III/2, pp. 232–3).

The word is therefore a signal of signals and may replace perceptions. This is the reason why Pavlov called speech the second system of signals. The physiological substratum of the function of the second signal system is the very same nervous tissue as that of the first signal system. Thus the functional principles of the latter are valid here too. The only difference is that in this case the various nervous functions (conditioned reflexes, dynamic stereotypes, etc.) build upon verbal stimuli instead of direct physical or chemical ones. That is, word takes over the duty of direct stimuli. The fact that words are conventional symbols is not restricted to speech: the system of signals is a 'general method' of our whole intellectual life, cogitative activity. The ideas which are materialized in words become signals in science, in art, but in everyday life, too, especially when we want to put them down in writing. Mathematics ($\int$ = integral, dy/dx = = differential, etc.) and music had established well-developed systems of signals for which a similar principle is valid as for speech: only those who have learnt their meaning will understand them. The comprehension of signals, the realization of their connexions, the conclusions they imply, the solution of problems induced by the chain of activities based on all these, furnish the preparation of activity thus suggested; all occur within the framework of the cogitative process.

Musical creation, its conception, categories and logic are all products of thinking. The logic of 'the musical way of thought' is, naturally, different from that of mathematics, for example, but this will not alter in any way the fact that it is an organic part of human cogitative mechanism. In music the process of thinking, and further, of the entire psychic (emotional, volitional, etc.) act is released by sounds. This fact is fundamental to our musical actions. Musical action and the perception of music itself are, however, always coupled to cogitative processes. Teplov (1947, p. 5) expresses it by saying that "the work of art does not represent a source of immediate aesthetic delight for the child. Before becoming this, it must convey something having meaning and contents, something that is comprehensible in the strict sense of the word". This is made conspicuous, first of all, not by passive listening to music, but by singing or instrumental playing. In order to be able to interpret a musical composition adequately one is obliged to understand it.

In thinking processes several possibilities are available for the solution of a problem. The act of will aiming at a solution is a complicated polyphasic manoeuvre. The first phase is that of the deployment of motives. The second phase concludes the struggle between possibilities and motives by arriving at a decision. In the third phase the operation is executed. In this procedure, too, i.e. in the execution of a conscious act, the entire human personality is involved: his perceptual, empirical, intellectual and emotional powers. The education of will-power is an essential precondition of success in instrumental performance. The basis of mastering an instrument consists of regular practising, in addition to the necessary musical mindedness. Let us not deceive ourselves: we must have considerable will-power to induce us to regular practice, even if we are passionately fond of our profession. For the sake of our aim, we must do without many things for years, which in itself requires a strong will-power. Thus the career of an instrumental artist depends as much on will-power as on talent; this must be clearly understood in the course of training.

THE ROLE OF EMOTIONS IN MUSICAL ACTION

The efforts and subtle action sequences of violin playing are related primarily to the internal life of emotions and intellect. By its very nature, musical activity confirms the validity of the assertion that an act of will is made intensive enough only if it is supported by adequate emotions. The reason for this is that music exerts its influence above all through the emotions, and because of this, the investigation of emotional phenomena has a special role in the psychology of musical actions. The inner life of man—as has been said—is a subjective reflection in the mirror of personality of an objectively existing world of reality. Within this psychic function, such reflections that classify the influences of the external world, or of our internal organs, according to their agreeableness or disagreeableness, are called emotions. Thus we perceive negative and positive emotions (pain and pleasure). Thus emotions represent a definite relationship between us and the objects and events of the world. The relationship upon which our personality enters with the phenomena of the surrounding world depends on the functional characteristics of our central nervous system. Essentially, Pavlov in 1932 characterized such processes as follows: "we are obliged to think that the nervous processes of the hemispheres during the establishment and maintenance of dynamic stereotypes are identical with what is usually called emotions, namely the two fundamental categories of positive and negative emotions in every version of subjective intensity" (Pavlov 1951, Vol. III/2, p. 230). In 1935 he said: "Our feelings of agreeable and disagreeable, easy and difficult, cheerful and sad, victorious and despairing, etc. mean either that our strongest instincts and the relevant drives develop into suitable executive acts, or that they are impeded. Sometimes they are related to the easy or difficult version of processing nervous events in the brain..." (Pavlov 1951, Vol. III/2, p. 335). Consequently, the emotional condition induced by man's external environment and internal motivation is a reflection of the functional integration of his central nervous system. Cerebral cortex, subcortical ganglia, as well as the autonomous part of the nervous system, take part in it collectively. The excitatory impulses imparting the emotional colour may arise both from the cortex and the subcortical substance, but they are nevertheless interrelated. The physical symptoms associated with the emotional state (pulse rate, ventilatory and blood pressure changes, etc.), similarly to those that have other causes, commence in subcortical centres, though a cortical activity of the highest order may also cause emotional conditions. For example when one remembers (in thinking about it), or in perceiving verbal stimuli as well, the organism will respond by emotions. Emotions in their turn may have an influence on the function of memory: fear, for instance, may partially paralyze it (exam-panic), while euphoria may stimulate it, and so on. It is inferred from these that the prevailing state of the nervous system leaves its imprint on human emotional manifestations.

Emotions are not simply experienced, but are expressed in a variety of explicit ways: by gestures, pantomimics, tone of speech, etc. Many start spontaneously, in agreement with the reflex nature of the psyche. The basic mechanism of emotional expression indicated above had already been possessed by the immediate ancestors of man, which is proved by the observation that certain means of emotional expression are found even in the animals having a well-developed nervous system (horse, dog, monkey). The evolution of consciousness in man has brought about a qualitative change in the expressive mechanism of emotion: it is regulated, controlled, and made intentional. The historical development of society has also had an impact upon the evolution of expressive means, since every era in history has its own demands upon increasing refinement in emotional expression.

The organs of the capacity of expression are set in motion by the effector muscles. The more differentiated their activity, the more colours and shadings of feeling can be imparted to the expression, and the more varied the means by which we make others realize our emotional state. This is the quintessence of technique both in respect of verbal and instrumental performances. Technique and its conscious improvement are not ends in themselves, but an inherent part of shaping the performing artist's personality. Consequently, we cannot speak of such a personality, either a pupil or a performing artist, if he is unable to interpret for us both his own emotions and those of the composition performed because of his insufficiency of technical means of expression. Where emotional influence and technical accomplishment are concerned, the teacher of music must also be a personality in the art of performance.

According to Yakobson (1958, pp. 206–28), emotions may be classified into the following four categories. (1) Moral feelings. They are related to our fellow-men, to the rules and requirements of living in a community. (2) Aesthetic feelings. The relation to events and objects becomes endowed by the attributes of an aesthetic emotion, if the approach is made in respect of a special order of values, bearing on the conception of the beautiful. The arts are an important field in the formation of aesthetic emotions. The latter are induced in music by perceiving, analyzing and understanding the melodic, rhythmic and harmonic elaboration of notes, and by the structure and characteristic mood of the composition. (3) Intellectual emotions. These are associated with the process of recognition; essentially they derive from the desire for knowledge. (4) Praxic emotions. They are induced by the concrete activity itself. It is a characteristic feature of an emotional response that during an uncomplicated, mechanical, work it refers rather to the final result and not to the process itself, whereas if the task is intricate and as yet not mechanical, automated, it is then primarily associated with the activity itself. In the course of teaching and in elaborating practice-technique it is useful to consider the properties of praxic emotions.

The learning of a musical instrument, as far as the nervous processes are concerned, implies the formation of a vast number of fresh dynamic stereotypes. This, as has been seen, is one of the sources of the rise of emotions. Any impediment of neural processing (such as the unexpected occurrence of sudden changes for the worse in technical difficulty) will arouse disagreeable emotions, whereas if its course is unimpeded, it induces pleasant feelings. Thus violin playing may become either a pleasant or an unpleasant activity. Since work ought to satisfy an emotional need, and become a habit and in itself a vital condition of man, the evolution of dynamic stereotypes should be made as free of impediments as possible. This is the only means by which we can promote the readiness of practice and performance of a future artist; that he should feel it a vital need to give full vent to his emotions in playing his instrument. This is mainly a problem of selecting correct methods of teaching and compiling a good syllabus.

THE METHODS OF EMOTIONAL EDUCATION

In the course of artistic creation we strive consciously to express emotions by artistic means, to communicate them to others. The birth of a composition or a performance that reflects our emotions will be the result. In order to develop artistic skills of performance one of the most important psychological requirements is the faculty to store emotions in the memory and to recall them possibly independently from external circumstances. This is one of the preconditions of a successful performance; in fact, it depends on correct technical methods of practising as well as on the actual disposition and physical fitness of the performing artist (Chapter Seven deals with the latter). In order to promote effectively the development of emotional life at least the main features of exerted influence must be known and employed. They are the following.

(a) Verbal guidance, in order to make the contents and characteristics of the respective emotion conscious.

(b) The power of expression, which is learned by imitation, by imitative responses. The pupil is thus able to learn by imitation. This method has some advantage as well as disadvantage. The advantage is that acquisition is relatively quick; it has the drawback, however, that precisely because of its convenience it may promote epigonism, a failure to develop original powers of performance. Provided the right words are chosen, a verbal suggestion about the mood of a composition may be more preferable than an introductory performance, because it urges the pupil to employ some original means of expression. Naturally, the preferred method should match the attitude of the pupil.

(c) The instrumental movements of a performance may be considered expressive motions, and this is indeed a proper method of teaching. This applies particularly to the teaching of bowing. Regarding these and other technical problems in general we should endeavour to allow an opportunity for the development of praxic emotions first. The pupil should 'be delighted' when he plays the violin, and should be pleased by his success in solving a technical task. Correct technical education will thus reinforce, re-affect the development of musical interpretation and performance.

(d) Allowance must be made for emotional adaptation. This, like adaptation in the sense organs, is revealed by a growing insensitiveness against repetitive effects. Every repetition has to involve new elements and new episodes so that the repetition of an event inducing emotional responses should not weaken but strengthen the emotions originally elicited. In the effort of mastering a composition several repetitions are needed. The teacher will listen to, shape and polish, it again and again. The pupil may become indifferent to, and tired of, countless repetitions, unless the teacher discovers new beauties for him in the piece, and challenges his fresh emotional reactions.

Insight and empathy must be taught as systematically as the technicalities of composition. In addition to, and together with, integrating the partial tasks described earlier, the whole personality must be moulded accordingly. This is the point where emotional education joins other, viz. intellectual, volitional and general human sides of training. Great importance must be attached therefore to the teacher's conduct, for his views will leave their imprint in the pupil. Its psychological basis is the phenomenon called 'emotional infection' (Yakobson 1958, p. 162). Thus, the child responds to laughing by laughing, to crying by crying. In adults this is exemplified by mass effects. Essentially, both are the result of the diffusion of the excitatory state. The teacher's attitude should be genuinely emphatic and convincing in all respects. If the teacher's attitude is impassive or neutral concerning the musical composition, or everyday life, the pupil cannot be expected to show positive emotions: he will fail to experience and to learn one of the performing artist's most prominent feature, viz. the ability of stirring the emotions of his audience. Without it he will become an insensitive imitator, at best a cool virtuoso.

PROBLEMS OF FITNESS FOR A MUSICAL CAREER

All that has been said brings us to the question of fitness, i.e. the question of whether the applicant should begin to learn violin playing at all; if so, what should be his aims, what could he expect for the time and effort spent to this end? Clear insight is desired about this on the part of the pupil, parent and, last but not least, of the teacher. Obviously, a good ear, capable of development, and normal motor faculties are preliminary requirements. Anyone can be taught to play the violin up to a certain standard, if these conditions apply; up to about the material of the first four grades. It is one matter if the pupil decides on music as a professional career, and another if he wants to enrich his general culture for his own amusement only. At this point the neural and psychic factors make themselves felt.

Teplov (1947, p. 24) defined musical aptitude as a peculiar coincidence of faculties on which a possibility for success in dealing with music depends. One can analyze the talent for music, he goes on, from several points of view. According to one, musical talent may be divided into: (a) psychic faculties needed for musical activity alone and (b) faculties necessary for any other branch of human activity. From another point, the faculties should be investigated as to whether necessary for every kind of musical activity or for a certain activity only. He divides musical activities as (1) listening, (2) active performance and (3) composition.

Instrumental playing comes into the second category in this classification. Analyzing it we have to make even more delicate distinctions: because while a musical ear is indispensable with every kind of musical activity, requirements differ in respect of amateur music-making, professional performance, and teaching. In view of this, the question of fitness, too, requires a more complex definition. The principal difference in the necessary faculties is not quantitative, but qualitative. Before discussing details, some basic problems must be clarified. Corresponding to the two main factors of instrumental playing the necessary faculties, too, are divided in two groups whose balance will be decisive upon the success of instrumental performance. These are: (1) aptitude for music and (2) developmental stage of the motor apparatus.

Talent for music is a complex whole, depending on a co-operation of various parts of the brain, while instrumental motor skill is an essential part of the individual's general motor aptitude. This is true even if this relationship is sometimes concealed by the practice necessary to develop musical movements. Both faculties are partly inherited, partly acquired by learning. The process of learning forms a part of non-musical human activities as well. The success of learning music is therefore affected by several 'non-musical' features (will-power, the quality of memory, etc.). In addition, learning to play an instrument is also a cogitative action subjected to the general rules and individual properties of thinking. Fitness therefore is a question that is settled by a collective appreciation of several components that characterize the whole personality.

AUDITORY CONCEPTS. SENSE OF ABSOLUTE PITCH

An ear for music means literally a sense of pitch. This is measured in cents, referring to the still audible differences in pitch. In average individuals this varies between 6 and 40 cents. By learning and practising music an existing level of threshold value may be lowered relatively quickly and to a considerable extent, the sense of pitch develops to a considerable extent. Guttmann's (1927) investigations show that the sense of pitch is most sensitive in singers and in those playing strings or wind instruments. The threshold of sensitivity improves markedly in the age of schooling: by 6 years it is about 70 cents, by 19 it is about 14 cents (data from Gilbert, see Teplov 1947, p. 101). Thus, the range of improvement in pitch sensitivity is so wide that a delicacy of pitch sensation cannot be a criterion of fitness, except in special cases. Some people are able to tell the pitch of isolated notes or sing one on demand at the pitch of its absolute frequency. If both faculties coincide, we speak of an active sense of absolute pitch, if the latter is absent, of a passive one. The accuracy of the sense of absolute pitch is considerably reduced in the outermost octaves.

Though a sense of absolute pitch is of advantage for a musical career, it cannot be a criterion of fitness in itself. Indeed, a sense of absolute pitch, even an extraordinarily high sensitivity to the relative height of notes, would be insufficient in itself to warrant musical talent. There are great many children who, though having excellent sensitive ears, do not understand, cannot experience emotions induced by music. Neither can they feel an urge to express such emotions. Others may not have an ear of outstanding sensitiveness, but they are able to grasp, and have a power to express, the feelings conveyed by music.

To possess a musical ear represents a very complex acquired function which, when trained, involves the hearing of timbre and pitch as well as harmonies and tonality. For this very reason, fitness for instrumental learning cannot be judged by testing merely the sense of pitch. The pitch-sensitivity of applicants may reveal something, usually rather inaccurately, about the choice of the suitable instrument. Those who possess a less sensitive ear may perhaps be directed towards instruments of fixed tuning. Interval hearing, i.e. the sense of relative pitch, which is indispensable to efficient music-making, is really a development of melodic hearing. It can best be improved by melodies in which the interval to be remembered is the first step, or comes at a prominent place. The sense of tonality is characterized primarily by the fact that it registers some notes as the outstanding, main notes of the tune, i.e. it recognizes their particular function within the melody. The tonic, i.e. the sensation of conclusion, is recognized first, generally between 8 and 11 years of age. The sensation of the dominant becomes common by 11 or 12 years of age. The sense for pureness of intonation is a yet more complicated function, because the assessment of intonation depends mainly on emotions. This theorem is confirmed by the observation that when we listen to an unknown melody, the auditory sensation is not preceded by a corresponding advance-conception, yet we are reasonably well aware of its pure intonation or otherwise by the performer. The assessment (sense) of intonation is therefore not far from a kind of sense of tonality; it represents a sensitiveness to tone-colour within the tonal system (Teplov 1947).

Fundamentally, the sense of rhythm possesses motor character, and is manifested by actual movement. According to McDougall's (1902) findings rhythm induces periodical changes in muscle tension, often without affecting the spatial location of the muscles. The conception of musical rhythm is, however, different from rhythm as it is understood in our everyday life. The latter serves to designate a sort of periodic recurrence, whereas musical rhythm postulates the presence of accents, of some prominent stimuli around which unemphasized ones are grouped. This is the reason why movement in itself does not create a feeling of rhythm in the musical sense, in spite of the fact that motor episodes are inherent in the sensation of rhythm. Movements will impress as being rhythmical only when some of its elements are emphasized. This is why it is sufficient to say 'one, one, one' to keep a regiment marching at command; the first step will organize the second. The accented and unaccented elements of music do not alternate in a haphazard manner, but they convey as much of the message as any other component of music. Thus musical rhythm must be sensed and understood. If the part of the tune to be stressed is not felt or understood (which part of the bar or which note), its rhythmical performance will not be possible. Rhythm is therefore tied to actual music: rhythm does not exist as something 'in general'; only a given melody can have a definite pulse: rhythm. Accordingly, as Teplov (1947) maintains, there is no correct method of teaching rhythm generally. Many writers believe that the fundamental musical faculties are musical memory together with an ear for music and a sense of rhythm. Teplov (1947, p. 304) disagrees and considers it a faculty for recalling auditory images, that is, an aptitude in possession of which we can make conscious use of the phonic ideas reflecting the motion of pitch.

PHYSICAL CONSTITUTION, THE DEVELOPMENTAL STAGE OF MOTILITY

Successful instrumental performance does not demand a special kind of physical constitution, or peculiar body structure in any sense. The size of certain parts of the body, especially the size of the hands, may at most support or hinder the execution of some technical manoeuvres (small-handed persons find certain fingering on the double-bass difficult, for instance). It has, however, no decisive influence on the performance of motor acts, obviously because the technical tasks of the musical material may be matched to the prevailing conditions of the body by suitable fingering and other measures. Extraordinary cases, such as the fluency of playing passages in tenths, constitute no criterion of being an excellent artist. In judgment of aptitude it is therefore not the 'long hand' or 'broad fingers' which count, but rather the neural characteristics of motor organization. We have already endeavoured to treat this problem in detail, and confirm our view that an assessment that relies on the size of the body and explicit physical signs, as is fostered by some German and Hungarian teaching methods, should be rejected as outdated. They have no more to do with success or failure in music than Gall's skull measurements had with mental abilities.

Naturally, constitutional factors are not altogether negligible in assessing fitness. Before passing judgement, however, we have to be careful. First, because not infrequently there are surprises as the child grows up. Further, the standard of violinistic skills and faculties is affected considerably by training, as will be shown in the following chapter. Its physical signs are: the muscles involved grow stronger, co-ordination improves, the mobility of joints increases, etc.

When the process outlined corresponds to the correct age group, and the motor requirements to that of the violin curriculum, physical disabilities do not enter in discussion. Suitable exercises will bridge over incidental difficulties.

METHODS OF PERSONALITY ASSESSMENT

Concerning practical methods of musical training it would be most important to arrive at an exact definition of the concept of musical mind. However, in the present state of research in musical psychology not even Teplov would venture to do so. He considers musical talent as a coherent system and peculiar composition of musical faculties. According to him the principal feature of musical talent is that by possessing it one comprehends music as the expression of certain contents. "He who hears more in music is more musical-minded" (Teplov 1947, p. 37).

We might proceed a step forward beyond these descriptions and arrive at some practical result if, as Sándor does (in one of his lectures in 1960), one raises the following questions as criteria for musical talent: how far can the pupil realize the interconnexion of the main structural elements of music, to what extent can he recall them after the sound effects have ceased, and how well can he render the music just heard? Naturally, reproductive ability is related also to the skill acquired in singing or playing an instrument. The musical faculties representing the musical mindedness are developed in the course of learning and practising; a talent may be assessed only by following the student along his course, as both Teplov (1947) and Michel (1960) emphasize. Every attempt which concerns recognition irrespective of musical activity is bound to fail. Similarly, neither component of musical faculties may be categorized or 'scored'; the results obtained by the various musical tests are therefore misleading.

Though standards of appreciating the actual level and quality of skills and aptitudes appear rather labile, there are some characteristic features within the process of development. Their regular and extensive investigation will enable us to assess the degree of musical talent, and in this way the fitness for a musical career. Michel (1960) emphasizes two attributes: (1) the ease and rate of acquisition, and (2) the rate at which progress is made.

These two factors have to be compared with the conditions of improvement, and with the individual state of affairs in which they occur. Under adverse conditions the same talent will perform less well than under favourable ones. In favourable circumstances better results are obtained even with less natural talent. We have only one relatively safe guide in this respect; an impressive performance achieved under very adverse conditions indicates outstanding talent. The fact that a musical talent may be fully recognized in the course of its development, raises the question of how far are regular annual examinations justified. In our view the argument that by being examined one obtains training in performing well at a concert is erroneous. The circumstances and atmosphere of an examination are not identical with those of a recital and will never be so. The examiners, whose duty is above all to criticize and not to enjoy the recital, do not represent for the player the same stimulus as is provided by being listened to by an audience. There is no applause which, as a direct emotional reaction to the performance, could reassure and delight the performer, and thus make him forget occasional mistakes. On the other hand, the situation does represent a very effective means of regularly inducing a wholly unnecessary and ultimately harmful state of stress (excessive tension). Thus an exam does not provide training in anything, neither does it afford an objective measure of evaluation. It is but an accessory means of teaching that is still believed to be indispensable, though it is no longer valid, thanks to a growing improvement in teaching methods. Examinations have already been abolished in the primary and secondary schools in Hungary. As regards musical education, abolishing of examinations would be desirable, too, at least in the corresponding class forms, and particularly for certain subjects in which proficiency could be assessed within the course of the term by the teacher, even at higher levels. Instead, public end-of-term recitals should be arranged which would be relatively easy to manage. This would leave, for want of something better, the entrance examination as a transition between training methods. In fact, we believe that the whole system of entrance requires reforms. For assessment of personality, and consequently of fitness, the investigations of Ivanov-Smolenski (1953, pp. 42 ff) merit attention. He found four characteristic types in children, in respect of their deductive faculties: (1) Labile type. Positive and inhibitory-conditional connexions are established with equal ease and speed. (2) Sluggish type. Positive and negative-conditional connexions are established and consolidated slowly and cumbersomely. (3) Excitable type. Positive connexions are established easily and rapidly, inhibitory processes sluggish and tardy. (4) Inhibitive type. Positive connexions build up with difficulty, inhibitory-conditional connexions are obtained easily.

Within these groups, as in the underlying Pavlovian groups of temperament, which are their basis, there are a number of transitory forms. Nevertheless, an experienced teacher of good insight can unhesitatingly point out the characteristic, dominant type of his pupil, in the course of long series of lessons and constantly changing tasks.

Though research in musical teaching-methods goes on all over the world, no acceptable musical typology has been elaborated as yet. This is not surprising since the problem is rather complex, and a strict classification or labelling of adults and even more of the developing child would be a great mistake. However, if the teacher with long experience of the child's capacities, and witnessing its progress and development through several years, does compare his findings with the characteristic neural types suggested by Pavlov and his school, as well as those by Jung (1921), then his diagnosis about the expectations of the music-learning person will be fairly reliable. It may be of assistance concerning activities of a musical nature if we are willing to take account of three characteristic processes of regular occurrence, often together or side by side, in close relationship. These are: (1) an aesthetic idea, based on intellectual and musical comprehension of the composition; (2) the will to convert the idea into sound; which is followed by the innervation of the requisite movements; (3) a critical review of the product by comparing it with the aesthetic conception.

Another measure for assessing fitness for a musical career might be the observation of success and improvement in these processes, the evaluation of the effect of the teacher's instructions, related to the progress made. In this connexion additional importance is attached to a 'real' interest displayed by the pupil in his efforts towards progressive improvement. It is revealed in that quality of practising which provides the fundamental factor in continual improvement in instrumental aptitude. The problems of practising represent a salient point of improvement in instrumental accomplishments. This is why particular attention will be given to them in the following pages.

Chapter Six

LEARNING AND PRACTISING IN VIOLIN PLAYING

GENERAL CHARACTERISTICS OF LEARNING AND PRACTISING

Part of our behavioural patterns is inherited, another is moulded by individual experiences of life. Thus all our activities, the simplest as well as more complicated ones, are eventually the results of learning and practising. The principal condition of learning to execute some concrete form of activity is that the sequence of actions required for its execution must become established, consolidated, and recalled even at a later point of time, and operative within certain limits in varied circumstances. The same is true of playing a musical instrument. The skills of instrumental performances improve, therefore, in the framework of the process of learning and practising. However, in analyzing the relevant features we should not let ourselves be deceived by the word playing, often used in connexion with music. Playing, learning and working are all different ideas; they represent specific kinds of action which, though having several common features, nevertheless display essential dissimilarities. One of the most significant is that while working one goes beyond the point that is of immediate interest, in playing one deliberately chooses what one is interested in, as well as the method of approaching it. There is hardly a composer who would enjoy copying by hand his orchestral score of several hundred pages. Where is the instrumentalist who would feel that the repetition day by day of certain technical exercises for warming-up is the sole purpose of life? Rubinstein (1958, p. 719) is right when he maintains that artistic creation means labour.

The same holds for learning. The attitude of the person who learns is not of a player, but of a worker. This is disclosed in the process of learning and its requirements. (1) In learning, as in working, a definite task must be tackled. (2) Preparation is obligatory; and in the course of it certain order and discipline must be observed. Violating them may have more serious consequences than violating the rules in games. (3) Learning thus consists in accepting obligations and executing them, irrespective of whether any part of it is pleasant or unpleasant.

Learning is not a spontaneous act: it is a considerable burden on the will-power and the conscience of the individual. The same applies, of course, to learning to play an instrument, including its entire cogitative process. The latter point must be emphasized, because many people approach musical performance from the emotional side of life only. As already mentioned, Teplov (1947) has insisted that artistic creation does not mean immediate aesthetic pleasure; rather one must toil through the realization of its contents in order to arrive at an understanding of artistic interpretation. Evidently, the interpretation of a musical composition is impossible without mastering the requisite action series, and without the comprehension of its musical and motor components. The placing of special emphasis on practice is of particular importance in the learning of a musical instrument. The ability of an instrumental performance of a piece of music is acquired during the activity of practising. We have therefore to look into the subject of practice in more detail.

IMITATION

Exploiting the faculty of imitation is an important factor in learning and teaching. Imitation is an unconditioned, inherited response; it is a reflex which is inborn and genetically fixed (Yakobson 1958, pp. 131–2). This is the basis of development for several new forms of activity. Spontaneous imitation becomes gradually conscious as the child grows; though the forms and methods may change, the basic features persist. Thus the first attempts of the pupil consist in an imitative rendering of what he has heard his teacher play, or at a concert, or by listening to a gramophone record. This conscious imitation alleviates acquirement, and teaching practice makes frequent use of it. Since it kindles emotions, demonstration-playing for the pupil (equalling the experience of listening to a recital) is an effective means of pedagogy. Several factors (such as timbre, dynamics, articulation, subtle distinctions of rhythm) which, being significant of the mood and musical interpretation of the piece to be learned, can be lastingly memorized by emotional means. The learning of music has certain elements that cannot be easily explained, but should rather be approached by feeling, and cannot in fact, be acquired in any other way.

One should be aware, however, of the inherent drawbacks of this method in regard to the process of learning. However attentive the pupil may be during the introductory performance, the several auditory and visual impressions alternate so swiftly that some delicate, and possibly decisive details of performance and executive movements, which affect the result of study, might become obscured in the process. At most we would recollect the over-all image of the piece and some motor manoeuvres, and this is not sufficient to reproduce the whole series of actions of the performance. Explanations must not be omitted, for they illuminate precisely those associations of musical imagination and executive motions, whose comprehension is essential. The most efficient method would be to link them to the demonstration-playing. About the function and certain requirements of explanation, we shall have something to say.

MEMORIZING

Memorizing is the first stage of learning. In Rubinstein's (1958, p. 360) definition it is the mnemonic fixation of new experiences or cogitative recognition, in order to utilize them in practice and in subsequent activities. Things are committed to the memory either involuntarily or consciously. Frequently, memorizing begins by accidental perception, to become conscious later in the process of memorizing. A typical example for accidental memory is the memorizing of a 'catchy tune'. In this case at least two factors have to be present: (1) the tune should have some suitable features to promote memorizing (such as some well-known pattern, impressive rhythm, easily identifiable harmony, etc.), (2) a receptive attitude to the characteristics and mood of the tune heard.

In general, the second point is decisive. Those who prefer dance music, will find hits catchy. On the other hand, they may listen any number of times to a symphonic piece of music broadcast on the radio, and yet will not remember it, however simple and tuneful it may have been. Similarly, there are many excellent musicians who know scarcely any of the hit tunes, in spite of their aptitude for memorizing. In addition, age characteristics also influence the thing committed to memory. The scope of individual interest, modified by the relevant age group, is also decisive in the objects to be retained in the memory, and in the extent to which it is to be memorized. In planning the schedule of a syllabus this has to be taken into account. For those who, for instance, decide on a professional career of engineering, and yet wish to continue with studying music, a different curricular schedule has to be devised and different methods have to be applied, owing to psychological reasons alone.

Though accidental memory is often stronger than conscious commitment to memory, the role of the latter is decisive insofar as the process of learning is concerned. In investigating the process of learning, greater attention will have to be given to the particulars of conscious memorizing. Experimental results have shown that the logic inherent to the subject has considerable impact on the rapidity and endurance of commitment to memory. Naturally not all that is memorized rests on intellectual relationships and not any sort of subject makes it possible (e.g. numerical data or series of numbers and historical dates, etc.). When the material cannot be arranged into a meaningful entity, memory often resorts to the structural units (divisions, symmetry, rhythmicality, etc.). Generally speaking, the basic condition for success in memorizing is a clear arrangement and consistency of internal relationships. This is why it is so important to get acquainted with the piece to be learnt before settling down to practise it, even if taken in sections.

Human memory is by nature selective; thus memorizing as an act of will is dependent a great deal on mental attitudes. Things relevant to the outcome of our actions will be memorized first. This means that the depth of commitment is significantly affected by the individual's emotional disposition as well. Commitment to memory does not depend entirely on the positive (pleasant) or negative (unpleasant) nature of the emotional state associated with the experience. It is always the emotionally more real, the more essential to the individual, that is retained. This tendency is so strong that in some cases an unpleasant thing is committed to memory more deeply than a pleasant one.

FORGETTING

Next to commitment, success in learning depends also on two related processes, namely, on storage and forgetting (oblivion). The extent of retention, of mnemonic storage, is above all determined by the efficiency of commitment (to memory). As pointed out, meaningful texts are retained better than nonsense.

Similarly, the general traits in the individual's character (whether he is egoistic or gregarious, unforgiving or generous, etc.) exert a marked impact on what he commits to memory, either spontaneously or consciously, and even more on what he will retain in his memory.

In learning instrumental music the principal means of memorizing and retention consists in practising, from which both processes originate. We have to keep on fighting against forgetting in order to retain the results of our learning. The main features of forgetting are as follows: (1) Its time dimension is unequal. During the first period that follows learning, more is forgotten than later. (2) Its spatial disposition is also unequal. The opening and concluding parts of what has been learnt are retained by the memory longer than the middle part. (3) In case of forced learning, i.e. when we strive to memorize too much at a time, or when in securing deeper memorizing we practise something too many times successively, forgetting will be greater, too. (4) What we learn in a tired-out state will fade sooner. (5) Parts which are of a similar or identical nature are forgotten sooner, because storage is impeded by a homogeneous inhibition. Schumann (1894) and Müller and Pilzecker (1900) supplied experimental evidence to the effect that images which had already been closely connected to certain others could be linked to new ones only with considerable difficulty. The experiments of Ranschburg (1905) have shown that similar ideas impede one another in consciousness, viz. we retain less easily those conceptions which have entered upon our consciousness concurrently with, or immediately after, similar ones.

Fig. 107. Two similar bars in Pugnani–Kreisler's Prelude and Allegro

Forgetting may be prevented by recalling and reinforcing fading engrams, i.e. by repetition. Owing to the aforementioned properties of forgetting, the time interval between acquisition and repetition obviously does matter as far as the efficiency of repetition is concerned. In order to improve upon the efficiency of repetition certain conditions have to be fulfilled. (1) The matter committed to memory should be refreshed after a couple of days, neither immediately after having memorized it, nor after a longer period (5 or 6 days). For violinists who keep to a regular daily schedule of practising this implies that if the new exercise was not practised one day, it must be inserted on the subsequent occasion. Later, after sufficient practice, it needs less frequent repetitions. (2) The middle portion of an exercise or piece should be exercised with particular care. (3) We should not strive to learn too much; relative to the energy spent, only a comparatively small fraction will be retained. Let us therefore avoid attempts to complete the learning of a difficult passage in 1 or 2 practice sessions. We should rather practise for short periods but on several occasions. (4) Practising, when carried to extremes, has a similarly inverse effect. Reactive inhibition will obscure what was practised before, and thus impede a uniform recollection of the material. (5) Learning and practice should be avoided as far as possible, if we feel exhausted. If this is impossible, let us drill only the most essential parts. Even if the results are not quite satisfactory, let us not insist on keeping on, but postpone practice to a time when we feel capable of shouldering greater burdens. (6) Particular care should be given to the practising of similar parts or passages to be repeated (such as the part which leads back to the tonic at the recapitulation) or repetitions in which some dissimilar bars are inserted. Such a dangerous point occurs, e.g., in the two bars in Pugnani–Kreisler's Prelude and Allegro shown in Fig. 107. Possibly these parts should be practised by interpolating other sections.

MECHANISM OF LEARNING AND PRACTISING

CHARACTERISTICS OF PRACTISING

As discussed in the preceding paragraphs, practising is an inherent part of the process of learning. Consequently, some of the attributes of the process of learning are characteristic also of practising: (a) it is not play-type, but work-type activity; (b) it is not a spontaneous event, and it is not identical with playful or spontaneous repetition; (c) it has a definite purpose, viz. the acquisition and perfection of skills and knowledge, and it fulfils some definite objective.

Practising is therefore an activity undertaken in order to acquire certain skills and to perfect them beyond the formative stage. The idea of practice is essentially different from the idea of repetition, in spite of the fact that both apply a frequent repetition of the same action. "Without repetition practising does not exist, but repetition in so far as it means recollection and fixation, does not wholly cover practising, since in the course of practising further perfection is also attained" (Rubinstein 1958, p. 686). Accordingly, practising has to be understood as something of a creative activity. Practising consists of a critically assessed and correspondingly corrected sequence of repetitions. Evaluation and correction are performed by the higher nervous structures, viz. they possess a psychic character. Among these psychic elements we find attention. Every practice needs attention. (The physiological mechanism responsible for concentration has been discussed in Chapter Five.) The attitude of the individual to the material and method to be practised is also psychic by nature (will-power, level of demand, etc. exert great influence on the process of practising itself as well as on its efficiency).

If practising is considered a unity of physiological and mental functions, which is a means of improving skill by forming part of the learning process, then the notion of a 'soulless practising' is meaningless. Whatsoever is done indifferently, i.e. excluding high-grade mental functions, cannot be but a kind of automatism (inadvertent repetition). It cannot in any way be called practising. Learning and practising as well as the respective sub-functions like recollection and identification have a common neuro-physiological basis. Every stimulus leaves a mark when it reaches the nervous system and induces excitation together with some associated response. This is particularly valid for stimuli on which attention is focussed, and which thus become conscious. This mark or engram is renewed by the recurrence of the stimulus and elicits the previous response under identical conditions. The ability of revival will become deeper by the recurrence of the stimulus and the response induced by it; the engram itself can be activated easier and easier. The connection established between stimulus receptors, central nervous structures, and effector organs (muscle groups producing motion or tones), through the action-specific nervous pathways, becomes more and more solid: *Bahnung* takes place. On the given stimulus a chain of conditioned responses is established. The neuro-physiological basis for *Bahnung* consists of a functional-morphological alteration of the neuron in response to the stimulus. Szentágothai (1951) has shown that in intensive functional strain the neuron synthesizes increasing quantities of its substance, its fibre becomes thicker and the dendrites more bulky. The neuron can conduct and transmit excitation faster by its growing surface than another neuron whose functional capacity was left unchallenged. Conductivity in the active fibres increases owing to practising and this will reduce reaction time. Reduction in response time is one of the results of practising and is due to a better conductivity of the reflex pathways tracked for the given activity.

Biochemical research of recent years has thrown new light on the storage of engrams (memory traces) by establishing its relationship to the ribonucleic acid (RNA) content of human brain cells. As a result of the experiments of McConnell (1962), Hyden (Hyden and Egyházi 1963) and John (1967) a new memory model was elaborated. According to this, whenever a sensory or motor neuron is excited, the discharge modifies the cellular equilibrium of ions. The latter induces a change in the pattern of bases in the nucleic acid so that it would contain more of adenine (one of the four bases, viz. adenine, guanine, thymine and cytosine) and less of cytosine. The modified ribonucleic acid synthetizes another type of protein. In retrieving the memory image, this newly produced protein is decomposed and the neuron is discharged. The cell continues, however, to synthesize the new type of protein, 'the engram is preserved'.

In the course of learning, practising creates, as it were, the conditions for a future automated execution. It is by no means a simple process. Conditioned motor reflexes, to which category instrumental performance also belongs, would develop owing to the co-operation of different neural structures. A reflection of our environment needs the functioning of every sense organ so as to complement each other. Thus auditory and motor activity, too, are influenced by the excitation of other areas. The objective of practising is the establishment and consolidation of such tone-producing motions that correspond to the composition. Stability is one of the pre-conditions of a deliberate retrieval. The others are: (1) constancy of stimulus, (2) adequate number, time, and schedule of repetitions, (3) critical supervision and control of the (motor) response of tone-production. All these are essential factors, since according to Rubinstein (1958) practising does its part in the perfection of skills by gradually transferring the weight of executive control from the cortical centres to lower centres; yet, without abolishing the role of the latter in the procedure. It is to be noted that the existence and extent of this shift is still debated by physiologists. A participation of the cortex in the co-ordination of automatical motions is substantiated by the observation that an impairment of human cortical sensory-motor areas results in considerable motor derangements. It is another empirical fact, however, that a correction of faulty but trained motions comes up against remarkable difficulties. Physiologically the reason for this is an inertness of the subcortical motor structures, a fact proved also by Pavlov's experiments. The characteristic feature of the cortex is, on the contrary, a rather broad range of dynamism and variability. In respect of practising, we believe this inconsistency to be only apparent. The vital point is that by automatizing motions the functional structure of neural regulation is modified. This modification is manifested by the change occurring in the object of concentration. As soon as automation gets established the focus of attention will be transferred to control the product envisaged by the motion in question. This shift of concentration is of outstanding importance, and consists of several episodes in the course of training. These are: (a) at the initial phase of practising attention concentrates on the stimulus (score pattern), it makes us conscious of the image of the stimulus; (b) when the image of the stimulus has become consolidated by repetition, attention turns towards the relevant proprioceptive modality (such as the sensation of stopping, or of bow length and weight, etc.); (c) with the development of proprioceptive modality it concentrates on the production (e.g. the quality of the sound produced, etc.).

The process outlined above provides for the perfecting of movements, and contributes to the reduction of energy expenditure as well as to the improvement

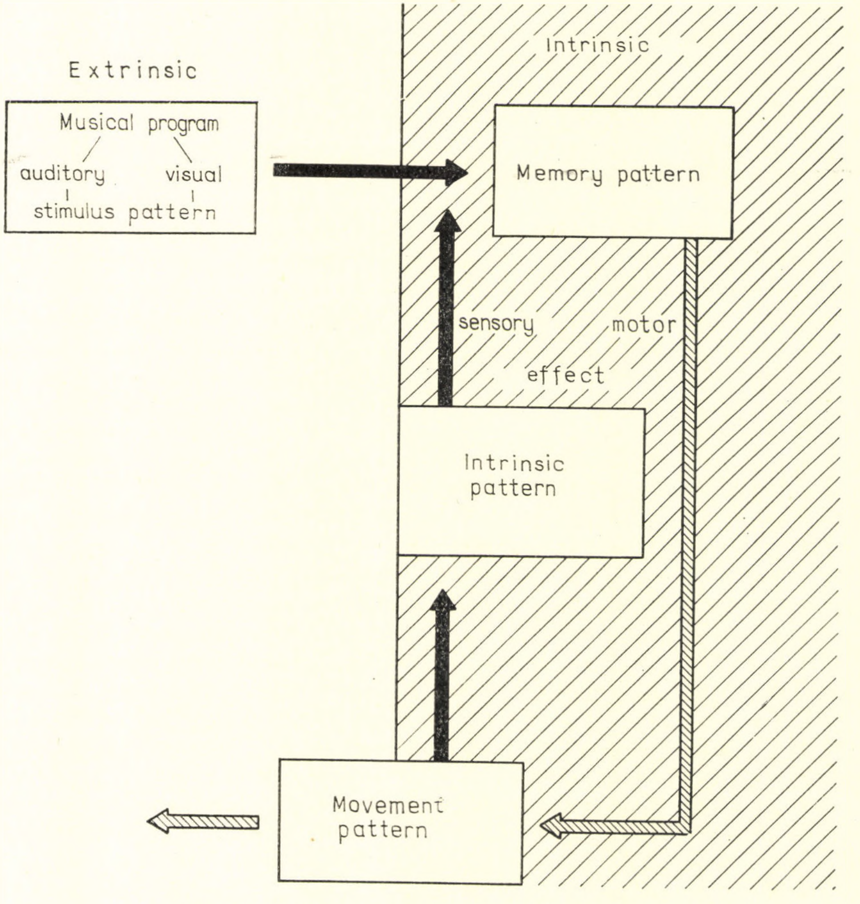


Fig. 108. Senso-motor process of learning

of accuracy, speed and quality in general. In learning to play the violin great importance is to be attached both to this process and to the method of carrying it out.

When a new piece of music has to be learnt (see also Fig. 108), the scheme of neuron actions would be the following: (1) The violinist concentrates on the score. The visual information will govern the motor apparatus through the cortex. Internal hearing is synchronous with the visual image (Teplov 1947). In this respect internal hearing, as a factor preceding motion, constitutes a part of the motor image. (2) Practising promotes the sequential establishment of motor images which are necessary for the performance (motor scheme). The function of fingers and other motor organs is yet imperfect, concentration turns therefore towards the motor performance. Hearing helps as a subsequent control. At first, it has a relatively small effect (as shown by false intonation, and slips), later, after the shift of concentration has occurred, it becomes increasingly active. (3) Careful repetition helps to commit successful motions to the memory, thus they grow dominant. The visual control becomes gradually superfluous both as regards the score pattern and the physical movements. Feedback signals coming from the motor apparatus begin to take the initiative in the control over the sequence of motor images. The information obtained about the first physical movement will start the subsequent one, etc. Hearing as a subsequent controller becomes a decisive factor. The technique of interpretation takes shape. (4) The violinist's psyche is greatly influenced by these events. As his physical movements improve, they recall further and diverse kinds of engrams; gradually an emotional background to the activity is established. A progressive automation of the motor sequences allows attention to be related to previous emotional experience, and the performer becomes able to compare the piece being played with the impressions gathered in his life. The emotions stimulated by music, and the intention to express these emotions, constitute the new focus of attention, as well as the final control and objective of the activity: violin playing becomes transformed into music. By this time the score is no longer necessary; absorption in the composition suffices to trigger off the sequence of automatized motions.

After having been organized in this way the nervous function becomes mainly cortical again, i.e. an activity of the cortical and subcortical connexion which, owing to the induced emotional state, is governed by the cortex. The relationship between the above mentioned process and musical conception is a dialectic one. Apart from the fact that in order to begin an instrumental performance a motivation of will-power must be present and concentrated on the music, the musical conception of even the first phase reaches far beyond that. Sensible learning itself—to be dealt with in detail later—begins by (mute or aloud) singing through the composition. By that time we have already obtained a musical conception of it. In respect of the factual instrumental performance, this conception is naturally rather sketchy, since in a composition designed for instruments there are some passages or chords of which an exact image is hardly conceivable in the required tempo, let alone to read them by singing. In these cases it is instrumental tone-production that promotes the improvement of musical conception. The sensation of the ear caused by the tone or chord produced will shape and perfect the idea of it. By being a function of motor development and of the improvement of voluntary activity, the perfection of musical conception will run a parallel course with the former in most cases. Practising in this way promotes an instrumental reproduction of music which is rather complex and corresponds to the interrelationship of musical and motor components. Any method of practice is efficient only if allowance is made for these conditions.

GENERALIZATION AND CONVERGENCE

It is a recognized fact that learning does not proceed uniformly. The course of acquiring a new skill can be usually illustrated by two types of learning curves. (1) Fast rise curve: the greatest progress is found in the initial period; later the process levels off. It is characteristic of a type of learning in which previously acquired knowledge and established skills aid the learner in his transition to a new domain. It is generally characteristic of the acquisition of sensory-motor skills. (2) Slow rise curve: it is characteristic of a type of learning in which an understanding of interconnexions is required, but may be indicative also of a deficient grade of interest or preparation.

There are, naturally, a number of learning processes which can be illustrated by intermediate curves; as a matter of fact, most cases will be of this kind. The manipulation of a musical instrument is principally a task of sensory-motor nature and not one of the logical type. In this way, skill in it can be acquired with no great difficulty provided that the new matter had been sufficiently prepared by an adequate training of preceding ones.

To the best of our present-day knowledge the acquisition of sensory-motor tasks proceeds in three phases: (1) generalization; (2) convergence; (3) stabilization.

Owing to an irradiation of excitation in the first phase, the learner does far greater muscular work than necessary for the execution (a greater number of muscles become innervated). In the second phase training brings about a convergence of excitatory processes, viz. the muscles which are superfluous, or at least dispensable to an expedient performance, are no longer excited. Excitation concentrates on the areas actually involved in the solution. In the third phase continued practising consolidates the newly developed dynamic stereotypes. Automation of the movement in question becomes established.

In the progress of the outlined flow of events not only excitatory but also inhibitory processes are involved; indeed, inhibition and excitation have an equal part in learning. In the second phase an inhibition of the excitatory processes takes place, which results in convergence and more perfect movements.

The borderlines of the three phases are usually blurred. Dynamic stereotypes begin to take form already in the first phase, and inhibitory events occur synchronously with the excitatory ones since both are indispensable to a mastery of the motion (Nemessuri 1968). Another important point to note is that during an efficient sensory-motor learning new positive conditioned connexions may be built only upon existing elements of motion.

PLATEAUS

From time to time there are periods in which practising is felt to be fruitless, progress is at a standstill or even regression may occur. These periods of stagnation are called plateaus.

Although they are not necessarily present with everybody, they are rather frequent, so it is of paramount importance that we should be aware of their source in order to prevent or relieve them by suitable methods, since they may severely affect the attitude of the pupil. He has an impression of labouring in vain, he has no good results consequently he tends to lose faith in his faculties. Matters are made worse by the teacher's reproachful remarks like: "you haven't practised, have you" and so on; which the pupil, with reason, considers unfair. Plateaus come about when certain inhibitory events become prominent. The underlying causes may be several. (a) No further progress is achieved by a gradual perfection of the methods employed so far. Thus, for instance, the motor problem can no longer be solved by simply accelerating the physical movements or by other, similarly quantitative means. Instead, a definite qualitative transformation is desirable. Such transformation requires an adequate preparatory period. In this period results are apparently absent. There are several examples of it in learning violin playing. Most new technical problems involve qualitative elements in principle, such as new fingering, new positions, instruction in ricochet, etc. The new element may also be mainly musical; instructions on the mordent require first of all new perception and an intuitive comprehension of music and rhythm. Teachers know by experience that they have to reckon with plateaus of varying duration almost without exception at the stages mentioned, and at several other parts of the syllabus. (b) An insufficient grade of automation in the already acquired skills may also cause a levelling off. Earlier skills that could be employed in new tasks are yet unstable, and thus they cannot be used to the extent required. A typical example in violin teaching occurs when the musical and motor functions of two fingerings have to be coupled, though they have not yet become consolidated in isolation; the exercises of connecting them encounter considerable difficulties. In regard to the problem of levelling off, the interaction between skills also deserves consideration. It involves two points, viz.: (1) interference between skills; (2) transfer.

INTERFERENCE BETWEEN SKILLS

By interference an inhibitory interaction of skills is understood, in which already existing skills impede the establishment of similar but new ones. It may take two forms. (a) Associative inhibition: this occurs when two different skills are built upon the same stimulus, as respective responses. In this case an associative connexion is created between the stimulus and the respective responses: $S - R_1$; $S - R_2$. If the first response (R_1) has already become settled, the elaboration of the second (R_2) is made more difficult. (b) Reproductive inhibition: it occurs when both firmly consolidated skills impede one another by interference if undertaken in succession during the performance.

In reality, interference is a far more complicated process; the relevant forms intermingle in various proportions. Another feature of interference is its occurrence not only between different kinds of skills, but also between the components of the same skill (as for instance, between the direction, speed and force respectively, of one movement), nor is interference influenced by a spatial or temporal adjacency of skills: in some cases interference between distant skills may be stronger than between near ones (Rubinstein 1958, p. 689). These events are rather common in the teaching of violin playing. An example of associative inhibition occurs when the pupil, for reasons of bow technique, is accustomed to begin upbows as upbeats with the middle part of the bow and is then asked to begin something new downwards. Initially he tends to draw the bow upwards. Instances of reproductive inhibition are not infrequent in connexion with fingering troubles of positional playing (as for instance at the beginning of Kayser's first exercise-book where the pupil has to play in the second and third positions for longer time). That temporal and spatial distances have no influence on interference is shown by the difficulties encountered in bilateral co-ordination: when left hand technique meets an obstacle, technical skills in bowing already fully established begin to show fits and starts. We quote two examples. (1) From exercise No. 24 in Book Two of Sándor's Violin School (Fig. 109): in practising the dotted quaver the bow jerks according to the rhythm of the left hand instead

Fig. 109. Rhythm example

of drawing a smooth quaver. This jerk is still discernible if we palpate the arm muscle even when its sound-production is scarcely audible. (2) At the moment of changing position the bow might skid: the right arm might try to follow the change in the rate of left arm motion. This can be reduced partly by using slow movements for the change of position and partly by concentrating on the right hand.

Both cases are typical of bilateral co-innervation. In terms of neuro-physiology, the underlying cause in the majority of such inhibitions is that the establishment of newly conditioned responses occurs by making use of new, yet untrained and slowly conducting pathways. When they are inserted in the mechanism already in existence, the response-time and function of the whole system will deteriorate. In addition, the innervation sequence might also change in order to comply with the task that needs new switching functions.

In order to devise useful methods of evading plateaus and inhibitions we must begin with their neuro-physiological basis. In practising, motion sequences are ingrained and conditioned response connexions between the signals of the factors decoupling the motion sequence and the corrective motions are established as well. Indeed, the latter take up most of the practice time but will help to make reflex correction possible later. Eventually, consciousness receives the respective signals of trouble and correction almost synchronously.

When the first and second fingerings are to be brought together, the second finger is usually 'embarrassed' when the change occurs in the middle of the piece instead of occurring at the beginning. The reason for this is that the note-image in the score (e.g. F) is basically identical with F-sharp, because the sign of sharp is generally at the beginning of the staff; the player has to remember whether it is sharp or not, and this causes an impediment (presumably an associative inhibition) of the motion sequence. When the skill of playing in both fingerings has already become automatized enough, movements and motor corrections, identification, proceed in a reflex manner. In spite of a change in conditions the actual stimulus (note-image, musical idea or engram) will trigger off the relevant series of motions, viz. the conditioned reflex chains follow one another in a modified order of succession, as dynamic stereotypes.

We may deduce the following from the above: (a) if isolated skills operate automatically enough, plateau phenomena are less likely to occur; (b) when reliably automatized, the skills also display corrective tendencies against factors which might interrupt the motion; a useful attribute favouring the elimination of occasional plateaus; (c) whenever a plateau or an inhibition is discovered, the only means to overcome it is practice. With respect to these principles the corrective measures should rely on a knowledge of the causative factors for each case separately.

TRANSFER

Transfer is a positive influence exerted by one consolidated skill upon another. It needs a kind of generalization, a selection of common features, i.e. an analytical, cogitative work. It is not necessary to have a similarity of elements (e.g. primitive movements), but identity of motives and components within the respective skills. Not only contents may be in common, but courses of action, methods

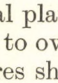


Fig. 110. Two crotchets: one bow, divided strokes

and technique of activities, etc. as well. Uniformity of sound is this kind of collective feature in musical motions. Two crotchets must sound as long when bowed by divided strokes (Fig. 110) as when bowed detached. In order to make transfer easier in teaching this bowing style, we may utilize the required uniformity of sound. Similarly, when upbows and downbows are practised, attention will have to be given to uniformity of volume, timbre, etc.

PRACTICE METHODS

On the basis of the practice features analyzed so far, certain immediate conclusions may be drawn in respect of practice methods. This is all the more important, as it is generally assumed that if the student knows how to practise well, he is already half way towards possession of the secrets of instrumental playing.

(1) While allowing breaks for relaxation, of course, practice is worth-while only with perfect concentration. In general, the number of repeated playings-through can be proportionately reduced according to the degree of co-ordination between the internal patterns of sound and movement. Thus concentration is also a factor of labour economy in practice.

(2) Directing attention towards the proper factors is essential. On the one hand, attention, as has been shown, transfers according to the various periods of practice, and therefore the natural sequence should not be violated; on the other hand, when practising separate sections, a correct decision should be made as to where concentration is to be applied in that particular section. It is likewise commendable to focus attention on one difficulty at a time. First, this will eliminate the dispersion of attention, promote rapid mastery of musical or co-ordination problems, and, at the same time, speed up the automatization of dynamic stereotypes. Second, the concentration process of instrumental practice must in all cases include a comparative component: the auditory results which are actually produced must be checked against the intended ones, and the course of practice, as well as the course of attention, must be controlled by the outcome of that comparison. If the results fall short of the expected achievement, practice should be continued; if they approach it, we might perhaps go on. This comparative activity is impaired when attention has to be divided among several musical or technical refinements at the same time.

(3) Before beginning instrumental interpretation, the player should acquaint himself with the principal lines of the material by loud or silent singing. This will secure insight into the musical conception in the first place. The picture thus gained should include the musical form, the melodic and harmonic construction, the rhythmic schemes and the tempo of the piece. The place and connexion to other parts of technical difficulties arising should be worked out. It must be stressed, however, that this non-manual work is primarily aimed at a speedier identification of the note-image and at an understanding of the composition, but has a relatively slight influence on instrumental mastery. Jahn (1951) and Pablo Casals (Corredor 1955) are right when they maintain that skill in movement cannot be acquired purely through imagination, but only by sensory experience, and preliminary reasoning out and understanding have merely a facilitating role. We consider therefore that Kovács (1916) is too exacting in his requirements for this phase of practice when he speaks of the memorizing of notes without the instrument, etc.

(4) Deciding the proper tempo for practising is an important point. Every single component movement, and each partial motion, finds its meaning in the whole; component parts always depend on the whole as an organic unity (Büchler 1962).

Hence reproduction of a piece (in its entirety) has to be considered one coherent flow of movements, and practised accordingly. Of course, difficulties arise only when technical problems are to be practised in pieces or parts requiring a lively tempo, since slow ones can be worked out at their original speed. In the performance of a piece the problematic task in motor technique (and therefore in practising) is created precisely by the quick sections.

Flesch (1928) has pointed out that in every instance of a technical difficulty there is a central point, around which things to be learned should be concentrated. This central point is the technical difficulty of the most problematic part of the composition, the mastery of which usually contributes to the solution of all other technical difficulties in the piece. This approach can be applied with special advantage to problems of fingering and bowing which often occur jointly. Suitable fingering can sometimes produce striking results: passages which at first sight seem unexecutable at once turn out to be easy, or initially faulty intonation can soon be avoided by skilfully chosen bow practice schemes.

However, the conception of violin playing as a uniform process of movements implies that technical difficulties practised separately are in themselves insufficient since they have to be re-introduced carefully into this flow. For example, if there is a technical problem requiring separate treatment within a bar, as soon as this has been mastered to flawlessness it should be practised again together with the bars before and after it. We may find that the bar rendered correctly by itself will still be halting within this context for a time. In view of this, practice can only be called effective, and the next problem only be tackled, when the worked-out part fits into the music, viz., into the flow of physical motions.

Movement and musical conception, as has already been mentioned, make up a dialectic sensory-motor unity. Not only does conception influence movement, but movement in turn affects conception. The speed, range and rhythm of the movements applied become fixed in the course of practice. If, therefore, a piece has been practised for a longer period of time in a tempo slower than required, the picture becomes distorted. To play a piece in the prescribed tempo is not merely a question of speeding up. We must clearly realize that to play something not in its own tempo is to practise a piece of music and movement that is wholly different from the original.

It may be rightly objected, in this respect, that many compositions are rather difficult to reproduce and that improvement may only be obtained by slow practice, at least of the problematic passages. While this is true, the choice of the slowest permissible tempo is the criterion. In our opinion, the lowest limit of slower practice-tempo in general is the level at which the spirit and structure of the composition as well as movements necessary for its performance retain their particular character. To meet these requirements, practice of parts and of the whole—*Totalverfahren*, as Jahn (1951) puts it—should be synthesized so that (a) parts of equal difficulty should be taken together, (b) uneven subject-matter should be subdivided according to technical difficulty, and parts of the same standard handled one by one. This is followed by a rehearsal of the whole at the level of actual familiarity even if some technical imperfections are still left in it.

Eberhardt (1922a) has already pointed to the energy economy obtained by separation of parts according to difficulty levels, and working on them in turn. Flesch (1928) also emphasizes the value of attending to difficulties separately (usually the separation is left hand–right hand). When dealing with concentration, we referred to the advantages of taking problems one by one in solving difficulties.

In addition, the tension necessary for the performance is sustained longer too by this method, because "we are not yet bored with it". For the same reasons we cannot agree with theories favouring slow practice almost exclusively. Citing the works of Kovács (1916), Sebestyén (1956), the recently deceased eminent cello teacher, broke a lance for slow practice on the basis of physiological arguments. He warned against faulty playing, saying also that mistakes leave engrams, unwanted traces in the nervous system. The engrams indeed should not be faulty; nor should they be anything else but what must be remembered. And yet, isolated stops have a different innervation from successive ones and cause different motor sensations, as Koeckert (1909) has shown. Among the movements, single ones may be practised slowly, but double, i.e. reciprocal movements must be practised in time. The reciprocal movements are difficult precisely because of the inherent rapid change of direction. Making a halt at the turning-point, which can hardly be avoided in slow tempo, represents a different type of work: a reciprocal cycle of motion needs one impulse of the will, whereas the former requires two. This fact was also pointed out by Mostras (1947). To perform free of faults but slower than normal will not suffice; the speeding up process will not be a simple matter since it demands different motor functions.

Thus, in our opinion, the problem cannot be solved by persistent slow practice or by practice using only occasional speeding up. Work should focus on the original speed from the very beginning, and should deviate from it temporarily only when it is judged absolutely necessary, as in the slower practice of more complicated sections which are aimed at becoming automatized. Though in the periods of practising at reduced speed it can hardly be avoided that group movements should break up into separate motion elements (in stopping, for instance), nevertheless, an effort ought to be made to bridge the gap between these motion forms, at least by adjusting their speed proportionately. Gát (1964) points out that in piano playing this can be achieved by making the distance covered by the touching finger proportionately longer. According to the well-known velocity formula of physics the re-adjustment of the original time is brought about by concentrating on a reduction of finger-elevation before touching. In this way the acoustic character of the original tempo is preserved, while the flow of movement is not impeded, and there is less risk that single motor elements will break up. With appropriate modifications, this method applies also to string instruments, except that the regulation of finger raising is restricted, because there are no keys and the nature of the instrument requires a more steady position of the left hand, thumb, and fingers. This will limit the exploitation of a proportionate slowing down.

If in spite of the proper application of the practice routine described here, problems arise, there can be at least two causes of it. (a) The given piece or exercise has not been properly prepared technically, so that the violinist is lacking the necessary basic musical and motor faculties, making a correct performance impossible at the existing level of his skill. This is true even with exercises which come next in order. (b) The teacher's mistake in assigning a work to be performed which is beyond the student's capacities, in considering the apparent but not the actual basis of his skill.

Both cases therefore concern lack of skill, for which the only correction consists in subsequent development of skill. Until then it may become necessary to remove temporarily the piece from the syllabus. Here the question arises whether a correct left-hand intonation, or the exact performance of technical tasks for the right hand, are always linked with a decreased tempo of practising? To clarify the connexion between speed and precision, Lénárd (1948) studied the relationship between quality standard and time expenditure of mechanical appliances made by first grade apprentices at the school of telecommunication mechanics, in 1935–1939. His results served to prove that swiftness and precision were not mutually exclusive features of work; 55 per cent of the fast workers and only 39 per cent of the slow ones produced a work that was passed by quality control. This experience is significant also for learning and teaching the technique of instrumental performance. It is not uncommon to find slow pupils who, in spite of a good sense of pitch, play out of tune. One can hardly expect them to produce better intonation by continued slow practice, since the main drawback of their technique is slowness. In these not infrequent cases, an improvement of intonation and a correction of right-hand mistakes could be arrived at primarily by an increase in speed. It is only by overcoming the sluggishness of the motor apparatus that better performance is brought about. It very often happens with practising some more difficult passages and 'hard places' that constant slow practice will not achieve the desired results; on the contrary, they are attainable by increase in speed.

Considering all choice of tempo for practising should not be done at random; it is better to determine it after having taken several factors into consideration, i.e. according to the degree to which the material has been mastered, the nature of the difficulties encountered, personal motor dispositions, etc.

(5) Excessive practice of one piece during the same practice session should be avoided. There is a limit to effective repetition, and increasing the number of repeats beyond it will make further practice ineffective in respect of habituation. According to Jahn's (1951) observation the number of faultless repetitions within one practice period ought to be about twice what was needed to attain at the first faultless performance. After this point another exercise should be practised, regardless of whether the new repetitions were faultless or not, and further correction should be made only on the following day.

(6) Whenever feasible, practice should be done rhythmically, possibly in the original rhythm. For rhythm is not merely a sequence of notes in time, but rather a complex of notes grouped around accented sounds (Teplov 1947). Apart from this, rhythm has the power of organizing movements and thus helping habituation. In the same way an accentuation foreign to the piece tends to be ingrained and it must be corrected at once. At this point some allowance must be made for the occasional practice of other, perhaps opposite, types of time patterns to correct certain mistakes. This, however, should be confined to the particular fault and for the shortest possible time.

(7) Apart from concentration, other psychic factors, such as the 'individual relationship' to the piece, have a significant role in successful learning. Personal interest in the piece is a primary feature of this attitude. This interest is, however, liable to decrease or even to cease, owing to drilling over too long periods. Every teacher knows the physical and mental symptoms of overtraining which they should endeavour to forestall. Still the question arises: how is it possible to establish, let alone define, the commencement of overpractising? It cannot be expressed in routine terms since in each case it depends on different factors. However there are certain signs whose presence indicate the danger: (a) levelling off in technical development becomes more frequent, and performance of problematic sections does not improve, and playing as a whole becomes slovenly; (b) fading out of the

musical conception and hence its poor realization; the skill already acquired in expressive power (phrasing, dynamics) fails or even disappears; (c) the appearance of new, unintentional expressions (change in phrasing, extraneous dynamic patterns, etc.). When these occur too frequently, they are particularly indicative of impeding boredom, subconscious avoidance of which tempts the performer to apply 'variants'.

We could give many other major or minor signs apart from those mentioned, which indicate a change in attitude towards the piece. If this is noted, a low performance level of the concert or exam-piece is fairly certain. In preparation for public performance, it is advisable to avoid such dangers in learning and practising by wisely chosen methods. Although there are many ways, a few mentioned here are certainly effective. (a) The time assigned to practising has to be assessed properly, and the elaboration of the piece should begin at the appropriate time and not earlier. In the course of technical 'shaping up' practice Eberhardt (1922a) recommends a method, the main features of which are contemplation, peace, and 'absence of excitement'. From several points of view, we feel that this is right: attention may be fully focussed on the essential auditory and motor impressions, and much mental strain is avoided; the comparative function of concentration may operate undisturbed; as already pointed out, the piece retains its stimulating influence so indispensable to performance. (b) As far as possible, technical and musical demands should be distributed evenly over the period of study. In this way, the pupil will feel renewed delight and also new stimulus to practising for each lesson. (c) Accompaniment of the pupil's playing may prove stimulating. Naturally, such rewards have their time and day: in our opinion, the pupil must know his part at least well enough to ensure that dividing his attention will not disturb him but, on the contrary, accompaniment will consolidate his idea of the composition, so that he becomes absorbed in the overall performance, and remembers the experience when practising at home, viz. when playing alone he will hear the whole.

THE LEVEL OF DEMANDS AND ITS ROLE

The discriminative faculty of the performer has a serious influence on every performance: the quality he wishes himself to attain in the execution of the action in question, and the result that will satisfy him. One of the main characteristics of the variety of human individuals lies precisely in the difference which exists between the level of demands, whether in a general or in a particular action, and the components of will-power necessary to attain this level. Genius is diligence, holds the saying. Sharpening the student's sense of discrimination, and with it, his zeal, is an important task for the teacher. We must realize, however, that the external influence exerted on raising the level of demands has its limits. No matter how much we should like to obtain the upper limit from the student, we must understand that our upper limit is usually not identical with his upper limit as regards the performance level attainable by him; viz. in most cases his is considerably lower. Generally, this is shown by the amount and intensity of labour spent by him on a particular piece.

If we do not take these arguments into account, the state of overpractising will be reached sooner, and this will impair even that level of performance which is still attainable by the student. It is therefore advisable to determine the time devoted to the teaching and practising of the piece in the light of the actual level of the student's capability of accomplishment and not to insist on a piece or exercise longer than necessary. No further improvement could be expected at that point of time, anyhow. Naturally, this does not mean that we should reconcile ourselves to the existing level of demands with equanimity. On the contrary, the level has to be raised consciously and constantly, both for self-education and for teaching. There are several means to this end: (1) developing a competitive spirit in the pupil, (2) encouraging the pupil to have confidence in his own skill, (3) assigning tasks which will give rise to a feeling of success.

In our view it is advisable to play works in which we can give the best of our knowledge. This is why we commend assigning pieces that the student can perform with success, for such a feeling is a great stimulus. Nevertheless, we ought to be careful that the task should not be too easy, for a feeling of success or failure develops only, according to Hoppe (1933), when one is challenged to achieve a performance approaching capacity limit, and where serious effort is required to attain it.

Failure, particularly if it occurs consistently, may lead to a breakdown. In order to avoid this, the teacher should analyze the reasons contributing to the failure, and point out how to correct the mistakes. In this way, failure might be turned to advantage in raising the standard of exigence. Failure and temporary setback are part of the career of us all; this must be understood also by virtuosos-in-the-making, and they must be prepared to face them. Really great talents have always been ready to profit by failure, and have made good use of the experience in the interest of success. Conditioning in this respect is particularly important in our days when status in the field of music is often established as a result of musical contests. It would not be expedient, therefore, to prepare the student, a young virtuoso, for success alone. He should know his real abilities as well as the way to exploit them to the best advantage, and he should estimate his chances accordingly.

THE FUNCTION OF EXPLANATION

In the course of teaching, as it has already been noted, we must give definite instructions about the task to be performed. This task is materialized by practising. Words are objective stimuli for man, hence they induce certain definite actions. From this it is evident that what we say certainly does matter: an accurate definition elicits precise execution, inaccurate wording results in inaccurate performance. Even to make someone feel the movement forms correctly will depend heavily on the words chosen. The feeling of stopping is instructed in a variety of ways: it is customary to use such phrases as "Press the string!" or "Cut the string!", etc. Each of these orders provides an opportunity for an excessive effort. The expression: "The finger on the string stands at the place of the note" seems to be best. Standing as a sensation implies stability but also a readiness to start. Similarly, if, for instance, we say: "Practise and work out this part slowly for the next lesson", we need not be surprised if we are given a musically unrecognizable reproduction having no resemblance whatsoever to the musical message of the part in question, either in metre or in phrasing, but merely a meaningless sequence of possibly correctly produced notes. To mention the opposite extreme: technical imperfections have remained unchanged, for 'slowly', too, is a relative idea, so that the student may have repractised the assigned part still faster than was necessary for an effective exercise.

In order to provide the student with correct ideas on practice-material, the teacher may adopt various methodical ways and means. First of all, as Michel (1960) pointed out, we must put it clearly what we expect the student should attain by practising the part in question. Immediately after this part of the lesson, the following points should follow: (1) we must analyse the succession of physical movements; (2) it is useful to explain the order of succession in each phase of the procedure; (3) we should give information on the force required in the execution of separate movement units; (4) we should strive to acquaint the student with the kinesthetic sensations that arise in the course of executing the motions correctly; and, finally, in connexion with our advice we must examine the impressions developed in the student during his practice.

Naturally, both the extent and the level of explanation must be adjusted to the individual characteristics and the age of the student. Practice instructions given too lengthily and at too high level should be avoided just as much as instructions of laconic brevity. Thus the teacher promotes efficiency in practising above all by giving a clear definition of the mode of practice. As a matter of fact, it is only after having met this condition that the teacher may make demands to be recognized and accepted by the student as right and well-founded. And this is one of the prerequisites of all successful teaching.

LEARNING AND MATURING

We must make a clear distinction between development achieved by learning and by maturing, not only in the course of individual personality development, but also in the process of developing the separate abilities. Maturity is a certain degree of personal development, characterized by the standard of differentiation of the organism and the nervous system. Development phases outlined in connexion with age-characteristics must be considered also in the learning process. From experiments with the development of motor skill in children it is known that to teach a new action before the child has become organically mature for this task is a useless effort. The child who had been taught prematurely would soon be overtaken by his fellow-pupil who was instructed later, but at the proper time. Instructions given much too early place a superfluous burden on the student. This should be kept in mind when working out a course of study.

We may easily deceive ourselves if we consider a feature to be the result of learning when it is merely a consequence of maturing. Thus for instance, nine-year-old children are known to make better progress in playing the violin than seven-year-olds do. We are wrong, however, if we look upon the child of nine as having more talent when his performance is merely more skilful and more musical than the perhaps less developed rendition of his fellow seven-year-old. Similarly, we may find that some technical elements work better when they recur than at the time we had just learned them, in spite of first not having consolidated them properly. The reason of this is the (transfer) effect of general progress affecting a particular detail: the increasing amount and refinement of skills, as in maturity, promote progress in other skills already acquired, especially those with which they have some common feature or procedure.

INCLINATION TO RECOMMENCE, HABIT, LOAD

The foundations of creative work in the performing arts of music are laid upon regular practising. We must therefore make practising an organic part of our living, i.e. a habit. One of the ways to this end is to practise always at the same time of the day. Time, like a conditioned stimulus, produces a sensation of deficiency which acts as a starter-impulse to begin practising when the moment has come. This is enhanced by the fact that practising music rarely creates a feeling of completion: we end only the process of practising, but in the performance style of musical compositions practised there always remains some flaw requiring a finishing touch. If the level of demand is adequate, this impression is stored as a drive to recommence and a challenge to practice on the next day.

As to the length of one practice-period, we do not find agreement in the literature on teaching methods. Flesch (1928) considers a span of four hours necessary for a concert violinist, and he suggests that this time should be divided as follows: (1) technique in general (scales, finger practice, etc.): half an hour; (2) repertoire (études, passages in pieces, etc.): two hours; (3) pure music (compositions played with accompaniment, if possible): one hour and a half.

For students, he considers a daily practice-time of three hours sufficient. Bloch (1919) also states two–three hours, but in the same distribution as outlined above (i.e. one, four, and three eighths of the full time devoted to the respective subjects). It is known, however, that many performers practise six–eight hours regularly, while others—at least so it is said—need only a very short time. It is difficult to prescribe a practice time for a concert artist, nor would it be expedient; every artist manages this on the basis of his own personal experience. In the case of students, however, it is essential to control both the time devoted to practising, and its utilization. To this end, certain physiological rules should be observed which would help avoid overpractice.

In the course of learning to play a musical instrument, practice-time keeps increasing yearly. By the end of the first year of learning it must be gradually raised to one hour a day. This is not an easy task for a child of seven or eight. In the course of training, however, the constitution, too, gradually becomes used to withstand the exertion required for practising. In its development, this training factor runs parallel with the functional evolution of the mechanism engaged in the performance. Nevertheless, both these processes require a certain intensity of stimulus. Below a certain grade of intensity and number of repetitions practising will remain ineffective. The adaptive responses of the human constitution fail to operate. On the other hand, severe exhaustion developed during the playing may spoil the performance of a piece 'otherwise mastered'.

The two extremes of practising, viz. insufficiency and exhaustion, can both be eliminated by a practice-schedule resembling that of training in sports. While it is unwise to allow a rest at the first sign of tiredness, practising for hours at a stretch is not advised, either. Relaxation periods should be distributed at regular intervals during practice-time. To a child who is yet a beginner, it is expedient to allow five–ten minutes for every quarter of an hour. During these breaks let him play or run freely about, and he should definitely avoid doing any other type of home-work. As net practice-time increases, total practice-time will grow to about one hour and a quarter by the end of the first year. Longer pauses are not expedient, because the muscles will have to be allowed a warming-up time once again, and the risk of inflammation and strains too is much greater.

In higher classes, it is advisable to distribute the recreation breaks proportionately and according to similar principles.

Tendo-vaginitis, sore muscles, stiff joints,etc. are usually avoidable by a proper distribution of these relaxation intervals, and by the rational methods of practising outlined above. In respect of pupils in the lower grades, correct development and organization of practising as a habitualized action is an educational task which the teacher can achieve only with the co-operation of the parents. Employing the time spent in practising into the daily schedule of life to the best advantage will be discussed in the following chapter.

Chapter Seven

QUESTIONS OF PHYSICAL FITNESS AND DAILY ROUTINE

PHYSICAL FITNESS

The instrumental artist needs a high standard of mental concentration to perform efficiently; in addition, the execution of finely co-ordinated movements requires a favourable physical condition. Both instrumental practice and performance require the maintenance of this condition to support the instrumental artist in unfolding his best faculties. An adequate daily routine helps the success of performance. Not only is he obliged to think of avoiding harmful effects, but has to consider the conditions which will assist him in attaining a high standard of physical fitness. In order to arrive at an understanding of it, we first have to deal with the physiological questions of fitness, exhaustion and recuperating one's strength, and next, to proceed on this basis to the principles which ensure an appropriate mode of living.

Physical fitness is a conception used primarily in sports and physical training. It expresses the extent to which an athlete is capable of mobilizing his physical and mental powers to tackle a given task. In several branches of sports the athlete's physical fitness can be made manifest in comparison with his working capacity by making use of metric units. In other human activities the degree of fitness is not always measurable to the same precision. Yet its significance is hardly in doubt. It is well known that excellent artists perform equal to themselves in some recitals, indeed, sometimes beyond every expectancy; while on other occasions they remain far below their own standards. The same may be observed also in the student. In this phenomenon mental alertness and bodily, physical fitness play a decisive part. When fitness is perfect, the artist or pupil may exploit his faculties maximally, whereas if physical fitness declines, the same faculties cannot come into full play. Naturally, the performance is determined not only by internal factors of fitness, but also by the external conditions of the performance. However, the artist has a better command over less favourable external circumstances as well as internal repercussions (stage fright, etc.) when he is fit. Distracting factors influence him less. In a poor physical condition, on the other hand, he will respond much more vigorously to the adverse effects of the environment (e.g. bad acoustics in the concert hall, sparse audience, etc.).

Physical fitness accordingly means a state of health that is characterized by a favourable standard of efficiency in human activity. It may be of a general nature and may be manifested in the solution of the various tasks of everyday life (domestic duties, sports, etc.). However, it has also a special manifestation which applies to a given activity, which is, in our case, instrumental performance. Physical fitness is a uniform feature of the construction, and is displayed by an efficient co-operation of our organs. In such cases, however, the respective organs and groups of organs operate economically as well as separately. This is easily verifiable, e.g., by investigating the function of the circulatory organs. If the pupil is told to play on one occasion when he is exhausted, at another time when he is rested, marked differences will be found as regards circulatory parameters, even in case of an identical musical material. In a physically fit condition pulse rate and blood pressure are lower to begin with, and after the lesson the values obtained are less high and they return to the initial level sooner than when the pupil is tired. The values obtained by the investigation of the respiratory gas exchange are even more remarkable. In a reposed pupil oxygen consumption and carbon dioxide production are much less than in a tired one, and the values raised by the performance return sooner to rest levels. The influence of physical condition is, however, visible without any medical consultation. A delicate co-ordination of movements and efficient instrumental performance are mainly consequences of a physically fit condition. Given an identical degree of experience, faults, misplacement of fingers, memory black-outs, etc. occur when the pupil's physical condition is not appropriate. On these occasions 'playing will not get on'.

A precise interaction of the muscles, which is a prerequisite of efficient instrumental performance, is closely related to the state of the central nervous system. The precisely determined distribution of excitation that corresponds best to the necessary motion, i.e. the controlled and ceaselessly changing relationship of excitation and inhibition, proceeds at the highest level of the nervous system. These parts of the nervous system are particularly sensitive to the ebb and flow of physical fitness. Physical fitness favours the motor performance, while fatigue has an adverse effect on it. In recent years another idea has been discovered concerning the notion of physical fitness, viz. the direct operative capacity of higher nervous functions. Obviously, without the intervention of the musculature and autonomous organs the latter cannot be manifested. However, cases may occur in which physical exhaustion and the handicap of bad physical conditions may be overcome by a great effort of will-power for a time. But it may bring about markedly unfavourable reactions after the performance.

EXHAUSTION

Exhaustion represents a decrease in the functional capacity of an organ or of the whole constitution, in consequence of some activity. It is mostly temporary, because after a rest or an intermission the original, adequate function is restored. Exhaustion may also arise when energy delivering substances securing optimum functions are absent or are present in reduced quantities. This situation, however, is insignificant, particularly so in instrumental performance. We cannot speak of special substances inducing fatigue, at most it could be asserted that the chemical transformations proceed at a slightly slower rate, and that certain intermediary products of metabolism accumulate in greater quantities. These products may induce changes in some functionally important organs and structures, as when, for instance, the colloidal state of muscle proteins may undergo some alteration, and is manifested by an exaggerated tension of the muscle or muscular stiffness which interferes with smooth muscular work.

On the other hand, muscular fatigue depends to a great extent on the nature of the work done by the muscle and on psychic factors. Rhythmical muscular work—and this is characteristic of instrumental performance—may be sustained far longer without any significant exhaustion. A very great importance is attached to the emotional state, in respect of the point at which exhaustion sets in. Under positive emotions tiredness occurs considerably later; on the other hand, in the presence of negative emotions the body will get tired sooner.

In addition to hardening, of which we have spoken above, the muscle may develop tenderness or even pain as a sign of fatigue. In particular it occurs where the performance is not interrupted by appropriate intervals of rest, or when the instrumental motion is characterized by continued tonic and phasic work of the same muscle groups. The nervous system in which the co-ordinative processes of the motor mechanism take place is even more sensitive in its response to fatigue. Though peripheral nerves may be considered practically inexhaustible, the intricate and complex reflectory processes in the central nervous system are to a relatively greater extent exposed to exhaustion. An exhausted state of the central nervous system will bring about a reduction in the functions of the whole bodily constitution. The functional alteration of the sense organs is of particular importance. It has been shown, for instance, that the sense of touch deteriorates considerably, discriminative sensitivity of vision and hearing is reduced, and the functional capacity of the autonomous organs is impaired.

Geréb (1962) discerns three stages of impending exhaustion, in respect of mental functions. These are: (1) activity slows down. At first, the rate of deceleration is slight, and motor disorders may develop; but working capacity is not seriously affected; (2) attention and concentration are reduced. Temporarily this may still be overcome by will-power; (3) weakening of will-power. This degree of exhaustion leads to a discontinuation of activity.—Pohlmann and Kranz (1927) have shown by experimental evidence that human auditory acuteness may show fluctuations, ranging up to 53 per cent, owing to exhaustion. Antropova (1953) reported visual sharpness to suffer a mean reduction of 33 per cent, owing to overstrain. Dmitriev and Zhidkova (1956) have found in 19–22-year-old students that the mean reaction time grew 0·3–0·6 sec following an 8-hour school-day.

These studies explain a number of situations occurring during instrumental lessons. The standard of performance during music lessons may suffer so much from the tiredness due to some non-musical activity as to be taken for unpreparedness. Accordingly, when confronted with a remarkably low and unusually poor quality of performance, we should enquire about the events of the day preceding appearance at lessons. Before concerts or training performances, on the other hand, we should endeavour to relieve the pupil, at least partially, from other duties, possibly for more than one day. We must emphasize, however, that the signs of exhaustion outlined here may have a variable range and duration. A tired pupil is sometimes unable to assess the degree of his exhaustion. He may complain of tiredness, and yet fitness is restored by a short walk, some gymnastic exercises and respiratory exercises. In other cases the same signs may be indicative of a disguised form of organic disorder, or real exhaustion which may last for several days, unless we advise a rest.

REPOSE

Tiredness is a natural and unavoidable result of activity and work. It reduces, and beyond certain limits prevents, activity. Repose, too, is a natural state by which the human body is regenerated, and is prepared to start work and activity again. Repose is a fundamental requirement of physiological functions. Its mechanism has been studied by various means and several observers. Recent research has employed the electro-physiological method. At rest, muscles were demonstrated to be in a relaxed state; moreover, with the assistance of electro-encephalographical investigation of normal brain activity the basic event of repose, i.e. sleep, was made available for observation. The electric discharge frequency of the normal brain was noted to rise while active, and decrease at resting state (to about 10 cycles per second). In sleep discharge frequency is reduced even more. The phenomenon has given rise to several, as yet far from consistent, explanations.

The events studied by actography appear to be more distinct. These studies concerned the involuntary movements occurring during sleep. It was shown that the deeper the sleep, the more immobile the body becomes. Parallel EEG studies have shown a further frequency reduction in electrical brain activity. During sleep autonomous functions also reduce speed, respiratory gas exchange proceeds at a slower rate, body temperature decreases, the heart contracts less frequently, blood pressure becomes lower. The organism of the human body operates at slow burning.

Repose is thus after all an indispensable period to recuperating bodily strength. Two main forms of repose may be distinguished, viz. passive relaxation and active recuperation.

PASSIVE RELAXATION

The main physiological characteristics of passive relaxation have been outlined above by stating that most vital body functions are set to slow burning. The most typical feature of passive relaxation is a resting state of the motor apparatus. The muscles are relaxed, the posture relies on passive support, and autonomous functions decrease accordingly. According to Hess (1956) the autonomous part of the nervous system may be affected in two ways. The working phase corresponds to an ergotropic effect. In this state the autonomous responses and metabolism become more vigorous, pulse rate and blood pressure rise, and a greater amount of hormones enter the circulation. This is what happens during violin playing, too. The opposite of the ergotropic working phase is the trophotropic or recovery phase. In this period events are opposite to those of the ergotropic phase. It corresponds to the phenomenon of passive relaxation.

The most effective form of passive relaxation is sleep. To the efficiency of activity and work a physiologically favourable kind of sleep is indispensable. Its characteristics are: regularity, satisfactory degree of deepness and sufficient duration. Sleep is regular if going to sleep and waking are kept to regular times. For an adult it is preferable to go to sleep at about 10 p. m. and to rise at about 6 or 7 a. m. Research has shown that it is more favourable to go to sleep long before midnight, even though the duration of the sleep remains the same. The duration of sleep is an individual matter and depends on age. A baby may be asleep almost all the day, small children need half a day. After puberty about a nine-hour sleep is necessary, adults should have about eight hours. Individual variations are not uncommon, and there are adults who require from nine to ten hours. The latter case is mostly temporary, and rarely occurs as a permanent condition. The deepness of sleep is not a matter of indifference as far as repose and recuperation are concerned. A deep and dreamless sleep is obviously the soundest. In case of sleep impairments, will-power and training may be effective, provided that no serious pathological symptoms are present. When falling asleep is difficult, we should not switch on the light 'to make the body tired enough' by reading. Falling asleep is promoted by a stimulus-free environment, silence and darkness. Let us get rid of all thoughts and concentrate on sleep. The same may be done when we awaken too early. Sometimes sleep may be impaired for days, particularly on occasions of disturbing circumstances, yet it may be of some comfort to know, however, that even to doze off or relaxation on waking is also useful. Much more so than reading in bed.

For a daily schedule sleep is thus the principal form of repose, though not its sole means. Short breaks in the course of the day are particularly commendable for artists whose career requires great concentration. Such short breaks are to be spent in a relaxed posture, either in supine position or sitting in an armchair or ordinary chair. It is made more effective by unstrained, loose and rhythmical respiratory exercises. Let us focus our thoughts upon breathing and muscular relaxation, and forget about the problems of the day.

As a professional musician, the artist does well to get accustomed to short passive reposes—for example in the intervals between recitals—on his armchair or couch as provided by prevailing conditions and circumstances. At first it will perhaps seem rather odd, but will prove later thoroughly useful and refreshing. Unfortunately, it is quite common in the interval of a concert for friends and enthusiasts to rush into the green-room and shower congratulations and questions on the artist, instead of giving him time and opportunity to rest. The correct practice to be followed is to leave the artist undisturbed in the interval and allow him to get sufficiently restored. This alone would be only an external condition of an opportunity to recuperate. Additional, internal factors are also necessary, and they have to be created by the artist himself. It often occurs that in the few short minutes of the interval the artist walks up and down in excitement and tries to attenuate his markedly nervous tensions by smoking, drinking spirits, or coffee. We consider it far better for the artist to lean back comfortably on his armchair or couch. He should attempt to relax, to direct his attention towards indifferent themes, or simply to remain idle. The mistakes committed in the first part of the night should be excluded from his thoughts as far as possible. He should perform some light respiratory exercises and keep his muscles as relaxed as possible.

The method outlined above cannot be brought into effect in a day's time; it needs practice and habituation, but is worth the time spent.

ACTIVE RECUPERATION

Active recuperation should complement passive relaxation; for those doing intellectual work we consider this of particular importance. Its main form is a more or less forceful muscular work, sports, if possible, in the open air. An alternation in the types of activity is in itself favourable; it is energy refreshing and restoring. An instrumental artist usually spends long hours indoors with a relatively small scope of motion and muscular activity. He requires his motor organs, which constitute a larger half of body mass, to be optimally engaged in activity, because this provides an opportunity for their maintenance, to preserve and even improve their functional capacity. Sports, walking, gardening conduce to an ergotropic innervation of autonomous organs. Machines may be spared by using them infrequently; the same would be detrimental to the living human body however, and it would decrease its working capacity and cause regressive changes.

A refreshed body is made fit for training by regular muscular exercise. The best, simplest, and easiest way to obtain it is from indoor gymnastics. Broadcast physical exercises, too, provide useful information on several exercises, both in the morning and/or in the evening. It is preferable to perform some simple jerks and respiratory exercises in the breaks of practising. We have studied simple reaction time and found that such exercises invigorate the higher nervous functions, activate stimulus reception and thus facilitate the subsequent period of practising. Another never-failing method of active recuperation and physical and mental refreshment is regular walking. It may be taken also as a 'promenade cure'. A person not yet accustomed to it may begin as follows. Start when rested and feeling fit, and in agreeable weather. Initially, he should walk some 10 or 15 minutes on level ground and at a comfortable pace. After having returned, he should rest recumbent or in a comfortable armchair. If he enjoyed the walk, he should continue daily, but increase its time by only one or two minutes each day. Eventually a one or two hours' walk may be attained. The pace of walking may be increased as well. Take one or two minutes' swift walking, followed by a more leisurely stroll of three–four minutes; thereafter another quick-speed period may be inserted. The efficiency of walking is considerably enhanced by walking uphill. Excursion is a more sportsmanlike sort of walking. In this case the physiological effects of Nature come more into prominence, including the stimuli of solar radiation, changes of temperature, humidity and atmospheric pressure, and air motion. The constitution of a tourist becomes gradually better adapted to the rigours of weather, his fitness and health will improve. Hence the saying: there is no bad weather, only a bad tourist. Several branches of sports may be suggested which, by being opposite activities, provide active recuperation, and are thus profitable and healthy for an instrumental artist. Particularly effective are bathing, sun-bathing and swimming. Bathing, adjusted to individual taste, would afford highly valuable stimulatory effects. The beneficial influence on the body of air and light baths to an appropriate extent cannot be substituted by other means. Unlike other physical exercises, swimming takes place in water and thus it secures the beneficial and stimulating effects of water together with the advantage of muscular exercise. The rhythmical work of limb and trunk muscles in swimming means an activation of the whole motor apparatus, as well as of respiration, which is necessarily coupled to the movements of swimming. It also stimulates metabolism, increases circulatory performance and makes cardiac muscle stronger.

MAINTENANCE OF ACTUAL CONDITION

No special rules are required for the maintenance of a good physical condition for the sake of public performance and to a way of life in support of it. The generally recognized principles of a healthy life are also entirely satisfactory for efficient artistic work. Neither drugs, nor other special excitatory material or liquids are necessary; indeed, they may even be harmful. Physiologically, there is no inducement to living an extraordinary 'Bohemian' life. Work and repose have to alternate in an appropriate rhythm and order.

Good physical condition and practice-hygiene are greatly influenced by environmental conditions and practice schedule. According to Láng's (1944) investigations, performance 100 per cent at +20° C and with adequate ventilation, dropped to 76·6 per cent at +24° C and without air motion. The experiments of Lehmann and Szakáll (1937) have shown that a working capacity of about 92,000 kgm effected at +18° C, decreased to about 78,000 kgm when temperature was increased to $+26°$ C. These data warn us that the microclimate of the room of practising and teaching is an important factor. Naturally, good illumination and silence are also essential and constitute the recognized preconditions of quiet and concentrated work. A lasting absence of adequate practising and teaching will have serious consequences for the level of general and actual physical fitness. In several instances the failure of instrumental performance is caused not by a lack of the pupil's talent or by teaching mistakes, but by physiologically and psychologically adverse environment.

The development of exhaustion, and through it the change in physical working capacity, are not even: they show a weekly and daily variation. The relevant studies have shown that among week-days first Wednesday, then Monday and Thursday are preferable for work. According to other experimental data the most efficient periods are between 9 and 11 a.m., i.e. usually the 2nd and 3rd lessons, and that afternoon lessons are more tiring than morning ones. In spacing out the week and the day for practising and teaching periods these factors have to be taken into account. One of the two instrumental lessons per week should fall on the optimum day, and, as far as possible, on a morning period. The way these conditions are to be met is primarily a question of local staff and place. The arrangement of practice sessions is also a problem of school administration, at least in part. A professional artist or student should, in any case, appoint the morning as the chief period of practising if possible; in the afternoon, on the other hand, he should begin practising about one and a half or two hours after mid-day meal. Practice may be made more varied by Moser's (1920, II, p. 62) suggestion, viz. that other kinds of musical activity, such as piano playing for instance, should be included in the work-period of the principal instrument.

The time-table of ordinary days will have to be modified on concert days. We should refrain from substantial meals before a recital. We propose, instead, a light meal some two–three hours before the performance. On the day of performance one should spend the time with light activity and rest. By that time there could be no need for vigorous practising. We have all heard of excellent artists having given a performance of outstanding artistry under adverse conditions or even when ill. Their great power of will and high sense of vocation helped them over the difficulties. Nonetheless, this should by no means be an excuse for neglecting to create the best possible conditions for an artistic performance.

STAGE FRIGHT

In the paragraph devoted to repose we have referred to the ergotropic innervation of autonomous organs in the course of which the human body operating at slow burning until then adjusts itself to working conditions. The transition is not sharp but gradual. Exact studies have shown that an ergotropic transition of autonomous innervation starts at a time when the work to be done is only spoken of, but muscles are still relaxed and the body at rest. The influence the higher nervous function exerts on the autonomous organs has been investigated by Bykov (1947) and his associates. In order to clarify the neuro-endocrine effects exerted on behaviour Lissák and Endrőczi (1960) have performed some fundamental experiments. According to the studies performed in sports physiology with reference to the ideas of these authors, pulse rate, blood pressure and respiratory gas exchange begin to rise to a notable extent when the resting athlete receives the call to start. These changes take place before he goes to the starting-post, and grow gradually more intense. This is called start fever. A similar physiological phenomenon occurs before the performance of an instrumental artist. Even before he steps on the platform the alterations described above are present and induce vivid subjective emotions, like heart beats, shortness of air and excitement (Schmale and Schmidtke 1966, Bassan 1966, Stadler and Szende 1965a, 1968).

Stage fright is, properly speaking, not a pathological condition, but a preparation of the body to tackle the task to be faced. Consequently, some degree of 'natural' stage fright is not harmful, but indeed necessary and advantageous. An artist cannot afford to be indifferent before his concert, but must mobilize and concentrate all of his mental and physical powers at top level to make his performance a success. In considering artistic efficiency a complete absence of stage fright, which may lead to apathy, is undesirable. In sports physiology the state in which the athlete is indifferent to the race is called start apathy; he appears to lack the will to win.

On the other hand, excessive stage nervousness is a more common inconvenience. It is manifested by the uncomfortable sensations of violently throbbing heart, elevated blood pressure, dyspnoea and anxiety which exert a disabling influence on the artist and confound his performance. As Michel (1960) has so aptly put it, the anxious inhibition by which stage fright is caused, interferes first of all with the recently acquired and thus relatively still unstable skills. Thus we may find on examination a recurrence of technical and musical faults which were believed to be definitely corrected, although the respective dynamic stereotypes were transformed only recently and not securely enough. Stage fright will disarrange the mechanism of recollection (e.g. as regards articulation and phrasing) and of motor co-ordination; the performance may thus be distorted. Anxious inhibition may also be induced or aggravated by some incidental circumstance of the performance, such as unfamiliar acoustics or illumination of the hall, etc. Consequently the performer must become acquainted with the acoustics of the hall, even though an empty hall produces different acoustics from one that is full.

Stage routine is the best remedy against inhibitions. The preparation of the would-be-artist for concert performances also demands a systematic approach in this respect. At first he should perform before a smaller audience recruited from class-mates and school-mates, i.e. before a friendly audience and in a room with which he is familiar. Later he should become gradually accustomed to a more critical audience and to unknown conditions. In the meantime the experience of success reinforces the necessary positive stimuli, and on the other hand an opportunity is given by a sober-minded analysis of occasional failures to utilize them in training for the stage.

Stage fright has an individually variable range; in fact, it may take different forms even in one individual. Conquering it therefore needs similarly individual methods. The elimination of these nervous complaints is usually not a medical, but a pedagogical-psychological problem. It is the teacher's duty to show the pupil the way by providing him with useful information and timely advice on the proper attitude at recitals. By fostering a correct sense of criticism, the development of depression caused either by mistaken self-confidence, or on the contrary, by an impression of insufficiency, may be prevented. An industrious training and preparation may, at the same time, eliminate the fear of an anticipated failure.

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