MUSIC
A SCIENCE AND AN ART

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"— not astonishing to any one who has reflected on the extraordinary ignorance of mankind about the most spontaneous and universally beloved of the arts, and their no less extraordinary indifference to its potent effects on the mental and moral character."

MACRAN: THE HARMONICS OF ARISTOXENES.

MUSIC

A SCIENCE AND AN ART

JOHN REDFIELD

Former Lecturer in Physics of Music, Columbia University

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TO MY WIFE

TO WHOSE EFFORTS AS MUCH AS

TO MY OWN

THIS BOOK IS DUE

FOREWORD

The present volume is not intended as a treatise on the science and art of music, nor does it presuppose upon the part of the reader any training in music either scientific or artistic. It is addressed to that portion of the intelligent reading public having an interest in music whether with or without training in it. The message it is hoped to convey is that music has a twofold root, one branch going in the direction of science, the other in the direction of art. The artistic approach to music is already cultivated with astonishing zeal, though with what wisdom may be open to question. That there is a scientific approach to music is quite ignored. It is as an urgent invitation to cultivate the scientific approach to music that the book has been written. If it shall establish that there is a scientific aspect to music, and shall persuade of the advisability of approaching music from the scientific as well as from the artistic side, it will have accomplished its purpose.

Thanks are due to the Macmillan Company for permission to use those illustrations which first appeared in SCIENCE OF MUSICAL SOUNDS by Professor Dayton C. Miller, and to E. Leitz, Inc., for permission to reproduce the Sphygmogram of the Human Pulse.

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CHAPTER I

INTRODUCTION

THE SCIENCE AND ART OF MUSIC

MUSIC is not something on a sheet of paper. Nor is it even the manipulation of a musical instrument by the interpretative artist. To the production of music three several individuals must contribute: the composer, the instrument maker, and the interpretative musician. Neither one alone, nor any two of them, can produce music. Not until all three have been brought into intimate collaboration, and the air between the instrument and the listener's ear is disturbed by the actual playing of the instrument, is music produced. That disturbance of the air is music. In the last analysis, music is something happening in the air; and it is nothing else.

That there is an art of music will be readily conceded. That there is a science of music as well is not quite so obvious; yet such is undoubtedly the case. And that music as an art can not attain the full growth of which it is capable unless fostered and nurtured by science, is equally true. Nor is music the only art dependent for success upon the development of a science lying beneath it as a foundation. There is an art of surgery; but that art is founded upon the rigid sciences of anatomy, physiology, and pathology. There is an art of photography too; but in the background of photography as an art are tremendous scientific laboratories with hundreds of investigators in chemistry and optics. There is also an art of stage illumination; but its state today would be sorry indeed were it not for the researches of such titan scientists as the late Charles Proteus Steinmetz and his army of assistants. So, too, is there an art of music; but this art should no more blind us to the existence of its corresponding science than do the arts of surgery, photography, and stage illumination, obscure our recognition of the fundamental sciences upon which those arts are founded.

Just what is the art of music as distinguished from its science; and to what precise degree is music an art rather than a science? The word "art" is used in two senses that have a bearing upon music. One use is to designate physical skill. In this sense we speak of the art of bowing in violin playing, the art of touch in playing the piano, and the art of voice placement in singing. The second use of the word is to designate something quite separate and distinct from physical skill; to indicate a process by which we contribute to musical materials furnished us a complementary beauty not before possessed by them, with the purpose in view of better fitting them to serve a human need.

The meaning of art in the sense of physical skill is easy to grasp. In other fields than music, but in the same sense, we speak of the art of flying an airplane, the art of swimming, or the art of serving a tennis ball. Other musical uses of the word in the sense of physical skill are, the art of fingering the violin, the art of pedalling the organ, the art of tongueing the wind instruments, the art of breathing in singing, and the art of playing the percussion instruments.

The second type of musical art is less easy to put into words; not because its significance is any less definite, but because immaterial things are by their very nature more elusive to the mind seeking to lay hold on them; they slip through the mind's fingers more readily than things which are concrete, are more difficult to image than things physical. Perhaps we can best approach an understanding of this second type of musical art by inquiring what is meant by the art of interpreting a musical selection. What do we mean when we say that one interpretation of a piece of music is "artistic" and that another is "inartistic"?

Suppose we take for consideration renditions of Schubert's "Ave Maria" by two violinists. Of a certain player as compared with another, a lay critic remarked: "He can't play 'Ave Maria.' 'Ave Maria' is a prayer; and what does a boy of eighteen know about praying!'' The younger player's physical mastery of his instrument was, perhaps, superior to that of the elder. The objection to his playing was raised not because of any lack in his physical command of the instrument, but solely because an emotional element was thought to be missing from his rendition that was believed to be present in that of the older man. What, precisely, was it that was held to be lacking? The players had been supplied with the same materials by the composer; the scores were identical. Did the younger player fail to present all that appeared in the score, or did the older player present more than was written? Undoubtedly the discrepancy arose from the fact that the older player gave his auditors something over and above what appeared on the page. Whether what he presented that was not in the score was something intended by the composer but too elusive to be reduced to musical notation, or was a genuine addition to the composition beyond anything consciously intended by the composer but nevertheless something properly belonging to it, we will not inquire for the moment. Just at present we will go no further than to recognize that the older man played something more than appeared in the score.

Perhaps our meaning is now clear as to the nature of interpretive musical art. It is quite evidently at times creative in character, and closely allied to the art of the composer. And what is it that the composer himself does? The composer takes the notes of the scale and the beatings of rhythms—very simple materials, and these he weaves into a tapestry of ineffable beauty—if he is really a composer. If he is not . . .

The composer and the interpretative artist have this in common: they each of them take materials that are supplied to them, and to these materials they contribute an additional beauty not present in the materials as supplied. And this adding of beauty to musical materials furnished is the second type of musical art; the first being, as we recall, mere physical skill. But each of these types of musical art utilizes physical things as their vehicles and means of expression. And the study of these physical things constitutes musical science. The interpretative musician of whatever kind uses some form of physical instrument, whether it be a violin, a piano, an organ, a wind instrument, an orchestra, a human voice, or a choir of voices. These instruments, all, are pieces of physical apparatus subject to the same physical laws that govern other machines. The composer, too, works with physical materials. He uses rhythms and musical notes, both of them atmospheric phenomena as truly physical in character as electricity, heat, or gravitation; and both of them quite as properly subjects for laboratory investigation as any of the latter phenomena.

What, then, is music—this thing that happens in the air when an instrument is played? What is the exact nature of the atmospheric disturbance occurring when music is produced? Just what would be shown if we could procure a print of the field between an orchestra and the ear of a listener during the playing of a symphony. This inquiry and its answer lies within the province of musical science. In the first place, the disturbance would be disclosed as almost infinitely complex. In the second place, a record of the events constituting the disturbance would show things as happening with almost incredible rapidity. And, in the third place, the disturbance would be found to be of astonishing feebleness from the standpoint of all our senses except that of hearing.

In a football game there are, at best, twenty-two players acting directly or indirectly upon the progress of the ball. In a symphony there are, at a conservative estimate, ten thousand forces acting all the time upon the motion of each particle of air. A hundred instruments to the orchestra will have on the average, let us say, ten partials to the tone of each instrument—a thousand in all. Some of the instruments will have many more than ten partials; perhaps none will have fewer than that number. And the differential tones arising from combinations of these partials would, I should say, bring the total of the forces operative easily to the number stated. This number, ten thousand, should of course not be understood in any sense as a computation of the actual number of forces bearing on a particle, but merely as indicating that the number is very great indeed. The number of forces actually operative would possibly be much greater than ten thousand. Of these myriad forces, a part would be found ranged on one side pushing the particle in a certain direction, the rest of them working together on the other side to propel it in the opposite direction. The air particle, like the football, is carried back and forth in one direction or the other depending upon the relative strength of the contending sides.

And the motion is as rapid as it is complicated. On a football field the plays are frequently too fast to be followed except by the eye of an adept in the sport. But the movements of an air particle musically propelled are of such incredible rapidity as to make those of the football seem as slow almost as geologic processes. Some of the musical forces "hit the line" many thousands of times per second, and every one of the players is in the game all the time.

But, while the disturbance is very complicated and very rapid, it is also very feeble. The weakest of these musical forces move an air particle by not more than one fourth of a billionth of an inch (*Encyclopedia Britannica*, v. XXV, p. 451). Ordinary sounds move an air particle perhaps a hundred-thousandth of an inch, and the loudest sounds we ever hear perhaps not more than a hundredth of an inch—about a half more than the thickness of this sheet of paper. As Rayleigh puts it, "the ear is able to recognize additions and subtractions of densities far less than those of our highest vacua." Thousands of Lilliputian musical forces acting every instant with the rapidity of thought on every air particle in the musical field, some to drive it toward the listener's ear and some to push it back—this wavering battle-front it is that the ear calls music. Funny ear!

Is it possible to hope for anything more than the most confused impression of such a complicated activity? It is if one will call upon science to assist the senses. By gently pressing the radial artery where it passes over the carpal bones we feel a succession of pulsations in our wrist produced by variations in the pressure of the blood against the walls of the artery. If the sense of touch in our finger were acute enough to feel the disturbance in musically agitated air, we should discover in the latter precisely such pulsations as those occurring in the artery. Our tactual sense being of course much too gross for this purpose, scientists have devised instruments by means of which these pulsations may be studied to any required degree of accuracy or detail. In this manner invaluable information may be acquired about this musical activity in the atmosphere to the production of which the composer, the interpreter, and the instrument maker, all, so enthusiastically but so blindly dedicate their lives.

Musicians are too short sighted. They are unable to see beyond the symbols on the music score and the machines they manipulate to express those symbols. What lies between the instrument and the ear of the listener, and what in that mysterious realm behind the composer, is all a deep secret to them, of whose existence even they are hardly aware. *Music is not something on a sheet of paper.* What we find on the paper is only a set of symbols designed to represent music—and sadly inadequate symbols they are. An instrumentalist speaks of studying music when he is as a matter of fact only learning the management of a musical machine designed to give expression to certain symbols on a sheet of paper. A student of composition imagines he is studying music when he is only learning to juggle musical symbols with sufficient skill to write running orders for the engineers of those machines. Strictly speaking, neither of them is studying music itself. If instrumentalists and composers realized how entirely inadequate these symbols are to represent the things that happen in musically active air, if they knew how small a portion of the atmospheric phenomena constituting music can be recorded in the staff notation and be produced by our musical machines, if in short they were aware that they are only dabbling tentatively and fearsomely in the beach ripples of a whole ocean of music that lies all uncharted and unsailed before them, they would begin to peer behind and beyond the symbols of music and courageously undertake a study of music itself rather than of its lame and halting hieroglyphics.

PART ONE

MUSIC AS A SCIENCE

CHAPTER II

MUSICAL TONE

Obviously it would be mere folly to hope for anything but the most confused impression of the complicated atmospheric activity called music if we attempt too soon to view the field as a whole. Only by giving careful attention at individual points *seriatim* can we hope to discover order in the chaos and begin to understand the interrelations of its myriad constituent parts. If we can single out from the disturbance some simple musical element for initial study, we may then perhaps be able to pass on to more and more complex ones, and at last arrive at a fair comprehension of the whole field of action. Such a simple musical activity is the tone of the flute in its middle register. Let us see if we can discover what a flute does to the air between it and a listener's ear. But even this simple activity will have to be approached with due care and heed if it is to be understood.

There has been much blind leading of the blind in respect to the nature of musical tone. Many of the things currently known about musical sound, unfortunately, are not true. This is due in a measure to lack of information on the part of writers on sound, but chiefly perhaps to infelicities in their methods of presentation. Although he should not be held at fault therefor, the average musician would probably take an advance step in his understanding of sound if he were to divest himself entirely of whatever information he may at present possess upon the subject. Especially is this necessary with respect to his notions about so-called sound "waves."

Sir Isaac Newton did clearer thinking about sound in his "Principia" than did many, or possibly any, of those who came after him; and the term used by him to designate the characteristic phenomenon of sound was "*pulsus*," meaning "pulse." The Latin word was used by Newton in discussing sound in the plural only, never in the collective sense of a succession of pulsations. The English cognate, "pulse," has come to have this latter collective signification almost exclusively, and is but rarely used to refer to a single throb. For this reason it seems to me better to use the derivative form, "pulsation," to designate the single throb. In my own thinking about sound I had used the term "pulsation" as being more accurate than "wave" for several years before I learned that it is the term also used by Newton. I was, of course, gratified to discover such high authority for its use.

We can clarify our notion of a pulsation by considering the beating of the pulse in our wrists. At the beginning of each of the pulsations the pressure of the blood against the arterial walls is very slight. This pressure increases, however, until at the peak of the pulsation it has reached the instant of greatest pressure, after which the pressure begins to decline, and continues its decrease until it reaches the same condition of low pressure with which the pulsation begins. It is necessary to go one step further in our analysis, and to recognize that the varying pressure on the walls of the artery is due to variation in the density of the blood during the pulsation, the varying density arising in its turn from the pumping action of the heart. The variation in the density of the blood within the artery is but slight, but the soft arterial walls offer so little resistance to the inside pressure—about a pound to the square inch (Martin: *Human Body*, p. 368)—that the impression upon the finger is very marked.

If we were to draw a graph (a line) representing the varying pressure of the blood upon the finger for several pulsations, it would look something like this: (Fig. 1). At the points A, B, and C, the pulsations are just beginning, and at the points X, Y, and Z, they have reached their moments of highest pressure for each of the pulsations. The first pulsation extends through the period from A to B, the second through the period from B to C, and so on. And, again, it should be noted that the graph represents not only the varying pressure against the arterial walls but also the variations in the density of the blood that cause the varying arterial pressure.

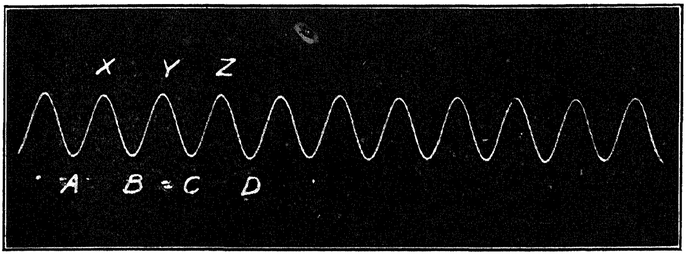


Fig. 1.

If, instead of drawing our graph of the arterial pulse by guess, we were to take it with an instrument called a sphygmograph, as is done by heart specialists, we should find the graph possessing many irregularities due to small variations of blood density within the pulsation, and looking something like the following: (Fig. 2). Like our graph drawn by guess, the sphygmogram possesses points of

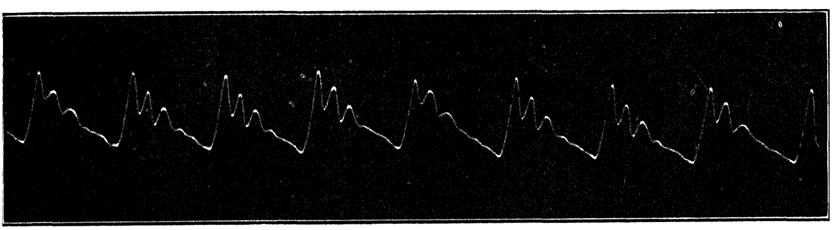


Fig. 2. Sphygmogram of human pulse.

lowest pressure at the beginning of each pulsation, and points of highest pressure at the peaks. But, unlike the graph drawn by guess, the sphygmogram has little hills and valleys on each side of the peaks. It is important to note these little hills and valleys, and to recognize that they themselves are due to variations in blood density, just as is the sphygmogram as a whole.

For the purpose of studying musically active atmosphere, Professor Dayton C. Miller, of the Case School of Applied Science, has constructed an enormously delicate piece of apparatus which he

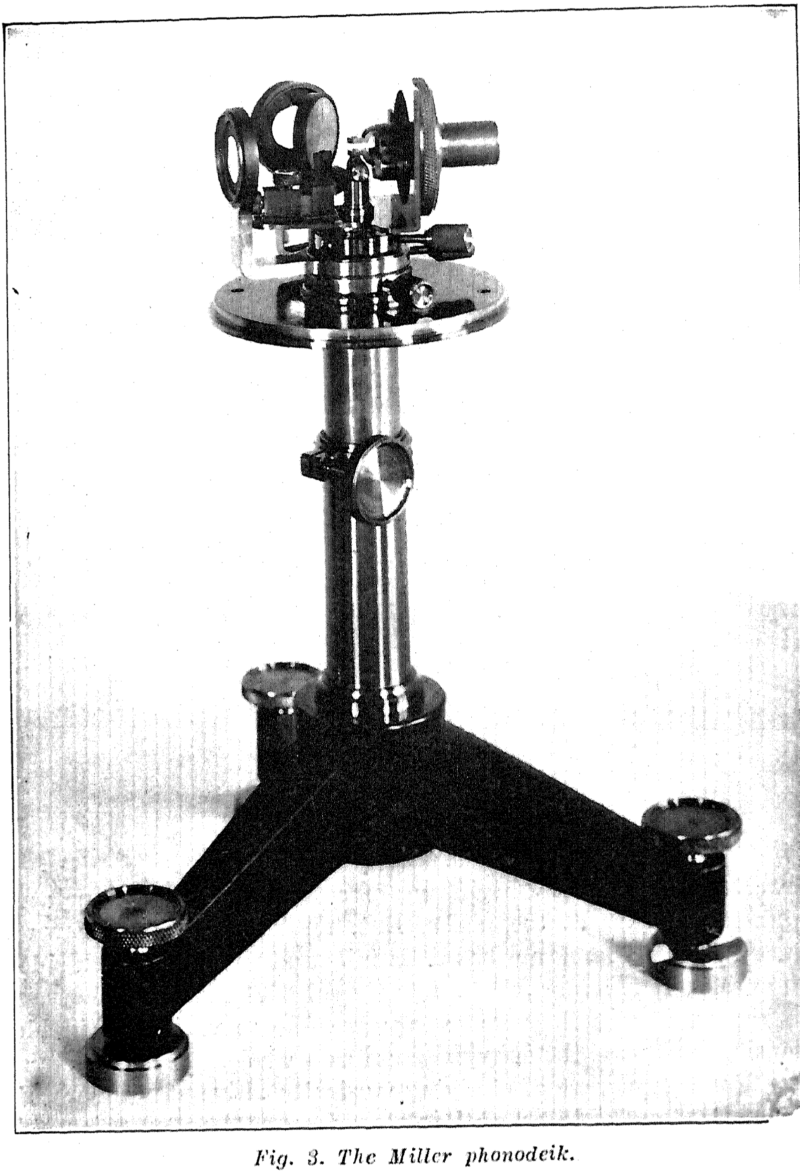


Fig. 3. The Miller phonodeik.

calls the "phonodeik." The word means, "showing sound." It consists essentially of a diaphragm so connected with a mirror that the mirror is rotated by the movement of the diaphragm. The diaphragm is of glass about a three-hundredth of an inch in thickness. A small mirror about a twenty-fifth of an inch square is mounted on a shaft which has a pulley. The shaft and pulley together weigh about a fourteenth of a thousandth of an ounce, and the shaft is supported at its ends on jewels much more delicate than those of a watch. A belt, fastened to the center of the diaphragm, passes round the pulley that is on the shaft which holds the mirror. When the diaphragm is moved by air pulsations, the mirror is thus made to rotate back and forth on its shaft-axis. A ray of light, thrown upon the rotating mirror, is reflected to a point which plays back and forth in a straight line as the mirror rotates. A sensitized photographic film, perpendicular to the reflected ray, travels in a direction at right angles to the line of light traced by the end of the oscillating ray. On this travelling film, the point of light traces a graph of the variations in the density of the atmosphere caused by sound pulsations, just as the sphygmograph records the variations in the density of the blood caused by the pumping action of the heart. Fig. 3 shows the appearance of the phonodeik.

And now we are ready to determine what the flute does to the air between it and the listener's ear. For the tone of a flute played softly in the middle register, the phonodeik gives the following graph: (Fig. 4). Remembering that the graph shows the varying

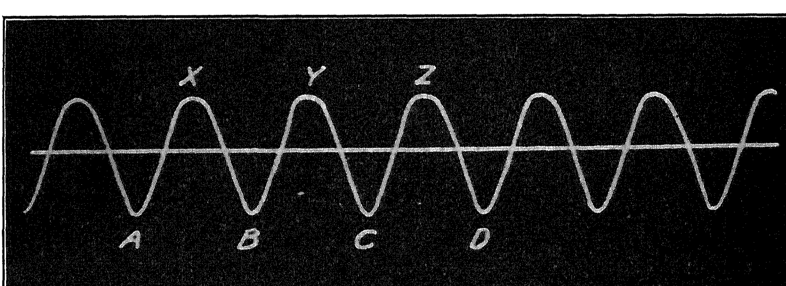


Fig. 4. Tracing from phonodeik graph of flute tone.

density of the air throughout the several pulsations, it will be seen that the density is least at the points A, B, and C, where the pulsations begin, that the density increases until it reaches the peaks X, Y, and Z, and that it then decreases until the ends of the pulsations, B, C, and D. The first pulsation extends from A to B, the second from B to C, and so on. From the beginning of the pulsation to the peak the density increases all the time, and from the peak to the end it decreases all the time. (The straight horizontal line should be disregarded.)

The graph of a violin tone on the E string, Fig. 5, is a little

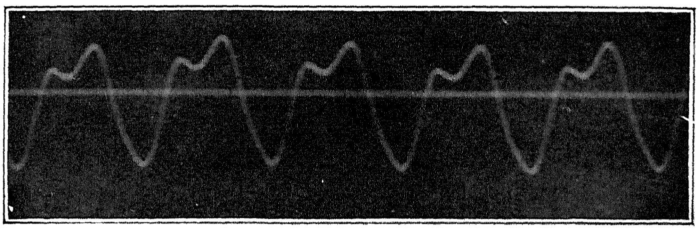


Fig. 5. Phonodeik graph of violin tone pulsations.

more irregular than that of the flute. Between the beginning of the pulsation and the peak the density does not increase *all* the time; there is a short period during which the density not only fails to increase but even decreases a little. From the peak to the end, however, the density decreases continuously.

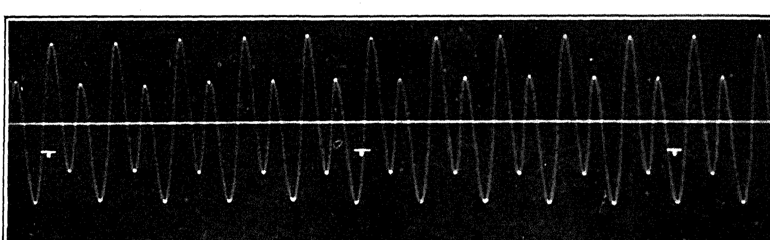


Fig. 6. Phonodeik graph of soprano voice pulsations.

In the graph of a soprano voice, Fig. 6, the situation is reversed. From the beginning of the pulsation to the peak the density increases continuously, but from the peak to the end there is a period during which the density not only fails to decrease but even shows a decided increase.

The graph of a clarinet tone in the upper part of the chalumeau register is still more irregular, Fig. 7. From the beginning to

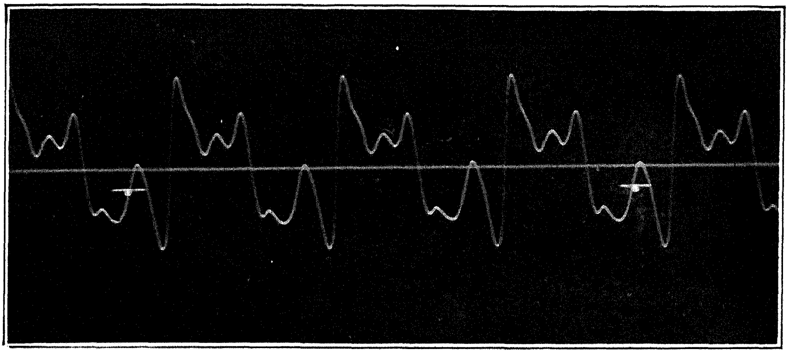


Fig. 7. Phonodeik graph of clarinet tone pulsations.

the peak the density is always increasing, but between the peak and the end there are four periods of increase: two small ones and two large ones.

In a graph of the baritone voice, Fig. 8, there are five hills between the beginning of the pulsation and the peak, but none between the peak and the end.

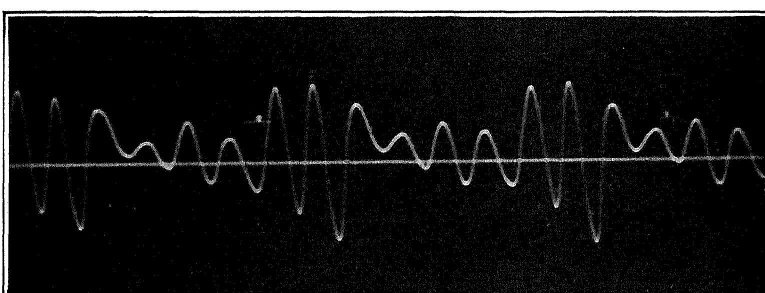


Fig. 8. Phonodeik graph of baritone voice pulsations.

Practically the same conditions subsist in the graph of the horn tone, Fig. 9; there are five hills between the beginning of the pulsation and the peak, and none between the peak and the end. In fact this particular tone of the horn is very much like that shown of the baritone voice.

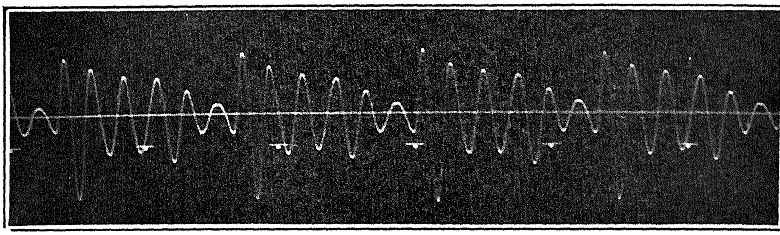


Fig. 9. Phonodeik graph of horn tone pulsations.

The graph of an oboe tone, Fig. 10, shows two hills between the beginning of the pulsation and the peak, and three between the peak and the end.

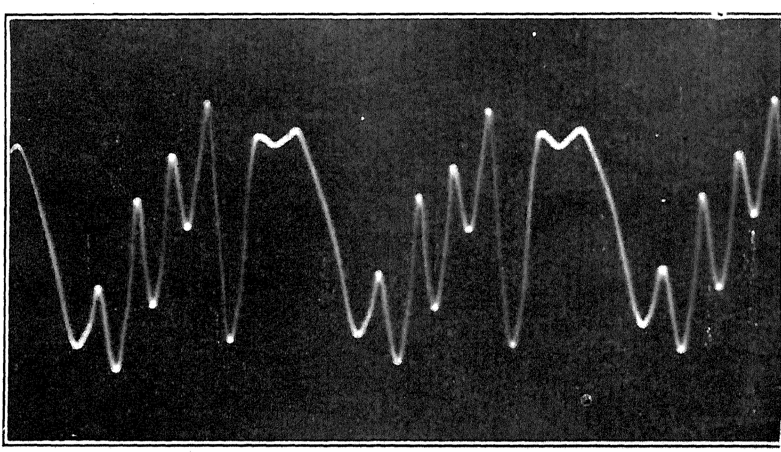


Fig. 10. Phonodeik graph of oboe tone pulsation.

In the graph of a tone of the bass voice, Fig. 11, there are five hills between the beginning and the peak, and none from the peak to the end; somewhat like the baritone voice and the horn.

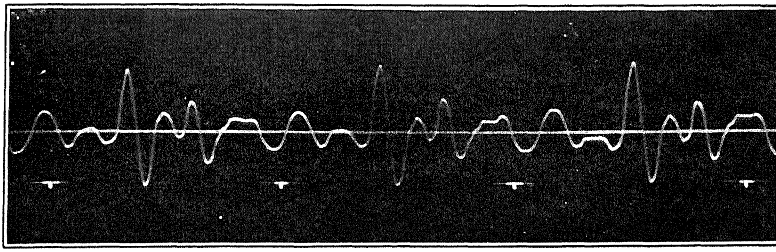


Fig. 11. Phonodeik graph of bass voice pulsations.

The graph of a clarinet tone in the lower part of the chalumeau register, Fig. 12, shows at least eight hills between the beginning of the pulsation and the peak, and one between the peak and the end.

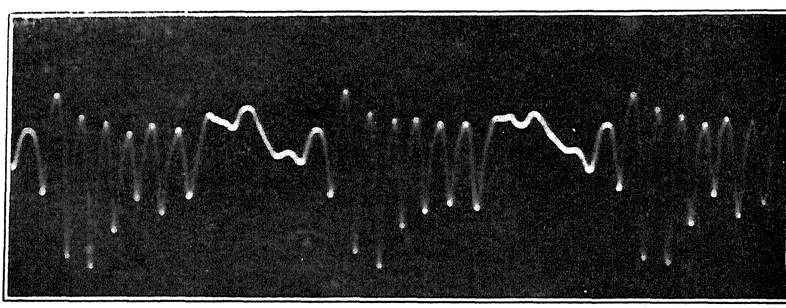


Fig. 12. Phonodeik graph of clarinet tone pulsations.

The graph of the tone from a bell, Fig. 13, is so irregular that it is impossible to discover a beginning, a peak, or an end, for any period that might be said to constitute a pulsation; i. e., the tone has no definite pulsatory period, it is *non-periodic*. All the other tones whose graphs have been presented are *periodic;* i. e., the tone is divided into periods during which the graph of any period is a duplicate of the graph of any other period.

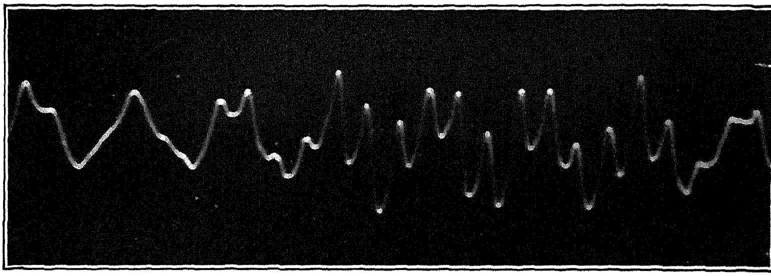


Fig. 13. Phonodeik graph of bell tone pulsations.

Disregarding, for the present, all tones of non-periodic character, and confining our attention to periodic tones only, we would if we were to examine a great many graphs discover that graphs can differ in three respects and in three only: in length of the pulsation, in width of the pulsation, and in contour. Taking the graph of Fig. 14 to illustrate our meaning, and drawing a line through the

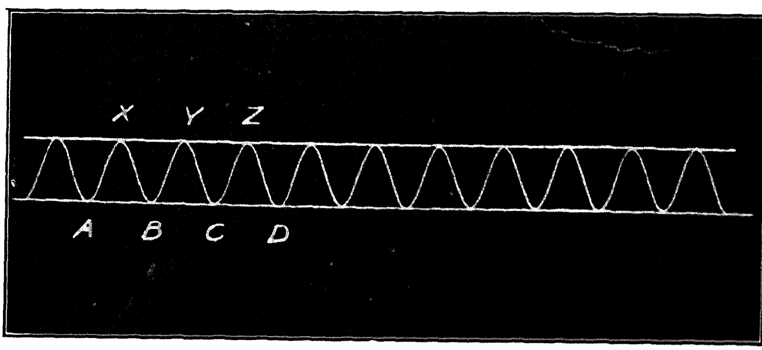


Fig. 14. Illustrating length, width and contour of pulsation.

points of beginning, A, B, and C, and another line through the peaks, X, Y, and Z, the distance from the beginning of any pulsation to the beginning of the next or, what amounts to the same thing, the distance from the peak of any pulsation to the peak of the next, is the *length* of the pulsation, and the distance between lines AC and XZ is the *width* of the pulsation. The *contour* of the pulsation is the shape of the graph from the beginning of any pulsation to the beginning of the next.

If we were to examine graphs of "violin A," made by many different instruments playing at varying degrees of loudness, we would find that while the pulsations might vary in width and in contour they would all be of the same length. From this we naturally infer that *pulsations of tones of the same pitch have the same length.* If we examine graphs of tones pitched higher, we find that the pulsations are shorter. And if we examine graphs of tones pitched lower, we find that the pulsations are longer. *Pitch,* then, *depends upon the length of the pulsation:* the longer the pulsation the lower the pitch, and the shorter the pulsation the higher the pitch.

The graph of a note on any instrument, Fig. 15, sustained *diminuendo-crescendo*, would show pulsations all of the same length,

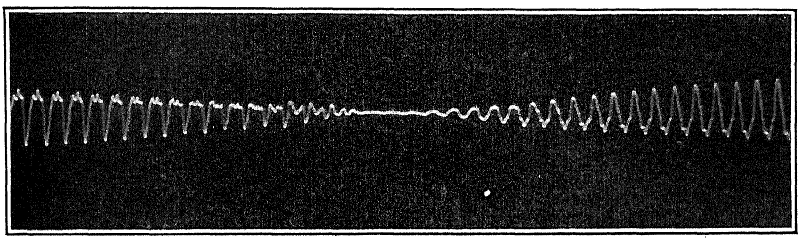


Fig. 15. Phonodeik graph of diminuendo-crescendo.

but growing narrower and narrower during the *diminuendo,* and growing wider and wider during the *crescendo.* We conclude, then, that the *loudness of a tone depends upon* the width of its graph or, what is the same thing, upon *the variation of density of the pulsation.*

The graphs of the tones of different instruments, shown in the figures already given, are not of notes having the same pitch. Still, if the same note, say violin A, were to be produced by all these instruments, the graphs would be found to exhibit for any instrument very much the same contours as the graphs already shown for that instrument. Apparently, different instruments give different contours for notes of the same pitch. And, since notes of the same pitch and loudness can differ only in quality, we conclude that *tone quality depends upon* the contour of the tone's graph or, what amounts to the same thing, upon *the rate at which the density changes within the pulsation.*

Pitch, then, is the sensory form in which the length of periodic pulsation manifests itself; loudness, the sense form in which the variation of density presents itself; and tone quality, the sense form in which the rate of change of density within the pulsation presents itself.

But what is it that makes the irregularity in the contour of some of the graphs? The smoothest of all tone graphs is that secured from the tone of a tuning fork, shown in Fig. 16. Mathematical

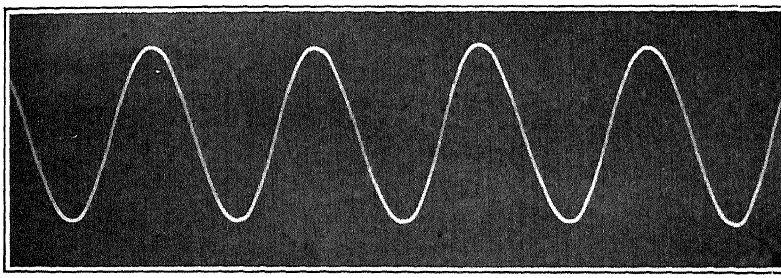


Fig. 16. Phonodeik graph of tone pulsations from tuning fork.

evidence too involved to be presented here shows that the tone from the tuning fork is the simplest of all musical tones. It differs but little, however, from the tone of the flute in the middle register shown in Fig. 4. The violin tone, Fig. 5, differs radically from it. But, if *three* tuning forks are sounded together, the first fork having a pulsation of the same length as that of the violin tone, the second having a pulsation half as long, and the third having a pulsation one third as long, the three forks having moreover the relative strengths respectively of 165, 60, and 27, we shall hear a tone whose quality is almost indistinguishable from that of the violin tone shown and whose graph, Fig. 17, is almost identical with that of Fig. 5. If a few more forks were added to the group, the latter forks having pulsations whose lengths were ¼, ⅕, ⅙, ⅐, etc., times the length of the pulsation for violin A, and the tones of each of the forks were subdued to the proper degree of weakness, then

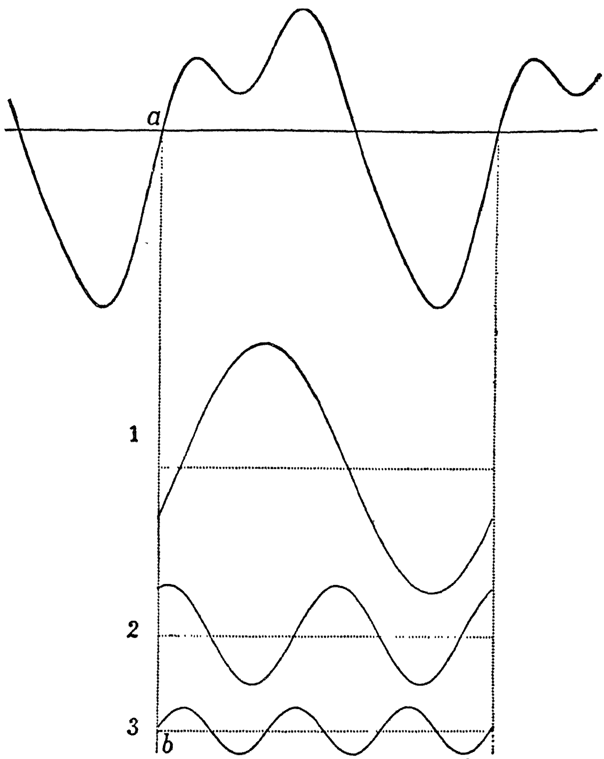


Fig. 17. Graph of composite tone and its three components.

the composite tone heard, and its graph, would approximate still more closely to the tone of the violin and its graph shown in Fig. 5. Evidently, then, this violin tone is composed of several simple tones whose lengths are related to that of the violin tone as 1, ½, ⅓, ¼, ⅕, etc., and whose relative strengths are 165, 60, 27, and some other numbers having values not yet determined. The tones of these several forks are called *partials* of the composite tone heard when they are all sounded, or when the violin tone is sounded. The partials are designated by numbers, the *first partial* of the violin tone being the one whose length is equal to that of the violin tone, the *second partial* being that whose length is ½ that of the violin tone, the *third partial* that whose length is ⅓ that of the violin tone, etc. The numbers, 165, 60, 27, and the other numbers not yet determined, representing the loudness of the several partials, might well be called the *coefficients* of the partials.

The coefficients of the first ten partials of the tone of the baritone voice of Fig. 8 are respectively 4, 15, 18, 12, 20, 60, 21, 16, 2, and 3. This means that the strongest partial in the tone is the sixth having a strength of 60, the next strongest partials being in turn the seventh, fifth, third, eighth, second, fourth, first, tenth, and ninth.

The coefficients of the first twelve partials of the clarinet tone of Fig. 12 are 29, 7, 20, 1, 2, 6, 6, 8, 16, 9, 30, and 35; which is to say that the strongest partial in this tone of the clarinet is the twelfth with a strength of 35, the eleventh coming next with a strength of 30, then in order the first, the third, the ninth, the tenth, the eighth, the second, the sixth and seventh equal, the fifth, and the fourth.

The determination of the coefficients for the partials of a musical tone is laborious, and involves rather difficult mathematics. The actual computation is usually effected through the use of a machine called the harmonic analyzer and shown in Fig. 18. A similar but more complicated analyzer, shown in Fig. 19, is used by the United States Coast and Geodetic Survey for computing the heights of future tides. The accuracy of the results reached by such methods may be indicated by the fact that these tide computations, made years in advance, are used by navigators to ascertain what harbor conditions will be at any moment of the future in any part of the world.

Exhaustive analyses of many musical tones, by different persons using different methods, extending over a period of many years, leads to the following conclusion now universally accepted: *Every musical tone is a composite of simple tones called partials, the lengths of the partials being respectively* 1, ½, ⅓, *etc., times the length of the composite tone, and the relative strength of the partials being anything between* 0 *and a number representing the loudness of the composite tone itself.*

The number of partials present in a tone depends upon three things: the instrument producing the tone, the location of the tone within the compass of the instrument, and the loudness of the tone. The higher the tone is located in the compass of the instrument, the

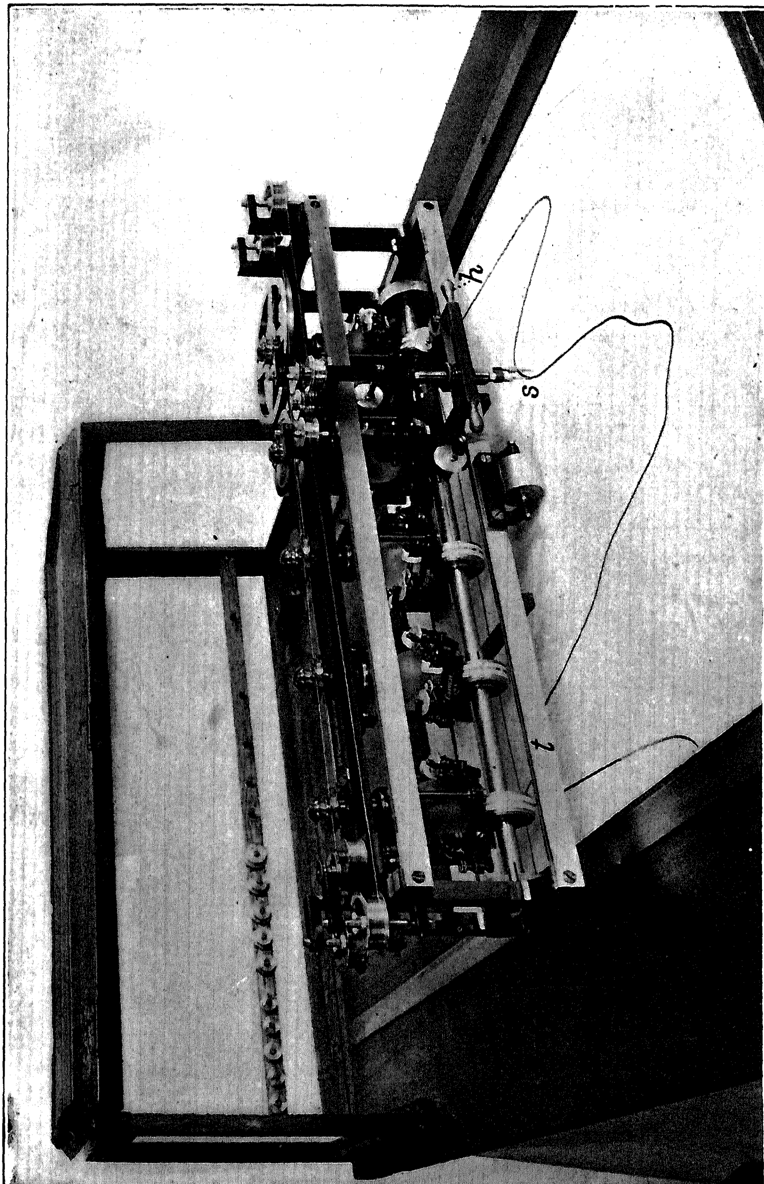


Fig. 18. Henrici's harmonic analyzer.

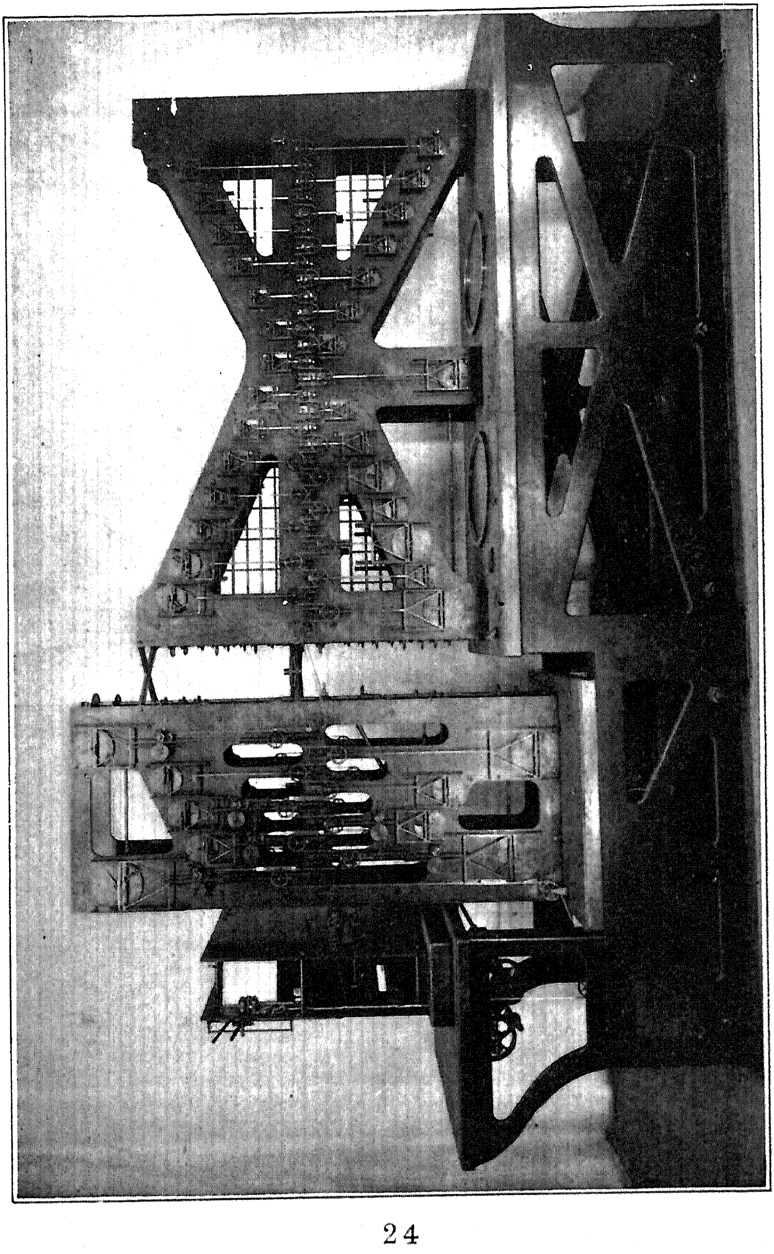


Fig. 19. U. S. Coast and Geodetic Survey tide-predicting machine.

fewer partials the tone will possess. The violin tone, analyzed above,

had very weak partials above the third. If the tone had been taken an octave or so lower on the instrument, it would have shown many more partials. The same rule holds also for the other bow instruments, the viola, the 'cello, and the double bass; and, of two bow instruments, the one having the lower compass will have the greater number of partials. The flute tone is rich in partials in the lower part of the lower register; but, above the first octave, the partials are all very weak except the first. This is evident from an inspection of the graph of the flute tone in Fig. 4. The clarinet is very rich in partials throughout the chalumeau register, but especially in the lower part of that register; the middle, or clarion, register has fewer partials, but is not quite so lacking in them as is the same register of the flute. The oboe and the bassoon are extremely rich in partials throughout their compasses, but especially so in their lowest registers. The French horn sometimes shows as many as thirty partials for the lower notes, not quite so many for the upper ones. The other brasses are also rich in partials, especially the small bored horns, trumpets and trombones.

The number of partials in a note of a given instrument depends also upon the loudness of the note for that instrument, an increase in loudness causing an increase in the number of partials. It is possible, however, that the same number of partials are present in the soft note as in the loud one, but that the higher partials in the soft note are below the threshold of audibility. From theoretical considerations this would seem to be the case.

Besides the many partials present in nearly all the tones produced by the instruments of an orchestra there will also be found present, in the tonal complex, tones known as *differential* tones. These are tones resulting from the combining of partials, each pair of partials producing a differential tone pitched lower than the upper partial. Differential tones can be presented more clearly, however, after some attention has been given to the subject of harmony. Further consideration of them will therefore be deferred until later.

In connection with partials and the composite tone which they form, illustrated in Fig. 17, two facts should be noted, Fig. 20: first, the partials do not present themselves to the ear as three distinct pulsations, 1, 2, and 3, but they unite to form *one pulsation*, ac, which is a composite of the three; and, second, the partials *sometimes* work *together* to increase or to decrease the intensity at the

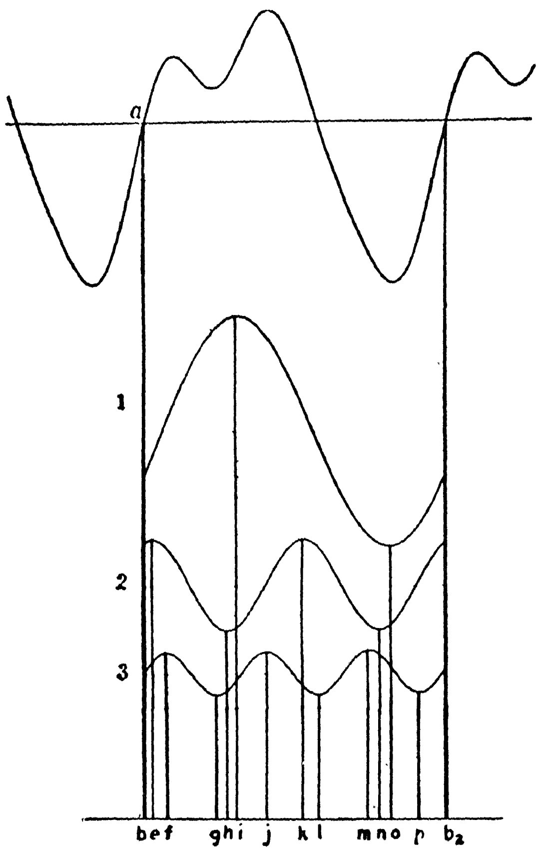


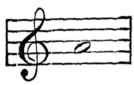
Fig. 20.

moment under consideration, but they *frequently* work *in opposition,* some of them tending to increase the density and others tending to decrease it. For example: at the instant b, in the figure, all three of the partials are working together to increase the density.

They continue to do so up to the instant e when partial 2 begins to decrease the density. The other two partials continue to increase the density up to the instant f, when partial 3 also begins to decrease the density. At the instant g partial 3 again begins to increase the density, and at instant h partial 2 begins to increase it. All the partials now work together to increase density up to the instant i, when partial 1 begins to decrease the density. At instant j partial 3 begins to decrease density, and at instant k partial 2 does the same. At instant l, partial 3 begins to increase, at instant m it begins to decrease, at n partial 2 begins to increase, and at o partial 1 begins to increase. At p partial 3 joins the other two in increasing the density, just as they were doing at instant b when we began our consideration. Of the twelve periods connecting the instants b, e, f, g, h, i, j, k, l, m, n, o, p, and b (which latter instant is a repetition of the instant b), there are only four periods during which all three partials are working together: during the period from h to i, and during the period from p through b to e (p to e constituting one continuous period), all partials are working together to increase density; during the period k to l, and during the period m to n, the partials all work together to decrease density. During the remaining eight periods the partials work in opposition, some to increase density and some to decrease it. And the same is true whether the number of partials composing a tone is greater or less than three, or whether the total number of partials acting on an air particle all proceed from the same instrument or from a hundred instruments.

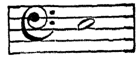
This makes clear our statement earlier that "of these forces a part would be found ranged on one side pushing the particle in a certain direction, the rest of them working together on the other side to propel it in the opposite direction. The air particle, like the football, is carried back and forth in one direction or the other, depending upon the relative strength of the contending sides." And whether the partials all come from one instrument or from many, whether they play in unison or in a complex harmony, it is *one composite pulsation* that is being presented to the ear at a given time, and not several pulsations.

It appears, then, that the playing of an orchestra produces in the air between it and the listener's ear literally thousands of pulsations, related to each other in such a manner that they coalesce into a single composite pulsation that presents itself to the ear. But we should be prejudicing our comprehension of the matter if we failed to note the actual lengths and widths of the pulsations as contrasted with the lengths and widths of the pulsations as shown in the graphs. The *actual* length of the atmospheric pulsation for



violin A, is about 2½ ft.; that of 'cello A, an octave lower, about 5 ft.; that of double bass A, three octaves below violin A, about 20 ft.; and of lowest E on the double bass, about 27 ft. The *actual* length of the atmospheric pulsation for the A an octave above violin A is about 15 in.; and for the A two octaves above violin A, about 7½ in. The atmospheric pulsation for *any* note is twice as long as for the note an octave higher on the staff. But in the graphs the pulsations are, for visual convenience, shown with a uniform length of something like one or two inches, no matter what the actual length of the atmospheric pulsations.

And, just as the lengths of the pulsations in the graphs are much less than the lengths of the actual atmospheric pulsations, so too the widths of the pulsations in the graphs are shown as vastly greater than the widths of the actual pulsations. For visual convenience again, the graphs are shown with a uniform width of about one or two inches. It has already been stated that the loudest musical tones move an air particle by not more than a thousandth of an inch, and a just audible tone sometimes by as little as one fourth of a billionth of an inch. The width of the *actual* pulsation produced by music is therefore probably never more than a thousandth of an inch, and often not more than a hundred-thousandth of an inch, approximately one seven-hundredth of the thickness of this sheet of paper. The actual length of audible atmospheric pulsations ranges from about 80 ft. for the lowest audible tone, to possibly half an inch for the highest audible tone; and the actual widths of audible pulsations from perhaps a thousandth of an inch, about ⅐ the thickness of this sheet of paper, down to a width that is almost nothing at all.

The pulsation of a tone of the baritone voice whose graph is shown above, Fig. 8, with the pitch  will have, as the length of its first partial, a trifle more than 7 ft. The remaining partials will have lengths given respectively by dividing 7 ft. by the number of the partial. And these pulsations within pulsations will have various widths depending upon the coefficients of the several partials, but none of them greater widths perhaps than a thousandth of an inch.

It should not be lost sight of, moreover, that the graphs represent the varying density of the atmosphere throughout the length of the pulsation. If in the graph, Fig. 21, it is understood that the

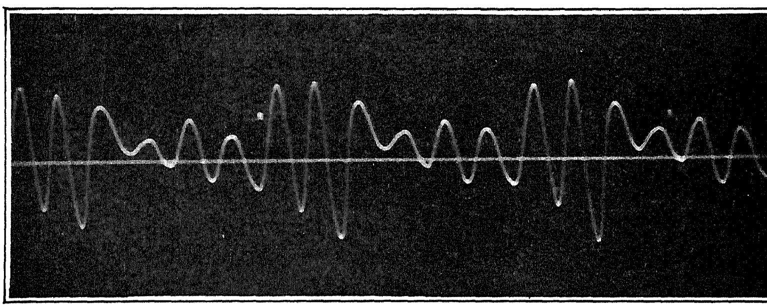


Fig. 21. Graph of baritone voice.

length of the pulsation as a whole is 7 ft., then the regions of least density in the pulsation will be at intervals of ⅙ of 7 ft., or 14 in., from the beginning of the pulsation, and the regions of greatest density will be midway between those of least density, viz., at distances of 7 in., 21 in., 35 in., 49 in., 63 in., and 77 in., from the beginning of the pulsation. The actual variation in the density of the atmosphere throughout the pulsation would, if greatly exaggerated, look something like Fig. 22 which gives the varying atmospheric density for about 20 ft., nearly three complete pulsations of 7 ft. each being shown just below the graph itself, with the regions of greatest density located below the highest points of the graph and the regions of least density located below the graph's lowest points. Remember, though, that the figure grossly exaggerates the variation in the density of the atmosphere, and that the actual variation is very small indeed, representing, in the words of Rayleigh, "additions and subtractions of densities far less than those of our highest vacua." The air particles will actually have moved from their normal positions through only infinitesimal dis-

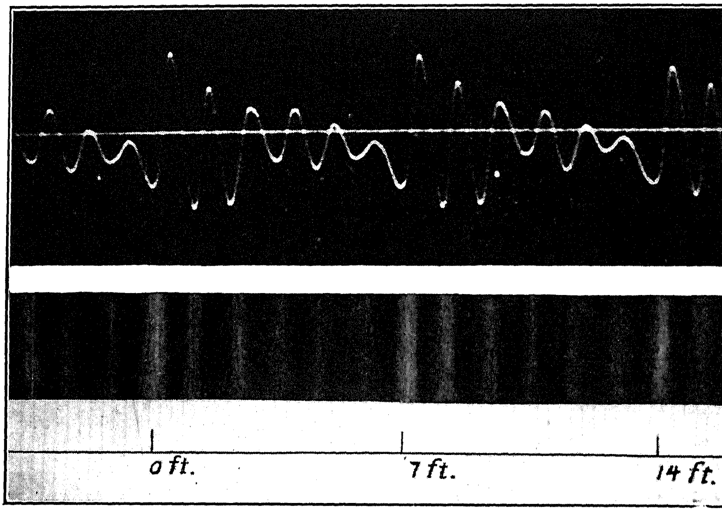


Fig. 22. How graph of tone shows varying atmospheric density.

tances, and the actual variation in density is microscopic as compared with that shown in the figure.

We thus see, to quote Newton, that "sounds . . . can be nothing else than pulses of air" (*Principia*, bk. II, sec. 8, scholium). And now let us attempt a definition of sound: *Sound is a succession of atmospheric pulsations capable of producing the sensation of hearing.* If the pulsations are too slow, too fast, too weak, or too strong, to be received by the ear, then we shall refuse to call them sounds. But if they come within the ability of the ear to appreciate, then we shall call the pulsations *sound,* and the sensations they produce *hearing.* And if a sound is to be musical, the pulsations must possess the further characteristic of being periodic. Therefore, *a musical tone is a succession of periodic atmospheric pulsations capable of being heard.*

We now have a fair notion of what musical tones really are. It would hardly be within the facts, however, to regard musical tones and music as one and the same thing. In order that musical tones shall constitute music they must fulfil other conditions yet to be examined. Some of these conditions can best be understood by approaching them, as we have done in our study of musical tones. from the standpoint of science; some of them, on the other hand, yield themselves to our understanding only if approached from the standpoint of art. We shall make both approaches. But, before doing so, let us try to ascertain how these musical tones that we have discovered are brought into being.

CHAPTER III

TONE PRODUCTION

The audible, periodic pulsations of the atmosphere which constitute musical tone are always produced by what Newton calls a "tremulous body." The tremulous body may be a string that is bowed, plucked, or struck; as in the violin, harp, and piano, respectively. It may be a single or double reed; as in the clarinet and oboe respectively. It may be a stream or sheet of air; as in the flute and calliope respectively. It may be a pair of stretched pieces of flesh; as in the brass instruments and the human voice. Or it may be a stretched skin, a thin metal plate, or a bar of wood or metal, to beat upon; as in the drum, the cymbal, the xylophone, and the orchestral bells, respectively. But, in every case, a tremulous body of some sort is necessary to produce the pulsations which we call tone.

The writer knows of no better statement of the process by which atmospheric pulsations are produced than that given in Proposition 43, Section 8, Book II, of Newton's *Philosophiae Naturalis Principia Mathematica.* The translation given follows closely that of Motte. "Every tremulous body in an elastic medium propagates the motion of pulses straight forward in every direction. The parts of the tremulous body alternately advancing and returning do, in advancing, urge and drive before them those parts of the medium that lie nearest and, by that impulse, compress and condense them; but, in returning, they allow the condensed parts to recede again and expand themselves. In consequence, the parts of the medium that lie nearest to the tremulous body move to and fro by turns in like manner as do the parts of the tremulous body itself; and, for the same cause that the parts of this body agitate these parts of the medium, these parts being agitated by like tremors will in their turn agitate others next to themselves, and these others agitated in like manner will agitate those that lie beyond them, and so on *in infinitum*. And, in the same manner as the first parts of the medium were condensed in advancing, and relaxed in returning, so will the other parts be condensed every time they advance and expand themselves every time they return. It follows that they will not all be advancing or all returning at the same instant, else they would always preserve determined distances from each other and there could be no alternate condensation and rarefaction; but, since in the places where they are condensed they approach to each other, and in the places where they are rarefied they recede from each other, therefore some of them will be advancing while others are returning; and so on *in infinitum*. The parts so advancing and condensed are pulses, by reason of the progressive motion with which they press upon obstacles in their way; and the successive pulses produced by the tremulous body will be propagated in rectilinear directions, and at nearly [1] equal distances from each other, because of the equal intervals of time in which the body by its several tremors produces the several pulses. And though the parts of the tremulous body advance and return in some certain and determinate direction, yet the pulses propagated from thence through the medium will spread themselves in all directions from the tremulous body, as from a common center, in surfaces nearly spherical and concentric."

Thus a tremulous body in air produces pulsations, equidistant from each other and spreading from a common center in all directions like expanding spheres. But every such tremulous body, if it is to serve in an effective musical instrument, needs to have its pulsations amplified; otherwise they would be so weak as to have little musical value. Every musical instrument, therefore, has two essential parts: the tremulous body called a *generator*, and an amplifying device called a *resonator*.

In all the string instruments the string is the generator. The

[1] The statement that the intervals of time between pulses are equal while the distances between pulses are only "nearly" equal, would appear to be inconsistent. Newton's words are, "aequalibus circiter ab invicem distantiis, ob aequalia temporis intervalla." Perhaps "circiter" should have been omitted.

resonator in the violin, the viola, the 'cello, and the double bass, is the bridge, the belly, and the back, of the instrument. In the mandolin and guitar it is the belly almost alone that serves as resonator. In the harp and piano the sounding board is the resonator. Moreover, with all these string instruments except the piano there is an air volume, more or less enclosed, which helps to contribute resonance to the tone.

In the single reed instruments, the clarinet and the saxophone, a reed, fluttering back and forth between the air cavity in the mouth of the player and the air cavity in the instrument, serves as the generator of the pulsations. The air cavity in the instrument constitutes the resonator. Whether the walls of the instrument itself vibrate, is a question of the greatest importance and one that is still in doubt. In the double reed instruments, such as the oboe, English horn, heckelphone, bassoon, and sarrusophone, an alternately opening and closing slit between two reeds serves as generator of the pulsations. The air cavity within the instrument, and possibly the walls of the instrument themselves, constitute the resonator.

In the flute a stream of air directed against the edge of the blow-hole flutters back and forth in and out of the instrument and generates the pulsations. The air contained within the instrument, and possibly the walls of the flute also, act as a resonator. In a calliope a sheet of air or steam directed against the edge of a metal tube and wavering back and forth across the edge of the tube, goes alternately inside and outside the tube and generates the pulsations. The air confined within the tube and, almost certainly in this case, the walls of the tube also constitute the resonator.

In the brass instruments, all of which have cup mouthpieces, the tightly stretched lips of the player alternately open and close to allow puffs of air to escape from the mouth of the player into the instrument, and thus act as generator of the pulsations. The air confined within the instrument from the mouthpiece to the bell, and possibly the confining walls as well, serve as the resonator. In the human voice the stretched vocal cords alternately open and close to allow puffs of air to escape, and thus serve as generator. The volume of confined air, from the vocal cords to the openings into the outside air at the lips and the nose orifices, constitutes the resonator. The question whether the vibration of the walls of the air cavity themselves contribute to the resonance by their vibration, becomes in the case of the human voice even more troublesome than usual. It is quite certain that they vibrate; but whether in doing so they add to the resonance or detract from it is not easy to determine.

In the drum the head to be beaten is the generator. The air confined within the instrument and the confining walls are the resonator. The cymbal and the gong have no resonators. In each of these cases the whole instrument is a generator and nothing more. In the xylophone the bars of wood are generators; there may or may not be metal tubes below to act as resonators. In the orchestra bells bars of metal are the generators; and, as with the xylophone, there may or may not be metal tubes below to serve as resonators.

But any musical instrument must do more than produce pulsations of sufficient density to be musically effective: all musical instruments except percussive instruments of indefinite intonation must produce tones of various pitches. The bass and snare drums, the gong, cymbals, and some other percussive instruments, produce tones of more or less indefinite pitch, or perhaps of no pitch at all. But such percussive instruments as the timpani, xylophone, orchestral bells, celesta, and piano, as well as all string and wind instruments, produce tones of different pitch all of which pitches are quite, or entirely, definite. How are tones of different pitches produced by these instruments?

A long bar of wood in the xylophone, or of metal in the orchestral bells or celesta, vibrates more slowly than a short one; a thin bar more slowly than a thick one; a bar of stiff material more rapidly than one of a material less stiff. And, of course, the slower the generator vibrates the more slowly its vibration is communicated to the atmosphere, and the greater the length of its pulsation. So, to produce a pulsation of greater length from any of these instruments, it is only necessary to have a bar of greater length, or of less thickness, or of a material less stiff. To produce a tone with a pulsation of less length, one must have a bar that is shorter, or thicker, or of a stiffer material. In the timpani the length of the pulsation is increased by increasing the size of the kettle, and therefore the size of the head, or by decreasing the tension of the head.

In the string instruments, whether of the bowed, the plucked, or the struck variety, the length of the pulsation is increased by increasing the length or weight of the string, or by lessening its tension. Thus we find the strings of the double bass, 'cello, viola, and violin, decreasing in length on the several instruments taken in the above order; the strings on a given one of these instruments decrease in thickness from the lower to the higher; and the tension of a given string is increased or lessened in tuning the instrument to shorten or lengthen the pulsation to the precise length required for that string. Sometimes a string is wound with metal to increase its weight without increasing its stiffness, and thereby to produce a pulsation of greater length.

The brass instruments are made with tubes of different lengths to produce tones of different pitches. The longer the tube the longer the time required for a condensation to travel to the end of the tube and escape into the free atmosphere beyond, and consequently the lower the pitch of the resulting tone. The tubing of the B♭ trombone is about twice the length of that of the B♭ cornet, and the tubing of the BB♭ tuba about twice that of the trombone. On the trombone there is a piece of tubing that can be slid to and fro to increase or decrease the total length of tubing, thus producing pulsations of greater or less length. On the valve brasses depressing a valve connects an additional length of tubing to the air column between the mouthpiece and the bell, thereby lengthening the pulsation and lowering the pitch of the tone by an amount corresponding to the additional length of tubing thus brought into use.

On the woodwind instruments and the saxophone, all of which have holes ranged along the sides of the tube, the farther it is from the mouthpiece to the first open hole the longer will be the pulsation and the lower the pitch. To produce a note of any certain pitch it is therefore necessary only to close all tone holes down to the hole corresponding to the desired pitch, leaving the latter hole open. The pitch, however, does not depend *entirely* upon its distance from the mouthpiece; for the greater the size of the tone hole the quicker the condensation can escape to the surrounding free atmosphere, and the shorter will be the resulting pulsation and the higher its pitch. That is, of two tone holes at the same distance from the mouthpiece of a clarinet but of different sizes the one of larger size will produce a note of slightly higher pitch.

We see, then, that a musical instrument is a device for producing atmospheric pulsations of such lengths as may be desired, and of a density sufficient to be useful for musical purposes. But intensity and pitch are not the only characteristics of musical tone. A third characteristic is the one called quality or tone color. In what way does a musical instrument impart to its tone the quality desired for that tone? In the preceding chapter we saw that the quality of a tone depends upon the relative strength of the partials composing it. How, then, does a musical instrument contribute to its tone those partials, and only those, which properly belong to that tone?

This is one of the most perplexing problems presenting itself to the maker of musical instruments; the problem of imparting to the tones of the instrument, and to each and every one of them, the color desired and considered appropriate to the tones of that instrument. The solution of the problem depends upon many things, and upon different things for different instruments. The general solution for all instruments, however, may be summarized in a single statement: *The tone quality of a wind instrument depends upon the varying rate at which an individual pulsation of that instrument is communicated to the atmosphere.* The graph of the tone of an instrument, such as those we saw in the preceding chapter, shows by its contour for a given pulsation this varying rate at which an individual pulsation of the instrument is communicated to the atmosphere. Whatever controls the varying rate at which the individual pulsation is communicated to the atmosphere controls the quality of tone produced by that instrument. Let us see if we can discover what it is that controls this "varying rate."

Possibly the easiest instrument to understand in respect to this inquiry is the trombone. The pulsations constituting the tone of the trombone are caused by puffs of air escaping from between the stretched lips of the player and travelling throughout the length of the tubing from mouthpiece to bell, to pass from there into the free atmosphere beyond the bell. While the action of the lips themselves has much to do with "the varying rate at which the individual pulsation is communicated to the atmosphere," it can easily be seen that an important influence in this respect is the size and shape of the air passage which the pulsation travels to the outside free atmosphere. If the tubing is small instead of large, that fact will influence the varying rate at which the pulsation escapes. If the tubing is cylindrical rather than tapering, that too will have its effect. If a part of the tubing is cylindrical and a part is tapering, as is true of the trombone, then the relative lengths of the cylindrical and tapering parts will help to control the varying rate of escape. The size and shape of the mouthpiece, and the size and flare of the bell, will also influence the rate of escape. In a word, the size and shape of the resonating air column plays an important role in determining the varying rate of escape of the individual pulsation. This at least would appear to be the case if the matter is viewed from the standpoint of theory alone. And practice corroborates the evidence furnished by theory. All the experience of trombone makers points unhesitatingly and unequivocally to the conclusion that, except for the action of the lips themselves, the only thing that materially influences the tone quality of the trombone is the size and shape of the pulsating air column, i. e., the size and shape of the trombone itself including the mouthpiece.

And what is true of the trombone is true also of all the other brass instruments with cup mouthpieces, whether trumpet, horn, tuba, or what not. It is the action of the lips themselves together with the size and shape of the pulsating air column from the lips outward to the free air beyond the bell that determines "the varying rate at which the individual pulsation is communicated to the atmosphere," that establishes the tone quality of the instrument.

In the woodwinds, and other wind instruments with lateral tone holes, the same principle holds true: the tone quality is determined by the manner in which the generator itself acts, and by the size and shape of the pulsating air column between the generator and the free atmosphere beyond the bell. Take the clarinet as an example of this class of instruments. The reed and the "lay" (the curve by which the mouthpiece recedes from the tip of the reed) of the mouthpiece, together, form one of the influences determining the tone of the clarinet. The remaining influence is the size and shape of the air column from reed to bell. If the inside diameter of the instrument is changed, the tone of the instrument is affected. If the size of the tone hole producing a given note is increased or diminished, or the height by which that hole's pad rises above the hole is made greater or less, then the tone quality of the note produced by that hole is modified. If the inside proportions of the mouthpiece are made to vary, then a new tone color is imparted to the instrument.

In the human voice the action of the vocal cords themselves undoubtedly has some influence upon the quality of tone produced by the voice; but the chief influence in determining the tone quality of the human voice is the size and shape of the air passages leading up to the free atmosphere beyond the lips and nose orifices. The proper shaping of these air passages for the various notes within the compass of the individual voice is the task of the specialist in "voice placement." When the pupil has learned properly to shape the air passages for each note within the compass of his voice, then his voice is "placed."

In the bowed instruments the way in which the string vibrates, as determined by the manner of bowing, is the predominant influence in the tone quality of the notes produced. But the faithfulness with which the vibration of the string is communicated, by way of bridge, nut and tail-piece, through belly, ribs and back, to the atmosphere surrounding the instrument is also an important consideration in determining the quality of tone produced.

With the plectral instruments, such as the harp, banjo, guitar, and mandolin, the same considerations hold except that bowing the strings is now replaced by plucking them; and proper plucking of the strings now assumes a degree of importance formerly belonging to proper bowing. In the piano the manner in which the string is set into vibration by the hammer, together with the character of the string itself and the faithfulness with which that vibration is communicated by way of the sounding board to the atmosphere, determines the quality of tone which that instrument produces.

In the percussion instruments, such as the timpani, and the bass and snare drums, the player is responsible for the place at which he strikes the head, for the manner in which he strikes it, and for the choice of stick with which it is struck—provided these matters have not all been prescribed by the composer. But the effectiveness with which the vibration of the head is communicated to the atmosphere is a matter beyond the player's control; that responsibility belongs to the manufacturer of the instrument, and was assumed by the maker when the instrument was constructed.

In fact, this dual responsibility between the artist and the maker of his instrument exists with respect to the music produced by any instrument. When the artist purchases his instrument he enters into a partnership with its manufacturer for the production of music, a relation by virtue of which each party becomes entirely responsible for everything done by the other. It is a precarious relationship that is not always satisfactory to both parties.

It appears, then, that a musical instrument, any musical instrument, is a machine constructed for the purpose of communicating to the atmosphere certain pulsations generated by a player who acts as the engineer of the machine. And of all pieces of modern machinery the musical instrument is constructed with the least skill and sincerity, and is the least efficient in doing the work for which it is intended. But more detailed consideration will be given in later chapters to the manner in which musical instruments produce their results, and to the possibilities of improving them.

Let us now ask ourselves why musical instruments are constructed. Why construct a machine to produce musical tones when everyone has a musical instrument given to him by nature, his voice? As a matter of fact not every person has a satisfactory voice; some voices are naturally so poor that but little improvement could be effected in them no matter what amount of time and attention should be given to voice study. Again, some people do not have the kind of voice they want. In his boyhood the writer knew a tuba player who weighed about a hundred and five pounds. He was the best musician in the band, and the leader of the organization; but the only part he would play in the band was *basso profundo!*

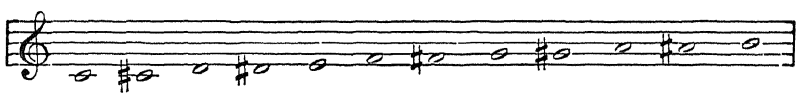
Nor was his an isolated case of a person wanting a voice different from the one given him by nature. Many male musicians can not by happy in the orchestra unless they are able to sing altissima melodies, and warble like a coloratura soprano; so they choose the flute or the violin as the instrument for them. Other men covet low tones of the contralto, and will be satisfied with no instrument except the clarinet.

All music, in the final analysis, is singing; or, at least, singing and dancing. We construct musical instruments to furnish us with an artificial voice when we have no natural voice, to supply us with a more powerful voice when our voice is weak, or to provide us with a voice more to our liking in compass or tone color. And, with these artificial voices, we sing in a manner such as our natural voices would never permit. Or, if our feet are too clumsy to dance as we would like, we become percussion players and dance to our hearts' content with sticks on our drum heads.

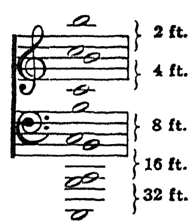
CHAPTER IV

THE MUSICAL SCALE

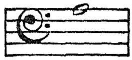
We saw in Chapter II that the length of the pulsation for violin A is about 2½ ft., for 'cello A about 5 ft., and for doublebass A about 20 ft.; in brief, that the pulsation for any note is twice as long as for a note an octave higher on the staff; and that audible pulsations range in length from about 80 ft. to about half an inch. The designation of the pitch of a note by stating the length of its pulsation is entirely reasonable, and for certain purposes quite useful. The notes from middle C to the B next above it on the staff,

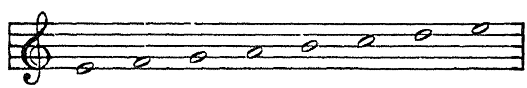
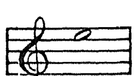


may be said to belong to the four foot octave, because the pulsation for middle C has a length of approximately 4 ft., the notes an octave higher on the staff to belong to the two foot octave, those another octave higher to the one foot octave, etc. The notes an octave lower than the four foot octave, for a like reason, belong to the eight foot octave, those another octave lower to the sixteen foot octave, those still another octave lower to the thirty-two foot octave, etc. The nomenclature of the various octaves, then, is as follows:



This is a very convenient method of identifying the octaves, and its use is to be commended.

It should be noted in passing, however, that there is no reason, either physical or psychological, for regarding notes of different pitch as being one "higher" and the other "lower." Considered from the point of view of the pulsation alone, there is no reason for regarding  as being "higher than  The pulsation of the former note is, indeed, shorter by half than that of the latter. But this fact offers no possible excuse for calling it a "higher" note. And, considered from the standpoint of hearing, the former note does indeed sound different from the latter. But this difference in sensation can in no wise be properly expressed in terms of height. How the practice arose of regarding notes of different pitch as being "higher" and "lower" history does not record as far as I am aware. My surmise is, however, that it probably originated from the fact that in primitive wind instruments such, for example, as the reed-pipe, a predecessor of the oboe, the "higher" of two notes was produced from a hole lying actually higher on the pipe than the hole of the "lower" note, the pipe being held in a more or less perpendicular position with one end in the mouth.

The ancient Greeks, for example, lacking anything like a staff notation, gave *names* to each of the notes of their scales, the name of the note indicating to the Greek musician the pitch of the note. The names for the several notes of the octave were, in order from first to last, as follows:  Hypate ("highest"), Parhypate ("next to highest"), Lichanus ("fore finger") Mese ("middle"), Paramese ("next to middle"), Trite ("third"), Paranete ("next to lowest"), and Nete ("lowest"). Their designation of Hypate  as the "highest" note of the scale, and of Nete  as the "lowest," was in precise contradistinction to modern ideas respecting pitch relations, and arose from the fact that *as the lyre was held in playing* Hypate was produced by the string *located highest* on the instrument, and Nete by the string *located lowest.*

If, in some analogous manner, notes of a different pitch on reed instruments came to be regarded as "higher" or "lower," depending on the location of the holes producing them, then it would quite naturally follow, when a staff notation was finally devised to represent notes of different pitch, that the "higher" note should be placed higher on the staff. Generation after generation of familiarity with the custom of placing "higher" notes higher on the staff would, just as naturally, lead us at length to regard the "higher" note as actually *sounding* higher—provided we do not stop to think about it. But custom should not blind us to the fact that there is no reason other than custom for speaking of one note as being "higher" than another. Nothing actually happening, either in the air or within consciousness, furnishes any justification whatever for the practice. If the practice is followed—and there is no reason why it should not be—it should be clearly borne in mind that the custom is in no sense justified by the facts.

While it is sometimes convenient to indicate the pitch of a note by stating the length of its pulsation, especially when as in identifying the octaves no great degree of accuracy is required, still such a method would not do at all where accuracy is necessary as, for example, in *defining* a standard pitch for violin A. This for the reason that it is impossible to measure the length of a pulsation with any degree of accuracy or ease. It is known that pulsations of all lengths travel through the air at the same rate of speed; otherwise notes of different pitch played simultaneously by a band at a distance would not reach us simultaneously. But what that speed for all pulsations is, it is impossible to state with any great precision. After a great amount of expert investigation extending over a period of more than two hundred years the best we can say at present is that at 68° Fahrenheit and under usual conditions of humidity sound probably travels *between* 1165 ft. and 1170 ft. per second. Its speed increases about two feet per second for each degree of increase in temperature, and is about four feet per second greater in air saturated with moisture than in air containing no moisture. If we could measure the velocity of sound easily it would be permissible to express pitch in terms of length of the pulsation even when we desire accuracy; but since we are unable to do this it is better to indicate pitch in some other way if accuracy is required.

Since pulsations of all lengths travel at the same rate of speed, it follows that a greater number of pulsations will reach the ear per second if they are short than if they are long. More precisely stated, the number of pulsations reaching the ear will be doubled if their length is halved, will be trebled if their length is only a third as much, will be quadrupled if their length is divided by four, etc. It is clear, then, that the pitch of a note may be indicated either by giving the length of its pulsation or by stating its *frequency,* i. e., the number of its pulsations reaching the ear per second. The statement of pitch in terms of frequency is preferable to its statement in terms of length of the pulsation, because of the ease with which frequency can be determined. A person of average intelligence can learn in half an hour to determine the correctness of violin A on a musical instrument to within 1/25 of a semitone, using nothing more than a tuning fork as apparatus. This would be equivalent to measuring the length of the pulsation for violin A to within .072 of an inch. To attain this degree of accuracy measuring the length of the pulsation directly would cost an able physicist weeks of work with elaborate and expensive apparatus. The advantage of expressing pitch in terms of frequency rather than in length of pulsation where accuracy is required is thus readily seen. Accordingly, violin A  in America is defined as a tone having 440 pulsations per second in air of ordinary moisture and at a temperature of 68° Fahrenheit. How tones of other pitches are related to violin A will now soon become clear. And, in referring to pitch, we will as convenience may at the time dictate use each of the pairs of terms, higher or lower pitch, shorter or longer pulsation, and greater or less frequency, to refer to the same set of facts.

As was shown in Chapter II, every musical tone is composed of simple tones called partials, the lengths of the partials being respectively 1, ½, ⅓, etc., times the length of the composite tone, and the relative loudness of the partials being anything between 0 and a number representing the loudness of the composite tone itself. Since the loudness of the partials must lie *between* 0 and that of the composite tone itself, it follows that a trace at least of every partial enters into the composition of every musical tone. It may be, however, that some of the partials will be very weak—

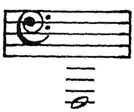
weak, perhaps, even to the point of inaudibility. Still they will all be present.

A musical tone, any musical tone whatever, consists of a combination of tones all sounding together—a chord, in other words. One of the tones of the chord is usually much more powerful than any of the others. Its pitch, in consequence, submerges the pitches of all the other partials and establishes its own pitch as *the* pitch of the whole chord. We therefore think of the chord constituting a musical tone as having a single pitch and as being a single tone, rather than as consisting of many tones of different pitches as is really the case. The loudest tone of the chord, and the tone that consequently gives its pitch to the whole chord, is frequently the partial of lowest pitch; this is not always the case, however.

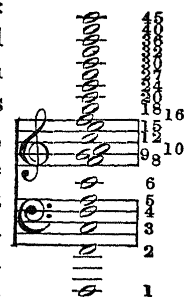
The partial with the lowest pitch and the longest pulsation, or what amounts to the same thing the partial with the least frequency, is called the *fundamental;* the other partials are called *overtones.* This lowest partial is called the first partial. The partial next above it in pitch, whose frequency is twice that of the fundamental and the length of whose pulsation is half that of the fundamental, is called the second partial; the third partial has three times the frequency and one third the pulsation length of the fundamental; the fourth partial has four times the frequency and one fourth the pulsation length of the fundamental; the fifth, five times the frequency and one fifth the length; and so on. That is, the frequency of any partial is found by multiplying the frequency of the fundamental by the number of the partial, and the length of its pulsation by dividing the length of the fundamental by the number of the partial.

The distances between the partials, considered from the standpoint of pitch, are called *intervals;* and some of the more important intervals have received special names. The first interval, that between the first and second partials, is called the *octave.* The second interval, from the second to the third partial, is called the *fifth.* The third interval, from the third partial to the fourth, is called a *fourth.* The fourth interval is called a *major third;* the fifth interval, a *minor third;* the eighth interval, a *major tone;* the ninth, a *minor tone;* and the fifteenth interval, a *semitone.* Moreover, the interval between the third and fifth partials is called a *major sixth,* and the interval between the fifth and eighth partials is called a *minor sixth;* in brief, all the intervals used in well established harmonic practice are determined by the partials of the musical tone.

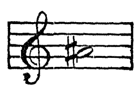
Let us observe the series of partials found in a musical tone. If, for example, F in the thirty-two foot octave,



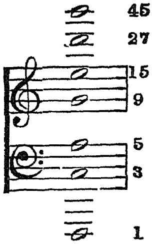
is bowed vigorously on the doublebass, the tonal complex presented to the ear is some-something like the following:



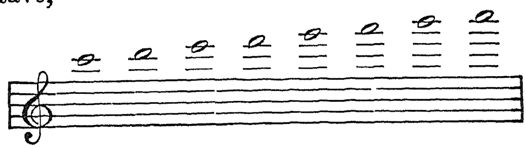
The numbers of the partials are placed just to the right of the notes representing them on the staff. It will be noted that certain of the partials are not represented on the staff, e. g., partials 7, 11, 13, 14, 17, 19, 21, 22, 23, 25, 26, 28, 29, 31. These partials are omitted not because they are not present in the tone played; they are present. But it is impossible to represent them on the staff with the system of notation now in use. The 7th partial, for example, lies between D,  and E ♭, 

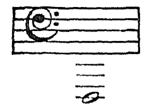
The 11th partial lies between A ♯,  and B, 

And so with all the other partials not here shown. Nor are they omitted because they are necessarily inharmonic, as is so frequently stated. Some of them are inharmonic and some are not. That is a question to be settled on its merits for each of the partials in question; it will receive proper attention later in connection with our consideration of harmony. Above the 32d partial very few of them can be represented on the staff; and all those except the 45th that can be so represented are octaves of notes already appearing lower on the staff. In fact, the only partials that can be represented on the staff are the 1st, 3d, 5th, 9th, 15th, 27th, and 45th, and others lying at distances of one or more exact octaves above them. And these partials, the 1st, 3d, 5th, 9th, 15th, 27th, and 45th, are respectively F, C, A, G, E, D, and B, the seven notes of the diatonic scale in C, as here shown:



In short, the seven notes of the diatonic scale in C in the one foot octave, are respectively the 24th, 27th, 30th, 32d, 36th, 40th, and 45th overtones of the fundamental F:



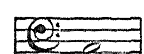


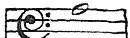
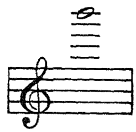
A tremendous amount of confusion has arisen from attempting to derive the scale in C from C as a fundamental. It cannot be done. By regarding F instead of C as the fundamental of the diatonic scale in C, i. e., by considering the Lydian rather than the Ionian as the fundamental mode of the diatonic scale, the obstacles in the way of a consistent musical theory largely disappear, and a simple, logical system of harmony founded directly upon the phenomena of the musical tone becomes possible. Heretofore this has been impossible. The whole theory of harmony can be developed from the assumption that the subdominant, F, is the fundamental of the scale in C. How fruitful this assumption is will be apparent to those who have floundered through the welter of contradictory and ineffective harmonic theory from Zarlino, through Rameau, down to the present time.

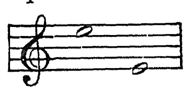
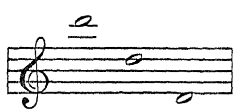
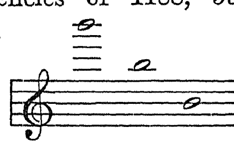
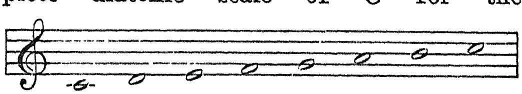
The complete series of partials is called the *harmonic series;* the resulting chord is frequently referred to as the *chord of nature;* and the scale defined by the 1st, 3d, 5th, 9th, 15th, 27th, and 45th partials is known as the *natural scale.* And from the facts now in our possession we are able to determine the frequency of each note in the natural scale. It will be remembered that violin A has 440 pulsations per second. But we have just now found that violin A,

is the 10th partial of F in the thirty-two foot octave,

This means that thirty-two foot F has one-tenth as many pulsations per second as violin A, i. e., 44 pulsations per second. And C,



being the third partial of this F, has three times as many pulsations per second as this F, or 132. A  being the fifth partial of this same F, has five times 44 pulsations per second, or 220. G,  the ninth partial if this F, has nine times 44 or 396 pulsations per second. E, the  fifteenth partial, has 660; D,  the twenty-seventh partial, has 1188; and B,  the forty-fifth partial, has 1960.

This defines the pitches of all the notes of the diatonic scale, but they are rather scattered. It will be easy to bring them closer together, however, by appropriately raising or lowering the extreme ones the necessary number of octaves, keeping always in mind that a note an octave higher than another has twice as many pulsations per second as the other. The four notes,  will have frequencies of 44, 88, 176, and 352, respectively. The notes,  will have frequencies of 132, 264, and 528. The notes,  will have frequencies of 660 and 330, the notes,  frequencies of 1188, 594, and 297, and the notes,  frequencies of 1980, 990, and 495. And now, if we collect our results, we have the complete diatonic scale of C for the four foot octave,  with 264, 297, 330, 352, 396, 440, 495, and 528 pulsations per second respectively for each of the eight notes. This is the diatonic scale in C at the pitch of 440 for A, which is the pitch of A defined as legal by the American Federation of Musicians. If we double, repeatedly, the frequencies of these several notes in the scale of C to get the frequencies for the corresponding notes in higher octaves, and repeatedly halve them to get the frequencies for the corresponding notes in the lower octaves, we shall have:

OCTAVE	C	D	E	F	G	A	B
3 in.	4224	4752	5280	5632	6336	7040	7920
6 in.	2112	2376	2640	2816	3168	3520	3960
1 ft.	1056	1188	1320	1408	1584	1760	1980
2 ft.	528	594	660	704	792	880	990
4 ft.	264	297	330	352	396	440	495
8 ft.	132	148.5	165	176	198	220	247.5
16 ft.	66	74.25	82.5	88	99	110	123.75
32 ft.	33	37.12	41.25	44	49.5	55	61.88
64 ft.	16.5	18.56	20.62	22	24.75	27.5	30.94

This gives the frequencies of all notes of the diatonic scale in C for all the octaves from the 64 ft. octave to the 3 in. octave inclusive. The highest note on the piano is C of the 3 in. octave with a frequency of 4224 pulsations per second. The lowest note on the piano is A of the 64 ft. octave with a frequency of 27.5 pulsations per second. Rather, 64 ft. A on the piano *would have* a frequency of 27.5 pulsations per second if piano tuners put the lowest notes of the piano in tune—which they almost never do. However, it should be here noted that the piano is not tuned diatonically but chromatically; this will be given due consideration later in this chapter.

If we should desire further to know the frequencies for the notes of the diatonic scale in other keys than C, it is not difficult to discover them. But we must first ascertain the relationships existing between the notes of the diatonic scale already established; then, upon the basis of these relationships, we determine the diatonic frequencies for the successive sharp signatures, G, D, A, E, B, F♯, and C♯, and for the successive flat signatures, F, B♭, E♭, A♭, D♭, G♭, and C♭. With reference to the frequencies already found for the key of C in the four foot octave, 264, 297, 330, 352, 396, 440, and 495, it should be observed that 297 is 1/8 more than 264, 330 is 1/9 more than 297, 352 is 1/15 more than 330, 396 is 1/8 more than 352, 440, is 1/9 more than 396, 495 is 1/8 more than 440, and 528 of the two foot octave is 1/15 more than 495. That is, if we successively increase the frequency of C, 264, by 1/8, 1/9, 1/15, 1/8, 1/9, 1/8, and

1/15, we shall get the frequencies of the remaining notes in this scale. And these relationships also establish the successive notes of the diatonic scale in any key. Thus we have a simple rule for determining the frequencies of the notes in any diatonic scale the frequency of whose keynote we already know, as follows: beginning with the frequency of the keynote already known, increase it successively by 1/8, 1/9, 1/15, 1/8, 1/9, 1/8, and 1/15, of its accumulating frequency.

Applying this rule to the frequency for G in the key of C, 396, we establish the diatonic scale for the key of G with the follow- frequencies: 396, 445.5, 495, 528, 594, 660, 742.5, and 792. Applying the rule repeatedly to determine the frequencies of the notes of the remaining sharp keys, D, A, E, B, F ♯, and C ♯, and using always as the frequency for the keynote the one last computed for that note, we secure the frequencies shown for the sharp signatures in the table below. To derive the frequencies for the flat signatures we begin with the frequency of F in the key of C and apply the rule repeatedly, using always as the frequency of the keynote the one last computed for that note. Thus we get the frequencies shown in the table below for the flat signatures. For convenience of tabulation the only frequencies shown are those belonging to the four foot octave. If frequencies of higher octaves are desired, they may easily be found by making the appropriate number of multiplications by 2. Frequencies for lower octaves may be found by making the appropriate number of divisions by 2. Of course one such multiplication raises the pitch one octave, and one such division lowers the pitch one octave.

But now we are in difficulty with respect to playing on a keyboard instrument such as the piano or organ. For, by referring to the first column of our table we discover that we have *three* different values for B ♯ and C. The next column shows three different values for C ♯ and D ♭. The remaining columns show respectively two different values for D, four for D ♯ and E ♭, three for E and F ♭, three for E ♯ and F, three for F ♯ and G ♭, two for G, four for G ♯ and A ♭, two for A, three for A ♯ and B ♭, and three for B and C ♭; *thirty-five* different values in all. And we have only twelve keys to the octave on keyboard instruments! What is to be done? Evidently we shall have to increase the number of keys to the octave

Key	B♯ and C	C♯ and D♭	D	D♯ and E♭	E and F♭	E♯ and F	F♯ and G♭	G	G♯ and A♭	A	A♯ and B♭	B and C♭
C♯	264.30	281.92		317.16		352.40	375.89		422.88		469.86	
F♯		281.92		313.24		352.40	375.89		422.88		469.86	501.18
B		281.92		313.24	334.12		375.89		417.66		469.86	501.18
E		278.44		313.24	334.12		375.89		417.66	445.5		501.18
A		278.44	297		334.12		371.25		417.66	445.5		501.18
D		278.44	297		334.12		371.25	396		445.5		495
G	264		297		330		371.25	396		445.5		495
C	264		297		330	352		396		440		495
F	264		293.33		330	352		396		440	469.33	
B♭	264		293.33	312.89		352		391.11		440	469.33	
E♭	260.74		293.33	312.89		352		391.11	417.19		469.33	
A♭	260.74	278.12		312.89		347.65		391.11	417.19		469.33	
D♭	260.74	278.12		312.89		347.65	370.83		417.19		463.54	
G♭		278.12		309.03		347.65	370.83		417.19		463.54	494.44
C♭		278.12		309.03	329.62		370.83		412.03		463.54	494.44

on keyboard instruments, or reduce the number of frequencies by some sort of compromise, or refrain from modulating at will from any key into any other desired key. Each plan has its advantages and disadvantages. The plan in vogue for the past century and a half, since the piano became popular, is that of compromise. The compromise is called *tempering the scale,* which Professor Horace Lamb, the distinguished Cambridge mathematical physicist, has dubbed "tampering with the scale."[1]

Let us now determine the plan employed in tempering the scale. We discovered that the relationships existing between the notes of a diatonic scale were expressed by the series of fractions, $\frac{1}{8}$, $\frac{1}{9}$, $\frac{1}{15}$, $\frac{1}{8}$, $\frac{1}{9}$, $\frac{1}{8}$, and $\frac{1}{15}$. That is, the intervals of the diatonic scale are not all the same size. Some of them are expressed by the fraction $\frac{1}{8}$, some by $\frac{1}{9}$, and some by $\frac{1}{15}$. The first, fourth, and sixth

[1] Dynamical Theory of Sound, p. 7.

intervals are represented by 1/8; the second and fifth by 1/9; and the third and seventh by 1/15. It is the custom to call all the intervals except the third and seventh "whole tones," in spite of the fact that they are of different sizes, some being represented by 1/8 and some by 1/9. It is also customary to call the third and seventh intervals "half-tones" although, being represented by 1/15, they are not halves of either of the two sizes of "whole tones." If each of the "whole tones" were divided into two equal parts, we should then have twelve "half-tones" although our so-called "half-tones" would be of three different sizes. But suppose these twelve "half-tones" were evened up so that they would all be of the same size; then how far off should we be from the thirty-five different frequencies necessary for the natural diatonic scale in all the fifteen flat and sharp signatures? It is this kind of compromise that has been in vogue for the past hundred and fifty years; and, because the twelve intervals of the octave are all equal, the temperament is known as *equal temperament*. And it is to the discovery of the frequencies for the twelve notes of the octave divided in equal temperament that we shall next turn as the goal of our inquiry.

Dividing the octave into twelve equal parts sounds very simple. But the person who takes up the problem expecting to find it easy will be quite likely to drop it like the proverbial hot potato. The first thing necessary is to get a clear notion of just what we mean by "dividing the octave into twelve equal parts." To do this we shall have to turn back for a moment or two to the relationships between the notes of the diatonic scale. To determine the notes for any diatonic scale we start with the frequency of its keynote. This we increase by 1/8 of itself; then by 1/9, 1/15, 1/8, 1/9, 1/8, and 1/15, of the successive frequencies. Each frequency is obtained from the preceding one by increasing the latter by some fraction of itself. But increasing a number by some fraction of itself is equivalent to multiplying that number by 1 increased by the fraction; i. e., increasing C, 264, by 1/8 of itself gives the same result as multiplying 264 by 9/8. Thus we can secure the notes of a diatonic scale by *adding* to the keynote 1/8, 1/9, 1/15, 1/8, 1/9, 1/8, and 1/15, of the successive frequencies, or by *multiplying* successively by 9/8, 10/9, 16/15, 9/8, 10/9, 9/8, and 16/15. That is, if we start with 264 and multiply successively by 9/8, 10/9, 16/15, 9/8, 10/9, 9/8, 16/15, we shall get the frequencies for the key of C given in the table above. The same holds true no matter what the keynote; and the frequency of the eighth note will always be just twice that of the keynote. For example, if we start with a frequency of 1 for the keynote, the frequency of the eighth note an octave higher will be 2.

It seems, then, that the increases necessary to produce the successive notes of the diatonic scale may be secured by multiplication as well as by addition. And it is increases of this multiplicative kind that have to be made in the case of our even tempered scale; only there will have to be twelve of them, and the increases will all have to be equal—multiplicatively equal. This means that we shall have to find a fraction which will double any number if that number is multiplied by the fraction twelve times. This fraction, if we could find it, would increase 1 to 2 by multiplying 1 by it twelve times. Now what fraction is it that will increase 1 to 2 when 1 is multiplied by the fraction twelve times? To put the question into the language of the mathematician, "what is the twelfth root of 2?" Our little problem of dividing the octave into twelve equal parts, then, requires us to find the twelfth root of 2. And this is not an easy matter. The number, when we find it, correct to six decimal places is 1.059463. Less than six decimal places are insufficient to give a rule accurate enough to tune the piano.

Those readers who understand the extraction of square and cube roots could find the twelfth root of 2 by extracting the square root of 2 correct to thirty-six decimal places, then extracting the square root of the result, and then extracting the cube root of this second result. This would give 1.059463; but the process involves a tremendous amount of computation. Those familiar with logarithms would turn naturally to their use for the extraction of the twelfth root of 2. But they would be disappointed in the accuracy of their results. Four, five, or even seven, place tables are inadequate where such accuracy is required; I have never tried twelve place tables. The best method I know of to compute the twelfth root of 2 is by the use of series. The mathematics is too complicated to present here, but the accuracy of the root 1.059463 may be tested by multiplying 1 by this decimal twelve times cumulatively to see whether it will give 2. It may take a couple of days to complete the multiplication, but when the task is finished the student will have the satisfaction of knowing that the number is correct instead of accepting on faith someone's statement for it. The results of the successive multiplications, correct to six decimal places, will be:

1.000000	1.259921	1.681793
1.059463	1.334840	1.781797
1.122462	1.414214	1.887749
1.189207	1.498307	2.000000
	1.587401	

Having now found our twelfth root of 2, it is easy to compute the frequencies for the twelve notes of the even tempered scale. Starting, say, with 'cello A whose frequency is 220, and multiplying by 1.059463 twelve times, we will have the frequencies for all the notes of the even tempered octave, and will arrive at 440 as a frequency for violin A just an octave above the point from which we started. Our results, raised where necessary to the four foot octave and correct to four decimal places, are:

C	261.6256	F ♯	369.9945
C ♯	277.1826	G	391.9953
D	293.6648	G ♯	415.3048
D ♯	311.1271	A	440
E	329.6275	A ♯	466.1637
F	349.2282	B	493.8833

The frequencies in higher or lower octaves can be easily found by multiplying or dividing by 2 the appropriate number of times. Thus, raising four foot C, 261.6256, to three inch C by multiplying it by 2 four times, we find that C of the three inch octave has, in the even tempered scale, 4185.41 pulsations per second instead of 4224 as in the diatonic scale. But 64 ft. A, the lowest note on the piano, has the same number of pulsations in the even tempered scale that it had in the diatonic scale, 27.5, because of the fact that violin A, 440, is the starting point from which all frequencies are computed, and because of the further fact that the octaves are kept pure in even temperament.

The thirteen decimal numbers at the close of the preceding paragraph but one, giving the ratios for all the intervals of the even tempered scale, are very convenient where computations are involved with reference to the even tempered scale. For example, in the immediately preceding paragraph we multiplied 220 by these ratios to get the frequencies for the even tempered scale on the basis of a frequency of 440 for violin A; this is much less laborious than to compute the frequencies by multiplying 220 by 1.059463, then multiplying this product itself by 1.059463, and so on for twelve successive multiplications by 1.059463. And the results obtained are the same by each method. Similarly, if one wished to compute the frequencies for the even tempered scale based on a pitch of 435 pulsations per second for violin A, he would simply multiply 435 by each of these twelve ratios. In like manner one could compute the frequencies of the even tempered scale for any other defined pitch of A, or for any other note whose pitch was defined.

Let us now compare the even tempered frequencies just obtained with the diatonic frequencies previously obtained to see how much the former differ from the latter. Arranging in corresponding columns the even tempered and the diatonic frequencies for the key of A, we find their values to be as follows:

	A	B	C♯	D	E	F♯	G♯	A
Even tempered	220	246.94	277.18	293.66	329.63	369.99	415.30	440
Diatonic	220	247.50	275.00	293.33	330.00	366.66	412.50	440
Discrepancy	0	−0.56	+2.18	+0.33	−0.37	+3.33	+2.80	0

The diatonic frequencies given are not those found in the table of diatonic frequencies, the latter being those for C instead of A as a keynote, but are secured by multiplying 220 successively by 9/8, 10/9, 16/15, 9/8, 10/9, 9/8, and 16/15. The discrepancies are the differences between the diatonic and the even tempered frequencies, the discrepancy being marked minus when the even tempered note is lower in pitch than the corresponding diatonic note, and marked plus when the even tempered note is higher than the diatonic.

It will be observed that the only even tempered frequency that agrees with the natural diatonic frequency is that of the keynote itself, A, and its octave. Of the remaining six notes of the scale, four are too sharp and two too flat. Those that are too flat, B and E, are but slightly so; the B by .56 of a pulsation, which is about 1/26 of the 14.69 difference between the frequency of B and that of C lying a tempered half-tone above it; the E by .37 of a pulsation, which is about 1/53 of the 19.60 difference between the frequency of E and that of F lying a tempered half-tone above it. These two notes, B and E, although flat, are so by amounts so small as to be scarcely discernible melodically (when the compared notes are sounded in succession) even to the acutely trained musical ear. The D is too sharp by .33 of a pulsation, which also is 1/53 of the tempered half-tone from D to D♯. The C♯, F♯, and G♯, however, are too sharp respectively by 2.18, 3.33, and 2.80, pulsations per second, i. e., by 1/8, 1/7, and 1/6, respectively of the tempered half-tones between these notes and the even tempered notes lying a half-tone above them. And these amounts, 1/8, 1/7, and 1/6, of a tempered half-tone, are large enough to be clearly discerned melodically by the acutely trained musical ear, and to be quite objectionable harmonically (when the compared notes are sounded simultaneously). Thus the even tempered scale differs from the natural diatonic scale on three notes by amounts that are perceptible even melodically, and that are harmonically objectionable. And what is true for the scale in the key of A will be found equally true for any other key. The second and fifth notes of the even tempered scale are microscopically flat, the fourth is microscopically sharp, and the third, sixth, and seventh, notes are objectionably sharp.

But while the even tempered scale diverges to an objectionable degree from the natural diatonic scale in any individual key, the divergence from the corresponding notes in the entire system of fifteen sharp and flat signatures is much less than would be expected. If the highest frequency in each of the twelve columns of the table of diatonic frequencies on page 51 be compared with the even tempered frequencies on page 55, and the amounts by which the even tempered frequencies are flatter than the sharpest corresponding diatonic frequency be reduced to decimals of a tempered half-tone, it will be found that the even tempered notes may *possibly* and *occasionally* be too flat by the following decimals of a half-tone:

B♯	C♯	D	D♯	E	E♯	F♯	G	G♯	A	A♯	B
.17	.29	.19	.33	.23	.15	.27	.17	.31	.21	.13	.25

If similar decimals be computed for the lowest frequencies in the same table of diatonic frequencies, it will be found that the even tempered notes may *possibly* and *occasionally* be too sharp by the following decimals of a tempered half-tone:

C	D♭	D	E♭	F♭	F	G♭	G	A♭	A	B♭	C♭
.06	–.06	.02	.11	.00	.08	–.04	.04	.13	.00	.10	–.02

The minus sign before the decimals for D♭, G♭, and C♭, indicate that the even tempered values of these notes, instead of being too sharp, are flatter than the flattest corresponding diatonic values.

It thus appears that in the whole system of fifteen signatures from seven sharps to seven flats the even tempered scale may *possibly* and *occasionally* diverge from the diatonic frequences by as much as a third of a tempered half-tone in *extreme* sharp signatures, and by as much as an eighth of a tempered half-tone in *extreme* flat signatures. This divergence is somewhat less than one would be led to expect from the comparatively large discrepancy in a single key where, as we found above, the third, sixth, and seventh, notes were too sharp by 1/8, 1/7, and 1/9, of a tempered half-tone respectively. That the tempered scale departs less from the diatonic values in flat signatures than in sharp signatures is a bit paradoxical, at least on the surface. But a convincing elucidation of the paradox would require more thought than the reader would probably care to give to it, and will be omitted.

Attention should be called, however, to a fact often not well understood and relating to the relative pitches of corresponding sharp and flat notes such as G♯ and A♭, C♯ and D♭, etc. It is sometimes stated[1] that a sharp note is *always* flatter than the corresponding flat note, "D♭ is higher than C♯, G♭ is higher than F♯, A♭ is higher than G♯, and so on." Reference to the table of diatonic values on page 51 will show that this is *never* the case. For example, C♯ may have a frequency of 281.92 or 278.44, but it is *never* as flat as D♭ whose frequency is 278.12, which is .32 of a pulsation per second flatter than the flattest value of C♯. The flattest value of G♯ is .47 of a pulsation sharper than the sharpest value of A♭. And so on for all the corresponding sharp and flat

[1] Pole: *Philosophy of Music*, p. 146.

notes: no sharp note is *ever* as flat as its corresponding flat note.

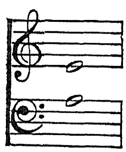
But, while the even tempered scale diverges from the natural scale, it permits of modulation into any sharp or flat signature whatever and requires but twelve keyboard keys to the octave with which to accomplish this. It is true that every tonality is somewhat out of tune; every note except the keynote is slightly at fault, and the major thirds, sixth, and sevenths, are decidedly too sharp. Nevertheless, the advantages of free modulation have so commended themselves to the western musical world that this scale has held the field against all comers for the past century or century and a half.

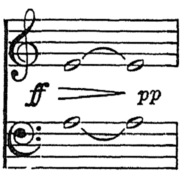
But, now that we have our even tempered scale computed, the next question is how we may proceed in order to tune the piano or organ to this scale. With perhaps twenty or twenty-five million pianos in use in the world it is astonishing how little is known concerning the manner in which a piano is tuned. The writer has made fairly diligent search of the existing literature upon physics, music, and piano and organ technology, in the English, French, and German, languages, without being able to discover anywhere a development of the rule by which the piano and organ are tuned. Occasionally one will find a rule stated, but without any evidence whatsoever being furnished that the rule is trustworthy. And the rules presented do not agree. Piano tuners employ rules which were given them without explanation or comment when they were apprentices, a time when inquiry would not have been welcomed as to why the rule was supposed to be reliable. The rules in current use among piano tuners are as diverse and contradictory as are their results. And there is precisely the same latitude for choice as to the rule to be followed in tuning a piano that there is respecting what multiplication table one shall follow. As for pianists, of course they know nothing whatever about how a piano should be tuned. They are not particularly anxious to proclaim from the housetops their lack of information on the subject, but they are every one of them aware that they could not tell how a piano should be tuned if their lives depended upon it.

This does not at all mean that piano tuners should be held at fault for their defective knowledge, since there appears to be no source of information to which they can go for relief. The avidity with which the better class of tuners pounce upon any prospective information is sufficient to satisfy the most exacting. But where shall they seek information; to whom shall they appeal? The writer believes there is not anywhere in print a development of the rule for laying the temperament of a piano or organ, or anything on the subject more satisfactory than the unsupported pronouncement of some individual that some alleged rule for temperament will put the piano or organ in tune. Nor is there any excuse for great mystery about the matter, since it is of no particular difficulty. Apparently scientists have regarded the question as of too little consequence to justify their attention, and practical tuners have lacked the scientific preparation necessary to elaborate the rule for themselves. At any rate the matter has been neglected. All of which is by way of explaining why a development of the rule for laying the temperament is here presented.

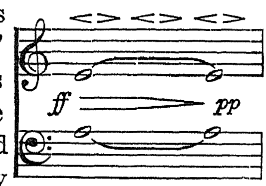
In the tuning of a piano there are three steps: laying the temperament, tuning the octaves, and tuning the unisons. During the first two steps all the strings of a unison except one are damped to comparative silence by the use of a strip of felt or by rubber plugs. The tuner is then able to hear more accurately what the remaining string is doing. Before any of the octaves or unisons can be tuned, the temperament must be laid; the tuner usually calls it "laying the bearings"—a very good designation, by the way. This process, essentially, is that of establishing the compromises that are necessary if twelve strings to the octave are to represent with any degree of satisfactoriness the thirty-five diatonic frequencies that are found in the octave.

The octave in which the temperament is to be laid is always chosen from the middle of the keyboard, usually the octave up or down from middle C, or the one between the F's lying above and below middle C. But, since the legal pitch is always defined in terms of A, it would be better to lay the temperament between the A's lying above and below middle C. The middle part of the keyboard is chosen because the partials of the tones in this region are better suited to the tuner's purposes, not because of the fact that the ear's power of pitch discrimination is more acute in this region, although this latter fact is unquestionable. Tuners do not depend upon their sense of pitch—at least they should not—except in the upper part of the keyboard; even the best sense of pitch is much too inaccurate for tuning purposes. Usually tuners are not persons of any considerable musical attainments; nor have they any need for being. Expert tuners not able to whistle or hum a tune are by no means unknown. For the proper tuning of the piano or organ dependence is placed upon "beats" instead of upon the sense of pitch, except for the extreme upper part of the keyboard. And what are "beats"?

If the fifth  be sounded loudly on a properly tuned piano, careful attention will disclose that instead of dying out



in a smooth *diminuendo* such as the combined sound of the two notes shows regularly recurring *crescendo-diminuendos* such as



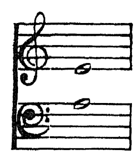
which the tuner calls "beats." If the beats of the two notes here under consideration were timed by the metronome, they would be found to occur at the rate of 45 (more precisely 44.7) per minute. If, instead of the E a fifth above A, the E a fourth below were sounded along with this same A, the beats would be found to occur at precisely the same rate. If, along with the A♯ a half-tone higher, is sounded F a fifth above (or a fourth below), the beats will be found to occur 47 (more precisely 47.4) times per minute. The beats between B and F♯ a fifth above (or a fourth below) will occur 50 (50.2) times per minute. The number of beats per minute between each note in the octave from 'cello A to violin A and the note lying a fifth above (or a fourth below) it, is as follows:

A	45	(44.7)	C	53	(53.2)	D♯	63	(63.2)	F♯	75	(75.2)
A♯	47	(47.4)	C♯	56	(56.3)	E	67	(67.0)	G	80	(79.7)
B	50	(50.2)	D	60	(59.7)	F	71	(71.0)	G♯	84	(84.4)
						A	89	(89.4)			

These frequencies for the beats may be found by multiplying the frequency of the note *from which* one counts the fifth above or the fourth below, by .2032; e. g., 'cello A, 220, multiplied by .2032 gives 44.7, the number of beats given in the table for 'cello A. It should be noted that the frequency of the beats for violin A is just twice those for 'cello A.

But what causes beats; and why do these beats have the precise frequencies they have? If two tones sounding at the same time have a partial in one tone of precisely the same frequency as a partial in the other tone, then both partials work *together* to produce a tone having their common frequency and an intensity greater than that of either of the partials under consideration; i. e., when one partial operates to produce a condensation in the atmosphere the other partial is also operating to produce a condensation, and when one partial operates to produce a rarefaction the other partial is likewise operating to produce a rarefaction. Thus the two partials together are able to produce a condensation greater than would either one alone and a rarefaction greater than would either alone, and the resulting tone is therefore of an intensity greater than that of either partial alone. But, if the frequencies of the two partials are not precisely the same then, no matter whether they start out working together or not, there will come a time when they will be working in opposition to each other, one operating to produce a condensation when the other is operating to produce a rarefaction. When this moment of opposition occurs, then the intensity of the resulting tone is less than that of either partial. There will also come a time when they will be working together, and when the intensity of the resulting tone is greater than that of either. And this repeated waxing and waning of intensity in the tone produced by the two partials constitutes the phenomenon called "beats." The frequency of the beats will be equal to the difference of the frequencies of the two partials producing the beats. For example, if two notes sound together, one having a frequency of 220 and the other having a frequency of 221, then one note will complete 220 pulsations in exactly the same time it takes the other to complete 221, and within this period of time there will be one instant when they will be working together and another instant when they will be working in opposition. At the former instant the intensity of their common tone will be increased, and at the latter instant its intensity will be decreased. That is, there will be one waxing and one waning, one *beat,* during the time it takes one note to complete 220 pulsations and the other to complete 221 pulsations; or, as was stated at first, *the frequency of the beat will be equal to the difference of the frequencies of the partials producing the beat.*

Now by referring to our table of frequencies for the even tempered scale on page 55 we will find that of the two notes,



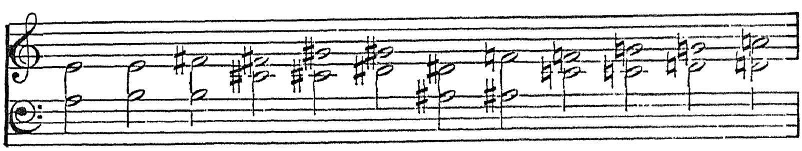
A has a frequency of 220 and E a frequency of 329.6275. The *third* partial of A would therefore have a frequency of 660, and the *second* partial of E a frequency of 659.2550; for the second partial has twice, and the third partial three times, the frequency of its fundamental. And the third partial of A and the second partial of E will differ in frequency by .745 pulsations per second or 44.7 per minute, the number given in the table above as the frequency of the beats between 'cello A and its fifth, E. If we sound with this same A the E a fourth below instead of the E a fifth above, then the *fourth* partial of this latter E will have the same frequency as the *second* partial of the E an octave higher, and the frequency of the beats produced will be the same as before.

The frequency of the beats between *any* note and its fifth above (or its fourth below) can be computed in the same manner. For example; the two notes

have frequencies of 293.6648 and 440 respectively. The *third* partial of D has a frequency of 880.9944 and the *second* partial of A a frequency of 880; the number of beats will therefore be the difference of the frequencies of these partials, .9944 per second or 59.7 per minute, as given in the table. All of the frequencies given in the table of frequencies for beats could be computed in this manner, but were as a matter of fact computed by multiplying the frequency of each note by .2032. Where did this decimal come from?

In the table of ratios for the even tempered scale on page 55, if 1.000000 is taken as the frequency for *any* note, say A, then 1.059463 is the frequency of A♯, 1.122462 is the frequency of B, etc., and 1.498307 will be the frequency of E, the fifth of A. And no matter where we start in the table of ratios, or what note we call the number with which we start, the seventh number from that with which we start will be the note a fifth above the note we started with; and the ratio of this fifth to its first note, found by dividing the frequency of the fifth by the frequency of its first, will always be 1.498307. That is, 1.000000 may be considered as the frequency of any note and 1.498307 as the frequency of its fifth. If, then, 1.000000 is the frequency of one of two notes under consideration, the frequency of its third partial will be 3.000000. And, if 1.498307 is the frequency of its fifth, then the frequency of the second partial of this latter note will be 2.996614. And, if these two notes be sounded together, they will produce beats whose frequency will be the difference between 3.000000 and 2.996614, i. e., .003386 per second or .203160 per minute; for which latter number we take the approximate value, .2032. Multiplying the frequency of any note, then, by this factor, .2032, we get the frequency of the beats between it and its fifth above or its fourth below.

Finally, it must be noted that the ratio for the tempered fifth, 1.498307, is a little less than 1.5, the ratio for the true fifth. A tempered fifth, then, must be made a little less than a true fifth, and a tempered fourth consequently a little greater than a true fourth. And, at last, we have the RULE FOR LAYING THE EVEN TEMPERAMENT: Beginning with 'cello A, and tuning the following fifths and fourths in the order given:



contract all fifths and expand all fourths by the following number of beats per minute:

A	45	F ♯	75	D ♯	63	C	53
E	67	C ♯	56	A ♯	47	G	80
B	50	G ♯	84	F	71	D	60

remembering always that the tabular number of beats belongs to the interval counted *from* the note set opposite the number. If the final note tuned, violin A, produced no beats when sounded with the note with which we began, 'cello A, then the resulting temperament is perfect.

After the temperament has been laid, then the octaves should be tuned, up and down from the notes in the octave already established, the octaves all being tuned free of beats. Finally, the unisons should be tuned in, also free of beats. In tuning the top octave or so it will be necessary to depend more or less upon the sense of pitch, because of the weakness of the partials in these extreme upper notes.

No tuner can tune a piano or organ accurately without using some physical measuring device for timing the beats. If a tuner does not so time the beats it means simply that his results will be inaccurate, as a moment's consideration will clearly show. Into the first fifth, that between A and E, the tuner must put 45 beats per minute; and the number of beats must be *45, not* 48 or 34 or some other number. Then into the next fourth, from E to B, he must put 67 beats, *not* some other number. Into the next fifth he must put 50; and into the remaining intervals he must put, in order, 75, 56, 84, 63, 47, 71, 53, 80, and 60. And the number of beats in each interval must be the number specified, *not* some number somewhere in the neighborhood of the specified number; otherwise the resulting temperament will not be even. But to *guess off* first 45 beats per minute, then 67, and then in succession 50, 75, 56, 84, etc., and to *guess them all correctly,* is beyond the *guessing* ability of any human being. The tuner who guesses off his beats ends up with an inaccurately tuned instrument. One would not expect a building superintendent to guess off the dimensions specified in his blue prints for the building he is to construct. The time will come when it will be regarded as equally ridiculous for a piano or organ tuner to try to guess off the frequency of the beats in his temperament; and that time will have arrived just as soon as pianists and organists shall have learned to insist on accurate work from their tuners.

Perhaps it should be specified that it is not necessary for a tuner to begin with 'cello A. He can begin with any note he prefers, just so he gives the fifth (or fourth) for each note the number of beats specified in the rule given for laying the temperament.

He could, for example, begin with violin A and tune the intervals in the reverse order from that given in the rule. Or, he could begin somewhere in the middle of the series given in the rule, and work both ways from his starting point. He could also lay the temperament somewhat higher or lower on the keyboard than the octave between 'cello A and violin A, provided he remembers that the number of beats for a note an octave higher is twice as great, and for an octave lower is one half as great. But if the temperament is laid *too* high or *too* low, then the beats will be too fast or too slow to count easily.

At this point attention should be called to the fact that some tuners attempt to tune by thirds instead of by fifths and fourths. Let us examine the feasibility of such a method. By referring to our table of frequencies for the intervals of the tempered scale on page 55, we will find that the frequency of any major third to its tonic, is 1.259921. The fifth partial of this tonic will have a frequency of 5.000000, and the fourth partial of the major third will have a frequency of 5.039684; and these two partials will have a difference of frequency of .039684. Any note and its major third sounded together, then, will produce .039684 beats per second or 2.381 per minute on the assumption that the frequency of the tonic is 1.000000. But 'cello A, whose frequency is 220, when sounded with its major third would produce 220 times 2.381 beats per minute, or 523. The number of beats per minute produced by each note in the octave from 'cello A to violin A, when sounded with its major third above or its minor sixth below, is shown in the following table:

A	523	C	622	D♯	739	F♯	880
A♯	554	C♯	659	E	783	G	932
B	587	D	698	F	830	G♯	987
			A	1046			

A similar computation establishes that the frequencies of the beats for these same notes, when sounded with their minor thirds above or their major sixths below, are:

A	713	C	848	D♯	1007	F♯	1198
A♯	754	C♯	897	E	1069	G	1269
B	800	D	952	F	1130	G♯	1344
			A	1426			

Of course it is out of the question to count accurately frequencies as high as these, either of the major or minor thirds. The frequencies most suitable for accurate counting are those occurring from once to twice per second; it is nearly impossible to count accurately frequencies greater than four per second, 240 per minute. So far as frequency of the beats is concerned, the frequencies of the major third beats could be counted if we were to lay the temperament from the lowest A on the piano keyboard to the A next above it, in which octave the frequencies of the major third beats would range from 65 to 130 per minute. But this plan becomes absurd because of the fact that the beats arising from the higher partials in this region can not be heard at all. Yet there are thousands of tuners attempting to tune instruments by laying the temperaments in thirds!

The rule for laying the temperament in the organ, either pipe or reed, is precisely the same as for the piano, because all these instruments use the same scale. The tuning of either of the organs, however, requires much more time than does the piano; it is a tedious task. Moreover the pipe organ gets out of tune with every change of temperature. The reed organ, on the other hand, is very reliable in its pitch once it has been put accurately into tune. For this reason a reed organ *whose scale is positively known to be correct* is the best standard for the manufacturer of wind instruments to use in tuning the wind instruments of the orchestra. Before a reed organ is adopted by the manufacturer as a standard for tuning such instruments, however, every one of its frequencies should be checked up to see whether they agree with those in the rule for temperament presented above. It is no more safe to assume that the average reed organ is in tune, than to make the same assumption with respect to the piano. The reason the reed organ is better than the piano as a standard for tuning wind instruments is that the tone of the organ can be indefinitely prolonged, while the piano tone quickly dies out. The indefinitely prolonged organ tone makes it easier to determine the frequency of the beats between the organ tone and the tone of the instrument being tuned. Each note within the compass of the instrument to be tuned should be sounded with the note of the same pitch on the organ, and the pitch of the orchestral instrument be so adjusted that the combined tone of the two instruments shall be free of beats. With sufficient care on the part of the manufacturer this desideratum can be attained with all the wind instruments except those with valves.

The accurate tuning of valve instruments is a matter of much greater difficulty than is the tuning of the other wind instruments, contrary to common opinion. It is impossible, with less than six valves, to put a valve instrument into exact even temperament; but it is possible to secure a much closer approximation to it than is usually done by manufacturers. An explanation of the tuning of valve instruments is so intricate, however, and involves so many computations, and the results would be of interest to so few persons, that the matter will not be presented.

The musical scale at present in use on musical instruments in the western world, together with the natural phenomena out of which it has arisen, has been presented with as much clarity and brevity, we hope, as the nature of the subject will permit. How the scale came to assume its present form, together with its probable future developments, will be considerd in Chapter 12. Immediately, one turns naturally to the question of the nature of harmony and of its relationship to the scale.

But before doing so it would perhaps be advisable to formulate, if possible, a definition of the musical scale. In doing so it is essential to keep three facts in mind: (1) Every musical scale, no matter in what country or in what period of history it has been found, ends with a note either an octave higher or an octave lower than the note with which it begins; (2) every such scale divides this octave into intervals; and (3) the intervals into which the octave is thus divided are intervals which, in that country and in that age, were considered suitable for the music there and then in use. All these facts, it is believed, are adequately expressed in the following DEFINITION OF THE MUSICAL SCALE: *A scale is a division of the octave into intervals suitable for musical purposes.*

And now we turn to a consideration of the nature of harmony, and of the nature of melody as developed from harmony.

CHAPTER V

HARMONY AND MELODY

It was some twenty-five hundred years ago that the ringing of a blacksmith's anvil led Pythagoras to undertake the investigation of sound. Among the things he learned was the fact that the sounds made by strings whose lengths are to each other as 1, 2, 3 and 4, are more pleasant when heard together than sounds from strings whose relative lengths must be expressed by larger numbers. This fact impressed Pythagoras as being especially interesting; but he was unable to offer any explanation for it, and the problem was bequeathed to his followers. The problem still awaits solution.

For nearly two thousand years these Pythagorean consonances, the octave (1:2), the fifth (2:3), and the fourth (3:4), remained the only intervals recognized by musicians as harmonic. In the fourteenth century the practice of singing in fourths and fifths, known as *organizing,* gave way to the use of *faux-bourdons,* singing at distances of a fourth *and a sixth* below the melody. The adding of this sixth to the fourth already in use was the most important event in the history of music; for out of it grew the whole system of harmony. The addition of a fourth *and* a sixth below the melody provides the interval of a third between the lower parts; and the music of the past six hundred years is superior to that of earlier date chiefly because of these thirds and sixths.

The writer has never been able to understand why the ancient Greeks failed to discover the consonance of the thirds. Their failure to do so was most unfortunate. If Pythagoras had succeeded in recognizing the consonance of the major third (4:5) and minor third (5:6), as he did those of the octave, fifth, and fourth, harmonic practice probably would have been as far advanced by the beginning of the Christian era as it is today, over nineteen hundread years later. This belief is based upon a comparison of the six centuries just past with the six centuries immediately preceding the Christian era. In such a comparison two important facts stand out with compelling force: (1) In the earlier of these periods music was a necessary part of the education of every man laying any claim to scholarship; for the past three hundred years this has not been the case. (2) The Greeks of that period possessed perhaps the most keenly analytical minds the world has ever known; musicians of the past six hundred years, especially of the latter half of it, have not been distinguished either for their willingness or for their ability to cope with the analytical problems connected with music. Had the Greeks been aware of the consonances of the thirds, as well as those of the octave, fifth, and fourth, it is more than likely that they would have developed harmonic practices more elaborate than any we possess today; witness the almost inexhaustible wealth of resource lavished by the greatest of their thinkers upon the relatively barren subdivision of the tetrachord. But, stumbling daily for the seven hundred and fifty years from Pythagoras to Claudius Ptolemy over the consonances of the major and minor thirds, the Greeks for some inscrutable reason never got those consonances into the focus of their attention; and the world in consequence is about two thousand years behind the schedule of what its harmonic development otherwise would have been.

Whether the recognition of the consonance of the thirds, when it finally came, arose through trial and error by singers, or by the discovery of some investigator in musical theory, will probably never be known. The practice of employing *faux-bourdons,* and the theoretical recognition of the thirds as consonant, both date from the early fourteenth century. According to Mersene (*Traité des Harmoniques,* A. D. 1636, Bk. IV, p. 60), the first musical theorist to recognize the consonance of the thirds was Jean de Muris, a man whose nativity is claimed by both France and England. By the time of Zarlino (1517–1590) the consonance of the thirds was well established, and has ever since been a commonplace of harmonic practice and theory.

This is not to say, however, that the reason why the thirds are consonant has ever been understood, any more than was the consonance of the octave, fifth, and fourth, in the time of Pythagoras. Just as Pythagoras recognized the consonance of the three simpler intervals without being able to assign a reason therefor, so too have modern theorists and practitioners of harmony recognized the consonance of the thirds without being able to give a reason for such consonance. Nor is this to say that frequent attempts have not been made to account for the facts of consonance; there have been many attempts, but they have been unsuccessful. Still we can not give over trying to account for the facts.

In view of the many unsuccessful efforts already made in the same direction, it is with considerable diffidence that the writer submits what appears to him to be an approximate solution of the problem of harmony. But the point of view presented brings into correlation so many of the facts of harmonic practice that he feels hopeful of the value of the theory. Perhaps the time has not yet arrived when a complete theory of harmony can be formulated. It is entirely possible that we do not as yet have at our disposal enough facts, both physical and psychological, to fill in all the gaps in such a theory. It is quite likely that further investigation in the physics of sound and in the psychology of hearing may furnish us with information that will enable us to bridge the gaps that today appear unavoidable in that theory. But it is confidently believed that a rough outline of the theory of harmony may today be unhesitatingly formulated. If a complete integration of the function is as yet impossible, we are at least able to identify some of the variables appearing in the result and to determine the values of their coefficients with a very fair degree of approximation.

Let it be understood clearly at the outset just what the task of a theory of harmony is. It is the business of a theory of harmony to take the *well established* facts of harmonic practice and, by means of that theory, to bring these facts into relationship with each other in such a manner that they will form a consistent whole, the theory being the principle which effects their unification. The *facts* from which we start, and which we seek to explain, are that certain combinations of tones have come to be regarded by the ear as agreeable, and as being necessarily related to certain other combinations of tones. It is the business of an harmonic theory to explain *why* the ear regards these combinations as agreeable and as necessarily related to the certain other combinations. Pythagoras recognized this as the essential nature of the problem, and faced it fairly; not every investigator in the field since has been as happy as Pythagoras in knowing what he was seeking. Furthermore, it is only the *well established* facts of harmonic practice that a theory of harmony is required to explain; harmonic practices that are yet struggling for recognition must wait until they have become *well established* bebefore they can claim the right to be explained by the theory.

The facts to be explained by a theory of harmony fall under four heads: (1) consonant chords, (2) dissonant chords and their resolution, (3) chord progressions, and (4) modulations. Among the chords clearly entitled to explanation are the major triad, the minor triad, and the dominant seventh chord, with their recognized inversions.

The harmonic facts that have become well established by musical practice, it seems to me, can all be accounted for through the following principle: *Those chords and chord progressions are satisfactory to the ear, and those only, to which the ear has adapted itself through long association with them as its auditory environment.* This gives formal statement to the principle which, it is believed, underlies harmonic phenomena; let us see what is implied in the formula as stated. What are the factors in the ear's auditory environment that have brought it to its present attitude toward tonal combinations?

The primary factor in the tonal environment of the ear is the musical tone itself. We learned in Chapter 2 that "every musical tone is a composite of simple tones called partials, the lengths of the partials being respectively 1, ½, ⅓, etc., times the length of the composite tone, and the relative loudness of the partials being anything between 0 and a number representing the loudness of the composite tone itself." Thus the tone, F in the thirty-two foot octave, is really a composite of the following tones,

and of several others most of which are not capable of being represented on the staff. Every musical tone, that is, is a chord—of a kind. This chord, present in every musical tone, is the Chord of Nature, and the series of partials constituting it is the Harmonic Series.

With respect to this Chord of Nature, present in every musical tone, two things must be noted: (1) every partial in the harmonic series is theoretically present; and (2) the partials are weaker the higher they are located in the series. By virtue of the latter of these principles, the lower partials of a tone impress themselves more strongly upon the ear than do the upper ones; also, at a certain height in the harmonic series of any tone, a point is reached where the partials become inaudible. This point is reached sooner for some tones than for others, depending upon the rate of decrease in the strength of succeeding partials from the lower to the higher. In Chapter 2 we found that the tone in the middle register of the flute is almost devoid of upper partials, while oboe and clarinet tones are quite plentifully supplied with them. The horn may show as many as thirty partials, a bass string of the piano as many as forty. But, in any instrument, including the human voice, it is the lower partials which are strongest and which have made the most powerful impression upon the ear; it is thus the lower partials to which the ear first adapted itself, and to which its adaptation is most perfect and complete.

Judging only from the evidence already presented, we should expect to find that the first interval to which the ear became harmonically adapted, and the first to be used in polyphonic music, would be the interval lying between the first and second partials, the octave. And of course this is exactly what happened as a matter of history; the first concerted singing by voices of different pitches was that called *magadizing,* singing in octaves. We should likewise expect that the next interval to which the ear would become accustomed, and the next to be admitted into polyphonic use, would be the interval between the second and third partials, the interval of the fifth. And this, too, is what happened historically;

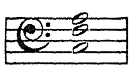
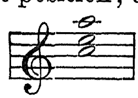
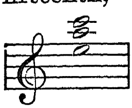
magadizing was superseded by *organizing,* singing in fifths. But singing in octaves *and* fifths resulted in producing parts separated from each other by a fourth—since the fifth divides the octave into a fifth and a fourth; i. e., fifths *and* fourths entered polyphonic music together, like Tweedledee and Tweedledum.

Thus the first, second, and third, intervals in the harmonic series, viz. the octave, the fifth, and the fourth, were respectively the first, second, and third consonances to appear in polyphonic music. And, if this startling coincidence should lead us to expect that the fourth interval of the harmonic series, viz. the major third, would in like manner be the fourth consonance to enter polyphonic music, we should not be disappointed; for this is precisely what occurred. And, just as the introduction of the fifth into the octave introduced also the fourth as its complement within the octave, so, too, the introduction of the major third into the octave and into the fifth introduced also the minor third as its complement within the fifth, the minor sixth as its complement within the octave, and the major sixth as the complement of the minor third within the octave. Thus, while the admission of the fifth into concerted music involved the admission of one companion interval, the fourth, the admission of the major third into concerted music involved the admission of three companion intervals, the minor third, the minor sixth, and the major sixth. As stated above, it was in the early fourteenth century that the momentous step was taken of introducing the major third with its attendant minor third, minor sixth, and major sixth. As *magadizing* had given way to *organizing,* so organizing now gave place to polyphony. Thus *harmony,* begotten of the *faux-bourdon,* was brought into being.

It appears, then, that the order in which the first five consonant intervals made their historical appearance in concerted music is also the order in which they appear in the harmonic series. The second partial, being next strongest after the fundamental, made the second strongest impression upon the ear and caused the ear to adapt itself first to the interval of the octave. The third partial, being next strongest after the second, caused the ear to adapt itself next to the interval between the second and third partials, the interval of the fifth; and, since the third partial divides the octave between the second and fourth partial into a fifth *and* a fourth, therefore the ear became adapted to fifths and fourths at the same time. Likewise the fifth partial, being next strongest after the fourth, caused the ear to adapt itself next to the interval between the fourth and fifth partials, the interval of the major third; and, since the fifth partial divides the interval lying between the fourth and sixth partials into a major *and* minor third, therefore the ear became adapted at the same time to the consonances of the major *and* minor thirds; also, since the fifth partial divides the octave between the fourth and eighth partials into a major third and a minor sixth, therefore the ear accepted the minor sixth as a consonance at the same time it accepted the major third; furthermore, since the sixth partial divides the octave between the fifth and tenth partials into a minor third and a major sixth, therefore the ear accepted the major sixth as a consonance at the same time it accepted the minor third, which was also the time at which it accepted the major third as a consonance. Or, as already stated, the consonances of the major and minor thirds and of the major and minor sixths were all accepted by the ear as consonances at the same time, in the early fourteenth century.

Still viewing the matter from purely *a priori* grounds, we should expect that the next interval to make its appearance as a consonance in concerted music would be the interval lying between the sixth and seventh partials; and that, in so doing, the seventh partial would introduce as consonances not only the interval lying between the sixth and seventh partials, but also (1) the companion interval into which the seventh partial divides the fourth lying between the sixth and eighth partials, (2) the companion interval into which it divides the fifth lying between the sixth and ninth partials, (3) the companion interval into which it divides the octave lying between the sixth and twelfth partials, (4) the companion interval into which the eighth partial divides the octave lying between the seventh and fourteenth partials, and (5) the companion interval into which the ninth partial divides the octave lying between the seventh and fourteenth partials. And this, too, is what is just now happening, although the process is as yet incomplete. The interval between the sixth and seventh partials (it has not yet received a specific name) first entered concerted music in the chord of the dominant seventh; its companion intervals appear in the various seventh chords, and in their derivatives, the chords of the ninth, eleventh, and thirteenth.

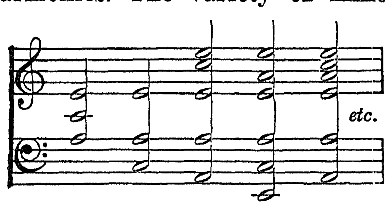
We see, then, that the order in which the intervals are found in the harmonic series *agrees at all points* with the order in which these intervals were historically accepted by the ear in concerted music. The historical development of harmony up to the present time would appear, then, to have been determined by the relative strength of the partials found in the musical tone. Let us next examine the harmonic series to ascertain whether it furnishes all the chords already accepted in well established harmonic practice.

Referring on page 47 to the series of harmonics for F, the fundamental note of the diatonic scale in C, we observe that the fourth, fifth, and sixth, partials  supply the major triad in its root position; the fifth, sixth, and eighth partials  supply the first inversion of the major triad; and the third, fourth, and fifth partials  supply its second inversion. We observe also that the tenth, twelfth, and fifteenth partials  supply the minor triad in its root position; the twelfth, fifteenth, and twentieth partials  supply the first inversion of the minor triad; the fifteenth, twentieth, and twenty-fourth partials  supply its second inversion. Furthermore, the fourth, fifth, sixth, and seventh, partials  supply the dominant seventh chord in its root position (the fact that this chord does not belong to the C tonality need not concern us at present; this discrepancy will be given consideration later); the fifth, sixth, seventh, and eighth partials  supply the first inversion of the dominant seventh chord; the sixth, seventh, eighth, and tenth, partials  supply its second inversion; and the seventh, eighth, tenth, and twelfth, partials  supply its third inversion. Most of the other seventh, ninth, eleventh, and thirteenth, chords that are well established in harmonic practice, together with their inversions, may be derived with equal facility from the harmonic series.

Two important points of an harmonic theory have now been established from a consideration of the partials in the harmonic series alone: (1) the relative strength of the partials in a musical tone has apparently determined the historical development of harmony; and (2) all the chords employed in well established harmonic practice are supplied by the partials of the harmonic series. Let us now consider whether the relative harmoniousness of the various chords in general use is also determined by these partials. Which is the more harmonious, the major triad or the minor, the minor triad or the dominant seventh chord? Furthermore; is the major triad more pleasant in its root position or in its first or second inversion; of the minor triad, is its root position or one of its two inversions more pleasing; and, of the dominant seventh chord, which is more satisfactory to the ear, some one of its three inversions or its root position? All these questions are important, both to harmonic theory and harmonic practice. Do these questions receive their answers from a study of the relative intensities of the partials in the harmonic series?

Of the major harmonies there is an almost endless variety; a few are here shown:

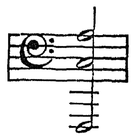
All these harmonies differ from each other in color, although they bear to each other a family resemblance which distinguishes them from the minor harmonies and from the seventh or any of the higher harmonies. The variety of minor harmonies is also very great:



They, likewise, differ from each other in color, but bear a family resemblance which distinguishes them from the major and from any other harmonies. The dominant seventh chords, too, are very numerous:

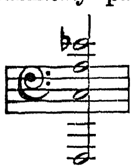
And they, also, differ among themselves in color, but have a family trait that sets them off distinctly from the harmonies of every other family.

All the harmonies belonging to the major family are produced by the first, third, and fifth partials, or by partials lying one or more octaves above these. Since the lowest partials which can possibly produce a major harmony are the first, third, and fifth, the harmony produced by these partials



may be considered the *fundamental form of the major harmony.* All the harmonies of the minor family are produced by the third, fifth, and fifteenth, partials, or by partials lying one or more octaves above them; and the harmony produced by the third, fifth, and fifteenth, partials

may be considered the *fundamental form of the minor harmony.* The dominant seventh harmonies are all produced by the first, third, fifth, and seventh, partials, or by partials lying one or more octaves above them; and the harmony produced by the first, third, fifth, and seventh, partials

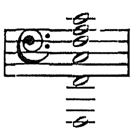


may be considered the *fundamental form of the dominant seventh harmony.*

The essence of the harmonic theory here presented is that the ear's attitude toward combinations of tones has been determined by the tonal environment to which it has been subjected. One of the elements of that tonal environment has been the musical tone itself whether presented to the ear by the human voice or by some other musical instrument. Considering this element of the tonal environment alone, we have been able to account for the historical development of harmony and for the well established harmonic combinations today in use. Does this element of the tonal environment alone account also for the varying degrees of approval which the ear gives to the numerous harmonies found in each of the harmonic families, the major, the minor, and the dominant seventh?

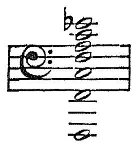
From the standpoint of musical tone alone, we should expect that a harmony would be the more pleasing (1) the lower the partials producing it were located in the harmonic series, and (2) the more nearly its constituent notes conformed in their number and pitch to the partials producing it in the harmonic series. We should expect a harmony to be more pleasing if the partials producing it were located low in the harmonic series, because the lower partials are stronger than the higher ones and have consequently had greater effect upon the ear in its adaptation to them. We should expect a harmony to be more pleasing if its notes agree in number and pitch with the partials producing it in the harmonic series, because the harmonic series has always presented that harmony to the ear in precisely the same way and the ear has consequently become adjusted to that precise combination.

The sounding together of the notes of the first six partials of the harmonic series produces a chord of the major family in a form so



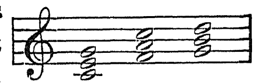
pleasant that Zarlino called it the "perfect harmony" (*"harmonia perfetta"*). It should be noted that the first five of these partials are the lowest, and the fewest in number, that can possibly produce a chord of any harmonic family, and that all of the partials producing the chord are represented. It should not be inferred, however, that Zarlino had any conception of partial tones, even the slightest inkling of their existence. His reasoning was based entirely upon the sounds produced by strings whose relative lengths were 1, ½, ⅓, ¼, ⅕, and ⅙. That the string itself *naturally divides* into segments of these relative lengths, and thus *actually* produces the *harmonia perfetta,* was a conception entirely beyond the comprehension of musicians of his day. It was not until two or three generations after Zarlino that this conception was first entertained by Mersene; and it was still another generation or two before the doctrine of partial tones received its full exposition at the hands of Sauveur, an exceptionally able student of sound who was, by the way, totally deaf all his life and dumb until his seventh year.

Zarlino was clearly justified in regarding the *harmonia perfetta* as the most pleasing of all harmonies involving a triad in its root position. This view is in entire accord with the consensus of musical opinion, and with the tenets of our theory. Our theory would further sanction the view that the dominant seventh harmony is the next most pleasing—more pleasing than the minor. In judging the validity of this contention, it should be taken into consideration that the E♭ present in this chord is not the E♭ either of the tempered or of the diatonic scale; it is somewhat flatter than either of these, and is the natural harmonic seventh of the chord of nature. When the E♭ is so pitched, the chord is smooth and pleasing to such a degree that it is entirely satisfactory and acceptable to the ear without resolution. On a keyboard instrument this, of course, is not true.

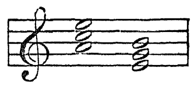


It will be found useful to note the combined strength of the various partials entering into the several harmonies. This can be conveniently expressed by taking the *sum* of the numbers indicating the different partials producing the various harmonies, it being understood always that a chord is more harmonious the lower the value of this sum. The fundamental form of the major harmony is produced by the first, third, and fifth, partials; and the sum of 1, 3, and 5, i. e., 9, would therefore indicate the combined strength of the partials producing this harmony. As a matter of convenience, let us call this sum, 9, the *harmonic index* of the major family of harmonies. The fundamental form of the dominant seventh harmony is produced by the first, third, fifth, and seventh, partials; and the harmonic index of the dominant seventh family of harmonies would therefore be 16, the sum of 1, 3, 5, and 7. The fundamental form of the minor harmony is produced by the third, fifth, and fifteenth, partials; and the harmonic index of the minor family of harmonies would therefore be 23, the sum of 3, 5, and 15. According to our theory, the numbers, 9, 16, and 23, should represent the comparative harmoniousness respectively of the major, dominant seventh, and minor harmonic families *considered as families*. This would not mean, however, that *any* harmony belonging to the major family would necessarily be more harmonious than *any* harmony belonging to the dominant seventh or minor families; far from it. That is a question to be determined, from the standpoint of our theory, by a comparison of the harmonic indices of the harmonies under comparison. And now we have a simple and convenient method for determining the comparative harmoniousness of any two harmonies whatsoever *from the standpoint of our theory.* Whether our theory is able to survive this rigorous test remains to be seen.

In considering the chords of the diatonic scale it should be observed that the three major triads

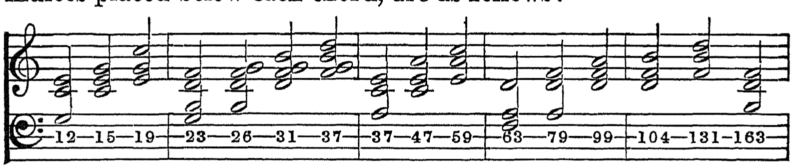


are identical in every respect except in that of pitch, and that the first of these triads may therefore be taken as representative of them all. Likewise, the two minor triads



are identical except in pitch, and the first of them may be taken as representative of both. On the other hand, the triad on the supertonic

differs, in the natural scale, from the other two minor triads in that its minor third and its fifth are both smaller than in the other two minor triads; which, of course, is not the case on a keyboard instrument using the tempered scale. This being understood, the various diatonic triads and dominant seventh chords, ranged in the order of their relative harmoniousness, and with their respective harmonic indices placed below each chord, are as follows:



It should further be noted that the F's used in the dominant seventh chords are the natural harmonic sevenths of the G's below them, which F's are somewhat flatter than the F's used in the triad chords.

The relative harmoniousness of the several chords as here given will be found somewhat at variance with the general opinion of those musicians who are used only to the tempered harmonies of the piano or organ. For example, the second inversion of the major triad, which we have placed at the head of the list, is not especially well regarded by harmonists. Whether the discrepancy between our theoretical estimate and the consensus of musical opinion is due to the fact that the root stands neither at the top nor at the bottom of the chord, or is due to the fault of our theory, is not easy to determine in the present state of our knowledge. Furthermore, the minor triads are universally more highly esteemed than the dominant seventh chords. This I suspect to be due to the mistuning of the tempered scale, more especially to the fact that the F's of the tempered scale are materially sharper than the natural harmonic seventh of the G below, which latter value is used in our computations. With these two exceptions, it is believed that the comparative harmoniousness of the chords as computed above will not meet with serious opposition from present-day harmonists.

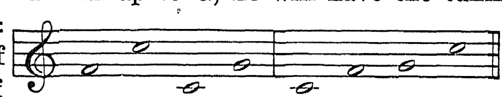
And this leads us to a consideration of the second element in the tonal environment of the ear—the musical instruments to which the ear is compelled to listen. So long as the ear is called upon to listen to isolated musical tones only, whether those tones be produced by the human voice or by some artificial musical instrument, the influence upon the ear is all in the direction of adapting the ear to the pure harmonies of the chord of nature. But just so soon as melodies or harmonies are produced by musical instruments other than the human voice, then the ear is subjected to a tonal environment tending to adapt it to intervals at variance with those of the natural scale. This has been, and is, an influence upon the ear of very great potency indeed.

Every thoughtful musician has been forcibly struck with the facility with which the ear adapts itself to new and strange harmonic combinations. The writer once heard Walter Damrosch say in a lecture something approximately to this effect: "The human ear is much like the back of a donkey; you can whip it into callousness to almost any kind of harmonic punishment." His phrasing seems to me a particularly happy statement of the psychological facts involved. Pope gave similar statement to the more general principle when he said,

> "Vice is a monster of so frightful mean
> As, to be hated, needs but to be seen;
> But, seen too oft, familiar with her face,
> We first endure, then pity, then embrace."

Heard for the first time, a new dissonance—if there be any such—affects us altogether adversely; but repeated hearing at length rounds off the sharpness of our aversion, and ultimately we come to accept the dissonant combination philosophically as one of the necessary evils of our musical existence. What have been the scalar discrepancies of the artificial musical instruments to which the ear has been subjected in the history of Western music?

Among the Greeks the most popular musical instruments were those of which the lyre may be taken as a type. Boethius states in his *De Musica,* according to Nichomachus, that the most ancient method of tuning the lyre was, c—f-g—c′, where we find a fifth above c and a fifth below c′ (Shirlaw: *Theory of Harmony,* p. 470; Novello, London). Such a tuning of an early instrument is what might be expected from the standpoint of our theory, that F is the fundamental of the diatonic scale, and that the first intervals to which the ear became accustomed were the octave and the fifth. If, beginning with F, one tunes a fifth up to C, then an octave down to C, and then a fifth up to G, he will have the tuning reported by Boethius:



This was the tuning of the four string lyre of the earliest days of Greek music. Another scale, used the world over and in all ages, is the pentatonic. This scale is secured by beginning with C, tuning a fifth up to G, then a fourth down to D, then a fifth up to A, then a fourth down to E, and then adding a C an octave above the initial C:

The hexatonic scale tunes its first four notes like the four string lyre, as above, then adds a fourth from G down to D, then a fifth from D up to A, and then a fourth from A down to E:

The heptatonic scale adds one more fifth, from E up to B, becoming:

This latter is the tuning for the Greek lyre of seven strings, the last three strings of which were added by Terpander, so legend says. This tuning of the diatonic scale by perfect fifths and fourths, alternately up and down beginning with F, produces what came to be known as the Pythagorean scale. Although this tuning gave an E, an A, and a B that were intolerably sharp for harmonic purposes, yet it was universally employed throughout Europe down to the sixteenth century, and is even yet used in tuning the harp and the bow instruments.

The history of the scale will be given more detailed consideration in Chapter 12; but it should be stated here that, while the harmonic infelicities of the Pythagorean scale were slightly alleviated by the mean-tone scale from 1600, A. D., to 1750, A. D., and by the even tempered scale since the latter date, yet neither of these three scales has furnished intervals that are at all satisfactory for purposes of harmony. As a consequence the ear has, from the earliest appearance of polyphony up to the present time, been subjected to perverting harmonic influences from the artificial musical instruments to which it has been compelled to listen.

The net effect of this perverting influence of mechanical instruments upon the harmonic sense which the ear had developed was twofold: (1) it broadened the tolerance of the ear in favor of combinations of tones not naturally harmonic, and (2) it dulled the keenness of the ear's appreciation for natural harmonies. While a certain catholicity of harmonic taste was thus undoubtedly gained, so that almost any combination of tones became somewhat tolerable, the fine sense of discrimination for pure harmonies possessed by the sixteenth and seventeenth century polyphonists was almost totally lost. And this leads us to a consideration of the third and final element in the tonal environments of the ear, the flood of musical compositions which have swirled about the ear for the last five or six centuries and by which the ear has been so powerfully influenced.

Generally speaking, it may be said that up to the time of Bach (1685–1750) composers of concerted music thought in terms of the human voice and the pure harmonies it naturally employs; thereafter they thought in terms of the keyboard and its even tempered scale. Except for music composed for the Russian Church, the harmony of the past two hundred years has been keyboard harmony. Under the vitiating influence of the keyboard, composers from the beginning of the eighteenth century on became more and more unscrupulous in the harmonic combinations they employed; the chords of the dominant seventh were followed by other seventh chords, by ninth chords and by chords of the eleventh and thirteenth, until today a certain degree of quasi-recognition as a harmony is accorded to the simultaneous sounding of the whole twelve chromatic intervals of the even tempered scale. It would seem that harmonic latitudinarianism could hardly go further. It is not too much to say that the sense of harmony is as extinct as the dodo; it has been sunk without a trace. Except for those *a capella* choirs which sing *and rehearse* without the use of any keyboard instrument as a crutch to lean upon, and except for the playing of a few of the very best string quartet organizations, real harmony has disappeared from the earth. In lieu of it we have the cacophony of the present day, as senseless and futile as it will be found evanescent. An imbecile could write music which would secure him a following as a composer nowadays if he could keep himself personally in the background so as to be judged only by his music.

Up to the present point we have considered the nature of consonance only. It remains to examine also the nature and function of dissonance, and to account for chord progressions and modulations. Fortunately this can be done much more briefly than has been possible in elucidating our present day notions of consonance.

Defining dissonance need not detain us long; it is simply a combination of tones that are not consonant. The function of dissonance, however, cannot be so summarily disposed of. That dissonance is of value in music is undoubted; its function is to serve as a foil for consonance. A person who has never been sick has no realization of good health; if there were no stormy weather we should not be aware of fine weather; the Garden of Eden cannot be said to have been good, because of the fact that there was no evil in it. Any consonance prolonged indefinitely would become intolerable, and progressively so until we were tortured into insensibility to it and it merged into that complex matrix of sounds of which we are unaware and which we call silence. A given consonance is pleasurable only if, before our point of satiety for it has been reached, it is replaced by some other consonance or by a dissonance. And just as a consonance cannot be too greatly prolonged, so too it must not be too frequently repeated. But neither may a dissonance be too greatly prolonged nor too frequently repeated; else our point of satiety for *it* will be passed and it will cease to give pleasure. It is customary for a concerted composition to begin on a consonance, although there seems to be no sufficient reason why this should be necessary in instrumental compositions; it would be difficult, however, for human voices to take an initial discord with accurate intonation. It may very well be that we have much yet to learn about dissonance. It is even possible that the laws governing the writings of effective dissonance may be as rigid and complicated as those for the writing of good counterpoint. It might be found advantageous, if we could discover how to do it, to build a dissonance up gradually over several bars into a dissonant climax, much as we now build up a harmonic and dynamic climax; it might also be well to know how to resolve a violent dissonance slowly, little by little, through increasingly consonant successive steps into a smooth and gently flowing harmony. Perhaps we should all be grateful if some one would show us how to do so.

The principle just enunciated, that no consonance or dissonance can be too greatly prolonged or too frequently repeated, might be called the *principle of harmonic variety*. Its effect is to avoid monotony in the use of harmonic materials. It is very broad in its application, and governs the use of both progressions and modulations. A progression occurs when the harmony passes from one consonance to another, from a consonance to a dissonance, or from a dissonance to a consonance. In a narrower sense a progression may also be said to occur when the harmony passes from one inversion to another within the same consonance, or when it passes in either direction between an inversion and the root position of the same consonance. The most complete progression is that which occurs between a consonance and a dissonance, in either direction;

the least complete occurs between different chords of the same consonance.

The use of a given consonance may be prolonged to a considerable degree without its becoming monotonous if the harmony progresses with sufficient frequency from one chord to another of that same consonance; but there comes a time, even with this precaution, beyond which a further prolongation of the same consonance would become tiresome, and a progression away from the given consonance is necessary. A choice must then be made between a progression to another consonance and a progression to a dissonance. If it is decided to progress to another consonance, the question then arises which consonance within the same tonality shall be the one next employed.

The question of the next consonance to be employed will depend upon whether a more or a less complete progression is desired. If a less complete progression is desired, then a nearly related consonance will be the one next employed. The nearly related consonances are those whose roots lie at distances of a fifth, either above or below the root of the given consonance. Thus for any given consonance, two nearly related consonances are available; one whose root lies a fifth above the root of the given consonance, and one whose root lies a fifth below; and a nearly related progression may be made either upward or downward as desired. Thus if C is the root of the given consonance, then the root of the nearly related consonance will be either G, a fifth above, or F, a fifth below. Having attained the consonance with the new root, and again desiring a progression to a nearly related consonance, the root must now shift a fifth in the *opposite* direction, i. e., it must return again to the consonance whose root is C. In this case the harmonies would all belong to the major family. Or, if the tonic root is A, the dominant would be E and the subdominant D; and the harmonies would, in this case, all belong to the minor family. If, then, the harmony is to be confined to the nearly related progressions, the only chords available are those of the tonic, dominant, and subdominant, with their various inversions; the consonances will be all major or all minor, with no dissonances employed. This, of course, is harmony of the simplest, most elementary kind; child's harmony indeed.

Before proceeding further let it be observed that in these most elementary chord progressions the root of the harmony oscilates back and forth, to and from the keynote for a distance of a fifth, no more and no less. It might be supposed that a still simpler progression would be that in which the root of the harmony would oscilate back and forth, to and from the keynote for a distance of an octave; for the octave is the first interval of the harmonic series, while the fifth is the second interval. And, indeed, this would be a still simpler harmony; so simple that the root would never change from the keynote, and the progressions available would be confined to those of the same consonance. Such a harmony could be prolonged for only a moment or so without the ear becoming surfeited with it; the composition would have to end almost before it had begun.

And a composition even whose harmonies are confined to the tonic, dominant, and subdominant chords, is too monotonous to have any real musical interest. The harmony of a composition becomes really interesting only when progressions to and from major and minor harmonies and dissonances are freely employed. This result is attained when the root is allowed not only to progress in either direction by fifths to and from the tonic but is allowed furthermore to progress in either direction by thirds and fifths to and from the tonic, dominant, and subdominant; however, the progression cannot employ any note outside the tonality, since this would result in a modulation. The root returns to the tonic by any desired succession of fifths and thirds that does not lead outside the tonality. It should be noted that the harmonies progress in such a manner that the root of the succeeding consonance or dissonance is always a note belonging to the preceding consonance or dissonance.

So much for the progression of the harmonies considered as wholes. The progressions for individual voices within the harmonies are governed by two considerations: (1) the voices for each consonance or dissonance must be so distributed that each of the notes necessary for that consonance or dissonance shall be represented by some voice; (2) the intervals produced by a given voice in passing from one consonance or dissonance to the next must be diatonic intervals, preferably not greater than a fifth for the bass voice and not greater than a fourth for the remaining voices.

A modulation differs from a progression only in that the tonic itself progresses instead of remaining fixed. In doing so the tonic may progress by fifths or thirds in either direction provided only that the tonic chord of the new tonality shall have at least two notes belonging to the dominant or to the subdominant chord of the old tonality. The return of the tonic to a former position is governed by the same laws that controlled its departure. The tonic returns at the end of a composition either to its initial position or to a position a minor third away from it.

By way of recapitulation, the theory of harmony set forth in the above pages may be summarized as follows: *Harmony is that relationship between simultaneous tones which the ear finds agreeable because of adaptation to its tonal environment.* The harmonic combinations to which the ear has become best adapted are those established by the first seven partials of the musical tone. Keyboard instruments in the past two centuries have impaired the adaptation of the ear to these pure harmonies to such a degree that almost any combination of tones is now more or less acceptable to it. Dissonance is any combination of tones that are not consonant. Dissonance in music serves the useful purpose of relieving the monotony of consonance; chord progressions contribute also to this same end. Chord progression may be effected within a given consonance by the employment of inversions, and effected from one consonance to another by allowing the root to progress by fifths or thirds to any position that does not necessitate the employment of notes foreign to the tonality. In modulation the root of the tonic chord itself may progress by fifths and thirds, but returns at the close of the composition to its initial position or to within a minor third of that position. The rigor of these principles governing pure harmony has been greatly relaxed in instrumental music of the last two centuries.

It is not contended that the theory here presented is anything more than the bare framework of an harmonic theory. It is hoped, however, that it will be found adequate *as a framework.* It is believed that it does possess several distinct advantages as a theory. In the first place it attempts to furnish *a reason why* certain tonal combinations are agreeable, viz., that the ear has adapted itself to them. Most attempts at harmonic theory do nothing more at best than to translate the original question into a more unfamiliar phraseology. Helmholtz, for example: even if his contentions with respect to the relationship between beats on the one hand and consonance and dissonance on the other were tenable (which they are not), still he would only have turned the question about the familiar phenomena of harmony into another question about the comparatively unfamiliar phenomena of beats, without even attempting to give an answer to the question in its new form; for he does not even hazard a guess as to *why* beats occurring a certain number of times per second should be unpleasant while beats occurring any other number of times per second should be pleasant—which is the crux of his whole theory. Even if he had accomplished all he thought he had, he would still have accomplished precisely nothing toward answering our quandary as to why one combination of tones is agreeable while another is disagreeable. And, in this respect, Helmholtz is representative of most harmonic theorists: they merely twist the question into a new and unfamiliar phraseology without attempting to answer the question in its new form. Perhaps these theorists are not aware that they are but trying to trick their followers by logical sleight of hand; at least it is more charitable to assume that such is the case.

Furthermore, the theory *does* show that *all* the diatonic chords have arisen as a natural consequence of the partials in the harmonic series, and that the historical order of their introduction into musical use is what might have been expected from a consideration of the facts with respect to that series. It shows also how the diatonic harmonies have been modified by imperfections in the scales of keyboard instruments, and how these vitiating tendencies have culminated in the harmonic laxities of the present day. Moreover, it accounts for the existence of dissonance, chord progressions, and modulations, and provides the fundamental principles governing the use of chord progressions and modulations.

And, to accomplish all this, recourse is had to but two fundamental principles, both of them familiar and universally accepted: (1) the principle of adaptation to environment, and (2) the psychological principle that a (tonal) stimulus indefinitely prolonged becomes disagreeable. This certainly is putting the theory upon rather solid foundation; if the superstructure shall be equally stable, it will undoubtedly be able to stand. But, of course, a great deal of work will have to be done by way of elaboration before the theory begins to assume an appearance of completeness and symmetry.

If a theory of harmony is not easy, a theory of melody is very difficult indeed. Much more baffling in its nature than harmony, melody has been given comparatively little thought so far as attempting to discover its essential character is concerned. Yet it is most desirable that melody be understood both for theoretical and for practical reasons. As a department of musical science it is just as much entitled to investigation as harmony, and from the standpoint of practical composition its claim is possibly even stronger than that of harmony for the reason that, while melody may exist without objective harmony, it is perhaps impossible for harmony to exist independent of melody. The question of the nature of melody therefore becomes of the highest importance, and may not be ignored either by the musical scientist or the composer. That the inquiry is of exceptional difficulty is unfortunate, but this does not offer excuse for neglecting it.

Of the several characteristics of melody, the most obvious is that it consists of a succession of single notes. Whereas harmony requires the simultaneous sounding of at least two notes of different pitch, melody requires the sounding of but one note at a time; indeed, if notes of more than one pitch sound simultaneously, the result ceases to be melody only and becomes harmonized melody. The first fact to be noted about melody, then, is that it is a succession of single tones.

But this is not all; the successive tones of a melody are related to each other. It will be readily conceded that a succession of single tones whose pitches are chosen at random would not constitute melody. Unless the successive tones are properly related to each other from the standpoint of pitch, we fail to get melody. Just what the nature of this relationship is we do not as yet know, but that some pitch relationship must subsist if melody is to result we are agreed. The next question to be considered is as to the nature of this relationship.

The pitch relationship between the successive single tones of a melody is undoubtedly harmonic in character. The melody wends its way through the successive harmonies in such manner that the several notes of the melody *belong* to the corresponding harmonies. From this point of view, the melody *is determined* by the harmonies belonging to it. But a diametrically opposite point of view might just as well have been taken. We might with equal truth have said that the melody *determines its harmonies,* instead of being determined by them. In fact, our first statement of the matter begged the question somewhat; we said, "the melody is determined by the harmonies *belonging* to it." But, if we admit that certain harmonies *belong* to a melody, then we necessarily imply that the harmonies depend upon the melody and are determined by it, even according to this statement of the case.

That the harmonies of a musical composition are determined by the melody is certainly a permissible view of the facts, and one that undoubtedly well describes the conditions existing in homophonic music. In fact this statement expresses precisely the essential characteristic of homophonic music: the melody goes pretty much its own gait, and the harmony adapts itself to the melody. But here again we have hedged; we said, "the melody goes *pretty much* its own gait," but not entirely so. If the melody went entirely its own gait with no consideration whatever for the resulting harmonies, i. e., if the successive notes of the melody were chosen quite at random, then the result would be a melody which it would be impossible to harmonize or, if harmonized, the harmonies would be of so strange a sort as scarcely to be recognized as harmonies by our western ears.

Some countries employ melodies much less capable of being harmonized than the melodies of western countries, many of the intervals used being essentially inharmonic. But no people, so far as I am aware, has ever utilized melodies which do not at least make use of the harmonic interval of the octave, and most of them employ also the harmonic interval of the fifth. What shall we say, then? This, probably, is not far from the facts: primitive peoples employ melodies which are much less capable of harmonization than do civilized peoples, because of the fact that their melodies are allowed to progress with almost entire freedom so far as pitch relationship between successive notes is concerned; but as peoples advance in musical maturity, their melodies become more and more conditioned by the necessities of a concurrent harmony. In the homophonic music of the western world for the past three centuries, melody has been allowed a greater degree of freedom in progressing from note to note than was formerly the case, with the result that melody during this latter period has taken on a much greater degree of beauty than it had during the polyphonic period, while harmony has had to shift as best it might. In the preceding three or four centuries of the polyphonic period melody was very strictly circumscribed, in its progression from note to note, by the necessities of a concurrent harmony, with the result that melody was much less beautiful than it later became; but the harmonies were correspondingly more beautiful. Since the rise of homophonic music a melody of exceptional beauty has been assigned to one voice, while the melodies for the other voices have been very inferior. In the days of polyphony none of the melodies assigned to the various voices was of exceptional beauty, one part being about as beautiful as the others. Summing up, then, primitive peoples employ melodies almost entirely free of harmonic determination, modern homophonic music employs melodies largely determined by harmonic considerations, and music of the polyphonic period employed melodies completely determined by harmonic considerations.

The fact of the matter is that, except for the music of primitive peoples, melody and harmony are but different points of view of a single musical entity. Melody can not exist independently of harmony, either objective or subjective, nor can harmony exist independently of melody. Melody may be emphasized at the expense of harmony, or harmony may be emphasized at the expense of melody; but if melody is emphasized to the entire disregard of harmony, we secure a music closely resembling that of primitive peoples and that is incapable of harmonization. And if harmony were emphasized to the entire disregard of melody, we should then have a music of a kind quite different from anything we have ever known except, perhaps, as illustrated by the player of a keyboard instrument when he amuses himself with a succession of chord progressions and modulations considered as ends in themselves and without making any use whatever of either melody or rhythm. I am not at all sure that passages of such character would not occasionally be useful in orchestral scores.

The point at present reached in our inquiry is that music might perhaps become exclusively harmonic, melody being entirely abandoned; it may be exclusively melodic as with primitive peoples, harmony being almost or entirely abandoned; or it may be a combination of the two emphasizing either harmony or melody, as in the polyphonic and homophonic periods respectively. If we confine our inquiry to the music of the past six centuries in the western world, then we find melody and harmony interdependent upon each other to such an extent that each becomes merely a different point of view of a single musical entity. What, now, is the nature of this interdependence between harmony and melody when viewed from the standpoint of melody, i. e., in what way has melody been determined by harmonic considerations during the six centuries under consideration?

During the polyphonic period the object of the composer was to produce beautiful harmonies and, this end being attained, the melodies assigned to the several voices must progress as best they might. No voice was allowed to monopolize all the melodic beauty; no part was of ravishing beauty nor of intolerable ugliness. The parts formed a musical community organized very much on the basis of a melodic democracy. The rules for the progression of the several voices during this period were multitudinous and intricate, but rested upon the general principle that the intervals for a given voice should be such that they might be taken with the least possible difficulty, due consideration being had for the interests of all the voices concerned. And what is an easy interval for the voice to sing? It should be a diatonic interval, it should not be too large, and if it is larger than an interval of the second it should be a consonant interval; the large dissonant intervals of the augmented fourth and fifth, of the diminished fifth, and of the major seventh, should be avoided.

It might be supposed that the *cantus firmus* of polyphonic music was a genuine melody in the modern sense. This, however, is hardly the case. The *cantus firmus* differed but little in its essential character from the counter melodies; it was rather merely a starting point from which to begin the composition. If one of the counter melodies had been assumed as starting point, the completed composition need not necessarily have differed greatly. The *cantus firmus* did, it is true, possess a slightly greater degree of individuality than the counter melodies, but its superiority in this respect was not marked; and its inferiority to the genuine homophonic melody was very marked indeed. In what way did it differ from the latter?

The homophonic melody makes much greater use of critical notes at strategic points of the melody than did the *cantus firmus.* By critical notes is meant notes belonging to the concurrent harmony that did not belong to the immediately preceding harmony; for example, if the harmony changes from that of the tonic to that of the subdominant, the homophonic melody is inclined to utilize the fourth or the sixth of the scale instead of the first, if the melody has reached a stragetic point; and if the harmony changes from that of the tonic to that of the dominant, the homophonic melody is likely to progress to the seventh or the second of the scale rather than to the fifth, provided the point reached in the melody is strategic. By a strategic point of the melody is meant, preferably, an accented note of the melody or, at least, a note occurring on the beat. It is this tendency toward the utilization of critical notes at strategic points that gives the homophonic melody its high degree of individuality and that constitutes its aesthetic superiority over the *cantus firmus.* Thus it appears that there is also a rhythmic factor in melody, and this factor we must next take into account. We have now reached a point in our analysis where we can say that melody is a succession of single tones harmonically related to each other and that are inclined to assume critical values at strategic points of the series.

The analysis of music into its constituent factors presents many difficulties, and not the least of these difficulties is the fact that its several factors are so inextricably intertwined with each other that, to explain any one of them, it frequently becomes necessary to explain also the others with which it is intertwined. We found that melody and harmony were so interrelated that melody could not be explained without taking harmony also into account; and now we find melody so interrelated with rhythm that it can not be explained without understanding that also. And we have as yet said nothing about the nature of rhythm.

If it can be done we should prefer to defer the formal analysis of rhythm to the next chapter; and perhaps it may be possible to do so. If we state here merely that rhythm is a relationship between the stress of successive notes such that the result is recognized as beautiful, perhaps the statement will be sufficiently intelligible without further elaboration. And this statement, together with the additional information that, under the influence of rhythm, notes tend to arrange themselves into stress groups which are repeated periodically according to definite plan, will perhaps furnish enough information to enable us to give a fair account of the rhythmic aspect of melody.

The notes constituting a given rhythmic group establish moreover, by their variation in pitch, a certain pitch contour. When, in the course of a melody, a given rhythmic group repeats itself, the pitch contour belonging to that group also repeats itself with more or less faithfulness. This affinity between the rhythmic aspect and the contour aspect of groups of notes within a melody is one of the most important characteristics of melody, and any explanation of melody which neglected to take it into account would fall far short of adequacy indeed. Finally, then, melody may be defined as a succession of single tones which are harmonically related to each other, which are inclined to assume critical values at strategic points of the series, and which tend to arrange themselves into groups possessing both a rhythmic aspect and a contour aspect, the groups repeating themselves periodically according to definite plan as the melody progresses.

As WITH the theory of harmony outlined in the earlier part of the chapter, so with the theory of melody sketched here; the writer feels inclined to beg the reader's indulgence because the material presented provides nothing more than a mere outline of the subject. It is impossible to develop these subjects here as they deserve without expanding this portion of the volume far beyond its reasonable limits. Moreover the writer realizes that he is here breaking ground more or less new, and that his theories of harmony and melody even if completely elaborated might be found to need revision and modification; he is, however, strongly of the opinion that the outlines of harmonic and melodic theory here presented will prove to be not entirely without permanent value.

CHAPTER VI

WHAT IS MUSIC?

WHAT is music? This is the question whose answer we have been seeking from the beginning. At the very outset we noted that there is both a scientific and an artistic side to music. We examined musical tone, and reached the conclusion that it is a succession of periodic atmospheric pulsations capable of being heard, and we observed the manner in which various musical instruments produce musical tones. We next studied the way in which partials of the musical tone arranged themselves into the musical scale, and found the scale to be a division of the octave into intervals suitable for musical purposes. Finally, we decided that harmony is that relationship between simultaneous musical tones which the ear finds agreeable because of adaptation to its tonal environment, and that melody is a succession of single tones harmonically related, assuming critical values at strategic points of the series, and arranging themselves into rhythmic contour groups which repeat themselves periodically according to definite plan.

When our analysis of music has been completed we shall have found that there are eight factors involved in music: melody, harmony, rhythm, form, tempo, dynamics, tone-color and nuance. The first two of these factors we have already discussed, and have barely touched upon the subject of rhythm. It remains to finish the discussion of rhythm, and to consider the remaining factors, form, tempo, dynamics, tone-color and nuance. We turn first to a further consideration of rhythm.

Of the several respects in which musical tones may differ, one is in the matter of duration: two musical tones otherwise identical may be unlike in that one of them continues to sound longer than the other. For example, the duration of a tone represented by a half-note is twice that of a tone represented by a quarter-note. *Rhythm* has to do with the relative stress of musical tones, and greater stress may be given to a tone either by accenting it or by increasing its duration. From the standpoint of duration musical tones arrange themselves into groups which occur periodically, at least in music belonging to the homophonic period. The simplest possible rhythmic group is usually one measure in length, but may have a length of two measures. Sometimes the same rhythmic group is repeated over and over, sometimes it alternates with other groups of equal length. And, in either case, throughout the entire composition there is the steady recurrence of the rhythmic stress called accent, repeating itself with but slight variation in every measure. Music such as this is called measured music, and the rhythmic units into which it divides itself are known as measures or bars.

The music of the past three centuries thus subjects itself to a kind of goose-step, bequeathed to it as a rule by various forms of the dance. But most of the music belonging to the polyphonic period was of the kind called unmeasured music, because of the fact that its rhythm was irregular and could not be reduced to periodic groups of any kind; no sort of goose-step would fit it. This is not to say that polyphonic music was lacking in rhythm, but means simply that its rhythm was of the irregular kind belonging to prose instead of the regular kind belonging to poetry. Prose rhythm is no less real than the rhythm of poetry, but it is much less obvious, more subtle. Probably the greatest obstacle modern choirs have to overcome in singing polyphonic compositions is that of rhythm. Schooled as they are in measured music, and in that only, it is almost impossible for them not to beat out the time either consciously or unconsciously; and of course this ruins polyphonic music. The duration of the successive notes of a polyphonic composition, as well as the comparative dynamic stress given to each one of them, is determined solely by the requirements of effective declamation of the words used in the composition. Bar lines are frequently omitted, and might better never be used; but, if not omitted, they should always be disregarded. *Rhythm,* then, is the system of stress groups into which successive musical notes arrange themselves, and is one of most important factors of music.

The *form* of a musical composition is the system of relationships existing between its consecutive parts when those parts are viewed from the standpoints of rhythm, melody and harmony. But since both the rhythm and the harmony of a composition are implied in its melody, it might be said with equal accuracy although with perhaps too great succinctness, that the *form* of a musical composition is the system of relationships between its consecutive parts viewed from the standpoint of melody. The form of a composition is determined through the operation of three principles: the principle of *unity,* the principle of *contrast,* and the principle of *balance.* The principle of unity requires that the several parts of a composition be sufficiently alike that they constitute an organic whole; the composition as a whole must be one composition and not several compositions. The principle of contrast requires that the succeeding parts of the composition be sufficiently different that the effect of the composition as a whole will not be monotonous. And the principle of balance requires that the contrasting parts of the composition be sufficiently equal in importance that no part will be unduly aggrandized at the expense of its contrasting part.

The simplest element of the composition, from the standpoint of form, is the *motive.* The *motive* is that portion of the melody which coincides with the fundamental rhythmic group of one or two measures. Two related motives form a phrase; the second of the two motives constituting a phrase may be an exact repetition of the first motive, it may be a repetition in point of rhythm but not in point of pitch contour, or it may differ from the first motive both in rhythm and contour and resemble it only in its length as a whole. The *section* contains two phrases, and the *period* contains two sections. The second phrase of a section may contain the same rhythmic material as the first, or the rhythmic material may be partly or entirely new. The first and second sections of a period are known respectively as the *antecedent* and the *consequent.* If the motive is one measure in length, then the period has a normal length of eight measures; but it may, by certain devices, be made either shorter than eight measures or longer. If the motive has a length of two measures, then the normal length of the period is sixteen measures; but it, likewise, may be either shortened or lengthened.

The subject of *musical form* can be fully treated only in a treatise devoted to that subject. Here it can only be pointed out that, under the influence of the principles of unity, contrast and balance, a succession of musical periods are formed into a *period-group;* two period-groups are combined into a *binary form,* or three period-groups are combined into a *ternary form;* and that two or more complete binary or ternary forms may be united into the *sonata,* the *symphony,* or the *concerto.* Thus, under the influence of the principles of unity, contrast and balance, melodic motives are developed into elaborate musical compositions. And without *form* no succession of musical tones could constitute music; so that we are compelled to add to our list of factors essentially entering into music the factor of *musical form.*

Tempo is another of the essential factors of music. The *tempo* of a musical composition is the rate of rapidity with which the constituent rhythmical units of the composition are made to progress; it is the rhythm's rate of progress. The tempo is of as great importance as any of the other musical factors. If a composition is rendered too rapidly or too slowly its effectiveness is greatly impaired. Tempo therefore takes its place legitimately as one of the important factors involved in producing music.

Another of the factors of music is *dynamics.* By the *dynamics* of a musical composition is meant the relative loudness of its successive parts. As will be shown in greater detail in the chapter on musical interpretation, much of the beauty of a composition depends upon its dynamic variations; these delicate gradations of intensity add much to the beauty of music if they are properly made, and detract just as seriously when they are not judiciously executed. And, since the effectiveness of music is so largely dependent upon dynamics, therefore we include it as one of the musical factors.

Tone-color is also an important element of musical effectiveness. It is usually provided for by the composer when he designates the instrument to be used in rendering the music. For one tone-color he designates the 'cello, for another the clarinet, and for still another the French horn. But he goes even further than this; he may call for "open" horn tones, for horns "stopped," or for horns "elevated." And in each case the player understands that the composer is calling for a tone-color of a certain definite kind, and plays accordingly. But, in the matter of tone-color, the player goes much beyond the requirements of the composer as designated in the score; he refines or coarsens the color, makes it more brilliant or more mellow, as his artistic judgment dictates. And, in doing so, he adds to or detracts from the effectiveness of the music in the degree to which his judgment has been good or bad. Tone-color, then, we include also in our list of the factors entering into music to help determine its effectiveness.

All the musical factors that we have so far enumerated, melody, harmony, rhythm, form, tempo, dynamics and tone-color, are factors of music which are largely in the hands of the composer to determine. The eighth factor, *nuance,* is entirely in the hands of the interpreter of the music; for, as we here use the term, *nuance* consists of small deviations from the requirements indicated in the score, the deviations being made for the purpose of increasing the effectiveness of the music. The interpreter may thus digress somewhat from the indicated rhythm, may introduce dynamic refinements not asked for in the score, may slightly hasten or retard the tempo, may embellish the melody a bit by the use of an appoggiatura or a vibrato, or may use his discretion in choosing between several possible tone-colors which might be employed in the rendition. These slight departures, deviations, or digressions, from the score in respect to melodic embellishment, rhythm, tempo, dynamics, and tone-color, we define as nuance in the sense in which we wish the term to be here understood. Since these are all departures from the score, therefore they are beyond control of the composer; and since these deviations are made at the discretion of the interpreter, therefore they are entirely dependent upon the interpreter. Seven of the factors of music, then, are materials in the hands of the composer to be used as he sees fit in the production of music; but the eighth factor, nuance, is the especial property of the interpreter to be employed in his artistic discretion to refine what the composer has presented in the score.

Music, then, utilizes eight factors: melody, harmony, rhythm, form, tempo, dynamics, tone-color and nuance. But it utilizes them in a particular way, to the end that the completed product compounded of these eight factors shall satisfy a certain very definite condition, viz., that the product shall be *beautiful*. Unless the end attained is such that we recognize it as beautiful, then that which we have produced is not *music*. The attainment of that which is beautiful is the necessary condition for the production of music; though we speak with whatever tongues, if we have not beauty it signifieth nothing—it is not music. But, just as beauty is the necessary condition, so too is it the sufficient condition; with whatever tongues we may fail to speak, if we still have beauty it is enough—it is music.

Music, then, is a utilization of melody, harmony, rhythm, form, tempo, dynamics, tone-color, and nuance, in such manner that the result produced is recognized as beautiful. If rhythm alone, or melody or harmony alone, produces what is beautiful, then it is music.

CHAPTER VII

THE MUSICAL LABORATORY

THE CENTRAL feature of a school of music should be the musical laboratory. There is no other means or instrumentality by which music can be so quickly, so effectively, or so economically advanced, and so surely placed upon a solid and enduring foundation. Sound is the raw material out of which the musician fashions the finished product called music, and his efforts would be much more effective if he thoroughly understood the material with which he works. The importance of this view can be appreciated only when it is realized that the instrumentalist is not the only person with the right to be called a musician. There are two other persons of equal importance with the instrumentalist for the production of music, the composer and the instrument maker; and each of them has as valid a claim as the instrumentalist upon the title of musician. Without the composer the instrumentalist would have no music to play, and without the instrument maker he would have no instrument upon which to play it. All three are indispensable to the production of music, each works with sound as the raw material which he turns into music, and each could greatly profit by a thorough understanding of that raw material.

The instrumentalist takes as his raw material, for example, the sound of the bowed string of a violin. In its raw state, as produced by the unskilled player, this sound is most exasperating; but, by properly treating it with his bow arm, the skilled violinist turns this rasping, squeaky noise into a tone that it is a joy to hear. Or the singer takes the sound of the human voice, which in its natural state is no more pleasant than the voice of the average animal, and, refining it of its harshness by strengthening its proper partials and by increasing its resonance, he moulds it into a thing of beauty. The composer takes as his raw material the notes of the scale and the beating of rhythms, and arranges them into a sequence constituting an exquisite melody, or fits them into simultaneous combinations forming beautiful harmonies. The instrument maker, too, takes sound as his raw material and shapes it into music as his finished product. In the childhood of the race the instrument maker fashioned squawkers from the quills of birds, and probably made life a pandemonium for the conservatives with his squawking. But with the passing years he came to be dissatisfied with the raucousness of his quills, and experimented again and again until today, as the result of his experimentation,

> "Sings out the melting clarionet,
> Like as a lady sings while yet
> Her eyes with salty tears are wet."

The singer, the player, the composer, the instrument maker, all use sound as the raw material out of which they fashion music as their finished product.

There is a very real sense in which the musician, whether interpreter, composer, or instrument maker, may be regarded as a manufacturer. The manufacturer is an individual who takes something which for his purposes he regards as a raw material and forms it into something else better suited to serve human needs which he calls his finished product. This, we have seen, is precisely what the musician does, whether he is an interpretive musician, a composer, or an instrument maker. But, as compared with other manufacturers, the musician assumes a very surprising attitude. Other manufacturers find it advantageous to study their raw material. If something is wrong with their finished product, they know that the fault must lie either with their manufacturing processes or with the material they are using; and they can not be sure the fault is with their processes until they are certain it is not in their raw material. They find it necessary, therefore, to know all about that material; they devote as much time and thought to the study of its properties as they do to perfecting their processes; and the perfecting of their processes, they find, depends largely upon the completeness of their knowledge of their material. Not so, our musician manufacturer. He is vastly superior to all such slow-going, painstaking methods. He thinks it quite unnecessary to know anything about the raw material he uses; all he needs to know is how to turn out the finished product. To be sure things sometimes turn out badly, but it never occurs to him that there is anything to be gained by a study of sound.

The fact is that there is not now in existence any considerable stock of knowledge about sound. It is quite doubtful, for example, whether anyone in the world today can give an explanation of so common a sound phenomenon as whistling with the lips. Professors of physics for the past hundred years or so have assumed a step-fatherly attitude toward sound; it has been the ugly duckling of the family. The other children, especially mechanics, electricity and heat, showing promise of ultimately becoming breadwinners, have received all the encouragement and attention. Sound has had to shift for himself, and still remains a rather anemic youngster. The situation may perhaps be made appreciable by calling attention to the fact that there are today scores of periodicals devoted to electricity and electrical engineering, but not even one journal devoted to acoustics or acoustical engineering. And yet it is probably true that sound touches human beings as often, and at as many and as vital points daily, as does electricity. It is moreover probable that no portion of the whole field of human inquiry gives stronger surface indications of producing in paying quantities than this same field of sound; and this would still be true even if production were measured in the cold standard of dollars and cents. The builder of auditoriums or musical instruments, the composer, the singer, the player of any instrument, the audience, every person in any way connected with the production or the enjoyment of music, stands to profit and to profit greatly by investigation in the field of sound. To doubt this is to believe that a blind hunter can shoot as many squirrels as a man with two good eyes and an intimate knowledge of the squirrel's habits.

The contemporary attitude of neglect toward the scientific side of music is a comparatively recent innovation. Up to two or three centuries ago a comprehensive knowledge of music had always been regarded as a necessary part of the equipment of every scholar; and by "music" was then understood precisely what the writer in this volume calls "musical science." For at least the twenty-two centuries from Pythagoras to Descartes no man could call himself educated without a thorough understanding of "music" in the precise sense in which it is briefly sketched in the present volume, a subject which in our modern phraseology we would call "musical science." But, in the latter part of the seventeenth century, the epochal investigations of Sir Isaac Newton gave such an impetus to the study of mechanics and mechanical devices that it resulted in a series of mechanical inventions culminating a hundred years later in an industrial revolution which entirely changed the whole structure of society and the conditions under which man had lived. A little over a hundred years ago Volta produced the first electrical current and Oersted discovered the relationship between current electricity and magnetism, thus ushering in the electrical age of the nineteenth century. Within the past thirty years the whole physical universe has been taken apart to see what makes it tick, and the physicists of the world are just now very busily engaged to see whether they shall be able to put it together some way or other.

Since Newton, then, the interests of physicists have been directed into other channels than the study of sound, and our knowledge of that subject is consequently much more fragmentary and less reliable than in other fields of physics. A few there have been, a very few, who have done work of prime importance in the field of sound. In the third quarter of the nineteenth century Herman von Helmholtz published his monumental *Sensations of Tone* which laid the foundations for all the work done in sound since that time, but which today is hardly more than a magnificent ruin. Perhaps the only man since whose work in sound is at all entitled to rank with that of Helmholtz is Miller, whose invention of the phonodeik and whose work in the analysis and synthesis of musical tone leave almost nothing to be desired so far as the quality of his work is concerned. But the amount of work yet to be done in tone analysis is so great in comparison with what Professor Miller has already done that the outlook is a bit discouraging to those who feel there is no one else so well qualified to do it as he. Perhaps the work on ether drift on which he has been engaged for the past few years is of equal importance and value; of that the writer is not competent to judge. But to those who know the importance of his work in sound, it was an evil day for music when he abandoned that work for the purpose of securing more accurate results on the Michelson-Morley experiment as a check upon the validity of the Einstein theory.

For even the small amount of work in sound that is today being done in the laboratories of universities, we should perhaps be grateful; but the writer is betraying no secret in saying that, in comparison with the work done in other fields of physics, the investigation of sound in the universities of the world today is sadly neglected and the laboratory equipment for such investigation pathetically meagre. Outside of Professor Miller's laboratory at the Case School of Applied Science, Cleveland, Ohio, there is not a creditable acoustical laboratory in any American university; and, to the best of my knowledge, the same may also be said of European universities. The University of Calcutta, India, has been doing some creditable work in sound; I do not know how extensive their laboratory equipment is. I hope it is better than that of universities in the western world. As for professors of physics, the knowledge of sound possessed by capable and representative physicists doing important work in their subject is sometimes astonishingly limited. If this is a secret, perhaps it is one that ought to be divulged. The whole situation may be summed up in the statement that sound is a sadly neglected field in physics. If university departments of physics are not to be blamed for their neglect of sound, they ought at least to justify their attitude; for the presumption is strongly against them. If sound is a phenomenon with which human beings do not come into touch, or if their contact with it is of slight consequence to them as human beings, then physicists are quite right in giving the subject but little attention; but if sound is a phenomenon with which man is brought into frequent, intimate and important contact, either in the form of noises or in the form of musical sounds, then physicists are on the defensive in their neglect of its study. It is the belief of the writer that sound in the form of noises is a deleterious phenomenon from which human beings are almost never able to escape, and that sound in the form of music is one of the most important of the salutary elements in man's environment; and if this is true, then the common and widespread neglect of the study of sound today is indefensible.

It was stated above that the central feature of a school of music should be the musical laboratory. What would be the nature of the work to be undertaken by such a laboratory? To specify the precise range of interests a musical laboratory would ultimately develop is of course out of the question; it is not difficult, however, to indicate what might profitably be the initial organization of its activities. The work would naturally fall into three divisions: one devoted to the general study of sound, another to the applications of sound, and a third to the investigation of hearing.

The first of these divisions, that devoted to the study of sound in general, would concern itself with the investigation of atmospheric pulsations, their nature and behavior. We saw in Chapter 2 that sound pulsations may differ in three ways: in length, in variation of density, and in rate of change of density. We saw also that the length of a pulsation may be accurately indicated in either of two ways: by the actual physical length of the pulsation as it exists in the atmosphere, or by the length of time required for its whole length to impinge upon the tympanum of the ear as the pulsation travels through the atmosphere, and that the frequency of these impingements manifests itself to the sensation of hearing in that characteristic of tone which we call pitch. We saw, too, that the variation in density of the pulsation manifests itself to the sense of hearing it that tone characteristic which we call intensity or loudness. And, finally, we saw that the rate of change of density in a pulsation manifests itself to the sense of hearing in that characteristic of tone which we call tone quality or tone color. Let us consider the advisability of investigating each of these tone characteristics, pitch, intensity, and tone color.

So far as the writer can see there is no occasion for further investigation of methods for the measurement of pitch, for the frequency of the pulsation producing a given pitch can even now be measured with far greater accuracy than is at all necessary for any need of music at present discernible. We shall see in Chapter 12 that a difference in pitch of one-third of a pulsation is about the smallest difference the most acutely trained ear is able to distinguish if the tones compared are sounded in succession, but that still smaller differences may perhaps manifest themselves to the ear as a change of harmonic color provided the tone whose pitch is being examined be sounded simultaneously with other tones whose pitches are fixed. But, even so, present accuracy in the measurement of pitch is entirely adequate; for Professor Miller states (*Science of Musical Sounds,* p. 40) that, with the aid of a clock-fork, the pitch of a tone may be measured to the ten-thousandth part of a pulsation.

Certainly there is no need for further investigation in the velocity of sound. The amount of expert effort that has been wasted on this barren inquiry is almost incredible. Two centuries of work on the subject enables us to do no better than to say that sound *probably* travels *between* 1165 feet and 1170 feet per second through air at a temperature of 68° Fahrenheit under usual conditions of humidity. And, if we knew its precise velocity to the fraction of an inch, the information would be of no more value to us than the knowledge of how many angels can stand on the point of a needle. For the only musical value a knowledge of the velocity of sound possesses is by way of determining the actual physical length of a sound pulsation as it exists in the atmosphere, and there is no occasion for *precise* knowledge of this length; to know that the pulsation for middle C, for example, is somewhere between fifty-three and fifty-four inches in length, is quite accurate enough for all musical purposes.

It would be musically useful, however, to have more accurate information than we at present possess with respect to the effect of temperature and humidity upon the pitch of musical instruments. Every player of a string instrument knows that an increase of temperature flattens the pitch of his instrument, every player of an orchestral wind instrument knows that such an increase of temperature sharpens the pitch of his instrument, and every woodwind player knows that his instrument is sharper after it is warmed up than when it is cold; but no one possesses very accurate knowledge of the precise degree of flattening of string instruments or sharpening of orchestral wind instruments resulting either from a change of temperature in the concert hall or from a warming up of the instrument. These discrepancies of pitch are moreover matters of the most vital importance to professional musicians, and additional information with regard to them might possibly be of use in overcoming these difficulties. It is perhaps not impossible that the time will come when the musicians' union will specify the temperature of the hall in which a symphony orchestra may play. I am not at all certain they would not be justified in such action. But this is beside the point of our present discussion.

In connection with the work of the musical laboratory, students in a school of music should be given some elementary training in the measurement of pitch by the determination of pitch frequencies. Every pianist should possess sufficient ability in the recognition and counting of beats to tell whether his tuner has actually put his piano in tune when the job is finished and paid for. And every wind instrument player should have sufficient knowledge of the same kind to tell whether the manufacturer has properly tuned the instrument he purchases. The ear's accuracy with respect to musical intervals is not sufficient for the tuning of a wind instrument any more than for tuning a piano; and a wind instrument player frequently discovers, weeks after the purchase of an instrument, a discrepancy in its tuning for some tonality, which discrepancy he was unable to discover at the time of its purchase. A knowledge of the frequencies in the tempered scale, and some skill in the technique of determining these frequencies on his instrument by the counting of beats, would have enabled him to reject the instrument at the time of purchase.

There is most urgent and immediate need for apparatus suitable for study and training in pitch discrimination for other intervals than the unison. One of the crying needs of the musical profession is for better training in intonation. Years of arduous and expensive vocal study are often rendered useless because the vocalist is unable to sing on the pitch; and the same is frequently true of the violinist. But there is at present no standard of intonation by which the student either of voice or violin may be trained other than the piano, and the piano so used as a standard is frequently out of tune; furthermore there is no criterion for determining how closely the student approaches even the tuning of the piano except the teacher's ear, and the ear of the teacher is a most unreliable judge. It is not surprising, then, that an erratic ear which judges from the standpoint of an inaccurately tuned piano does not produce better intonation on the part of voice and violin students than is frequently the case. Physicists or psychologists should produce a device embodying some standard of the scale more accurate than the dubiously tuned piano of the teacher, and utilizing a more reliable criterion as to accuracy of the student's results than the more-than-questionable ear of the teacher. The stroboscopic devices at present in use, of which the tonoscope is an example, are entirely inadequate for judging accuracy of melodic line as it is employed in professional music; and this is the only kind of judgment that has any practical value for the training of prospective musicians.

It is possible to construct a piece of apparatus before which the vocalist could sing, or the violinist or wind instrumentalist could play his music, and that would show to the eye note by note the degree of accuracy with which the musician approaches the melodic line attempted. A device of this sort would be of the greatest possible value in the correction of faults of intonation upon the part of professional singers and instrumentalists, and should find an immediate place in the studio of every teacher of voice or of the bowed or wind instruments. Many an investment of $25,000.00 to $50,000.00 in preparation for a vocal career, now rendered valueless because of the debutant musician's faulty intonation, could be salvaged by this means. The writer has not the slightest sympathy with the ill considered pronouncemnts of some that pitch production can not be improved by training. The contention is not only untrue, it is vicious. The construction of a device for visually judging the accuracy of melodic line employed in practical professional music should be one of the earliest tasks of the musical laboratory.

So much for the work of that part of the musical laboratory having to do with study of the length of the sound pulsation, its frequency, and the pitch of the tone produced by it. We have seen that there is no need for great precision regarding the length of the actual pulsation as it exists in the atmosphere, and that we are able to measure the pitch of isolated musical tones with much greater accuracy than we have any apparent musical need for, but that there should be furnished to students of music some elementary training in the measurement of pitch by the counting of beats, and that there is most urgent and immediate need for the construction by physicists or psychologists of some device to show precisely the degree of accuracy with which the musician approaches the melodic line attempted in the practical production of music. Now to consider the present status of our knowledge with respect to tone intensity, and our immediate needs in that direction if any.

The measurement of tone intensity is one of exceptional difficulty just at the present time, but one of the greatest musical importance and urgency. What respective numbers of sopranos, altos, tenors and basses should be used in order to provide a well balanced chorus? How many strings should there be in a symphony orchestra as compared with the woodwinds and brasses, and how many 'cellos and doublebasses as compared with the violas and violins? How much is gained by doubling the size of a symphony orchestra? Does the addition of a dozen more players justify the additional expense? In view of the annual deficit for the orchestral season and the difficulty of meeting it, is it permissible to reduce somewhat the size of the orchestra? No academic questions these; they are sometimes life-and-death matters for musical organizations; and we shall never be able to do any better than guess at their answers until physicists and psychologists work out in the laboratory a practicable method for the measurement of sound intensity. Until that time the orchestral conductor will guess that he needs more players, the board of directors will guess that he can get along without them, and neither will have any way of determining whether the respective guesses have been right or wrong.

The Bell Laboratories have devised a method of measuring sound intensities that seems to be satisfactory except for the expense involved. The method there employed requires the use of a large amount of complicated apparatus, and the technique involved in using it is so delicate that only those of the highest engineering skill are capable of conducting the measurements. It is possible, however, that further investigation might develop a simplification of the method or discover a new method less complicated and expensive. This would be highly desirable indeed for musical purposes if it were possible. In case it is not possible, then the next most desirable solution of the difficulty with respect to music is the compilation by present methods of measurement of a set of dynamic constants for the various musical instruments employed in the commoner instrumental ensembles: the symphony orchestra, the jazz orchestra, the chamber music ensembles, and the band. This set of constants should show the maximum and minimum tone intensities of all the musical instruments employed in these ensembles for representative notes throughout their respective compasses. For example, the maximum and minimum tone intensities of typical notes, both stopped and open, on each string of the violin should be measured and the results entered in the prospective table of dynamic constants. And the same should be done for the viola, the 'cello, and the doublebass. Similarly, the maximum and minimum tone intensities for representative notes throughout the compass of all the woodwind, brass, and percussion instruments should be measured and entered in the table. Measurements of tone intensities should also be made for increasing numbers of instruments playing the same part, so that it might be known precisely what gain in volume is made by increasing the number of instruments assigned to a given part. When all this had been done, then both conductors of musical organizations and those who employ their services would possess positive knowledge as to the most effective and economical instrumental combinations for musical ensembles of various kinds and sizes. In all probability it would be discovered that there is a great deal of money injudiciously expended through the utilization of ineffective instrumental combinations.

It should not be difficult to induce the Bell Laboratories to undertake the compilation of these dynamic constants for musical instruments; for these laboratories are closely related to the American Telephone and Telegraph Company, and the latter concern is deeply interested in music as utilized in radio work. If, for example, a band of fifty men is to be employed for broadcasting purposes, it is of very vital interest to those who bear the expense to know they are getting the most efficient possible combination for their money. Musical conductors are more than willing to do the best they know in the matter of instrumentation as in other matters; but, in determining the best possible assignment of instruments for their organizations, they are handicapped because of a lack of positive knowledge respecting the comparative dynamic values of the various instruments they utilize, and the best conductors are precisely the ones who most realize the seriousness of this handicap. That the difficulty is realized by the musical profession is evidenced by the fact that at least two of the later writers on instrumentation, Rimsky-Korsakov and Clappé, have attempted to make estimates of the dynamic values of the instruments used in the orchestra and the band, Rimsky-Korsakov making estimates for the instruments of the orchestra and Clappé for the instruments of the band; but, of course, both were compelled to content themselves with guesses since there was nothing else to do.

The technique for the study of tone quality is already well developed, and considerable work in this field has been done at the Case School of Applied Science. There are two effective methods of investigating tone quality at present in use. The method involving the use of the phonodeik is doubtless the more beautiful and powerful of the two, but it is also the more expensive. The method in use at the Bell Laboratories is much more expeditious and inexpensive, "the operations are entirely automatic so that it requires only about five minutes from the time the machine is started until a completed picture of the sound spectrum comes out of the camera-box" (Fletcher: "Physical Criterion For Determining Musical Pitch," Phys. Rev. 2d ser., vol. 23, no. 3); but the completed analysis furnished by this method is not presented in so graphic and convincing a form as in the graph produced by the phonodeik.

A well ordered musical laboratory should carry the work of tone analysis much further than has yet been done. It is highly desirable that the tone quality of each note on a musical instrument should be carefully analyzed as a means toward evening the scale of that instrument from the standpoint of tone quality. It frequently occurs that neighboring notes on a musical instrument differ so much in tone quality that it is almost impossible to use the instrument in certain tonalities; this is the case, for example, with the clarinet. In order to remedy such a defect it should be possible to compare the tone qualities of these notes more accurately than is possible with the naked ear, and thus to bring the faulty note into agreement with the better one. Musical instruments will never have as even scales as it is possible to give them until a more accurate method for comparing the qualities of their notes is devised than that furnished by the naked ear. There is scarcely a musical instrument in existence whose scale is not open to serious objection because of unevenness in tone quality; and one of the most important aspects of the work of a musical laboratory would be the devising of ways and means for the improvement of musical instruments. An exhaustive analysis of the tone quality of each note produced by a musical instrument would be one of the important means to this end.

But a musical laboratory should devote a part of its attention to the study of noise as distinguished from sounds which are musical. There are several reasons why this is advisable. In the first place there is an element of noise in the sounds produced by all musical instruments, and in some cases the noise element is so outstanding as to become decidedly objectionable. Ortmann has made a valuable study of the noise element in the tone of the piano, and presents the results of that study in Chapter 9 of his *Physical Basis of Piano Touch and Tone*. He recognizes four sources of noise in the tone of the piano: the impact of the finger upon the key, the impact of the hammer upon the string, the impact of the key against the key-bed, and friction noises of the action including the impact of the rebounding hammer; and he reports that the amount of noise produced by the playing of compositions such as the March Militaire of Schubert-Tausig, a Chopin Polonaise, or a Liszt Rhapsody is sufficient that the composition can be recognized, in an adjoining room separated from the piano by a solid wall, through the rhythms produced by the noises of the instrument alone even when all the strings are damped so that they produce no musical tone whatsoever. The amount of noise produced by the playing of any of the orchestral instruments would surprise anyone who has never given the matter thought. These noises can be easily isolated in the case of the wind instruments simply by fingering them as would be necessary in playing music written for them, but without blowing into them to produce any tone. The noise so produced by any of the valve instruments is astonishingly large, but perhaps not any larger than that produced by the saxophone; the noises of the flute and clarinet are not so great, but it is still sufficient in the case of the clarinet to be quite objectionable. The bowed instruments are much less "noisy" than the wind instruments, but they are not entirely innocent in this respect. Of course it would be highly desirable to reduce to the minimum the incidental noises produced by an instrument in playing it, and it is entirely likely that musical instruments can be greatly improved in this respect by giving the matter intelligent and thoughtful consideration.

It is desirable to devote some study also to noises arising from other sources than the playing of musical instruments. The amount of noise to which the average individual is subjected is beyond all reason; and almost all of it could be eliminated. The subject is entirely too large to be given adequate treatment here, but it may be stated that most noises arise either from transportation, from factories, from building operations, or from thoughtless acts of persons. The subject is tempting, but it is impossible to enter into a discussion of it at the present time. Such a discussion would, however, arrive at this conclusion: by intelligent thought and action, the noises of a city like New York could be reduced in amount until they would not exceed those found at the present time in a community of 25,000 population; and that end could be attained without at all interfering with the efficiency either of the city as a whole or of its individual citizens; that efficiency would instead be tremendously increased. Indeed the economic waste due to impaired earning power of workers of every kind and class who are weakened by the nervous strain arising from noise is possibly the greatest single extravagance we moderns permit ourselves. In the absence of any other agency for the investigation of noises and of methods for minimizing them, the musical laboratory might well devote a portion of its attention to that subject.

So far we have been confining ourselves more or less closely to the work of that portion of the musical laboratory devoted to the study of sound in general. Let us next consider its work in what might be called the applications of sound, those utilized in music. One of the most important tasks of this division of the musical laboratory would be a study of the theory and design of musical instruments. The need for work in this field is not at all realized and appreciated. There is today not a single musical instrument of which it can be said that we know fully why it behaves the way it does; and, except for the flute and pipe organ, there is no instrument that has been made the subject of an exhaustive scientific study. It would naturally be supposed, by those familiar with the extent to which research is considered necessary to most branches of industry, that of course the manufacturers of musical instruments would maintain research laboratories for the improvement of their product; but this is not at all the case. In the whole world I know of but one concern engaged in the manufacture of a musical instrument that maintains a laboratory of sufficient importance and seriousness of purpose that its work may fairly be designated as scientific; and that laboratory confines its investigations to a study of the reproduction of piano playing. In the investigation of the piano itself this laboratory is not interested, although it is conducted by the largest piano manufacturing concern in the world. Except for the present writer, I believe there is at present no one who is even attempting to give scientific thought to the improvement of musical instruments. A generation ago D. J. Blaikley was doing work in this line for one of the English concerns manufacturing band instruments; and splendid work he did, too. But Blaikley is retired and, so far as I know, there is no one else carrying on his work with that firm; probably because there is no one to do it. At about the same time on the continent Victor Mahillon, who wrote the articles on acoustics for the ninth edition of the *Encyclopaedia Britannica* and who was senior collaborator on the same articles for the current edition, was also doing valuable work along the same line as Blaikley; but Mahillon is dead without anyone to carry on his work. Musical instruments today are manufactured by rule of thumb handed down generation after generation from master-mechanic to apprentice, and no concern manufacturing musical instruments is in the slightest degree interested in improving them for the very good and sufficient reason that it is impossible to manufacture musical instruments badly enough that they will not find a ready market. Of course if some concern should break away from the present practice, establish a research laboratory and improve its product, its competitors would be compelled to do the same; but at present everyone is safe because no one takes the initiative. In the meantime, if anything is done toward the improvement of musical instruments it will have to be done by a musical laboratory or by some laboratory of a similar kind.

The specific needs of the various musical instruments and the possibilities of improving them are treated in considerable detail in Chapters 14 to 18, and will therefore not be presented here. It need only be noted at the present time that a musical instrument is purely and simply a piece of physical apparatus, and that compared with a dynamo or a gas engine it is usually a very simple piece of apparatus—so simple in fact that almost anyone can construct it after a fashion. The manufacture of musical instruments is a branch of industry that has not yet been touched by science; but a generation or so of the application of scientific principles to their manufacture would produce as great improvements in them as we have seen in either the dynamo or the gas engine. If manufacturers in other lines realized the crude and primitive condition of musical instruments as at present constructed, and the possibilities that exist for improving them by scientific treatment, we should find them in a wild scramble to get out of more highly competitive manufacturing lines into this; and the result would be a tremendous improvement of musical instruments, and therefore of music itself; for the music of any age depends upon the kind of musical instruments which that age possesses. *Composers can go no further than the possibilities of the instruments for which they write.*

And this suggests the next task of the musical laboratory: the design of musical instruments utilizing entirely new methods of tone production. It is not reasonable to suppose that a laboratory could give continuous and serious attention to the study of sound as a general physical phenomenon without occasionally discovering new methods of producing sound; and some of these new methods could undoubtedly be utilized for the construction of musical instruments. As an illustration of what is here meant by new methods of tone production, attention may be called to the vacuum tube oscillator which has come into use in recent years as a means of producing a musical tone from electricity. It should be remembered in this connection that we at present utilize but few methods of sound production that are employed for the production of music: we may use a string that is bowed, plucked or struck; we may use a single or double reed that is made to flutter back and forth by blowing upon it; we may use a stream of air which flutters back and forth into and out of a pipe of the flute type; we may cause the lips to flutter back and forth in the mouthpiece of the brass instruments; or we may use a piece of wood or metal or stretched skin to beat upon; and these complete the list of the means at present utilized for the production of tones in musical instruments. It seems hardly possible that there are not other methods of producing tones that could be utilized musically, and that the systematic study of sound would not lead to the discovery of some of them.

Except for the flute and the pipe organ the improvements made on musical instruments up to the present time have been made through the method of blind trial and error. Blind trial and error is a better method than none in the discovery of useful facts; but it is not efficient, and is excessively profligate of human resources. The study of science for the past century or so has pointed the way to a much better, a much more economical method of arriving at new truths desired: the method of trial and error *guided by a fund of well established facts* governing the conditions that surround the trial made. The seeker after new truths is no longer compelled in his quest to grope entirely in the dark; he has at least a feeble light to guide his footsteps into reasonable pathways toward their retreats, and that light is furnished by the proved and well known facts regarding the nature of the field to be explored. It is this knowledge of well established facts about the territory to be examined that makes for efficiency in the investigations of such institutions as the Bell Laboratories and the laboratories of the General Electric Company or the Eastman Company; it is the lack of such knowledge that accounts for slow and halting progress in the improvement of musical instruments. A generation or so of efficient scientific investigation of music and musical instruments would show as astonishing and momentous developments, in the production of better musical instruments and better music as have been witnessed in recent years in telephony and electrical engineering. Blind leaders of the blind can hardly be expected to win in the race of modern industry.

But individual musical instruments are in no greater need of improvement through expert scientific experimentation than is that complicated musical instrument which we call the orchestra. The investigation of problems of orchestration is today left entirely to the unassisted imagination of the composer. It is quite possible that the most surprised individual at the premier of a new orchestral composition is the composer himself. His reaction might very easily be, "Well, is that the way it sounds!" The orchestral composer labors under peculiar and often almost insurmountable difficulties, for he has no way of ascertaining before public performance whether his instrumentation will produce the effect he has in mind because he has no instrument on which he can try it out. Melodies and counter melodies he can test on the piano; but these are precisely the factors which need no test, he already knows how they will sound. And the harmonies he has employed he can approximate on the piano, although a given harmony on the piano and on a combination of orchestral instruments are two quite different things. But the tone colors imparted to melodies or harmonies by the instruments of the orchestra must be left entirely to his imagination; he has no orchestra with which to test these factors. The best he can do is to guess as accurately as possible regarding the effects he will attain, put his composition into final form for public performance, and trust to luck—and to the tender mercies of a critical public. The odds against him are too strong to afford a fair chance.

What can be done to more nearly even the odds? Again, the difficulty arises from a lack of sufficiently accurate and detailed information; and this lack the laboratory of instrumentation would supply. The first duty of such a laboratory would be to compile a reference library of records of orchestral instruments playing in every conceivable combination. If, when such a reference library had been compiled, a composer wished to know the effect, for example, of a bassoon melody against a viola counter melody with a background of eight-part harmony furnished, let us say, by pianissimo rolls on the timpani, he could go to a library attendant and, if the library were sufficiently complete, be furnished with a record of precisely such a combination of instruments. Having secured his record, the composer could take it to the sound booth for leisurely study and comparison with his tentative score. The record, or other records along similar lines, would perhaps furnish him with all the information he could desire. If not, then he would go to the orchestral laboratory proper where his score would be tried out by players on the instruments themselves, and a record be made of it for future reference and filed in the library. This audition of his score on the instruments themselves would very quickly and very positively settle all the questions in the composer's mind, and enable him to secure precisely the effect he was seeking. How superior to present conditions such facilities would be for the composer in instrumenting his composition can easily be understood; and composers would respond to such improved conditions by producing compositions correspondingly superior to their present output. A good workman is entitled to good tools; if we are interested in having superior compositions produced for our enjoyment, let us provide reasonable facilities for their production.

We have noted the importance of studying the applications of sound as a means to the improvement of musical instruments and instrumentation; but such a study is equally important for the purpose of discovering the nature of harmony and melody, as a means toward the composition of more effective music. It must not be forgotten that we as yet know but little of the nature of harmony, and almost nothing of the nature of melody. There are those who would have it that these are matter entirely past all finding out; but there are also those who are not yet willing to affirm positively the impossibility of the problem. An attempt was made in Chapter 5 to outline a theory of harmony and melody, and in Chapter 12 hereafter some suggestions will be offered as to possible future developments in harmony. The nature of harmony and melody may, or may not, be subject to analysis and reduction to simple terms; but, if they should be found subject to such explanation, it would almost certainly follow that the simplified point of view so obtained would provide a new outlook upon harmonic and melodic possibilities that could be utilized advantageously for purposes of musical composition. The prize is undoubtedly more than worth the attempt, and the investigation of harmony and melody should be one of the important tasks of the musical laboratory.

The laboratory would inevitably be compelled to devote a considerable part of its attention to investigations of hearing; for hearing is the sensory manifestation of the physical phenomenon which we call sound, and is the ultimate goal toward which all musical activities tend. Indeed, we have no possible interest in sound, either musical or otherwise, except in so far as it becomes a stimulus for hearing; and hearing as affected by sound is the culmination of all our inquiries. Fortunately, much of the ground to be covered in the investigation of hearing could be safely left to investigators outside the musical laboratory. The nature of speech sounds, and the manner in which they affect the sense of hearing through the mechanism of the ear, is so intimately related to telephony, and the researches of the Bell Laboratories are so exhaustive and painstaking, that these matters may wisely be left to the researchers of that organization.

Mention was made above of the importance for musical purposes of the measurement of sound intensities for various musical instruments. So used, the term "sound intensity" is a bit too loose to be definite; "loudness" is the more precise statement of that which has importance from the standpoint of music, and loudness is a psychological rather than a physical phenomenon. Moreover, the quantitative relationship between an increase of density in an atmospheric pulsation and the increase in loudness of the resulting sensation is a relationship that can not be expressed in simple terms. This relationship as computed by Steinberg of the Bell Laboratories ("Relationship Between the Loudness of a Sound and its Physical Stimulus," Physical Review, Oct. 1925) is possibly too complicated to be expressed in any but mathematical terms, but this much at least may be said: in respect to loudness, the ear does not report things as they occur in the atmosphere; however, the loudness of a sensation may be accurately computed when its atmospheric disturbance has been accurately measured. To determine the loudness of the tone produced by any musical instrument, then, it is necessary first to measure the atmospheric disturbance it produces and next to compute what the effect of that disturbance will be upon the sensation of hearing through the mechanism of the ear. This may, perhaps, serve to illustrate both the thoroughness and the character of some of the investigations conducted at the Bell Laboratories.

It is entirely possible, however, that some matters connected even with speech and hearing, in which the musician would have a decided interest, would never be investigated by these laboratories because they are not of sufficient interest for telephony. They may, undoubtedly, be depended upon to explore the field of speech and its effect upon hearing; but whether they ever do the same for singing is not quite so certain. Speech utilizes sounds of two kinds: musical tones involving the use of the vocal cords, of which the vowels are examples, and noises with or without the use of the vocal cords, as represented by many of the consonants. For purposes of speech, the noises and the musical tones are of about equal importance; but, for purposes of singing, the consonantal noise sounds are minimized as much as possible and the musical tones of the vowels are correspondingly emphasized. There is a second distinction between speech and singing: singing employs a melody based upon pitch intervals never less than a semitone and frequently greater, while speech employs a melody based upon pitch intervals much smaller than a semitone as a general rule; moreover, the compass within which the melody of speech is permitted to oscillate is quite limited, while the compass of the melody for singing may be an octave or more. It is conceivable that the Bell Laboratories, through their possible interest in speech melody, might be led to the investigation of singing melody also; but, if not, then the investigation of singing would probably fall upon the musical laboratory without outside assistance. And the importance of investigating singing is obvious; it is discussed in some detail in Chapter 18.

One very important field in which there is great need for study is in acuity of pitch discrimination for intervals other than the unison. Psychologists have already done considerable work in acuity of pitch discrimination for the unison, but I do not know of any work that has yet been done in pitch acuity for other intervals; and it is precisely the other intervals which are of most interest and musical importance. It is, of course, desirable to know how small a deviation from a unison can be recognized by the ear; but it is much more desirable to know how small a deviation from the major and minor seconds and thirds, the fourths, the fifths, and the major and minor sixths and sevenths and the octave, the ear is able to recognize, for these are the intervals most useful for musical purposes. No musician except the singer ever has another instrument as a crutch to lean upon and to determine the pitch of the notes he must produce; and the singer should be ashamed of it—but usually is not. Other musicians must take the pitch of their next note by moving upward or downward by some diatonic or chromatic interval; and it is highly desirable to know how reliable the ear is as a guide for the taking of these intervals. As stated above, I do not know of any studies along these most important lines. It would be my guess that the ear would be found fairly reliable for intervals of the octave, the fifth and the fourth, but quite unreliable for all other intervals. This guess is based upon the belief that the tempered scale of the piano has not greatly contaminated the ear for the octaves, fourths and fifths, which are approximately correct on the piano, but that it has practically ruined the ear for the other intervals. Having determined the intervals for which the ear is at fault, training could then be addressed toward its correction for these faulty intervals. And, as heretofore stated, faulty intonation is one of the most serious handicaps against which the young musician is called upon to struggle.

Further study of the criteria for the testing of musical ability is also greatly needed. The tests at present in rather general use are entirely too unreliable to warrant the confidence placed in them.

Teachers both in elementary schools and in professional schools of music attach an importance to them to which they are not at all entitled. Students are frequently accepted or rejected by sincere but ill advised teachers of music upon the basis of these tests, when it is rather the tests themselves that should be rejected. To satisfy his curiosity on the subject, one of the leading musical educators in America took these tests along with several thousands of children for whose musical education he was held responsible; he failed, with a grade of 40 percent! And yet this man is at the top of the profession in American music education, and was an eminently successful professional musician before entering the field of music education. I suggest the giving of these tests to a large number of professional musicians of recognized standing as a means of testing the tests! All measuring instruments have to be calibrated occasionally.

The musical laboratory would need a department also for the study of rhythm, and for the discovery of new rhythms that might be musically useful. Rhythm, melody and harmony constitute the backbone of music; they are the primary factors, and the other factors named in Chapter 6 are derivative and secondary. We need to know as much as possible about rhythm, melody and harmony; and the only way to acquire further information about them is to give them sincere and protracted study. Methods for the investigation of rhythm will be discussed in detail in Chapter 13; the matter is mentioned here only by way of indicating that it is a subject to which the musical laboratory should give attention, and that the subject is one that is properly assigned to the psychological division of that laboratory; for rhythm is more nearly a psychological than a physical phenomenon. In its physical aspect rhythm is too simple to deserve much attention, but its implications are of great importance psychologically, and perhaps even morally.

We have noted very briefly, and with insufficient elaboration no doubt, some of the matters which might justifiably engage the attention of a musical laboratory as initial studies during its earlier days. As the work progressed, the field of its investigations would of course all the time grow wider and deeper. Increased knowledge naturally brings an increase of questions to be answered and problems to be solved; indeed, the scholar is essentially an individual who knows enough about his subject to ask intelligent questions in regard to it, and has acquired the knack of finding answers to a few of his questions. How was it that Newton expressed the idea? "I do not know what I may appear to the world, but to myself I seem to have been only like a boy playing on the seashore and diverting myself in now and then finding a smoother pebble or a prettier shell than ordinary, whilst the great ocean of truth lay all undiscovered before me."

PART TWO

MUSIC AS AN ART

CHAPTER VIII

MAN AND MUSIC

To UNDERSTAND why man brought music into his life it is necessary to take a glimpse into the conditions of that life and to discover if possible his need for music. The need for it being recognized, it will then be easier to comprehend his efforts to supply that need and to trace the steps by which the end was attained.

Of our five major senses, those of touch and taste are quite unable to furnish us with any information about objects unless the objects are in immediate contact with the sense organs. If we are to receive a tactual impression of any object, that object must be brought into physical contact with some part of the body. If we are to taste an object, it must be placed in the mouth and minute portions of it must be dissolved so that they may be carried to the taste organs deeply buried in the tongue.

But to stimulate the sense of smell the object need not be in immediate contact with the organs of smell, indeed it may be removed at a considerable distance. Minute portions of the object, or gasses from it, are borne on the atmosphere to stimulate the organs of smell. With some animals the sense of smell can reach much farther than with man. It is possible that primitive man had a sense of smell which was more acute, but with civilized man its reach is but a few yards at best. At any rate civilized man is much inferior to many other animals so far as smell is concerned.

Hearing is effective over much greater distances than smell, but the sense with the longest reach of all is sight. With primitive man, and with the other animals, sight reported the enemy at the greatest distance of any of the senses—if he was not behind something.

In that case, it was necessary to depend for warning against the enemy upon smell or hearing. This was also the case during sleep; and sleep has always been unavoidable. It is "nature's great restorer," and without it the physical organism would soon be worn out and its active existence ended. Sleep is approximate unconsciousness attained for the purpose of suspending voluntary activities that the system may have a better opportunity to recuperate, and we are entirely unable to get along without it.

Now upon what shall the animal depend during sleep for protection against the enemy? The eyes are closed and, so far as the sense of sight is concerned, the enemy is quite at liberty to steal safely upon his catch. If during sleep the senses of hearing and smell were supplied with means of cutting them off effectively from receiving sense impressions, as the eyes are supplied with lids, the sleeping animal would be entirely unprotected against the enemy stalking him and would soon be exterminated. At least one of the senses capable of acting over a considerable distance must be left on guard if the animal is to survive the sleep necessary for physical recuperation. And the most effective of the two senses able to act over a distance during sleep is that of hearing, because of the fact that its reach is much farther than that of smell.

It is possible that the necessity for leaving the sense of hearing on guard during sleep is the reason why our ears are not supplied with flaps as our eyes are with lids. This would seem to be indicated by a comparison of human ears with those of certain other animals. Some animals have ears much less effectively shaped than others for protection against the enemy during sleep. Human ears are entirely open, asleep or awake, for the reception of sounds. The ears of the horse and the dog are not very effective in reporting sounds unless they are turned toward the source of the sound, and are in consequence much less reliable as protection against the enemy during sleep than human ears. The enemy of the sleeping horse or dog is able to steal much nearer than is the human enemy; and the horse or dog, once awakened, found it necessary to run much faster to escape his enemy than did the human animal. Possibly this is why the horse and the dog are more fleet than man. The rabbit sleeps with his ears laid close along his neck shutting out sounds almost completely; and, for his size, the rabbit is much more fleet than either the horse or the dog. Some varieties of domesticated dogs have ears with long flaps that very effectively shut out sounds during sleep, but the protected condition of their domesticated existence renders protection from the enemy unnecessary during sleep. Such dogs will usually be found to spend a greater portion of their time asleep than undomesticated dogs with more open ears. And of different species of domesticated animals those with ears more suitably shaped for closing spend more of their time asleep, generally speaking, than do those having open ears.

While the extremely open shape of the human ear was no doubt very useful for protection from the enemy during sleep under primitive conditions, that shape has become an unqualified nuisance under the highly mechanized conditions of modern civilization. We no longer depend upon our ears for protection from danger during sleep, but take our sleep in cubicles as effectively closed against the enemy as may be necessary or desired. The dog, the rabbit, the donkey, whose ears we contemplate with a smug superciliousness due only to our ignorance of their undoubtedly superior adaptation to the present environment, all these are able to shut out the sounds which interfere with their sleep, while we poor humans are entirely unable at any time to shield ourselves from sounds however much we may wish to do so.

From the cradle to the grave our ears are bombarded with sounds. Go where we will, in city or forest, on land or at sea, sounds still pursue us. The airman can not escape them, they follow the miner into the depths of the earth. Even when we are asleep they creep through the ears into consciousness and give rise to dreams. Only complete unconsciousness or death can deliver us from the tyranny of sounds.

It is not so with the other senses. Only occasionally is touch, taste or smell sufficiently stimulated to cross the threshold of consciousness. Sight can be terminated at will by a simple lowering of the eyelids, and nature herself gives half-time off from seeing by the device of nightly darkness. But the whole of conscious life is spent in a weltering sea of sound.

Most sounds are unpleasant. The hissing of steam, the clatter and roar of transportation, the shrieking of cars rounding a curve, the blatant honking of vehicular traffic, the deafening rattle of the riveter's hammer, the shrilling voices of the market, would drive us to madness did we not like beasts of burden becomes somewhat accustomed to our afflictions. And, as modern life becomes more and more complex, the more intolerable become its sounds.

It was not always so. In early days there was a time of such Arcadian simplicity that its sounds were agreeable. The gentle rustling of leaves and swish of water, the chirping of insects, the hum of bees, the singing of birds, soothed and calmed man's spirit instead of ruffling it. When man spent his days in the fields or forests or upon the mountains, his nerves were not worn ragged by ugly sounds. But Arcady is gone and the din of industry is here; and, from the standpoint of sound, it is an evil world in which we live.

Man early began to regard certain of the sounds about him as more agreeable than others. He saw no way to deliver himself from unpleasant sounds, but perhaps he might neutralize these by surrounding himself with sounds that were pleasant. Could he make pleasant sounds? It was not long until he found he had this ability. If he blew against the edge of a hollow reed, he discovered that a very pleasant sound was brought forth; it was mellow, soothing, soft. And he could *make* it, just as his woman made fire! When he blew a little harder he found he could make another sound; that was two. The two sounds were alike, in a way; yet they were different, too. But they both sounded pleasant. As he gained proficiency he learned that he could make five or six sounds on the same reed. That was quite a family of sounds for one reed.

He wondered if he could make sounds with another reed. He would try a long reed. Yes, the long reed made sounds too, a family of them. But they were different sounds than those made by the first reed. He would see what would happen with a short reed. Again a family of sounds different from those of the other two families. But all the sounds were pleasant. One day he found a reed just the length of the first, and it made sounds just like the first—alike in every way, no difference at all. He tried a third reed of the same length and it made sounds exactly like the other two. Now he knew how to get reeds that would make sounds exactly alike; then he and his companions had fine times making sounds together, the same sounds at the same time.

Later he made another discovery: if he pressed the end of an open reed squarely and firmly against both his lips and blew into it, this also made a sound. It was not such a very good sound; but it was not such a bad sound either after he became more used to the new method. It was a very interesting game when he had time for it. Finally he learned that the hollow horn of an animal with the tip cut off made better sounds by this new method than the reed. He could, with the horn, make just such a family of sounds as by blowing against the end of the reed.

As time passed he and his companions succeeded in making many kinds of instruments to produce pleasant sounds: instruments to blow, instruments to beat upon, instruments with strings to be plucked or rubbed with a bow-string. They also learned to make pleasant sounds with their voices, imitating the sounds of their instruments. Many pleasant times they had together making sounds. And they found the sounds helpful in many ways: when they went to battle, when they worshipped, when they danced, when they drove out evil spirits. The making of pleasant sounds with their own voices was helpful, too, when they were at their work; it seemed to make their tasks easier.

From man's earliest days to the present he has always made music as a means of relieving the irksomeness of his condition. In what activities has music been of service to him? He has found it useful in war, in revelry, in labor, in worship, and in healing the sick. In all lands and ages music has been utilized as an inspiration to battle. From the siege of Jericho to the battle of the Marne the value of music in establishing and maintaining military morale has been most highly esteemed. It is doubtful whether a war could be fought without music any more than it could without explosives or whatever else might be used as the physical agent of destruction. Music is a spiritual priming used to produce the physical detonation of war. As the cap is to the rifle, so music is to the army. So long as men indulge in war, so long will music be employed as its necessary incitant. Even if war should ultimately become a contest of machines alone music would probably still be used to raise funds to construct the machines; witness the bond campaigns of the late world war.

Music has also been found of especial value as an aid to labor, particularly where the labor is of such nature as to require concerted bodily movements. The heaving of the Volga boatmen immortalized a Russian folk melody; the negro chain-gang breaking stone gave birth to the "Hammer Song"; the sailor's heavier tasks are lightened by the chantey; the handling of cotton bales by colored longshoremen is facilitated by the crooning of a strongly rhythmic melody; and rather tardily modern industry is beginning to learn that a lively tune will speed up lagging fingers and furnish grateful relief to aching muscles.

But the activity which finds itself completely dependent upon music is dancing. It is doubtful whether dancing would be at all possible without music. This appears the more reasonable when it is remembered that the earliest form of music was rhythmic only, entirely without melody or harmony. A group of negro children patting to the dancing of one of their number is a survival of the first of all methods for producing music. This hand-and-foot-patting. however, soon gave place to the more efficient methods of the rattle and the drum. Dancing is rhythmic movement of the body with no other end in view than such movement alone; and the auditory accentuation of this rhythm is music of a primitive kind. The complete dependence of dancing upon music is thus apparent; whatever the occasion for the dance, it must have its musical setting.

Music has always been closely associated with religious worship. The extent to which music contributes to the state of ecstasy constituting worship is indeed a question. Can this ecstatic condition be fully induced without bringing to bear upon the worshiper the powerful influence of music? It may well be doubted. Worship is essentially a state of feeling rather than of thinking. The devotee enters his holy of holies when he attains a feeling of oneness with divinity; and this feeling is perhaps more completely attained through the influence of music than by any other means. It may well be that music establishes more intimate touch with divinity than anything else. Nor is it meant to confine this potency to "sacred" music alone; any music is sacred that engenders gentleness.

Like the priest, the medicine-man has always employed music more or less in his ministrations. The driving out of an evil spirit, and the production of anaesthesia for a surgical operation, have alike been found occasions where music might be turned to advantageous account. Its specific use in mental and nervous diseases and as a means to general convalescence is coming more and more to be appreciated. As a spiritual purgative for the hypochondriac its value must have been noted by many a music lover subject to that malady. And it appears probable that the therapeutic value of music is much greater than is yet understood.

But the most frequent use of music is not as a means to any end, whether war, work, worship, or cure of disease, but as an end in itself: the frank enjoyment of music without any ulterior thought or purpose but simple relief from the general irksomeness of life. It is out of such conditions as these that music has arisen. Man found himself plunged into a world of unpleasant sounds from which he could in no wise escape. To alleviate his condition, man undertook to create for himself a world of beautiful sounds; and, having created a sound-world that was beautiful, he called it *Music.*

In what way does this world of beautiful sounds differ from that world of sounds which are not beautiful—what is the nature of musical beauty? We shall endeavor to find out, if possible, in the next chapter.

CHAPTER IX

THE NATURE OF MUSICAL BEAUTY

"I am quite at one with those who hold that the ultimate worth of the beautiful must ever depend upon the immediate verdict of the feelings. . . . The beauty of a composition . . . inheres in the combinations of musical sounds, and is independent of all extra-musical notions."—HANSLICK: *The Beautiful in Music.*

"La musique est un acte spéciale de l'intelligence intervenent dans le chaos de a vie affective pour y mettre ordre et beauté. . . . Directment, la musique ne peut traduire aucun sentiment déterminé; mais, de la vie psychique elle traduit l'intensité, le dynamisme intérieure et général, avec tous ses degrés. . . . Elle néglige les représentations el les concepts qui accompanent l'état affective; elle n'en retirent que l'énergie. . . . Elle est pour ainsi dire le dynamometre de la vie sentimentale. . . . La musique atteint donc la personalité dans son essence. En s'attachant à reproduire le dynamisme de la passion prise à sa source profonde, et rien de plus (pour ce qui concerne l'imitation directe), la musique acquiert autant de généralité que se puissance; car cette énergie dont ele marque l'intensité, ce n'est pas celle que déploie tel individu en aimant ou en détestant tel autre individu, c'est la force vitale elle-meme, prise à sa source, dégagée de toute les applications concretès et saisie dans son universitalité."

—COMBARIEU: *La Musique, Ses Lois et Son Evolution.*

THE NATURE OF MUSICAL BEAUTY

EVERY fundamental inquiry, whether in the field of science or of philosophy, starts out from at least one notion belonging uniquely to its own field which it is compelled to leave undefined; because, if that notion were defined in terms of some other, then that other notion would be left undefined, and so *ad infinitum*. In the field of arithmetic, number is left undefined; in geometry, it is distance, point and space that are undefined; in physics, it is space, time and force; in astronomy, space and time; in biology, life; in psychology, consciousness; in ethics, goodness; in logic, thinking; in metaphysics, being; etc. Sometimes an attempt is made to put a statement about these fundamental notions into the form of a definition, but the result is usually a circumlocution instead of a genuine definition; and, even if a real definition is attained, there is introduced in the course of the definition a new notion which still remains undefined. In the field of aesthetics, fundamental analysis can be pushed no further than the undefined notion "beauty" or the undefined notion "beautiful." If we attempt to define "beauty" we are compelled to say that it is that which gives rise to the judgment, "It is beautiful." And if we further attempt to explain what we mean by "beautiful," by asking why it is that we say a thing is "beautiful," then we are driven to some such circumlocution as, "It is beautiful because it possesses beauty"; we accomplish nothing in the way of a real definition because we have ended with the term "beauty" which we set out to define; we have merely reasoned in a circle. We are thus forced to define "beauty" in terms of "beautiful," or vice versa.

It appears more reasonable to define "beauty" in terms of "beautiful" than to reverse the definition. If we say a thing is beautiful because it possesses beauty, then we involve ourselves in the assumption that beauty is a quality possessed by the thing itself, which may circumscribe our analysis more strictly than we wish since it prevents us from taking the view that beauty inheres to any degree whatsoever in the beholder as distinguished from that which is beheld. But if beauty is something which inheres alone in the thing beheld, and does not depend in any degree upon the beholder himself, then any given object would make the same aesthetic appeal to every beholder; every person would say of it either "It is beautiful" or "It is not beautiful." But this is contrary to the facts; for of a given thing some people may say "It is beautiful" while others say "It is not beautiful." Nor, if we assume that beauty is a quality that inheres alone in the thing beheld, could we even say that beauty has any relationship to the beholder; for it is inconceivable that a relationship could exist between things totally unlike, which the beholder and the things beheld would be if beauty depended not at all upon the beholder.

But if, on the other hand, we define "beauty" as that which gives rise to the judgment, "It is beautiful," then we involve ourselves in no such limitation upon our analysis; for, in saying it is "that which gives rise to the judgment" that it is beautiful, we have made no assumption whatever as to whether beauty is a relationship existing between the beholder and the beheld, or whether it is something that inheres wholly in the beholder; we should still be prevented, however, from saying that beauty inheres exclusively in the thing beheld, because of our assumption that there can be no relationship between the beholder and the beheld if they are totally unlike, i. e., if beauty depends not at all upon the beholder. Let us therefore define beauty tentatively as follows: Beauty is that which gives rise to the judgment, "It is beautiful." This leaves us at liberty to affirm that beauty inheres entirely in the beholder, since this affirmation does not controvert the facts with respect to the differences of opinion which arise between different individuals respecting the beauty of a given thing; for we are agreed that individuals may differ from each other, but not that a given thing may differ from itself. This definition also leaves us at liberty to affirm, if we may finally wish to do so, that beauty inheres in part in the beholder and in part in the thing beheld and is a relationship between the two.

It appears, then, that beauty can not be a quality inhering exclusively in the thing beheld, but that it may be a quality inhering solely in the beholder, or that it may be a quality inhering partly in the beholder and partly in the thing beheld and be a relationship between the two. But, if we affirm that beauty inheres solely in the beholder, then it immediately becomes impossible for any person to say with certitude, "*It* is beautiful"; the utmost he can possibly say with certitude is, "*I regard* it as beautiful," and we have entirely eliminated the possibility of any standard of beauty. In this case, any statement to the effect that "*It* is beautiful" or "*It* is not beautiful," with respect to any given thing beheld, is entirely unwarranted, and the utmost any person could advisedly say with respect to a given thing is, "I like it," or "I do not like it"; beauty, as such, would have entirely disappeared, there would be no such thing as beauty, and the only thing that would remain would be the taste of the beholder.

In many ways this is an entirely permissible answer to the question as to the nature of beauty. The only objection to this view is that it fails entirely to account for any consensus of opinion with respect to the beauty of a given thing; if under this hypothesis *a sufficiently large number* of persons were to view a vivid sunset or an elevated railway, half of them in either case, as we know from statistical science, would say "It is beautiful" and the other half would say "It is not beautiful"; and the division of opinion would be precisely the same with respect to the beauty of a Gothic cathedral or a slum tenement, with respect to an "Ode to A Skylark" or a market report, with respect to a "Leonore" symphony or a beginner's efforts on the violin. Furthermore, if there is no standard of beauty, then it is useless for an artist to strive after the attainment of the beautiful, or to learn the technique of his art; for, no matter what he shall produce as an artist, one half of any *large number* of people will say of his work that it is beautiful and the other half will deny it, and one artist will succeed just as well as another either artistically or as a box-office attraction.

But these are conclusions which few will be willing to accept, and such as do not accept them are forced to abandon the position that beauty inheres solely in the beholder; and, since we have heretofore abandoned the view that beauty inheres solely in the thing beheld, it therefore becomes necessary to accept the alternative view that beauty inheres partly in the beholder, partly in the thing beheld, and is a relationship between the two. We are thus at present in a position to say: Beauty is that relationship between the beholder and the thing beheld that gives rise to the judgment, "It is beautiful."

What, now, is the nature of this relationship? Obviously there are two factors involved in the relationship: the beholder, and the thing beheld. Let us examine first the thing beheld. The thing beheld may be an object of nature, or it may be something produced by man; in the former case the beauty we experience is designated as natural beauty, in the latter case we designate it as artistic beauty; and, accordingly, we have two general classes of beauty, natural beauty and artistic beauty. The beauty of a sunset, of a landscape, of the human body, or a bird or any other animal, of the clouds, the sky, the sea, the mountains, of the flowers or other vegetation, all these we call natural beauties. But the beauty of a picture, on the other hand, or the beauty of a statue, a cathedral, a song or a symphony, a poem, an oration, a drama, a dance, a dress, a piece of jewelry, a rug, a piece of tapestry or of furniture, all these are beauties belonging to the field of art. Art, then, is that activity of man which results in the production of something which gives rise to the judgment, "It is beautiful."

Most of the arts make their appeal to us through the senses, particularly through the visual and the auditory senses. The mother of all the visual arts not utilizing motion is architecture, and from it has developed all the static visual arts: landscape architecture; interior decoration; the plastic arts, sculpture, carving, embossing, and certain aspects of silversmithing and costume; the graphic arts, drawing, painting, etching, engraving, and certain other aspects of silversmithing and costume. But there are two visual arts that employ motion: dancing, and miming in so far as the latter art is silent. There are other arts which are auditory in character, making their appeal through the sense of hearing: oratory, poetry and drama in so far as they are spoken, and music. But there are certain other arts which make their appeal not through the senses but through the intellect: all literature which is read instead of being spoken, fiction, essays, and all unspoken poetry and drama. The question might arise whether perfumery may not be called an olfactory art, and cooking a gustatory art. Probably this question will have to be answered in the negative because of the fact that we can not advisedly say of a perfume, or of a drink or a food, that "It is beautiful"; we must say rather, if we speak advisedly of a perfume or of a drink or food that satisfies us, that "It is good," by which we mean something slightly different than when we say "It is beautiful."

From another point of view the arts may be divided into two classes: the presentative arts and the representative arts, the representative arts being those which undertake to *represent* something other than the sense stimuli alone which serve as the vehicles through which they make their appeal, and the presentative arts being those which do not undertake to *represent* anything whatever but seek only to *present* to us certain sense stimuli which become immediately the means through which the feeling of beauty is aroused. Architecture, for example, and including landscape architecture, is not an art which seeks to *represent* anything whatever to us; it rather presents to us certain visual sense stimuli which become immediately the occasion for the judgment, "It is beautiful." A Gothic arch is beautiful, not because it *represents* to us something other than itself, but because it *presents* in itself something which is immediately and directly, and without the intervention of any kind of *tertium quid,* recognized as beautiful. Most of the plastic and graphic arts, on the other hand, undertake as a rule to *represent* something other than the sense stimuli which serve as the vehicles through which that other is offered for our contemplation: a statue, for example, usually attempts to *represent* to us something further than the lines and surfaces in three dimensions which serve as the vehicles for that representation, it undertakes to represent a human figure, perhaps; and a drawing usually attempts to *represent* to us something further than the two-dimensional lines and the third-dimensional perspective which themselves serve as vehicles for the representation; likewise a painting usually attempts to *represent* something further than lines, perspective and colors, it undertakes to represent a landscape, let us say. In so far as sculpture is considered as consisting of lines and surfaces only, or a drawing as consisting of lines and perspective only, or a painting of lines, perspective and colors only, to that extent these arts are *presentative;* but in so far as these arts are considered as consisting of anything more than lines, surfaces, perspective and colors, to that degree these arts are *representative* and not presentative. The arts utilizing motion, dancing and miming, possess both a presentational and a representational element: in so far as the movements *per se* of dancing or miming are recognized as beautiful, to that extent these arts are presentative; but to whatever extent they undertake to offer us anything further than pure movement *per se,* if for example the movements seek to tell a story, then to that extent these arts are representative. The literary arts, too, are both presentative and representative: in so far as the sounds of the words themselves are recognized as beautiful, to that extent the literary arts are presentative; but in so far as they attempt to tell a story or to paint a picture, to that degree they become representative arts.

It is obvious that music is one of the auditory arts, since it makes its approach to us only by way of the sense of hearing. But the question whether music is a presentative or a representative art is one which has raged through the pages of musical criticism ever since the day of Hanslick. The polemic literature of the subject has of course not employed the terminology "presentative" and "representative," but that has been the question nevertheless under other terminologies. According to Schopenhauer it was Goethe who first characterized architecture as "frozen music." There is at least one very important characteristic in which music and architecture are alike, in my opinion: they are both presentative arts and neither of them is representative, although neither Goethe nor Schopenhauer pointed out this common aspect. It is also undoubtedly true that music and architecture are alike in their employment of design; but, in this respect, music is no more like architecture than it is like painting or any of the other graphic or plastic arts; for music, architecture and the plastic and graphic arts all employ the principle of design. Indeed, if this is the only point of similarity between music and architecture, then Goethe might better have characterized painting as "frozen music"; for music employs the principle of color in a manner precisely analogous to its use in painting, which principle architecture does not employ. I am inclined to believe that the analogy between music and architecture runs deeper than the mere utilization of the principle of design, that music and architecture are alike in the fundamental respect that both are presentative instead of representative arts.

Let us consider further this question as to whether music is presentative or representative. Since music can reach us only by way of the auditory sense, and since the auditory sense can be stimulated only by sounds, then it becomes possible for us to paraphrase our problem into the inquiry, "Can musical sounds *represent* to us anything further than the sounds themselves, i. e., must their appeal be confined to the *presentation* of the sounds themselves?" To answer this question it will be necessary to examine as closely as possible both the musical sounds themselves and the individual contemplating them, for we defined beauty as that relationship between the beholder and the thing beheld that gives rise to the judgment, "It is beautiful"; and to discover the nature of this relationship between musical sounds and the person hearing them, we must understand if possible both the sounds and the auditor. Let us first consider the nature of the musical sounds, and then the nature of the individual comtemplating them.

We saw in Chapter 6 that the only factors entering into music are rhythm, melody, harmony, form, color, tempo, dynamics and nuance, and that nuance is a derivative of the other seven factors. The relationship known as musical beauty, then, must be one subsisting between the individual and some one or more of the seven factors, rhythm, melody, harmony, form, color, tempo and dynamics. It is evident, I think, that none of these factors is capable of presenting any concept to the individual as a concept. Take as an illustration the concept of thunder. Strauss, in his "Alpine Symphony," does undoubtedly present to the individual, more or less imperfectly, the percept of thunder, but not the concept. In so far as he succeeds in presenting thunder to the hearer it is presented as concrete thunder, not as thunder in the abstract. And the same is true of his presentation of the whistling of the wind in the same symphony, or of Respighi's presentation of the same natural phenomenon in "The Pines of Rome." And it is undoubtedly true that a few other sounds of nature can be concretely presented to the musical auditor more or less imperfectly, the degree of verisimilitude depending upon the faithfulness with which the sounds of nature can be imitated. It is conceded, then, that music can more or less imperfectly imitate sounds of nature as concrete phenomena, but it is insisted that music can not represent sounds of nature as abstract conceptions; nor is it possible for music to represent to the individual any abstract conception whatsoever. Indeed, *music can present to the hearer only concrete sense stimuli; it is entirely beyond the ability of music to present an abstraction of any kind whatsoever.* In a word, it may be said that music can, after a fashion, express a few of the nouns used in discourse provided the objects for which the nouns stand are such as produce sounds; for example, it is possible for music to express, rather incoherently, such nouns as "thunder," "wind," "water," "birds," and perhaps a very few other nouns. It is also possible, perhaps, for music to express a few verbs as predicated of nouns, such as "Wind whistles," "Thunder rolls," "Waves lash," "Birds sing," or "Horse runs." It is even conceivable that music could, in a very halting manner, express an occasional preposition of location, provided the sounds produced by the objects and the actions, for which the nouns and the verbs stand, are presented in proper sequence; for example, it might be possible in music to express very imperfectly the statement, "The horse runs into the forest," by imitating musically first the galloping of the horse and next imitating the whistling of the wind through the tree-tops. But at best such predicaticn could be expressed only very incoherently and with the utmost lack of precision. And it is only a very few nouns, verbs or prepositions which can be so expressed in music: nouns and verbs expressing objects and actions producing sounds, and a very few prepositions expressing location; all other nouns, verbs and prepositions used in discourse, and all the other parts of speech, such as adjectives, adverbs, conjunctions and pronouns, are entirely beyond the power of music to express. And, since all thinking is done in words, and can be done in no other manner, then, to the extent that music is unable to express the various parts of speech, to that precise extent music is unable to present discourse.

Let us, for example, consider to what extent music would be able to express the thoughts embodied in such discourse as, "Fourscore and seven years ago our fathers brought forth on this continent a new nation, conceived in liberty, and dedicated to the proposition that all men are created equal.'' In this sentence there are at least twenty-three distinct ideas that are conveyed to the mind by the words of the discourse. Of these twenty-three ideas, how many can music express? Can it express the idea ''Fourscore and seven''? No judicious person would contend that it can. Can it express ''years,'' or ''ago,'' or ''our,'' or ''fathers,'' or any one of the eighteen remaining ideas embodied in the sentence? Not a single one of the whole twenty-three ideas is at all capable of being expressed through the medium of music. And this illustration is typical of the inability of music to express all connected thought embodied in discourse.

What, then, would a composer do who undertook to set the Gettysburg Address to music? The only thing it would be possible for him to do would be to parallel, in the music, the feelings and emotions aroused by the words of the address, and to deepen and intensify those feelings and emotions, if possible, by such scoring as would be conducive to that end. He must confine himself to the emotional appeal that music is capable of making, and must entirely forego any attempt to express the abstractions that are embodied in the immortal language of the great commoner. If he succeeds in embodying in the music this emotional parallel to the feelings aroused by the address, and is further able to deepen and intensify those emotions, then he has done all that music is capable of doing; and, when he has accomplished this, he has done quite enough to justify his efforts, and perhaps enough to immortalize himself. What better could he do? Should he start out with eighty-seven notes from the percussion, and . . . ? Even the suggestion of such a procedure is nauseating.

What, then, becomes of the inane maunderings about Beethoven's having set forth a philosophy of life in his music, and of his C minor symphony being a drama of fate? I would be loath to deny to those persons whose psychoses are confined to such as can be awakened by the tabloid illustration or the movie screen, and who occasionally find themselves included by mistake in a concert audience, the privilege of concocting any picture or scenario to accompany the music that may add to their childish pleasures, provided only that they remain silent about it and allow those who came to enjoy the music an opportunity to do so. What they write in the columns of musical criticism we do not need to read, you know. And what shall we say of program music? In so far as music succeeds in *imitating the sounds of nature,* to that extent program music may succeed in painting a picture or in telling a story; but, to whatever extent program music utilizes any sounds not *directly and immediately imitative,* to that extent program music fails of its purpose. When in "Til Eulenspiegel" the D clarinet squeals to the top of its compass, for example, Strauss fails entirely to depict the putative hanging of his hero; what he much more faithfully portrays is the sticking of a pig. There is, it must be conceded, such a thing as program music; but it is unquestionably a rather childish type of music, and one not worth the efforts of a serious composer.

What shall be said of form as an element of musical beauty? There is no possible doubt that the skilful elaboration of a musical theme is a genuine source of musical beauty to one who is familiar with the laws governing such elaboration. This type of beauty is precisely the same as that which inheres in the element of design found in a work of architecture, or of sculpture, or of painting, and is purely intellectual in its method of approaching the emotions. I am inclined to believe that this type of musical beauty is also identical with that which is recognized as "beautiful" in a mathematical demonstration, or in a game of chess; but of the identity of the beauty of musical form with this latter type of beauty, I do not feel entirely certain. But that there is beauty of musical design is undoubted, although it is a type of musical beauty which is hidden to all but the few of a musical audience who are acquainted with the principles governing musical form. One sometimes wonders whether the emphasis given to the element of form in the writings of musical critics is due to the fact that the critic is well aware he is writing over the heads of his readers when he elaborates upon the formal element of a composition. Rhythm, melody, harmony, color and dynamics, on the other hand, are elements of musical beauty which can be appreciated and enjoyed by the humblest of hearers; and these are the elements that determine the longevity of a musical composition so far as the multitude is concerned. But all the seven types of musical beauty make their appeal to the emotions, and to the emotions only; the beauty of musical design appeals by way of the intellect, the beauties of rhythm, melody, harmony, color, dynamics and tempo, by way of the sense of hearing; but all appeal to the emotions finally.

Except for program music, then, music is a presentative art; it is representative only to the limited extent that program music is able, through the use of sounds *directly and immediately imitative of the sounds of nature,* to paint a picture or tell a story; and, as we have seen, the ability of music in this direction is very limited indeed. Music further, like every other art, makes its appeal to the emotions and to the emotions alone; in so far as it appeals by way of the intellect, it is only as a means of approach to the emotions for an element of musical beauty, musical form, which the sense of hearing is incapable of adequately reporting. Musical beauty, then, is that *emotional* relationship between music and the hearer which gives rise to the judgment, "It is beautiful." That musical beauty was anything else had hardly occurred to anyone until, in 1854, Hanslick produced his "Vom Muiskalisch-Schonen," perhaps the most influential volume ever written on musical aesthetics, in which he unduly emphasized the formal element of musical beauty. That Hanslick experienced a change of heart, and that he realized he had done his work entirely too well, is, I believe, evidenced by the confession made in the preface to the seventh edition of his work in 1885, which confession is set at the head of this chapter. In this same preface he, apparently, apologizes and excuses himself for overemphasizing the formal element of musical beauty, by explaining that the work in question must be considered an outgrowth of the time in which it was written. To too many musical critics, however, Hanslick still seems to be the be-all and end-all of musical criticism.

We have now examined, as carefully as we could within the limits of a chapter, the various elements of music with respect to the manner in which they are brought into relationship with the hearer, and have reached the conclusion that the relationship is an emotional one. It remains to examine the musical equipment which the individual brings to the hearing of music, between which individual equipment and music the emotional relationship which we call musical beauty is established.

The question of the extent to which musical characteristics are inherited is entirely too complicated a problem for the writer to attempt its discussion, although he once heard an eminent musical psychologist assert in public that his laboratory had established musical characteristics as inherited *because the children of musical parents were almost always musical!* That these children had a musical environment seemed not to have occurred to him. But whatever debt the individual may owe to inheritance for his musical equipment, there is no doubt that he owes much to his environment. Certainly, to a very large extent, music is an acquired taste; and in so far as the taste for music is acquired, to that extent it is dependent upon the musical environment to which the individual is subjected. The "best" music is the music to which one is accustomed; and the music one becomes accustomed to depends upon two factors, the musical idiom of the country in which one spends his childhood, and the formal training in music furnished one as a part of his education.

Every country and people has a musical idiom more or less distinctive, and every child of that country and people will acquire that musical idiom just as he acquires his mother tongue. The Chinese child will acquire the use of the pentatonic scale without harmonies. The Scottish bairn will feel quite at home with either the pentatonic or the heptatonic scale, with or without harmonies. The Russian child will employ the minor scale more often than the major, while the American child will almost always employ the major scale. The Spanish child will become accustomed to rhythms quite unlike those of the Jewish child, and the rhythms of both of these will be entirely different from those learned by the Afra-merican child. And, in each case, the rhythms, the scales, and the harmonies, to which the child becomes accustomed in his earlier years will be regarded by him as those most meet and suitable for musical purposes, and will serve as the foundation upon which will be based any future musical training he may receive.

But the kind of musical fare supplied to the individual during the course of his educational training will also be of very great influence in establishing his standard of musical taste. Into the formal training of his musical taste three elements enter: the music he hears at school or at his music lesson, the music he hears at home, and the music he hears at concerts; and these three elements are perhaps of nearly equal importance. If the music he habitually hears at school, at home, and at the concert, is always of the kind his age and people regard as worthy, then his mature taste for music will generally be such as they would call classical; if the music provided him either at school, at home, or at the concert, is not of that kind which is held to be the best, then his mature musical taste will to that extent be unclassical. But the kind of music he hears during his hours of recreation, especially the music to which he dances, will also be of great importance in determining the character of his musical taste; the rise of jazz in America, and its spread over Europe with the seeming probability of its finally giving flavor to operatic, symphonic and chamber music, furnishes evidence of the importance of dance music in the formation of a general musical taste.

The inherited musical characteristics of the individual, if such there be, together with the musical idiom of his country and the kind of music supplied to him during his formal and informal musical education, determine the character of the musical taste which he brings to the hearing of music, and constitutes the individual and personal factor with which music is brought into emotional relationship through hearing.

We have defined musical beauty as that emotional relationship between music and the hearer which gives rise to the judgment, "It is beautiful"; and we have noted that the music itself consists of rhythm, melody, harmony, form, color, dynamics, tempo and nuance, and that the individual himself consists, musically speaking, of the sum total of all the musical influences which have been brought to bear upon him during the process of his musical education, both formal and informal. We defined art as that activity of man which results in the production of something which gives rise to the judgment, "It is beautiful." Musical art, then, would be that activity of man which results in the production of such rhythm, melody, harmony, form, color, dynamics, tempo and nuance, as gives rise to the judgment, "It is beautiful." In the following two chapters we will discover that there are two types of musical art: creative musical art, which is the field of the composer; and interpretive musical art, which is the province of the interpretive musical artist.

CHAPTER X

THE ART OF INTERPRETATION

In Chapter 1 an attempt was made to indicate that there is both an artistic and a scientific side to music. It was pointed out that the word "art" is sometimes used in connection with music to indicate mere physical skill, and at other times to refer to something quite separate and distinct from physical skill—the contributing to the music by the interpreter of something more than appears in the score.

The first step in the preparation of an interpretive artist is for him to acquire the necessary physical skill incident to the practice of his art. This involves the training of the muscles concerned in the playing of the instrument he has chosen. If he is to be a singer, he must train the muscles of his trunk, throat and mouth; if he is to be a pianist, he must train the muscles of his hands and arms; if he is to be an organist, he must train the muscles of his feet and legs as well as those of his hands and arms; if he is to play a string instrument, either bowed or plectral, he must train the muscles of his hands and arms, and the harpist must train his feet also; if he is to play a wind instrument, he must train the muscles of the trunk, throat, mouth and hands; and if he is to play a percussive instrument, he must train the muscles of his hands and arms.

This training of his muscles must, if he is to become a competent interpretive artist, be continued until the performance of the muscular acts involved become entirely automatic and effortless, to the end that all his conscious processes shall be left entirely free and untrammeled for the more strictly interpretive aspect of his rendition. Until he has acquired such technical proficiency that the physical production of the music offers no conscious difficulties whatever, he is not in a position to give proper attention to the interpretative phase of his performance. The performer whose program includes numbers of a technical difficulty somewhat beyond his capabilities will fail to qualify as an artist in the presentation of his program. This does not imply that every interpretive artist must possess a technical equipment equal to the greatest technician in his line; it does mean that every artistic interpreter of music must know his own technical limitations, and must so choose his program that no number on it shall present technical difficulties that he can not meet without effort. Fortunately this limitation in his choice of program places no limitation upon his success as an artist; for the musical value of a composition frequently varies inversely with its difficulty. It means simply that the interpretive musician must know his technical limitations and respect them; if he does so he may be really a greater artist than a greater technician who oversteps his technical limitations.

It is perhaps not necessary to elaborate upon the details of the technical training required in preparation for various branches of interpretive music. The singer must learn to breathe in such manner that he shall always have an adequate supply of breath for the presentation of the music, and must learn to so place his tones that they shall have the requisite quality; the pianist must attain digital and manual dexterity; the violinist must master bowing and fingering; the player of a wind instrument must surmount the same breathing difficulties as the singer, must have a control of the tongue and lips far surpassing that of the singer and, if he is a woodwind player, must have a digital dexterity approximately equal to that of the violinist or pianist. And all of them except the pianist must attain an acuteness of pitch determination, and a deftness in the control of the pitch of his voice, string or wind instrument, sufficient to give adequate control of intonation.

But the interpretive musician who possesses nothing but technical skill will fall far short of qualifying as an artist, for technique is little more than the alphabet of interpretive musical art. It is essential, of course, but inadequate; it is a necessary but not a sufficient condition for artistic success. The second qualification he must possess, and an equally important one, is the ability to contribute to the composition that portion of it which the composer failed to record in the score. The composer may have failed to record his composition completely for either or both of two reasons: because a part of what he had in mind was too elusive and evasive to be reduced to our imperfect musical notation, or because he lacked time to record everything and believed he might safely leave to the interpreter the task of discovering his full intention even though it was not completely recorded.

It is not possible to put all of a composition on the printed page. The score at best can be no more than a rough outline of the music—its bare skeleton. The soft, warm flesh and the coursing blood of it must be supplied by the interpretive artist. If the interpreter lacks the musical insight to recognize in the composition anything except the outline appearing in the score, then we properly refuse to accolade him an artist—his playing is inartisic. But if, besides having physical mastery of his instrument, he possesses also the ability to read that portion of the composition not appearing on the page, then we say his playing is artistic and that the player is an artist. And what is that portion of the music which the composer fails to put into the score because of the imperfections of our musical notation?

We arrived at the conclusion in Chapter 6 that there are eight factors entering into music: melody, harmony, tone color, dynamics, rhythm, tempo, form and nuance. With the form of a composition the interpretive artist has nothing whatever to do; that factor is the exclusive province of the composer alone. The structure of a composition in its broader aspects have been determined once for all by the composer, and it must in this respect stand forever as it left the composer's hand. But with the other factors of music the interpretive artist has somewhat to do, and with some of them very much indeed. And four of these factors tempo, dynamics, rhythm, and color, our system of musical notation is inadequate to designate accurately.

The tone color to be employed in rendering a composition is a matter which must be left almost entirely to the discretion of the interpretive artist; the composer is seriously circumscribed by the lack in our system of musical notation of symbols and terms to indicate accurately his intentions in this respect. A very few such terms exist, but for the most part the composer is forced to trust himself to his interpreter so far as choice of tone color is concerned. This places upon the interpreter the responsibility, so far as the limitations of his instrument will permit, for a judicious use of different tone colors to suit different phases of the varying emotional content of the composition. The singer will employ "white" tones for some purposes, and "dark" tones for others. The bassoon will be raucous or soothing as occasion may demand. The violin will be mellow or brilliant, the horn will croon or blare, as the need may arise. Every musical instrument possesses a color range of greater or less extent, and it is the duty of the conscientious interpreter to have at his disposal as large a portion of that range as is possible to him. Without it his success will be seriously hampered.

In the matter of dynamics our musical notation is better suited to the composer's purposes. Through the use of various derivatives of *piano* and *forte* he is able to indicate several degrees of dynamics between the softest possible and the loudest possible tones; but, even here, it is possible for him to indicate his wishes only very roughly indeed for the reason that the terms indicating the various dynamic degrees have no precise quantitative implications. *Piano,* or any other dynamic term, may be understood by the interpreter to mean quite a different thing than was intended by the composer, and its implication to one interpreter may be not at all the same as to another.

The result is that the presentation of a composition, so far as dynamics is concerned, is unavoidably left very largely in the hands of the interpreter. And for the exercise of this discretion he is with entire justice held strictly accountable. If the dynamic ebb and flow of the composition does violence to the hearer's conception of the composer's intention, the interpreter becomes the subject of justifiable adverse criticism. And, with the possible exception of rhythmic variations (to be discussed below), it is probable that no phase of the interpreter's work so unmistakably marks him the artist. A *diminuendo* that drops suddenly from a *forte* to a *piano*, or a *crescendo* that jumps abruptly from a *piano* to a *forte,* is quite properly anathematized in any circle of discriminating musicians. An interpreter who fails in his conception of what is dynamically proper, or lacks the technical equipment properly to execute that conception, is quickly and wisely ruled out of the honorable order of musical artists.

With respect to tempo the composer is situated much as he is with respect to dynamics; he has available a set of symbols and terms to indicate variations of tempo, but they too indicate his intentions only approximately. If he expresses a desire for a *ralentando,* this may be taken to mean much or little—the precise degree to which the tempo is to be slackened is not definitely indicated. The exact amount by which the pace is to be progressively diminished is a matter to be determined by his interpreter. And the same is true if he wishes an *accelerando* or any other modification of an even tempo; he can express his wishes roughly, but the precise implications of the terms he uses depends upon the discriminatory powers of the artist interpreting him.

The rhythmic symbols the composer employs in his score are largely subject to the same limitations. A dotted eighth note is theoretically three times as long as a sixteenth; but, as a matter of fact, the time value of the sixteenth following a dotted eighth as played by competent artists varies greatly. How short should the sixteenth be made as compared with the dotted eighth? One artist will give it a much greater value than another, and the same artist will give it different values under different circumstances. Very careful computations by Ortman from records of piano playing (*Physical Basis of Piano Touch and Tone,* Dutton, 1925, pp. 142–6) showed that deviations of 20% to 80% from the indicated time values of reiterated eighth notes in a simple, straightforward phrase moving at steady tempo are not at all unusual in the playing of the best-known pianistic artists. It would surprise anyone who has not investigated the matter to find how often the dotted eighth note is almost precisely *two,* instead of *three,* times as long as the sixteenth following it. If the reader will not take the estimate too literally, I should like to say that artistic musical interpretation is probably 75% due to discriminating deviations, in tone-intensity and tone-duration, from the composer's score.

In respect to rhythmic deviations from the score the composer is entirely at the mercy of his interpreter, and the interpreter should again be held strictly accountable for a judicious use of that discretion as best he may; and to his hearers is the duty of holding him to strict accountability for the use of his discretion and of eliminating him from the ranks of artists by criticism if he fails to employ it wisely.

Has the interpreter any part in determining what the melody or the harmony of a composition shall be? In the days of the polyphonic school, the use of accidental notes was frowned upon both by good taste and by popular opinion, and the bull of Pope John XXII which in 1322 had forbidden their use in plainsong had the final effect of excluding them entirely from the *canto firmo* in polyphonic compositions. But the contrapuntalists soon learned that euphonious counterpoint was quite impossible without the occasional use, in subordinate parts, of notes foreign to the mode. To provide good counterpoint, and at the same time to avoid the violation of church law, the contrapuntal writers omitted most of the sharp or flat *symbols* from the accidental notes necessary, and depended upon the singers to recognize the appropriate accidental notes and supply them. That portion of the singer's studies having to do with this matter was known as *musica ficta;* and from his studies in this subject the singer learned to recognize the conditions under which certain notes should be flatted or sharped, and sang accordingly when those conditions arose. As a consequence, the writings of the polyphonists only occasionally show which notes are to be sharped or flatted. For the singers of that day, well trained in *musica ficta,* this was a safe enough procedure; but when modern singers, entirely unacquainted with *musica ficta,* undertake to sing polyphonic compositions the results are sometimes rather unfortunate.

In the days of polyphony, then, the interpreter had much indeed to do with determining what the melody and the harmony should be. And the same applies in like degree to the singing of these old compositions by modern choirs unless the publisher, or in his default the choirmaster, has properly indicated the notes to be sharped or flatted which were not so shown by the composer.

In former days, too, the cadenza was a matter which was left to the artistic discretion of the interpreter. The cadenza usually occurred during a pause on a 6–4 chord on the dominant immediately preceding the close of the composition or of an important movement of the composition. The vocalist or instrumentalist then presented his cadenza, which might be an extempore improvisation or might have been carefully prepared by him in advance for the occasion. Ultimately it became the practice for the composer to fill in the cadenza himself instead of entrusting it to the discretion of the interpreter. Today the impromptu cadenza has almost disappeared; but the cadenza may sometimes still be somewhat modified by the interpreter if he sees fit to do so.

Broadly speaking, the melodic line today may not be changed by the interpreter; but he does sometimes claim the privilege of embellishing it a bit with appoggiaturas, turns, mordents, portamentos, and other graces. But, you say, that is not art; he must not embellish the melody, he must produce it just as the composer wrote it. You are well within your rights in so contending; and the interpretive artist is also quite within his rights in embellishing it if he wishes to do so. You do not like embellishments; he does. Well, what of it? *De gustibus non disputandum est* (as a matter of fact, very frequently it is nothing else but disputing). You like carrots and do not like parsnips; I am just the other way. What is to be done about it? Nothing, so far as can be seen. It is the undoubted prerogative of the musical artist to embellish a melody if he sees fit to do so; and it is just as undoubtedly the prerogative of his hearers to criticise him for so doing if they see fit.

The vibrato is another melodic embellishment to be employed under the same conditions. I speak of the vibrato as a melodic embellishment because of the fact that it is undoubtedly a trill between two notes differing in pitch by a very small amount. Certain psychologists have recently been publishing studies reaching the conclusion that the vibrato is moreover a variation in tone-intensity occurring simultaneously with the trill; but their reasoning is based upon grossly insufficient data, and their conclusions frequently are not warranted even by the data adduced. If they were to check up their results, which seem to be based solely upon observations of the human vibrato, by studies also of the vibrato upon other wind instruments and upon the bowed instruments, they would be compelled to modify their conclusions.

Is the vibrato permissible? The vibrato is universally used on all melodic instruments, and no person possesses the authority to issue an ex cathedra pronouncement to the effect that it may not be used. Any musician may use it in solo interpretations if he approves of it, and any hearer may condemn such use if he feels impelled so to do. But each of them must be prepared to take his medicine as gracefully as possible if the consensus of opinion finally shows him to be in the wrong. But the use of the vibrato by several instruments playing in unison should never be tolerated, at least not until such time as the several players shall all learn to produce it synchronously. The laxity of many great orchestral conductors in allowing this offensive use of the vibrato by their string players is incomprehensible. They should either forbid entirely the use of the vibrato by several players on the same part, or should require the players to produce the vibrato *together*. Anything less is inexcusable.

One of the most hazardous duties imposed upon the interpreter is that of determining the exact tempo at which a composition shall be taken. What precise implication shall be attached to the composer's expression of his wishes embodied in the terms *largo, andante, allegro,* etc.? It is a risk that must unavoidably be assumed by the interpreter; yet by how narrow a margin in this field is success divided from failure! If he adopts a tempo a shade too slow, the music drags and becomes dull; if he chooses a tempo a fraction too fast, the composer's language becomes nervous and inarticulate and the message he sought to express fails to be conveyed. It is a precarious course he must steer between Scylla and Charybdis, yet one he has engaged to take and his courage must not fail him. The slightest deviation to either side of mid-channel will mean the wreck of his artistic aspirations. But then, it is all in the day's work of the interpretive musician; he must do as well as he can and hope for approval from his hearers.

Sometimes the composer relieves the interpreter of much of the responsibility respecting the tempo by marking his music metronomically. Such assistance the interpreter gratefully accepts, but even so he is not entirely without responsibility in the matter. For a metronomic mark of sixty per minute, for example, can not be understood in the sense of being mathematically accurate, and the interpreter must still use his discretion as to what precisely sixty per minute is intended to mean. The risk has been reduced somewhat, but not entirely removed.

If the discretionary duties of the interpretive artist in respect to tone color, dynamics, rhythm, melodic embellishments, and tempo, are all grouped under the single term *nuance,* then we may say that nuance is the especial province of the interpretive artist. So defined, nuance is a matter beyond the control of the composer and, in regard to it, he must depend upon the interpreter to exercise his best discretion; and for the judicious use of that discretion his hearers must hold the interpreter strictly accountable. For the ultimate outcome of a musical performance there is, then, a division of responsibility between composer, interpreter, and audience; and if either party shirks its responsibility, the performance of the music will not be satisfactory.

The question arises whether it is ever possible for an interpreter to go beyond the intention of the composer and to discover in a composition possibilities not apparent to the latter. Of course it is obviously impossible to determine accurately the precise boundaries of a composer's intent. But it seems not at all unreasonable to suppose that interpreters of exceptional ability are sometimes able to discover details of musical beauty not manifest to the composer in the throes of composition. It is even possible that a composer truly inspired may sometimes not have any very definite and precise intent, but is possessed rather of only an overwhelming conviction that what he has in mind would, someway or other, be very beautiful although the precise manner or measure of its possibilities is not very clearly apprehended at the moment. And so he hastily scrawls it down, and hurries on to snare the next fleeting beauty before it shall have escaped entirely into the distance. If this is at all the psychological condition of the composer writing under inspiration, then certainly he does not have time to elaborate fully in his own mind all the possibilities inherent in what he writes. That is a task which may safely be delegated to the interpretive artist with his greater store of time to draw upon.

Interpretive musical art is thus often genuinely creative in character. It is, admittedly, the art of elaboration and is therefore a creative process of lower order than that of the composer proper, but it is of great value and usefulness nevertheless and not to be lightly esteemed.

The art of the conductor of any ensemble differs from that of another interpretive musician only in that he plays an instrument of different character—a human instrument. Whether he be the leader of an orchestra, a band, or a chorus, the instrument he plays is essentially an aggregation of human beings. The player of any instrument except an ensemble has to deal with a piece of physical apparatus only. The conductor handles a collection of human beings and must learn to manipulate their sensibilities much as a fiddler fingers his violin. The technique of the conductor is therefore quite different from that of the player of the physical instrument. The physical side of the conductor's technique is simple —he must learn to handle the baton; the spiritual side of the technique is difficult—he must learn to handle a lot of human beings who are deeply sensitive, sometimes to the point of being "difficult." This requires the quality of leadership in the ordinary acceptation of the term; and if he lacks this he will never attain the highest standing as a conductor no matter what his attainments as a musician may be.

We have so far discussed two phases of the interpretative musician's equipment: his technical equipment, and his interpretive duties with respect to nuance in the broader sense. There remains still another qualification which the interpretative musician must possess. He must have the ability to build a good program; and program making is not a simple matter. As a matter of fact program making is a branch of musical composition. It might be said to involve a still broader application of the principles of musical form than is employed by the musical composer. Just as the composer is governed by certain rather inflexible laws in the composition of a sonata, so too is the interpretative musician governed by rather rigid principles in compiling a program; and the principles of program making are less well understood than the principles of form governing the sonata, because they have not yet been given as much serious study. We will know more about program making when we have given it more thought; the construction of a successful program is almost as delicate an undertaking as the building of a beautiful melody—and quite as little understood.

Not every person who can acquire the technical skill to manipulate his instrument can become an interpreter of music. Unless he possess the ability to read between the lines of the score, to discover that part of the composition which the composer failed to record, unless in a word he possess that quality called "musicianship," he can never become an interpretive artist. In the introductory chapter we referred to the rendition of Schubert's "Ave Maria" by a youthful musician of marvelous technique who nevertheless could not make "music" out of the composition because he lacked the ability we are here referring to. The lay critic there cited thought his failure due to the fact that he was too young to play music of that character. Perhaps that may have been the reason. At any rate, not every artist can play every kind of music.

The point may be further illustrated by referring to the singing of negro spirituals. It is the writer's opinion that no white person can sing a spiritual—nor any colored person reared under white conditions. The singer of a spiritual should have spent at least his youthful days within a stone's throw of the cotton patch or the cane field. The philosophy of life absolutely essential to the proper singing of the spiritual is that this present world is one of constant tribulation that may not be escaped, but that it doesn't matter much because it's only going to be for a little while, and there's a bright home waiting over yonder. A naive view? If so, then do not desecrate the simple nobility of

"Nobody knows the trouble I see,
Nobody knows but Jesus,"

by attempting to sing it. The authentic throbbing rhythm, the soft-moaning wail, that can be imparted to it only by the resigned fatalism of the plantation negro will be missing if you do. Indeed, the person who has never heard spirituals in a negro "meetin' house" may almost be said never to have heard them at all. Elsewhere they are likely to be but ribald caricatures.

We have adverted repeatedly to the criticism of musical interpretation by the hearer. Criticism of the music presented is undoubtedly an essential feature of any musical performance. It may be expressed in words, and again it may be that tacit criticism expressed only in the terms of box office receipts. In either case, the progress of music is furthered only by criticism that is sincere, honest and fearlessly expressed. Not what some other hearer thinks about the music, be he never so wise, but what every individual hearer himself thinks about it, is the kind of criticism that benefits music. To bolster up the popularity of poor music by specious approval only prolongs the agony of eliminating it from musical programs; the quicker poor music is eliminated the better for everyone concerned including the interpreter and composer. The proper thing to do is to express fearlessly one's own personal impressions of the music, no matter what someone else may think about it nor who he may be. Anything less than absolute sincerity is inimical to the welfare of music.

And what shall we say of the professional critic? Undoubtedly a professional musical critic who is well informed and sincere may be of great service to his community; but this he will not be if he lacks either one of these qualifications. It is perhaps seldom that a professional musical critic is insincere in the sense of expressing an opinion of music or its interpretation in direct contradiction to what he actually thinks about it. Insincerity of this sort is fortunately rather rare; but insincerity of another type is entirely too common, the insincerity of expressing a musical opinion when he has none, and the insincerity of presenting to his clientele as criticism that which he well knows is not criticism at all.

Of course the laborer is worthy of his hire, and the person who devotes himself exclusively to the writing of musical criticism must live by his efforts unless he possesses independent means or is endowed; but the fact that the musical critic receives remuneration for the expression of musical opinions undoubtedly involves him in a difficulty. Little as we may care to admit it, the fact is that the professional musical critic is primarily a newspaper man. With respect to musical events in his community, he combines within himself both the reportorial and the editorial aspects of journalism. It is his duty both to report anything occurring that is musical news, and to comment upon its musical significance if any; and, since he is required to furnish his material daily, he is sometimes led to report what has no real musical news value, and to discuss editorially the significance of events which are in themselves entirely insignificant. Little damage is done perhaps by simply reporting the fact that a concert was given at such and such a place by such and such a person or organization; but to criticise the performance in detail, in case it were really of too little significance to deserve criticism, is a betrayal of the trust reposed in him.

Sometimes he avoids this difficulty by falling into another: he does not give undue critical attention to a performance not entitled to it, but instead he presents with the most owlish solemnity a high-sounding disquisition, or a glittering and saccharine prose poem, about some collateral musical subject that will please and entertain his readers but which has nothing whatever to do with the criticism of music. In his critical capacity proper, his reportorial duties for the time being kept in abeyance, the musical critic may discuss three subjects and three only: the musical composition presented, the interpretation of the composition, or the instrument used in interpreting it. Musical compositions sufficiently new that their musical status is not yet entirely established are quite proper subjects for the critic to discuss. A composition whose status is already fully established, but which the critic thinks is too highly esteemed, is also a quite proper subject for critical consideration—provided the criticism is adverse or is in reply to adverse criticism of such a composition. But there is no possible excuse for favorable criticism of a composition which is conceded by everyone to be a masterpiece and concerning which there is no adverse opinion. It is not pertinent for a musical critic to waste his reader's time in attempting to prove that Beethoven's C minor symphony is worthy music; we do not wisely carry coals to Newcastle, nor do we attempt to prove the multiplication table to persons of normal intelligence and education. If the critic were convinced that the Beethoven fifth is *not* respectable music, then he has a legitimate thesis to discuss with his readers; not otherwise.

The manner in which the composition is rendered by the artist presenting it is likewise a proper matter for discussion by the musical critic. This discussion may take either or both of two directions: an estimate of the adequacy of the artist's technique, or a consideration of his interpretation of the composition—whether he succeeded in presenting to his audience the message which the composer wished to convey. This phase of the critic's duties is so well recognized and understood that it is unnecessary to elaborate upon it; merely to mention it is sufficient. The third of the subjects which the critic may discuss is not so generally recognized—the discussion of the instrument employed in his presentation. There are three elements involved in the presentation of any musical composition, the composition itself, the interpretation, and the instrument employed. I see no reason why the instrument the interpreter uses should not be condemned if it is inferior or commended if it is a superior one. This is already done when the instrument employed is an orchestra; the critic properly calls attention to the good or bad qualities of the orchestra as a whole. And the same is done with reference to a band as a whole. We also frequently find critics commenting either favorably or adversely upon the singer's voice. I can not see why it is not equally justifiable to commend or condemn likewise the violin or piano that the instrumentalist uses if it is either superior or inferior enough to justify comment. I believe the time will come when this type of musical criticism will not be regarded as unusual or unjustified.

But the musical critic may be insincere not only by dignifying with criticism music which is not entitled to it, or by foisting upon his readers as criticism that which he very well knows is not musical criticism at all but is merely "fine writing" presented for their entertainment only; he may also be insincere simply by accepting a position as musical critic when he knows himself to be entirely incompetent for the duties of the position. And how often it is, unfortunately, that we find a simpering reportorial verbal facility masquerading as musical criticism. Some newspapers employ musical critics who know music and who have the sincerity and courage to say what they think about it; but too often the preponderant qualification for the music critic's chair seems to be a catch-penny, tabloid vocabulary and a bumptious assumption of musical omniscience. Perhaps it is quixotic to expect any newspaper man of today to refuse to do anything which will pay him well, entirely devoid as he appears to be of any self respect, but it is not too much to expect managing editors to exercise at least rudimentary intelligence in making appointments to the music critic's position.

But, even so, all will be well if music lovers have but the courage to pay no attention to the ebullitions of the occasional pseudo-critic. They thrive and wax fat upon the music lover's well known inferiority complex; he knows what he likes but, he sheepishly amends, he doesn't know much about music. Nevertheless he may still have the advantage of the critic, who sometimes neither knows much about music nor even knows what he likes. Musical criticism, anyway, is but a seeking for specious reasons to justify our musical prejudices, to paraphrase Bradley's famous aphorism on metaphysics. If you know what you like in music, speak out! The only advantage the critic has over you is in the matter of vocabulary. And, if you perhaps feel inarticulate everywhere else, you can at least express yourself with adequate effect at the box office. If you like to hear music, go to hear the music you like, refuse to hear the music you do not like, and leave the bandying of words about it to such as enjoy that pastime; in so doing you will make your largest possible contribution to the progress of music. Only do not make the mistake of assuming that you do not like music which you have not heard often enough to become acquainted with it; the only taste we have that is not acquired is the taste for milk. And many of our tastes are very much worth acquiring; the taste for good music is one of them.

CHAPTER XI

THE COMPOSER AND HIS WORK

So MUCH nonsense is indulged in with respect to genius in general and musical genius in particular that it becomes necessary for one who would explain the musical genius to prepare the way for a consideration of that subject by some observations on the general aspects of genius. If this chapter should fall into the hands of a reader who is averse to thinking in general terms, he can skip it and leave to the writer and other readers the pleasant pastime of attempting to gain if possible a little more information about a subject which intrigues them.

The genius is an individual who possesses—perhaps I might better say is possessed of—an *extraordinary* interest in the subject which interests him most. The interests of the vast majority of persons are not overwhelming in any particular direction, but are fairly well divided between all those having to do with the conditions of their existence. The genius, on the other hand, is comparatively little interested in most of the things conditioning his manner of life, but is tremendously interested in some certain one of them; he is essentially a one-sided individual. It is this overwhelming interest in one particular aspect of his life that constitutes him a genius.

Newton and Einstein are examples of persons extraordinarily interested in understanding the physical aspect of existence. Jesus was extraordinarily interested in showing men how better to adjust their contacts with their fellow men. Socrates had an extraordinary interest in the same direction. Aristotle was extraordinarily interested in the unification of the whole of man's knowledge. Roger Bacon had an extraordinary interest in releasing knowledge from the prison-house of authoritative learning. Darwin was extraordinarily interested in the relationships between different species of living organisms. Napoleon was extraordinarily interested in subjugating the rest of mankind. Henry Ford is extraordinarily interested in furnishing local transportation to persons of moderate means. Luther Burbank was extraordinarily interested in economic botany. Edison is extraordinarily interested in improving the physical conditions of everyday life. George Bernard Shaw and H. L. Mencken are extraordinarily interested in the extirpation of cant. Lenin was extraordinarily interested in putting to test the economic theories of Karl Marx. The list might be greatly extended, but these will serve as illustrative.

To the vast majority of persons, whose interests are fairly equally distributed, the genius is a silly ass, the one-sided individual is a crank; a well-rounded, symmetrical development produces individuals of the desirable type—like bullets out of the same mould. Why should Einstein care whether space and time are independent? Why should Jesus and Socrates bother about their fellow men? Look what it got them. Why should Darwin investigate the relationships of species, to set the world by the ears? And Napoleon's ambition; well, he got what he deserved anyway! Burbank's fussing around with vegetables and posies was hardly he-man stuff, if you should ask them. G. B. S. and H. L. M.; modern Quixotes jousting with windmills, as they see it. How much does Ford accomplish by enabling people to get somewhere else quickly and easily; why should they go somewhere else? Edison and his laboratory! A funny old nut, to say the least; almost impossible to get him to buy a new suit of clothes, or eat his meals, or go to bed. Karl Marx may have been right, and again he may not have been; who cares to find out? Aristotle with his unification of knowledge; highbrow stuff. And Bacon might better have left knowledge imprisoned. Thus appears the genius to the "plain man."

Since the interest of the genius in his subject is extraordinary, he believes not a word of what he is taught in regard to it; others may be content to believe that two and two are four, but he will have to look into the matter before he can agree to it. The only criterion of truth within his subject is what he personally thinks about it. To Einstein the unquestioned and unquestionable foundations of the physical universe mean less than nothing.The wisdom of the ages and the authority of inspiration do not concern Darwin. When Ford is hard up for cash the only feasible plan he can think of is to lower the price of his car below cost of production, or to raise wages or shorten the working day or week. The way to increase the wealth of nations, according to Lenin, is to put the production of wealth into the hands of those who know nothing about it. "Ye have heard it said . . . ," said Jesus, "but I say unto you. . . ." The genius is not concerned with accepted truth regarding his subject; he is interested only in establishing the foundation of its truth.

Mankind is composed of two classes, leaders and followers; if a man is unable to follow others, others will follow him. His followers become a school and, in the end, they apotheosize him. But in the twilight of the gods, he yields his place to a rebel who supplants him. Thus we arrive at successive approximations to the truth.

The musical genius is a person possessed of an extraordinary interest in music, and who is not below the normal of general intelligence. Normal general intelligence is essential; otherwise the person becomes a musical freak, like "Blind Tom," instead of a musical genius. The general intelligence of "Blind Tom" was of much too low an order to make possible the general training in music essential to the genius. Mozart, on the other hand, had adequate intelligence for a general training in music and became a genius. The fallacy in most people's thinking about the musical genius, or genius of any kind, is in believing that he needs no training—that genius is a god-given attribute and nothing more. The person with a god-given musical ability, but who fails to receive a rigid training in music, never advances beyond the point of freakhood.

The point, which is of the utmost importance for an understanding of the matter, is that the musical genius must have careful and rigid training in music. Every great composer has had thorough training in his craft. Mozart, Beethoven, Bach, Wagner, Strauss, there are no exceptions. That men like Mousorgsky and

Elgar were largely self-trained does not alter the fact of their having been trained. And, to an astonishing degree, the amount of genius ultimately shown by a composer often varies as the thoroughness of his training. Perhaps most persons would agree that the god-given element in Mozart's genius was incomparably greater than in that of Beethoven, and this notwithstanding that the latter was much the greater musical genius. How much less of a genius Beethoven would have been if his father had not flogged him to the study of music can never be known. Certainly Mozart was much the apter pupil, and Beethoven just as certainly was the greater musician. Name me one great composer who was not well trained in musical composition, and I will admit that the composer is born not made. But until that time I shall insist that the composer is born only in the same sense that the plumber or the undertaker is born, and that all three of them have equal need for learning their trades and learning them well.

Nothing is more vicious and destructive of musical progress than the notion, so universal among those whose intelligence remains unfortunately juvenile, that there is some kind of black magic about musical composition and that the composer shakes compositions out of his sleeves much as the prestidigitator shakes out rabbits. This childish notion has done more to limit the supply of really great music than could possibly be estimated. The music of the world perhaps would not have been much different if Irving Berlin had never lived; yet probably three-fourths of the world's great music was written by individuals in whose genius there was less of the god-given element than is possessed by Irving Berlin. But they learned music, and he did not; and, as a consequence, they will remain immortal while his music reputation a generation hence will be hard put to it to maintain a zero level. This is not to criticise Berlin except in the sense of regretting that his father did not drive him to the study of music, as did Beethoven *père*.

Another gem of asininity is the notion that training in formal composition will curb the spontaneous utterance of god-given talent in composition. So would the sand-lot ball player be ruined by a few years' coaching under Muggsy McGraw; so would the radio putterer be spoiled by an apprenticeship in the laboratories of the General Electric; so would the back-woods fiddler be contaminated by a few years' study with Leopold Auer; and in just such manner were all the composers ruined whose writings have made music great and mankind happier. But it is useless to inveigh against this silly superstition, for these pages will scarcely come to the attention —except possibly at second hand—of those ill enough informed to suffer from its blight.

The first requisite for the musical composer is a desire to bring musical beauty into the world. The naïve desire to "be a composer" will not carry him far: a sincere longing to augment the sum total of musical beauty may, if he have the dogged determination to try often enough, sometime bear fruitage of which he may say without shame, "I made it." His probabilities of success will depend largely upon the number of serious attempts made, for of course most of them must never get past the waste paper basket. If this is too high a price to pay for success, let him go into stocks and bonds or the dry cleaning business; creative music is not for him.

The second requirement for the composer is sufficient general intelligence to enable him to receive a thorough training in musical composition. This item should not be overestimated; his intelligence quotient need not be excessively high. Beethoven, to take an illustrious example, could read, wrote with difficulty and spelled very badly, and his mathematical attainments were limited to such computations as could be performed upon his fingers; multiplication was as much of a mystery to him as the Greek pastoral poets. The ability to qualify for admission to an American high school at the age of fourteen is evidence of ample native intelligence to guarantee success in a rigorous course of training in musical composition. Not one boy or girl in a hundred need be deterred because of dumbness from looking toward musical composition as a career.

The third qualification is training for the work. And a boy should have no more hesitation or diffidence in determining that he will be a composer than in deciding to become a bookkeeper or a dentist. If he has a strong inclination toward dentistry or bookkeeping, that is what he should do; but, if he has a strong inclination to become a composer, it is unwise to spoil a good composer to secure a poor clerk. And if a girl wishes to compose music, she should go about learning how to do it with no more compunction that she would go about learning stenography or millinery if that were her ambition. The unfortunate thing is that musical composition is hedged about, by the uninformed, by so much mystery and hocus-pocus that it never occurs to boys and girls that it is a career open to them upon the same terms as any other; they no more think of undertaking it than a colored boy would think of going through a moonlit graveyard at midnight. It is abominable to so deceive and frighten our youth. I wish I might bring to every boy and girl the good news that musical composition can be learned just as anything else can be learned.

Not many boys have appetites for mathematics that can be called at all ravenous; yet if a boy wishes to be an engineer he proceeds to learn the requisite amount of mathematics simply because it has to be done, and without bothering about the question whether he has any considerable mathematical ability. He does the same with respect to his physics, his chemistry and his drawing. And he becomes a useful and valuable engineer as a general rule. If a boy wants to be a composer he should likewise go ahead and learn the requisite amount of harmony, counterpoint, musical form and orchestration; and the silly and futile question whether he possesses extraordinary ability in these subjects should never present itself to him or to his parents. Of course no one knows whether he has exceptional ability in any of these directions, and never will know until he has studied these subjects for some time. And when all is said and done, it is of small consequence whether he so possesses exceptional ability. If he wants to be a composer badly enough, he will acquire the knowledge of the subjects necessary to that end whether the acquisition be easy or difficult.

Some engineering students find mathematics easy while others find it difficult. Those who find it difficult simply have to work harder to master it; but that fact does not by any manner of means prevent their becoming engineers. Indeed, any experienced teacher will bear testimony that the plodder frequently turns out better in the end than the brilliant student. If a boy of your acquaintance had an ambition to become an engineer, would you say to him: "Why, my dear boy, do you imagine you can do anything with such a subject as calculus? You don't understand. Calculus is a tremendously difficult subject. I had an awful time with it; so you can readily see what a very difficult subject it must be. No, my boy; you steer clear of calculus. It would be much better for you to get a push-cart and sell bananas and apples and havlah. That wouldn't be nearly so hard. In fact I think that is just about the right thing for a boy like you."—is this what you would say to him? It is not! You say: "That's fine, young man. Engineering is a good profession. I'm glad to know you are going into something worth while." And if you know a boy (or girl) who wishes to be a composer, are you going to say to him: "No, I strongly advise you against it. A composer has to know harmony and counterpoint and musical form, and those are enormously difficult studies. I never could understand them; and if as great a musician as I found them impossible, certainly it would be foolishness for a boy like you to try."—is this to be your response to the compliment he pays you by confiding in you? If so, you are no friend of his, and you are no friend of music.

If you failed to acquire an effective command of harmony, counterpoint and musical form, it was because you lacked a sufficient incentive to do so or because you had poor teaching. If the prerogative were mine, I would stand up against the wall to be shot at sunrise all those individuals who "teach harmony." Harmony, as an end in itself, is a fit subject for investigation by the incorrigible scientist only. Harmony, as a means to musical composition as an end, is a field of fascinating discovery. So, too, are counterpoint and musical form. The incentive is almost everything in any pursuit. Some day, perhaps, teachers of musical theory will emerge sufficiently from the shadow of the hoary past to apply modern educational methods to the teaching of their subject. If that time ever comes, musical theory will become a task to be mastered because of the ability it gives the student to accomplish the thing upon which he has set his heart. All friends of music will hail that day.

Do not misunderstand me. I do not claim that all serious students of musical composition who are well taught can succeed in equal measure. Some will do better than others, as they would in engineering, medicine, journalism, accountancy, the bond business, or any other line of endeavor. But, given an inclination toward musical composition as a life work, normal general intelligence, a thorough training in the technique of composition, and the same amount of industry that would be necessary for success in another field, and nine out of ten persons so equipped will become competent, appreciated composers useful to themselves and to the rest of the world.

And it will avail nothing for some person, inadequately trained, too lazy to give honest effort to any calling, and who never was more than half in earnest, to frown, wrinkle his brow, attempt to look profound, and say, "Music is different." No one takes what he says seriously, not even himself. Of course music is diffierent. So is everything different from everything else. But all pursuits are alike in at least one respect: success in any line of endeavor requires earnestness of purpose, thorough preparation, and serious application to the vocation chosen. Without these success cannot be attained in musical composition or in any other field. Occasionally —say once out of ten times—success cannot be purchased with all three of them; and once in a thousand times, perhaps, success is attained without any of them—served deferentially on a silver platter by a uniformed butler, so to speak. But the odds against being the thousandth case make it unsafe to depend much upon it.

In any pursuit thorough training is of the utmost importance, and in musical composition perhaps oftener than in any other line is the training incompetent. I could never accept the theory that a person can teach a subject he does not know. If I wished training in differential equations I should want to be sure the teacher with whom I should study could solve differential equations impossible to me. The study of voice with a teacher who cannot sing, or of violin or piano with a teacher who cannot play the instrument he teaches, has never appealed to me as advisable. Nor can a student learn musical composition from a teacher who cannot compose. That is the fatal defect with those who "teach harmony." The student may be able to pick up from such a teacher numerous bits of detached information *about* musical composition, but he will never learn to compose.

Do I exaggerate? A young lady, more than ordinarily thoughtful and intelligent, was telling me she had about reached the conclusion that she wanted to compose. She contended that melodies did occur to her, very often, and "good melodies, too." "Do you jot them down?" "No." "You should do so; you might be able to use them later." "I can't." "Can't write a melody that you have in mind!" "No." "You graduated in piano from a reputable conservatory, didn't you?" "Yes." "Didn't you study harmony?" "Yes, and got good marks in it; I took honors in counterpoint." She was intelligent; she laughed as heartily as I did. The case is typical of a tremendous amount of teaching in musical theory. The fault is that musical theory is frequently taught merely as subjects in which the student is required to receive passing grades, and not as a means toward musical composition as an end which the student has definitely in view.

The first essential, then, in preparation for musical composition is to study with a teacher who is a composer. This, of course, raises a difficulty. How much of a composer must a teacher of musical composition necessarily be? Other things being equal, the better the composer the better the teaching in musical composition. But, great or not, the teacher must be a composer and have the composer's viewpoint, to the end that the purpose of the study shall always be directed toward musical composition as its objective. Unless this objective is kept always in view, either by the student himself or by the teacher for the student, the study will be purposeless and accomplish nothing.

What should be the method of acquiring harmonic knowledge? For the thousand years preceding Roger Bacon, the method of acquiring knowledge of the world in which we live was a lost art. If information was desired about the organization and operation of this present world, it did not occur to anyone that the proper procedure was to investigate that world as a means of finding out. The thing to be done, the thing everyone did, was to turn to Aristotle to see what he said about it. The book of knowledge had been completed, signed, sealed, and delivered by him; to know about anything it was only necessary to ascertain what The Philosopher had said about it. What he said was final; and, if he said nothing about a subject, it was unknowable. It was a very simple, convenient, and comfortable arrangement for everyone concerned—up to the time of Roger Bacon.

But about the middle of the thirteenth century Bacon began to teach a new, strange doctrine, entirely unheard of and sufficiently foolish; his revolutionary doctrine was that, to learn about nature, one should make inquiry of nature direct. Put the question to her in such form that she could not avoid answering it, and then abide by her reply. If her answer was not in harmony with the teachings of The Philosopher, *then The Philosopher was wrong.* In short, Bacon advocated the experimental method as a means toward the acquisition of knowledge. Of course his ideas were absurd, and were so recognized and characterized by the scholarship of his day; he was hounded out of his university, Oxford, and for twenty-five of his forty-two mature years he was kept under lock and key. It was three hundred years before his teachings began to receive acceptance; but the whole world today pays him homage as the founder of modern science.

In regard to the study of harmony the world of music is today in the same frame of mind respecting the acquisition of harmonic knowledge as was the medieval world with respect to the acquisition of scientific knowledge; if anyone today wishes to know anything about harmony, it is only necessary to ascertain what The Masters have said or done in regard to it. The notion of seeking harmonic information by appealing directly to harmonic phenomena through laboratory experiments is today as strange and unheard of as were Bacon's revolutionary teachings with respect to science. Harmonic knowledge is still in bondage to the principle of authority. Not what the facts are with respect to harmony but what The Masters have done about it, is the final answer to all harmonic questions. Of course all this will have to be changed. And, so enlightened has the world become respecting the method of acquiring knowledge, that it will probably not take three hundred years for the change to be made.

The place to study harmonic facts is in the laboratory. The harmonic practices of The Masters will all have to be subjected to laboratory verification, and modified to the degree that they are found capable of improvement. The teachings of technical writers on harmony will have to be subjected to the same scrutiny. And the laboratory will be found as powerful a means of advancing harmonic knowledge and practice as it has been in other fields of investigation.

And the same considerations apply to the subject of orchestration. Here, too, the seeking of information is conducted upon the basis of an appeal to authority. What The Masters have done is the only question to which an answer is sought. In my more impatient moments, I sometimes think that a treatise on orchestration is little more than a thesaurus of epitaphs from the tombs of musical compositions—a faithful account of the deeds of the dead. But of course this is an unfair view to take of the matter. What the musically great have done in bygone days is very important and useful information for us to possess. The thing we should guard against is allowing our pursuit of information to stop with them. In fact, I doubt whether they would be at all pleased with a smugly satisfied attitude on our part; I surmise they would regard us as very unworthy administrators of their musical estates if we failed to take advantage of every opportunity to develop and increase them.

And how pitifully handicapped The Masters have been in the investigation of orchestration. The equipment of the orchestral composer has always been a piano and a book—a book of orchestration. The equipment of the orchestral composer should be a complete outfit of all the instruments of the orchestra—and a skilful player for each of the instruments. We do not so handicap our investigators in other fields. The chemist has an inspiration with respect to the solution of some problem he is investigating; he thinks perhaps the plan he has in mind will solve the problem. We allow him a laboratory in which to test out his theory and, if his plan proves to be wrong, he makes other guesses and tests them out until he finally hits upon the right one. We do not treat our composers equally well. If a composer has an inspiration respecting the solution of some problem in orchestration, we compel him to be content with a guess. We furnish him no laboratory in orchestration with instruments and players where he can test out his plan to see whether it be practicable or no. With such a laboratory he could test his idea and, if it were wrong, he could keep on devising other plans and testing them until he should finally succeed in producing the precise effect he desires. We must cease handicapping our composers so in their efforts to provide us with music. It is not fair to them, and it is a very short-sighted policy even from a purely selfish standpoint. To furnish a composer with a piano and a book as his only equipment is penny wisdom and pound foolishness. If his orchestral effects sometimes fail to come off, can we hold ourselves blameless?

But, assuming that the composer has had adequate training in harmony, counterpoint, musical form and orchestration, assuming further that he has sufficient earnestness of purpose to guarantee adequate industry in the pursuit of his calling, what then is the nature of the composer's task itself? What is his particular and special task as a creator of music?

The materials with which the composer works are the first seven of the eight factors of music enumerated in Chapter 6. The eighth factor, nuance, he leaves to the interpreter; but the remaining factors, melody, harmony, tone color, dynamics, rhythm, tempo, and form, he claims as his own. He devises rhythms, melodies and harmonies, he estimates tempos, tone colors and dynamic shadings, and he casts all into a form suitable to his purpose; he tests everything out as best he can with the resources at hand, to see whether it produces the effect he desires; he discards and rebuilds; he modifies, polishes, and repolishes, guided always by his artistic judgment of what will add to its beauty. And when he has finally put it into what he hopes will be satisfactory shape, he subjects it all to the test of a public hearing. Sometimes he is pleased with the result; often he is grievously disappointed. The public finds it good or bad, as the case may be, and he begins upon another work hoping to do better next time. The whole process may be easily traced in the sketch-books of Beethoven; no better guide-book to the field of musical composition can anywhere be found.

The exercise of his artistic judgment to determine whether his composition shall finally be beautiful is not so difficult a matter for him as might at first thought appear. He is familiar with the literature of music, he knows what other composers have done, and his artistic taste has been carefully trained; his judgment is as good with respect to his own work as with respect to the work of another except that he may have a prejudice in its favor. If he is able to dissociate himself from this personal predilection, he is as able to judge of its worth as are the ablest and most sincere of critics when it is produced, provided he has had an equal opportunity for a favorable hearing of it. But if his hearing of it has been limited to his imagination, as is so often the case with compositions for large ensembles, his judgment may be very seriously at fault. But with an experienced composer, like Beethoven in his ninth symphony or his missa solennis, neither of which he ever heard, his judgment is very likely to be trustworthy.

The composer of the better class will always confine himself to the production of that which is simply beautiful, leaving to the musical charlatan the attempt to go further. His appeal will be through beauty to the emotions alone; he will not attempt to paint pictures or to express ideas as such. As shown in Chapter 9, the expression of ideas is no part of the function of music, and the judicious composer will have the wisdom not to attempt it. But to the whole field of the emotions he has immediate access, perhaps in a more intimate sense than the worker in any other field of art. Joy and sorrow, humor and blank despair, religious ecstasy and the frenzied abandon of the dance, all these are his to evoke if he but have sufficient skill. This is his province and he will do wisely to confine himself to it, leaving the painting of pictures to the graphic artist and the poet, and leaving to the essayist and the dialectician the presentation of philosophies and of moral and religious systems.

Indeed he must do so whether he would or not. No one may prevent the hearer of music from musing on any pictures he may wish to conjure up, any fanciful story he may wish to concoct, or any philosophical speculations he may desire to entertain; but neither may any composer, however able he may be, put into his composition any one of these things or convey from his mind to the minds of his hearers the smallest thought pertaining to any one of these fields. The composer who attempts it is more than likely to end in making himself ridiculous. Within its own field music is a mighty power; outside its own province it has not the slightest potency whatsoever.

PART THREE

THE FUTURE OF MUSIC

CHAPTER XII

HARMONIC POSSIBILITIES

THE MUSIC of the future! How regrettable that we shall not be able to hear it. The great music of the past and of the present we enjoy with ample good reason. But just as the compositions of Beethoven and Wagner are superior to those of a thousand years ago, so too will composers a couple of centuries hence improve upon the masterpieces of today. For, in musical matters, the world will hereafter move faster than it has done up to the present. It sometimes seems that our only present musical interest is to learn *to make* music; we are not at all concerned with learning *how* to make music. The artist, the composer, in preparation for his career appears to have not the slightest desire to discover *how* to make music, his sole solicitude being to make music somehow or other—and, above all, *to sell* the music he makes. Some day it is going to dawn upon us that it might be profitable to inquire *how* music is made. When that time comes, the world will witness such strides in musical progress as it never yet has seen. We have abundant justification for coveting the fruits of the musical harvest our progeny will reap half a dozen generations hence.

Not the least of the advances in the future progress of music will be in the field of harmony. It should scarcely be necessary to state that harmony has not yet reached the end of its development. Just as the composer of any generation has not been content with the harmony of his day, so too will future composers fail to find satisfaction in harmony's present status and will employ many harmonies today unknown. But future harmonic development will hardly take the direction of a further development of the tempered scale. The efforts of contemporary composers to find relief in a further elaboration of the tempered scale are foredoomed to failure; that path ends in a blind alley, and will have to be retraced. The tempered scale has already passed the limit of its usefulness.

The various scales that have arisen at different times the world over prove conclusively that the human ear can learn almost any kind of scale. And, *for purposes of melody alone,* it is probable that one scale is about as good as another. The scale one prefers, and that seems most natural for melody, depends solely upon the musical heritage of the land in which one spent his childhood.

But, for purposes of harmony, scales differ greatly in value. Some scales can not be harmonized at all, being essentially inharmonic in character. Others are but poorly suited to harmonization. Such a scale is that of Pythagoras, which held the musical stage in Europe from about 600 B. C. to about 1600 A. D. The Pythagorean scale is an alternation of perfect fifths and fourths, beginning on the subdominant (F) and ending on the leading note (B), the fifths being tuned up and the fourths down. The fifths and fourths of the Pythagorean scale are all harmonic except the fifth upon B and the fourth upon F, which are tritones; but the thirds, sixths, and sevenths, are badly out of tune. This probably accounts for the fact that the thirds and sixths were not recognized as consonant until long after the fifths and fourths.

It is doubtful whether the Greeks ever employed polyphony of any kind. But about the year 900 A. D. a practice began of singing in fifths and fourths—at that time the only intervals recognized as consonant except the octave—the practice being called "organizing." Counterpoint arose about 1300 A. D., and reached its diatonic culmination in Palestrina about 1600 A. D. "Sumer Is Icumen In," an elaborate canon, appeared early in the thirteenth century, but perhaps arose by lucky accident rather than as the result of conscious contrapuntal effort.

With the development of counterpoint, 1300–1600 A. D., the inharmonic thirds, sixths, and sevenths, became more and more objectionable. Meantime, in the fourteenth and fifteenth centuries, *musica ficta* had appeared, a system of chromatically altered notes.

This led naturally to modulation, ultimately into all the twelve chromatic keys. About 1600 A. D. musicians began to view music vertically as well as horizontally; and between this time and the death of Bach, 1750 A. D., harmony attained full bloom.

Elaborate harmonies and universal modulation rendered the Pythagorean scale intolerable, and reform became necessary. To relieve the situation, the "mean-tone" scale was devised. The "mean-tone" scale was so called because its first two intervals were equal, instead of being respectively ⅛ and ⅙ as in the natural scale. The rule for tuning the "mean-tone" scale is: (1) beginning on the sub-dominant (F), tune fifths up and fourths down alternately to produce the four successive notes, C, G, D, A, flatting each note equally and by an amount sufficient to place the resulting A a pure major third above F; (2) tune the remaining seven notes of the chromatic scale as pure major thirds above the notes already established. This "mean-tone" scale did indeed secure eight pure major thirds out of a total of twelve; but the fifths, fourths, and minor thirds were now out of tune—much after the fashion of the game "pigs-in-clover." Not much had been gained for purposes of harmony, and about 1750 A. D., a further change was made to the even tempered scale. This scale, at best, consists of an alternation of fifths tuned up and fourths tuned down, beginning on F and ending on E♯, flatting each note equally and by an amount sufficient to produce an E♯ a perfect octave above the initial F. This even tempered tuning provides satisfactory fifths and fourths, as does the Pythagorean scale, but leaves all the thirds, sixths, and sevenths, badly inharmonic. It is in fact a modified Pythagorean scale, and is but little if any improvement over the Pythagorean. It has one, and only one, virtue—a doubtful one: all tonalities sound exactly alike; no tonality is any better, or any worse, than any other tonality. About this time the piano established itself as a household instrument, and fastened the even tempered scale upon the music of the world. Since the death of Bach, the piano has ruled the music of the Western world with a rod of iron.

But the even tempered scale is poorly suited to musical purposes because of two faults: it is inharmonic, and it is monotonous in tone color. The most perfect scale at present known is the natural scale sometimes called the "just," devised about 150, A. D., by Claudius Ptolemy, the astronomer and mathematician. As a starting point for his just scale, Ptolemy employed a scale first recorded so far as we know by Didymus (63 B. C.–10 A. D.), but which was probably well known at the time and not original with Didymus; for Didymus was an indefatigable compiler, and apparently nothing else. The scale of Didymus is represented by the seris of fractions, 1/8, 1/9, 1/15, 1/8, 1/8, 1/9, and 1/15. Ptolemy improved this series of intervals by transposing the fifth and sixth so that the series became, 1/8, 1/9, 1/15, 1/8, 1/9, 1/8, 1/15. This simple change effected an enormous improvement in Didymus' scale; for the combined interval 1/8 and 1/8, the rather dissonant Pythagorean third, became a pure major third, 1/8, 1/9, and the combined interval, 1/9, and 1/15, increased its consonance by becoming a pure minor third, 1/8 and 1/15. This change gave the scale three pure major thirds instead of two, and the combined interval, 1/9, 1/15, now occurred but once instead of twice; the number of pure minor thirds, 1/8, 1/15, remained two, as before. Ptolemy's improvement resulted in a scale consisting of a series of six ascending pure thirds, alternately major and minor, beginning on F. All its fifths, fourths, thirds, and sixths, were now pure except the fourth upon F and the fifth upon B, both of which are tritones as in the Pythagorean, the "mean-tone," and the even tempered scales.

It will be recalled that the eighth, ninth, and fifteenth intervals of the Chord of Nature were defined respectively as the major tone, the minor tone, and the semitone. The just scale of Ptolemy consists of major tones, minor tones, and semitones arranged ascending in the following order, M m s M m M s, where "M" stands for a major tone, "m" for a minor tone, and "s" for a semitone. This series of intervals, M m s M m M s, is known as the Ionian mode if the fifth note is used as a dominant, and the Hypo-Ionian mode if the third note is used as a dominant. If the first interval of the series, M, is carried over to the final position so that the series becomes m s M m M s M, then the series is called the Dorian mode if the fifth note is used as a dominant, and the Hypo-Dorian if the third is used as a dominant. If, again, the first interval, m, is carried over to the final position making the series s M m

M s M m, then we have the Phrygian mode if the sixth is used as a dominant, and the Hypo-Phrygian if the fourth is used as dominant. The next series, M m M s M m s, is the Lydian mode, or the Hypo-Lydian mode, depending upon whether the fifth or the third is used as dominant. The following series, m M s M m s M, is the Mixolydian mode with the fifth as dominant, and the Hypo-Mixolydian with the fourth as dominant. The final series constituting a mode, M s M m s M m, is the Aeolian mode with the fifth as dominant, and the Hypo-Aeolian with the third as dominant. The additional series, s M m s M m M, cannot be used as a mode because the tritone on its tonic,  is a dissonance.

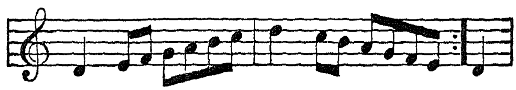
The just scale of Ptolemy thus gives rise to twelve modes, with six different scales and twelve different harmonies. As compared with these *six* scales each with *two pure* harmonies, the even tempered scale has only *two* scales, the major and the minor, each with *one impure* harmony. It is now easy to understand what was meant when it was said that the even tempered scale is inharmonious and monotonous.

But this is not all. All these considerations apply within any given signature such, for example, as the key of C. In the even tempered scale there are only twelve different tonalities; but in just intonation there are at least fifteen different tonalities from seven sharps to seven flats, for the B tonality is not the same as the C ♭, nor is the C ♯ the same as the D ♭, etc. The modulational superiority of the just scale over the tempered now becomes apparent. In even temperament there are two modes in each of twelve tonalities—twenty-four in all. It is therefore possible, theoretically, to modulate from a given key in the tempered scale in any one of twenty-three different directions. But in the just scale there are twelve modes in each of fifteen tonalities—one hundred and eighty in all. It thus becomes possible, theoretically, to modulate from a given key in the just scale in any one of a hundred and seventy-nine different directions. In practice it is necessary to reduce this number materially, but the number of possible modulations still remains much greater than in the tempered scale.

Of the twelve modes that are found in the natural scale, no two sound alike harmonically, and seven of them differ melodically.

The melody of an ancient Greek hymn, or of a thousand-year-old church plain-song, sounds strange and unfamiliar to our ears solely because we are no longer accustomed to any except two of the modes formerly used. Two of them we do still retain, the Aeolian and the Ionian (our minor and major modes, respectively); but the other ten are gone, lost like the ten tribes of Israel. And some of them were so piquant and winsome. I challenge any musician to whistle, or hum, to himself for half an hour the scale of the Phrygian mode,

without falling in love with it. The Dorian,



is a little shyer to woo, but amply repays the necessary effort. More and more, discriminating composers of today are yielding to the bewitching charms of modal melodies.

It is matter for the deepest regret that the same cannot be said for modal harmonies. This is not the fault of the harmonies, however; for where can the composer today find the opportunity of forming a hearing acquaintance with them? So far as I have been able to ascertain there is no place in New York City, outside the services of the Russian Church, where modal harmonies can be heard. Russian Church choristers sing all their lives without accompaniment by any artificial musical instrument; but who else in America does? And no person can sing the natural scale on certain days of the week, and sing beside the piano on the remaining days. He must sing either the one scale or the other; he can not sing both. And few musicians, today, can refuse to bow the neck to the piano. The writer once asked a leading contemporary composer of Russian Church music, a man who has had his *a capella* choir all his life, how he liked church music sung with the piano or organ. First, a shrug; then, "I don't like it; it sounds *bad!*" I wondered what explanation he would offer for the indubitable fact: "What do you think is the reason it doesn't sound well?" "I don't know; maybe it's a notion on my part, but I don't like it."

Sir Hubert Parry says, "An ideally tuned scale is as much of a dream as the philosopher's stone, and no one who clearly understands the meaning of art wants it" (*Art of Music*, pp. 45–6). In reply to this I can only say that the only person who does not prefer pure harmonies to tempered is the person who has never heard them. By way of testing the matter I have had pianos tuned, under my direction, in just intonation for the key of C, and then allowed accomplished musicians to listen to the pure harmonies. After familiarizing themselves with the sound of just harmonies for a few minutes, their reaction when the same harmonies are then tried out on the tempered piano is, "Why, the tempered piano sounds out of tune!" Of course the tempered piano *sounds* out of tune, for the very good reason that it *is* out of tune. Such expression of opinion from the musicians was not at all surprising and, indeed, was confidently expected; but I confess to considerable surprise, the first time it occurred, at finding the piano tuner emphatically agreeing with the musicians.

The difference between pure harmonies and tempered I can characterize only by saying that major harmonies sound *more major,* and minor harmonies sound *more minor.* The characteristic major and minor colors seem to be intensified, the drabness of tempered harmonies to be replaced by such vividness of coloring that the various harmonies stand out with startling clearness. Musicians who undertake to speak authoritatively on the relative merits of pure and tempered harmonies should acquaint themselves with pure harmonies before issuing pronunciamentos.

The cacophony of the present generation is chiefly the expression of a desperate desire to escape the monotony of the tempered scale. The adoption of this scale reduced the number of modes to two, both rather inharmonious, and the number of tonalities to twelve; and music became insufferably dull and tame. The result was a striving after *outré* effects by the introduction of chords more and more dissonant, the division of the scale into fractional intervals less and less harmonious, and finally the frank abandonment of harmony altogether. The sooner composers turn their backs upon all this, the better for themselves and for the rest of us.

The pristine loveliness of Palestrina and his contemporaries, and of present day Russian Church music, is entirely lost when produced in the tempered scale of the piano or organ; Hamlet is simply left out of the play. An adequate conception of such music can be formed only when it is presented as intended by the composer, by a choir that has sung always without being associated with any artificial musical instrument. The writer does not strenuously object to the use of the hand organ in church in lieu of a band to lead the officiants when they are simply marching around; but, when human voices begin to worship musically, then the wind-box should remain discreetly silent.

As a matter of fact it is not so difficult as might be supposed for a choir to acquire the natural scale. To do so, two things are necessary: the first is to keep the ears of the singers uncontaminated, by never allowing them to hear the tempered scale of the piano or organ either at church or in the home; the second is always to sing the major thirds, sixths and sevenths, also the fourths when used in a dominant seventh harmony, *as flat as the ear will stand.* We learned in Chapter 4 that the major third, sixth and seventh of the tempered scale are too sharp respectively by ⅛, ⅐, and ⅙ of a tempered half-tone. These errors of intonation, to which the tempered scale inclines the ear associated with it, must be remedied. After a few months of singing under the regime here suggested, a choir will find itself able to keep the pitch, and that they are slipping into harmonies of a beauty theretofore entirely unknown to them. But to do this the choirmaster should choose his choristers from homes having no pianos, and at church the piano or organ *should never be touched under any circumstances either at rehearsals or during the services.*

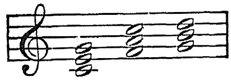
It might be thought that the natural scale could not be played in the orchestra because of the impure scale of the wind instruments; but this is not the case. If the wind instruments are built in even temperament, as they should be, then as we found in Chapter 4 no note of the instrument will differ from the natural scale by more than a third of a tempered half-tone in any of the fifteen tonalities from seven sharps to seven flats; and the *occasionally* faulty notes can be sharped or flatted the necessary third of a tempered half-tone *or less* by adjustments of the player's embouchure. A more serious difficulty in getting an orchestra to play in just intonation is that of keeping the players from associating with the piano or organ; this, for professional musicians, is a very difficult matter indeed.

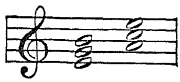
The writer has succeeded in devising a second just scale which is in every respect the equal of the scale of Ptolemy. It will be noted that the Ptolemaic scale, M m s M m M s, has a major tone, M, in the middle, dividing the remainder of the scale into two parts which are exactly equal, each part being composed of a major tone, a minor tone and a semitone. Each of these two equal parts of the scale is known as a *tetrachord.* The first tetrachord is M m s, and the second is m M s. Each tetrachord contains the same intervals, but they are differently arranged: both tetrachords end with a semitone, but the first tetrachord begins with a major tone, and the second begins with a minor tone.

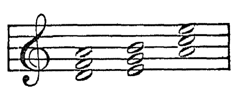
My new just scale differs from that of Ptolemy only in that the two tetrachords are identically alike; each tetrachord begins with a minor tone, ends with a semitone, and has a major tone in the middle. The result is a scale with the following intervals: m M s M m M s. It is tuned as a series of six ascending pure thirds, alternately minor and major, beginning on D. It may be secured from the Ptolemaic scale by tuning the D of that scale a pure minor third below its F. From another point of view, Ptolemy's scale might be defined as three ascending pure fifths beginning on F, and two ascending pure fifths beginning a pure *major* third above F. In a similar manner, the new scale might be defined as three ascending pure fifths beginning on D, and two ascending pure fifths beginning a pure *minor* third above D.. All the fifths, fourths, thirds, and sixths, of this new scale are pure with the exception of the fourth upon F and the fifth upon B, which are tritones just as in the Ptolemaic, the "mean-tone," the even tempered, and the Pythagorean scales. This scale, like Ptolemy's, has twelve modes; but *no mode of the new scale sounds like any mode of the Ptolemaic scale either melodically or harmonically.* The modulational possibilities of the two scales are equal, and the new scale can be used in the orchestra with the same facility as the Ptolemaic.

It might be stated in passing that no other scale of seven intervals can ever be devised that shall be equally harmonious with the just scale of Ptolemy and with the new just scale here presented. If this universal and categorical negative is found obnoxious to any reader, he can satisfy himself of its truth by making the necessary computations upon which the statement is based. In the first place, no scale can be as harmonious as these without utilizing the consonant intervals contained within the octave, the fifth, the fourth, the major and minor thirds, and the major and minor sixths. In the second place, the only intervals which can be combined into pure fifths, fourths, major and minor thirds, and major and minor sixths, are the intervals of the major tone, the minor tone, and the semitone. In the third place, the solution of the two simultaneous indeterminate equations, $p + q + r = 7$ and $(9/8)^p (10/9)^q (16/15)^r = 2$ where p, q and r represent respectively the number of major tones, minor tones, and semitones, in the scale, shows that the only number of major tones, minor tones, and semitones, which can be combined into a scale of seven intervals is three major tones, two minor tones, and two semitones. And in the fourth place, a working out of all the possible successions of three major tones, two minor tones, and two semitones, will show that no other succession than M m s M m M s and m M s M m M s gives so large a number of pure fifths, fourths, major and minor thirds, and major and minor sixths, it being kept always in mind that a major tone and a minor tone constitute a pure major third, a major tone and a semitone constitute a pure minor third, a major tone a minor tone and a semitone constitute a pure fourth, two major tones a minor tone and a semitone constitute a pure fifth, two major tones a minor tone and two semitones constitute a pure minor sixth, and two major tones two minor tones and a semitone constitute a pure major sixth. These computations furnish the necessary and sufficient conditions for the statement made, that no other seven interval scale can be devised that shall be equally harmonious with the just scale of Ptolemy and with the new just scale here presented.

Since this new just scale is here receiving its first presentation, it might be well to consider somewhat further its comparison with the Ptolemaic scale. In the Ptolemaic scale the triads



are pure major, by which is meant that each of the triads consists of a pure major third and a pure fifth. A pure major third consists of a major tone plus a minor tone, as stated in the preceding paragraph, and a pure fifth of two major tones plus a minor tone plus a semitone. The triads  of the Ptolemaic scale are both pure minor triads, consisting of a pure minor third and a pure fifth; it being understood that a pure minor third is a major tone plus a semitone. The supertonic triad of the Ptolemaic scale  differs from the pure minor triad in that both its third and its fifth are smaller than those of the pure minor triad, for this supertonic has a third composed of a minor tone plus a semitone, and a fifth composed of a major tone plus two minor tones plus a semitone. Since this supertonic triad differs from the pure minor triad in these two important respects, it should be known by a different name; and since this triad is the tonic triad of the Dorian mode, it would seem that it might appropriately be called the *Doric minor triad,* and that its third and fifth might be called respectively the *Doric third* and the *Doric fifth.* The triad  in the Ptolemaic scale is a dissonance known as the diminished triad, and consists of a pure minor third and a tritone fifth, it being understood that a tritone fifth is composed of one major tone, one minor tone, and two semitones. The Ptolemaic scale, then, has three pure major triads, two pure minor triads, one Doric minor triad, and one diminished triad.

The triads of the new just scale are quite different. The two triads  are pure major triads, and the three triads  are pure minor triads. But the triad  differs from a pure major triad in that its fifth is a Doric fifth instead of a pure fifth. To differentiate it from the pure major triad, it might be called the *Doric major triad* since it has a Doric fifth. The triad  again is a dissonance, consisting of a Doric third and a tritone fifth. It resembles the diminished triad of the Ptolemaic scale in that its fifth is a tritone fifth, but differs from that diminished triad in that its third is a Doric third instead of being a pure minor third. But since it is at present not necessary to distinguish dissonances, we need not seek a differentiating name for it. The dominant seventh chord of the new scale  differs from the corresponding dominant seventh chord of the Ptolemaic scale only in that its fifth is a Doric fifth instead of being a pure fifth. The dominant seventh chord  in the new scale is identical with the same chord in the Ptolemaic scale if the minor third is utilized in the latter scale instead of the major third,  as is sometimes done.

Summarizing the harmonic differences between the Ptolemaic scale and the new scale, the triads on C, F, E, and A, and the dominant seventh chord on E, remain the same; the triad on G, which is pure major in the Ptolemaic scale, becomes Doric major in the new; the triad on D, which is Doric minor in the Ptolemaic scale, becomes pure minor in the new; the diminished triad on B remains approximately the same dissonance in the new scale that it was in the old; and the dominant seventh chord on G has a Doric fifth in the new scale instead of a pure fifth as in the old. The harmonies that are changed, then, are the triads on G and D and the dominant seventh chord on G.

What, now, are the net effects of these harmonic changes? The Doric major triad on G of the new scale is not as smooth a harmony as the pure major triad on G of the old, but it *is* as pleasing as the tempered major triad of the piano. The pure minor triad on D of the new scale is a smoother harmony than the Doric minor triad on D of the old. And the dominant seventh chord on G of the new scale is not as smooth as the same chord in the scale of Ptolemy, but it *is* as pleasing as the dominant seventh chord on the tempered scale of the piano. The D triad is better, the G triad and dominant seventh cord on G are not quite so good; upon the whole, the two scales are harmonically equal.

And the harmonies belonging to the several corresponding modes of the two systems differ greatly. In the Ionian mode ("the major mode") of the Ptolemaic scale, the tonic, dominant, and subdominant, harmonies are all pure major harmonies; in the corresponding mode of the new scale, the tonic and subdominant harmonies are pure major but the dominant harmony is Doric major. In the Aeolian mode ("the minor mode") of the Ptolemaic scale, the tonic and dominant harmonies are pure minor while the subdominant harmony is Doric minor; but in the corresponding mode of the new scale, the tonic, dominant, and subdominant, harmonies are all pure minor. The writer has not yet had opportunity to investigate thoroughly the harmonies of all the modes in the new scale, especially the plagal modes. Moreover the location of the dominant in the new mode corresponding to the Phrygian mode of the old scale is somewhat in doubt. At present it appears to be a question whether this new mode would follow the analogy of the Phrygian mode and take its dominant on the sixth of the mode, or would take its dominant on the fourth instead; of course it could not have its fifth as dominant, since the triad on that note, B, is a dissonance. Assuming tentatively that the dominant for this mode would be the sixth note, the harmonies for the six authentic modes of the Ptolemaic scale, and of the new scale, would be as follows: (As a means of identification the new modes are designated by the names of the first six letters of the Hebrew alphabet)

AUTHENTIC MODES OF THE PTOLEMAIC SCALE

Mode	Scale	Tonic harmony	Dominant harmony
Ionian	M m s M m M s	Pure major	Pure major
Dorian	m s M m M s M	Doric minor	Pure minor
Phrygian	s M m M s M m	Pure minor	Pure major
Lydian	M m M s M m s	Pure major	Pure major
Mixolydian	m M s M m s M	Pure major	Doric major
Aeolian	M s M m s M m	Pure minor	Pure minor

AUTHENTIC MODES OF THE NEW SCALE

Mode	Scale	Tonic harmony	Dominant harmony
Aleph	m M s M m M s	Pure major	Doric minor
Beth	M s M m M s m	Pure minor	Pure minor
Gimel	s M m M s m M	Pure minor	Pure major
Daleth	M m M s m M s	Pure major	Pure major
He	m M s m M s M	Doric major	Pure minor
Waw	M s m M s M m	Pure minor	Pure minor

The dominant harmony for mode Gimel is given as pure major upon the assumption that the dominant would fall upon the sixth note, C, of that mode. If it should develop that the dominant falls on the fourth note, A, instead, then the dominant harmony would of course be pure minor.

A plagal mode, in either scale, is produced from its relative authentic mode by extending the authentic series of intervals three notes downward, and then dropping the three topmost notes of the series. The plagal mode retains the same tonic as its relative authentic mode, but the dominant changes its location. The dominants for the plagal modes of the Ptolemaic scale were given on page 186; what the dominants would be for the plagal modes of the new scale has not yet been determined. Most of the harmonic principles governing the new scale are as yet entirely unknown. Indeed, the principles governing modal harmonies in the old scale have never been adequately investigated, although Morris' *Contrapuntal Technique in the Sixteenth Century* is a long step in that direction. The polyphonists of the sixteenth century wrote marvelous harmonies, but without knowing much about harmony as such. What the harmonic laws were that governed them in their composition of music they did not know, and neither do we. The harmonic principles underlying strict counterpoint, if investigated and formulated, would probably open the way to an entirely new field for composers. If anyone should imagine that the harmonizing of modal melodies is already well understood, let him listen to even the most scholarly of organists as he attempts to accompany plainsong and he will quickly be undeceived.

The person who wishes to investigate the pure harmonies of either the Ptolemaic scale or the new scale here presented, may do so with but little difficulty. A very simple and inexpensive job of tuning on his piano will enable him to study all the modes of the C tonality, which is representative of all the tonalities; he will be handicapped only by his inability to study modal modulation, but he will find that it will take some time for him to learn all he wishes to know about the harmonic possibilities of a single tonality. The person who is sufficiently interested in the matter to wish to investigate should call in his piano tuner and ask to have his piano tuned (or, rather, a part of it) as follows: (1) leave the strings for the black keys, and the F strings, as they are; (2) starting from F, tune a fifth up to C, then a fourth down to G, then a fifth up to D, tuning each of the intervals "pure," i. e., absolutely free of beats; (3) tune A an absolutely pure major third above F; (4) from A, tune a fourth down to E, then a fifth up to B, each interval being tuned absolutely pure. This tuning will provide the just scale of Ptolemy. To secure the new just scale herein described, the tuning should be done as follows: (1) leave the strings for the black keys, and the strings for D, just as they are in the tempered scale; (2) from D, tune a fifth up to A, then a fourth down to E, then a fifth up to B, tuning each interval absolutely pure; (3) tune F an absolutely pure minor third above D; (4) from F, tune a fifth up to C, then a fourth down to G, each interval being tuned absolutely pure.

This being done, the investigator can acquaint himself with any of the modal harmonies belonging to the key of C, in whichever of the just scales his piano has been tuned to. Of course he can not play in any key except that of C; but the corresponding harmonies will sound precisely the same in the key of C that they would have done in any other key to which his piano might have been tuned. To acquaint himself with the modal harmonies belonging to *either* of the just scales, he can then play selections from Palestrina, Orlando di Lasso, or others of the contrapuntal school; or he will find Olsson's *Ten Variations On Ave Maris Stella* (Augener) an admirable study of modal harmonies for his purpose. The occasional B♭'s found in the latter composition will have to be omitted unless his instrument has been tuned for these notes also. If this is to be done, the B ♭'s should be tuned as pure fifths below the F's. Occasional F ♯'s are also found in modal compositions. If this note is also desired on the piano, it should be tuned as a pure minor third below A. When the tuner puts the piano back into even temperament, he can save time by beginning his tuning from the strings for the white key that was originally left unchanged, F or D as the case may be; the black keys, it will be remembered, are still in even temperament (except for the B ♭'s and F ♯'s, if those notes were changed).

If players of string or wind instruments are to employ either of the just scales in producing music composed in the modes, it will be necessary for them first to learn *accurately* the sound of these scales as produced by some instrument of fixed intonation, such as the piano tuned in one tonality to the just scale desired. Having learned *accurately* what the desired just scale sounds like, it would then be possible for them to reproduce that scale on their string or wind instruments. And the advantage to be gained thereby, of being able to produce correctly music composed in the modes, would amply repay all the necessary effort involved.

It was said in the first paragraph of the present chapter that "the efforts of contemporary composers to find relief in a further elaboration of the tempered scale are foredoomed to failure." Perhaps, in view of the present rather widespread interest in the subdivision of the tempered half-tone, it may be worth while to give this matter further attention.

So far as melody alone is concerned, there is no reason why the half-tone may not be subdivided to the extent of the ear's ability to distinguish differences of pitch. And what is that ability? Stumpf, who spent his lifetime investigating the psychology of tone, was usually able to distinguish differences of pitch as small as one-third of a pulsation per second anywhere within the four octaves lying in the middle of the keyboard (Zeitscrift fur Sinnespsychologie, V. 16, p. 358). But this was not under *musical conditions*. The conditions were those of the laboratory, where the two pitches to be compared could be examined with any required degree of care and deliberation. Furthermore, Stumpf's ability in pitch discrimination was beyond that even of most trained investigators. Stucker found some thirty professional musicians in Vienna to be somewhat less acute than Stumpf in their power of pitch discrimination (Zeitschrift fur Sinnespsychologie, V. 42, p. 396). Vance found ordinary ears untrained in music to be unable to distinguish differences of pitch of less than one-and-a-half to two pulsations per second within the two octaves in the middle of the keyboard, even under laboratory conditions (Psychological Monographs, V. 16, no. 69, p. 133). Upon the whole, it is probably safe to say that skilled musicians under conditions of musical production are able to distinguish melodically about a hundred gradations of pitch to the octave in the middle of the keyboard, the part of the scale to which the ear is most sensitive. This would mean that under musical conditions the *best trained* ears would be able to recognize melodically about eight different pitches within the half-tone in the middle of the keyboard, and fewer at points above or below this.

For purposes of melody, then, it might be feasible to subdivide the half-tone into not more than eight equal parts, i. e., into sixteenths of a tone. But such minute subdivisions would require musicians of exceptionally keen pitch perception if music so written was to be reliably performed. And the intervals so rendered would be entirely beyond the ability of the audience to appreciate. It is even doubtful whether eighth-tones could be appreciated by the audiences who attend musical programs of the better sort. Minute musical intervals were, indeed, employed in ancient Greece in some of their scales (not in their diatonic scale, however), and are utilized even today in India. Doubtless, *for purposes of melody alone,* modern western audiences could ultimately learn to get appreciative enjoyment out of intervals considerably smaller than the half-tone; and it is possible that such music may sometime become of melodic value.

But, for music that is to be harmonically rendered, it is quite another matter. Very few of these minute intervals are so located that they can be brought into harmonic relations with the other notes of the scale in which they would be found. *Harmonically,* most of these infinitesimal scale divisions are excluded. Some of them can be utilized; it remains to discover which of them can be so used. It must be insisted that the harmonic intervals have been very positively established, although not with very great precision, by the notes of the harmonic series, the lack of precision being due to the ear's adaptation to slight mistuning of the harmonic intervals arising from inaccuracies in the scales of artificial musical instruments.

The intervals less than an octave that the ear tolerates as harmonic are those lying close to the fifth, the fourth, the major and minor thirds, the major and minor sixths, and the minor seventh. Tabulated, some of these intervals already known to be tolerably harmonic are as follows:

Fifths			Fourths		
Pure	= 3/2 =	1.500000	Pure	= 4/3 =	1.333333
Tempered	=	1.498307	Tempered	=	1.334840
Doric	= 40/27 =	1.481481	Doric	= 27/20 =	1.35

Major thirds			Minor thirds		
Pure	= 5/4 =	1.250000	Pure	= 6/5 =	1.200000
Tempered	=	1.259921	Tempered	=	1.189207
Pythagorean	= 81/64 =	1.265265	Doric	= 32/27 =	1.185185

Major sixths			Minor sixths		
Pure	= 5/3 =	1.666666	Pure	= 8/5 =	1.600000
Tempered	=	1.681793	Tempered	=	1.587401
Doric	= 27/16 =	1.687500	Pythagorean	= 128/81 =	1.580247

Minor sevenths

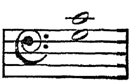
Harmonic		= 7/4 =	1.750000
Diatonic	(F/G)	= 16/9 =	1.777777
Tempered		=	1.781797

These intervals are already known to be tolerably harmonic because, at some time in the history of western music, each one of them has been used musically and recognized as more or less harmonic.

But it is furthermore more than likely that other values for these intervals would be tolerated by the ear as harmonic if the ear were tested for such values. For example, the fifth is known to be tolerably harmonic when it is as sharp as 1.50 and when it is as flat as 1.481481, and for the intermediate value 1.498307. It is quite probable that it would be tolerated as harmonic for other intermediate values than 1.498307, and for values slightly sharper than 1.50 and slightly flatter than 1.481481. It is possible that there may be in the immediate neighborhood of the fifth as many as a dozen harmonically distinguishable pitches each of which the ear would call harmonic if it had a chance to pass upon them. And the same reasoning holds true for the other intervals, the fourth, the major and minor thirds, the major and minor sixths, and the minor seventh. What would be the harmonic possibilities that would follow from such conditions if it were found true that there actually are a dozen such distinguishable pitches for each of these intervals that the ear would call harmonic if it were put to the test? *For each one* of the twelve different harmonic values of the major third, there would be twelve different values of the fifth to be combined with it into a major triad. And *for all the twelve* values of the major third, there would be one hundred and forty-four different combinations of the major third and the fifth that the ear would sanction as a major triad; *one hundred and forty-four different forms of the major triad each in its root position possessing a distinct tone color.* There would likewise be one hundred and forty-four *forms of the* minor triad each *in its root position* with a distinct tone color; and the number of chords of the dominant seventh *in its root position* each possessing a distinct tone color would be one thousand seven hundred and twenty-eight.

Of course we do not know that there are twelve tolerably harmonic values of the major third, or of each of the other harmonic intervals less than an octave; but we *do* know that there are three, and we strongly suspect that there may be more than three. Whether there *are* more than three, we shall never know until someone puts to the test in the laboratory the ear's tolerance for mistuned harmonic intervals. And this much, further, we know: the ear's tolerance for mistuned harmonic intervals is a matter of the greatest possible importance for music, and the question has never yet been investigated. The subject of harmony is not a closed book except in the sense that we do not have musical laboratories equipped and ready to investigate harmonic problems, nor investigators to make use of the laboratories. With such laboratories and investigators, we should discover that the possibilities of harmonic development have as yet hardly begun.

But composers of the future will not only employ new harmonic systems, they will also learn to utilize much more effectively the harmonic materials now employed. At present, if a composer writes



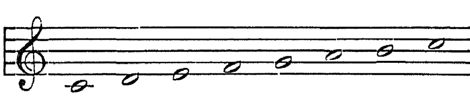
he generally expects to hear just these two notes. But what the ear really has presented to it is

especially if the two notes of the score are produced by instruments of good volume. Indeed, if *any* two notes of different pitch are sounded simultaneously, *a third note is heard* having a pitch which is lower than that of the higher note and which may or may not be of the same pitch as the lower of the two notes. These third notes arising from the simultaneous sounding of any pair of notes in the score were first discovered by the German organist, Sorge, in 1745, and were later discovered again by the Italian violinist, Tartini, in 1754.

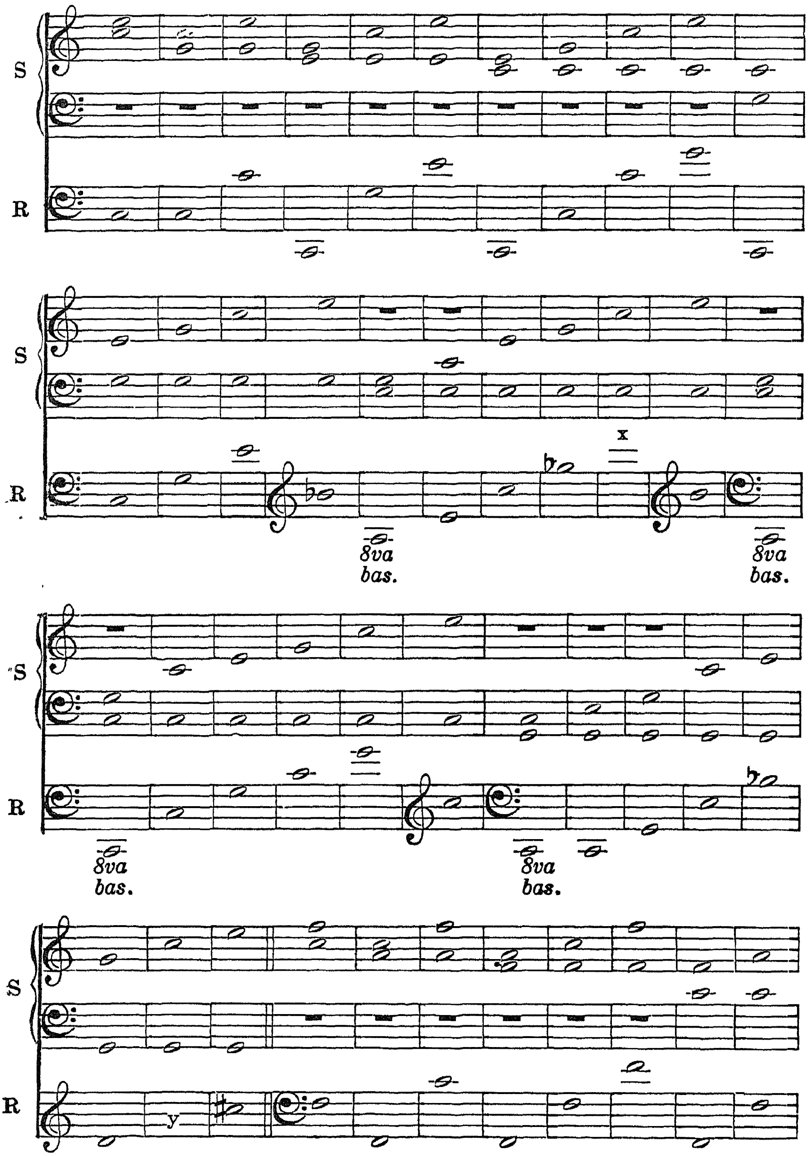
These third tones are known by several names: *resultant tones, differential tones, Tartini tones,* and *terzi tuoni* (*third tones*). The resultant tone is much weaker than either of the two score notes, but may be distinctly heard if the score notes are sounded by instruments of good volume and the resultant note is listened for carefully. Nor are these resultant notes at all imaginary; they have a physical existence in the atmosphere just as truly as do the score notes that are played. They arise in the same way that beats arise, which was explained in Chapter 4. It was there stated that if two notes were sounded simultaneously, one having a frequency of 200 pulsations per second and the other having a frequency of 201, then there would be within the interval of the second a waxing and waning of the intensity of the sound produced by the combined notes, this waxing and waning constituting what is called a beat. But the same principle applies to the simultaneous sounding of two notes of any frequencies whatsoever. Thus the two notes,

having frequencies respected of 264 and 198 pulsations per second, would produce beats at the rate of 66 per second, the difference of the two frequencies 264 and 198. But this periodic waxing and waning of atmospheric density which we call a "beat" might just as well have been called a pulsation; for that is all a pulsation is—a periodic waxing and waning of atmospheric density. It follows, then, that these 66 beats per second are essentially 66 faint pulsations per second. Now if pulsations occur not more than twelve or fifteen times per second, the ear is able to recognize them as separate and distinct auditory phenomena, and we call them "beats." But if they occur more frequently than twelve or fifteen times per second, then the ear is unable to recognize them as separate and distinct auditory phenomena; instead, the pulsations coalesce into one continuous auditory phenomenon which the ear recognizes as a tone with a definite pitch which is determined by the number of pulsations occurring per second. In the case under consideration, the 66 pulsations per second is recognized by the ear as the note whose pitch is

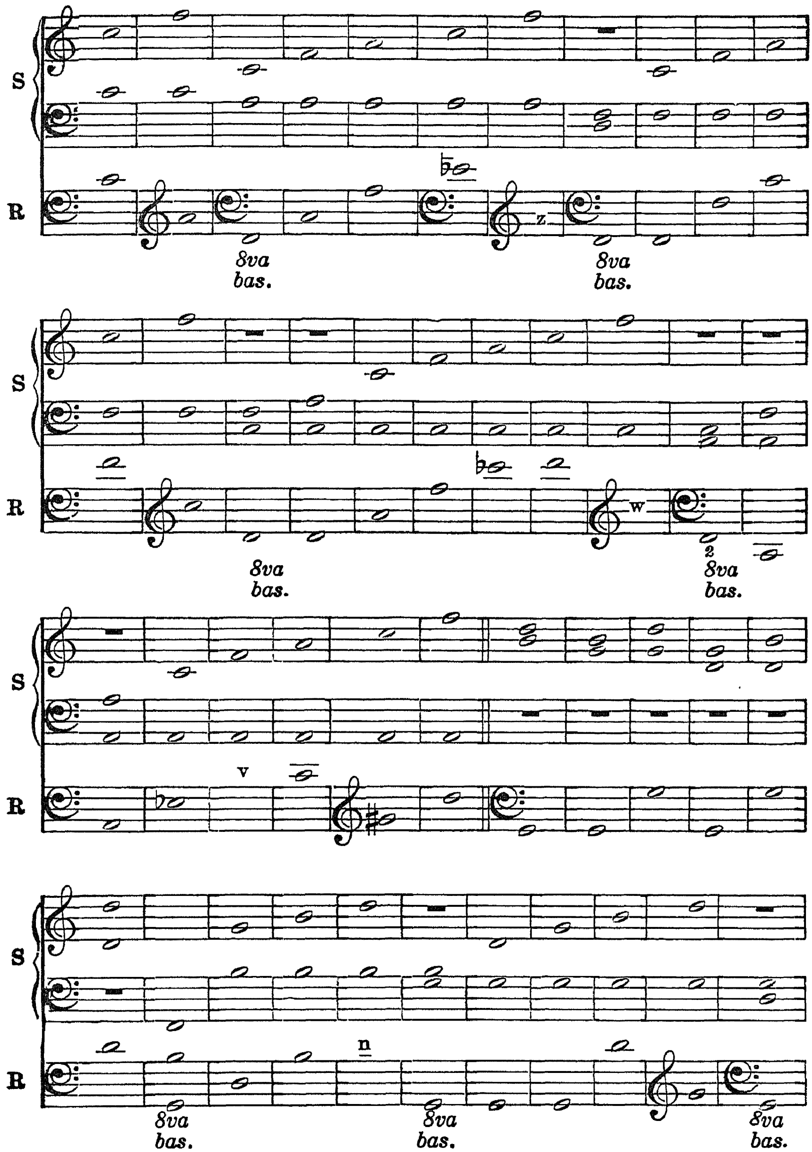
Keeping in mind that 264, 297, 330, 352, 396, 440, 495, and 528, are the respective frequencies of the successive notes of the diatonic scale,



and that a note an octave higher has a frequency twice as great and a note an octave lower a frequency one-half as great, we can compute the resultant notes produced by any pair of notes found in a score in the key of C. For notes near the middle of the keyboard, the resultant notes produced by some of the more usual intervals employed in harmonic writing in the key of C are as follows:



x lies between F and F♯ y lies between G♯ and A



z lies between A♯ and B
w lies between C♯ and D

v lies between A♯ and B
n lies between C♯ and D

u lies between E and F
s lies between A and B♭
t lies between C♯ and D♭
r lies between A♯ and B
m lies between C and D♭

The staves marked "R" show the resultant notes arising from every pair of notes in the key of C for all the tonic, dominant, and subdominant, chords on the double-staff, the score notes being marked "S." Two score notes produce one resultant note; but as additional notes are added to the score, the number of resultant notes increase very fast. Three notes in the score produce three resultant notes; four score notes produce six resultant notes; six score notes produce fifteen resultant notes, etc. The number of resultant notes produced by any number of score notes is given by the formula $R = \frac{n(n-1)}{2}$, where R stands for the number of resultant notes and n for the number of notes in the score. Thus the number of resultant notes produced by eight part harmony is one-half of eight-times-seven, or twenty-eight.

The sounds thus presented to the ear become rather astonishing as compared with the notes appearing in the score. The following bars look innocent enough:

Yet here is what is actually presented to the ear:

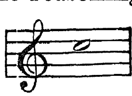
The opening bars of a Magnificat by Orlando di Lasso, with the resultant notes produced by them, are as follows:

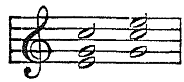
Magnificat

Orlando di Lasso

In taking these resultant notes into account it must never be forgotten that they are much weaker than the score notes, but we must not conclude that they are therefore of no consequence. They help to *color* the harmonic complex presented to the ear, and thus have their part in determining whether that complex shall be pleasing or displeasing. Helmholtz and many of his followers attached considerable importance to resultant notes arising from partials and from resultant notes themselves. There is no doubt that such notes exist; but it is quite certainly a mistake to attach much importance to them. If resultant notes produced by score notes are weak, and of course they are, how much more so are the resultant notes produced by the resultant notes themselves, or by partial tones. It is surprising that so keen a thinker as Helmholtz should so completely have lost sight of their extreme weakness. In my opinion composers can not safely ignore the resultant tones produced by the notes in the score, but may safely disregard the extremely weak resultant tones produced by partials and by resultant notes themselves.

It appears, then, that the notes of the score are not all that is presented to the ear when music is produced. Over and above the score tones there is produced a faint additional harmony (or dissonance) as a kind of harmonic matrix in which the score is embedded, and which either contributes to or detracts from the effect of the score harmony. This matrix harmony is at present almost entirely disregarded. It is, indeed, realized that there is some vague difference between "open harmony" and "closed harmony"; but the precise laws governing the distribution of harmonic parts is as yet *terra incognita*. The principles controlling harmonic matrices and the effective use of them are matters for the future harmonist to discover. When these principles are known, the harmonic materials employed in present or future systems of harmony can be utilized to much greater advantage than is at present possible. The composer of the future will employ his harmonic matrices with a nice discrimination, marshalling them at will to serve his purposes.

It should also be stated that nothing perhaps is more subsersive of effective harmonic practice, nor of consistent harmonic theory, than the gratuitous assumption, now so universal as to be almost the corner-stone of harmony, that tones an octave apart are harmonically identical. The reasoning which would sanction the claim that  and  are harmonically the same notes is precisely the same *kind* of reasoning that would also sanction the claim that  and  are harmonically the same note; in the first case we are identifying the first and second partials, and in the second case we would be identifying the first and third partials; the two cases differ in degree only, not in kind.

The inversion of any note of a chord constitutes a new harmony entirely distinct in color from that of its original chord, both in respect to its score tones and in respect to its matrix. The original chord and its inversion *do* admittedly both belong to the same family of harmonies, but further than this the similarity of the two chords should not be urged. The distinction between the first and second inversions of the tonic triad,  is far greater than that between the root positions of the dominant and subdominant triads,  Indeed, the latter two chords differ only in pitch, while the former two differ in their very essence. Musicians know this, of course, but the distinction is too often lost sight of in the teaching and practice of harmony.

The importance of the musical laboratory for harmonic investigations is second only to its importance for the improvement of musical instruments; and it is high time the laboratory study of harmony was begun. Harmony has too long been regarded as little more than a system of symbols on a sheet of paper. Not that the symbols have not, in a measure, stood for something behind and beyond them, but that what they stand for has too often been largely forgotten in a near-sighted examination of the symbols themselves. Passing notes, altered notes, appoggiaturas, enharmonic changes, suspensions, anticipations—these are paraphernalia by which, through a process of infinitesimal accretions, harmony has arrived at its present state. And these certainly are largely visual instead of auditory concepts. Especially has this been true since the death of Purcell. Up to the time of Bach and the adoption of even temperament, music retained a much more liberal infusion of the objective ingredient. Thereafter, the symbols of the staff notation came more and more to stand for mere subdivisions of the keyboard, until today we have "eye music" brewed without the slightest intention apparent of making any possible appeal to the auditory sense. Harmonic investigation and invention are limited today, not only to those tones which can be represented on the staff but, even further, to those appended to the ends of black and white levers belonging to a musical machine constructed on the avowed principle that in its music every tonality shall sound just as bad as its worst. Whatever sounds can be evoked by the black and white levers, these sounds may the harmonist consider in his studies and investigations. All other sounds must be eschewed; they are taboo and he may not touch them, may not even think of them in his most intimate moments; not because they are too sacred to be contemplated, but because they do not exist. There are, says harmonic theory, precisely twelve tones in the octave, no more no less; and these are they which are found at the ends of the black and white levers.

It is time to forswear such nonsense. There are approximately a hundred gradations of pitch within the octave which are melodically discernible to the normal ear; there is an infinite number of pitches that can be heard within the octave, although the ear can not distinguish all of them as separate pitches. It is time to erase and entirely wipe out the whole staff symbolism *so far as harmonic investigation is concerned.* As has already been stated, and it cannot be too often repeated, *music is not something on a sheet of paper;* it is something that happens in the air and can be listened to. And this statement is as true of harmony as it is of music as a whole. The proper procedure so far as harmonic investigation is concerned is to entirely forget staff symbolism and the limitations it imposes upon the division of the octave, and to institute an investigation of the phenomena of sound, upon which the whole system of music depends; for more things occur in musically agitated atmosphere than are often dreamed of in our harmony.

CHAPTER XIII

RHYTHMS OF TOMORROW

THE MOTHER of music is Rhythm, and she is as fecund today as in the dawn of civilization. Especially since her union with Melody she has peopled the earth with a multitudinous progeny which have always been the comfort and solace of mankind. But the Lilith from whom Rhythm herself was descended is the Dance. Understood in a sense broad enough to include the march, it was with the dance that all rhythmic forms have arisen. "Dancing is rhythmic movement of the body with no other end in view than such movement alone," we said in Chapter 8. The desirability of rhythmic movement as an end in itself has always been felt by mankind, at worship, work or play. Where his work has been such as could be rhythmically performed, man has always found it desirable so to labor. The dance was an essential element of the ritual employed to appease his gods, at least up to the time in the history of religion when it began to be taught that his God was kind and benevolent instead of vengeful. Man has ever regarded the dance as a most satisfactory form of play, and he is still as inveterate a dancer during his hours of diversion as in the childhood of the race. Even when his diversion takes the form of attendance at a program of music, he wishes to feel the beat of rhythms coursing through his body.

From the standpoint of rhythm, as elsewhere, it must be insisted that music is not something on a sheet of paper. Rhythm is not a set of symbols on a music score, nor is it even an auditory expression of those symbols; in the last analysis rhythm is a muscular response to that auditory stimulus, and finds its natural expression, in the absence of inhibitions to the contrary, in muscular movement of some kind or other. The rhythm of measured music is essentially periodic in character, and it must necessarily be continued for a sufficient length of time that the muscles may adjust their reactions to this periodicity if actual rhythm is to result. Otherwise no rhythm comes really into being; it remains a mere set of symbols on a score.

Some of our modernist composers too often forget this. A rhythm which changes every bar or two is denied the opportunity of establishing itself in the consciousness of the auditor, and dies a-borning; it never breathes. The so-called rhythms spawned in such abundance by many of the modernists are too often essentially only so many negations of all rhythm whatsover; their duration is too brief for them to become established as muscular reactions in their hearers, and no rhythm actually arises. The jazzists are wiser in this respect; they pound their rhythms home, over and over again, until the whole muscular system surrenders with complete abandon to the rhythmic frenzy; dignity, reserve, propriety even, may go hang, "we're gonta live anyhow till we die."

Rhythm is periodicity of stress in auditory stimuli finding expression in muscular reaction, and must continue for a sufficient period of time that the muscles may become adjusted to the periodicity. The muscular reactions need not necessarily result in bodily movement however. At the concert, for example, the hearer may inhibit bodily movement in response to the rhythmic stimuli because convention forbids it; and, if a hearer's inhibitions sit too lightly upon him to prevent bodily movement in response to the rhythmic stimuli, we smile more or less tolerantly. But whether the muscular response manifests itself or not, it exists if the rhythm exists.

It may perhaps be questioned whether jazzists have introduced any rhythms that are novel; but it can not be doubted that they have greatly emphasized the significance of rhythm for dance purposes. The characteristic figure of jazz is a pronounced accentuation of the fundamental four-four rhythm of the foxtrot with, at times, the superposition upon it of an additional triple rhythm. This triple-quadruple cross-rhythm is not an invention of jazz musicians;

it was used in the drumming of Dahomey negroes at the Chicago World's Fair in 1893, and was brought by them from Africa. There is something insinuating about this rhythm that seems to stir the savagery lurking beneath skins of every color; it is, in all probability, the most seductive rhythm to which white folks have ever danced. But it is only one of many such cross-rhythms in common use in Africa. African explorers report, although with what accuracy the writer can not say, that so expert in the use of cross-rhythms do those natives become that they are able to dance one rhythm with their feet, another with their hands, and still another with their heads. Certain it is that the Africans have developed far more elaborate rhythms than those employed in European and American music, and that many of these African rhythms might be imported and studied to good profit by composers interested in further development of the rhythmic aspect of music.

But, as musically desirable and profitable as such importation might be, it is not necessary to explore Africa either to discover new musical rhythms or to determine their usefulness for musical purposes. The musical laboratory would accomplish these ends far more quickly, economically, and effectively. At a tithe of the expense of an African expedition, apparatus could be constructed for the investigation of rhythms which would entirely exhaust the list of rhythmic possibilities, and play any rhythm thus produced as long as might be desired for its detailed and exhaustive study by composers and dancing masters who might be interested in its possible use. The mechanical aspect of the apparatus would be so simple that it need not detain us; it is only the results it would accomplish that are of sufficient interest to justify detailed description.

Our knowledge of rhythms at the present time is limited to rhythms of the simplest, most elementary character; for the most part we employ only simple rhythms of the double, triple, and sometimes of the quintuple varieties. The vast majority of our rhythms are of the double type. Our system of musical notation even lacks characters to represent third-notes or fifth-notes; it has characters only for half-notes, quarter-notes, eighth-notes, etc. If we wish to notate a triple rhythm we are driven to the expedient of making three quarters or three eighths the rhythmic unit; and to represent a quintuple rhythm we must make five quarters or five eighths the rhythmic unit. But in nearly all cases the rhythms employed are simple as distinguished from combined rhythms; almost never do we combine rhythms of different types. The six-eight and twelve-eight rhythms are essentially combinations of double and triple rhythms, however, and jazz has sometimes combined triple and quadruple rhythms to good advantage. The success of these tentative efforts in combining rhythms of different types suggests further excursions in this direction. It is more than likely that other combination rhythms could be utilized advantageously in music. Perhaps such rhythms are better designated as cross-rhythms than as combination rhythms.

To make clearer our meaning as to cross-rhythms as well as to suggest a method for more effectively investigating them, let us suppose that we have devised a mechanical beater for the drum so constructed that it will beat with perfect accuracy double, triple, quintuple and septuple rhythms, or any combination of them. For the investigation of double rhythms let it be supposed that our apparatus is so arranged that it would beat two, four, eight or sixteen notes to the measure, would accent any desired note or notes of the measure, and would omit any note or notes that we might wish. It is possible that, even with so simple and so thoroughly exploited a rhythm as the double, we might by this mechanical method discover some new, usable double rhythm or rhythms. To discover a new rhythm under present conditions it is first necessary to conceive the rhythm and then to learn to reproduce it. The conception of the new rhythm must be got out of nothing at all, a pure creative act; and this is not at all easy. But, with our apparatus, it would not be necessary first to get the conception of the new rhythm; the apparatus would supply this. We would simply produce mechanically, one after another, all the possible variations of the double rhythm that could in any way arise, and carefully study each one of these variations to discover whether any of them possessed an appeal to our rhythmic sense and could be put to practical musical use. If any one of them should be found to have musical value, the only thing remaining would be to learn to reproduce the rhythm; the necessity for bringing it into existence by pure creative act would have been obviated by the use of the apparatus.

The same method of procedure would apply to the investigation of triple rhythms. Our machine would beat three, nine or twenty-seven notes to the measure, and would accent any desired note or notes of the measure or omit from the measure any note or notes we might wish. By producing one after another all the different varieties of triple rhythms that could possibly arise, and by giving each one of them careful and detailed study, we might perhaps discover some new triple rhythms that would be of practical musical utility. And, if so, the only thing remaining would be to learn to reproduce it and to introduce it into musical use. Likewise our apparatus would beat for us five or twenty-five notes to the measure accenting any note or notes of the measure we might wish or omitting any desired note or notes, thus affording us the possibility of studying one after another in detail all the varieties of quintuple rhythms that could in any manner arise, with the opportunity of discovering that some of them might be of practical musical utility. In like manner our apparatus would also produce all the possible varieties of septuple rhythms of seven or forty-nine notes to the measure that could possibly arise, and furnish us the opportunity of studying them at our leisure to discover whether any of them might have practical musical value.

But if our apparatus would be useful for the study of simple rhythms of the double, triple, quintuple and septuple types, its value would be incomparably greater in the study of cross-rhythms arising by combining rhythms of these various simple types; for, because of the rhythmic complexity of the combinations so arising it is almost impossible to conceive a new cross-rhythm by pure creative act and is even very difficult to learn such a new rhythm once it has been conceived. The apparatus would entirely obviate the necessity for so conceiving such new cross-rhythms, and would provide all the leisure necessary for learning them once desirable ones had been discovered. Let us consider how we would proceed in order to produce such new cross-rhythms and to study them. First let us combine double and triple rhythms for the production of double-triple cross-rhythms. To do this it would be necessary to so adjust our apparatus that it would at the same time beat double rhythms and triple rhythms, the initial note of the measure for each rhythm being struck at the same instant. With our apparatus so adjusted we could work out, one after another, all the possible combinations of double and triple rhythms for the purpose of discovering any possible double-triple cross-rhythm that might have musical value. As noted above, we already employ a few such double-triple cross-rhythms in music, the six-eight, the twelve-eight rhythms and the triple-quadruple cross-rhythm utilized in jazz; but it is quite possible that many other musically valuable cross-rhythms could be discovered of the double-triple variety if we were systematically to produce all the varieties that could in any way arise and were to give them all careful and detailed study.

In precisely the same manner by which we had produced and studied all the double-triple cross-rhythms that could possibly arise, so too should we produce and study all the possible double-quintuple cross-rhythms, all the double-septuple cross-rhythms, all the triple-quintuple and triple-septuple cross-rhythms, and the quintuple-septuple cross-rhythms. But we should not stop even here in our study of cross-rhythms arising through the process of combining them; we should go even further, and produce and study all the possible double-triple-quintuple cross-rhythms, all the double-triple-septuple cross-rhythms, all the double-quintuple-septuple and triple-quintuple-septuple cross-rhythms, and finally all the double-triple-quintuple-septuple cross-rhythms, that could in any manner arise. Before we had finished we should have discovered that there would be thousands of such cross-rhythms that could arise. Of course the vast majority of the cross-rhythms so produced and studied would be found entirely worthless for musical purposes, but some of them would quite certainly be immediately useful; and each rhythm could be so quickly and so easily investigated that we could well afford to produce the bushel of rhythmic chaff to gain the few grains of rhythmic wheat that we should quite certainly get. Such a method of discovering new rhythms is so simple and expeditious that a single year of its use might quite conceivably turn out more usable musical rhythms than have been produced in the whole history of music up to the present time, Africa included.

It is somewhat surprising, everything considered, that some such method of rhythmic investigation has not heretofore been utilized. Dancing masters are said to be very anxious to discover rhythms suitable for novel steps to be introduced as new popular social dances. These could be discovered in abundance by systematic rhythmic investigation of the kind here suggested. A mechanical beater for the drums, of the kind above described, and a couple of ball room dancers apt at picking up new steps would afford all the equipment necessary. When the apparatus had been set for the production of a new rhythm, it would be necessary for the dancers to listen for a while to see whether they could get the feel of the rhythm. If it was impossible for them to get the feel of it, it would be necessary to abandon that rhythm and try another; but, having once succeeded in feeling the beat of the new rhythm, the only thing remaining would be to devise a suitable step to accompany the rhythm, and the new dance would be born. Associations of dancing masters and publishers of dance music would reap enormous returns from a very small expenditure in this direction.

Ballet masters and composers of ballet music would profit just as generously, except in dollars and cents, from investigation of the same kind. For ballet music, the investigation of cross-rhythms would probably be especially fruitful. For example, having discovered a combination of three rhythms that could be made to run as a team in one harness, what could be more interesting than their utilization for the presentation of a triangular ballet story where each of the three rhythms would be identified with one of the three characters in the ballet, each being heard always when its corresponding character appeared on the stage and dying away whenever the character to which it belonged was not present? Ballet music composed in this vein would possess all the dramatic interest of the ballet story itself.

Music of this sort would have all the characteristics of what might be called rhythmic counterpoint. To make entirely clear the meaning of "rhythmic counterpoint," it should be borne in mind that these rhythms and counter rhythms could all be satisfactorily presented on instruments of indefinite intonation, such as the drums, and that the rhythms themselves would be treated contrapuntally without any possible reference whatever to pitch-notes of any kind, either melodic or harmonic. But after the rhythms had been successfully woven together into a satisfactory contrapuntal rhythmic fabric, then each of the rhythms could be provided with an appropriate melody or countermelody to provide an harmonic development such as would be desired. The writer is quite sanguine as to the possibilities of such a contrapuntal use of rhythms themselves, as distinguished from melodies and countermelodies all progressing under a single rhythm. For ballet purposes as well as for absolute music, composition in which rhythms themselves were treated contrapuntally would open a whole new field of musical composition of a most fascinating character. Indeed the writer is of the opinion that the subject of rhythm is as yet almost entirely undeveloped, and that it holds wonderful possibilities as yet but little dreamed of.

CHAPTER XIV

IMPROVING ORCHESTRAL INSTRUMENTS

WITH respect to at least two of the three individuals involved in the production of music, the composer and the instrument maker, there still lurks in the popular mind entirely too much superstition. Attention was called in Chapter 11 to the fact that the composer of music is popularly regarded as somewhat in the nature of a magician, and that musical composition itself is held as almost if not quite one of the black arts. To the childish mind of that Caliban creature which we call the public, the maker of a musical instrument is unapproachable, ineffable, a Sphinx-like Presence, before whom it craves only the priceless boon of prostrating itself in speechless and palpitating awe. To the uninformed musical enthusiast, one of the loquacious sort, the Buddha was quite an insignificant figure as compared with Stradivarius.

And yet a musical instrument, any musical instrument, is as much a piece of machinery as is a pump, a machine constructed for the sole purpose of accomplishing a certain piece of physical work, the production of periodic pulsation in the atmosphere. In fact those musical machines known as wind instruments, and including the human voice, come much nearer being simply pumps than would ever be suspected by the unthinking. A pump produces pulsations in a stream of water, or whatever fluid is being pumped; and it does nothing else. A wind instrument of any kind, including the human voice, produces pulsations in a stream of air; and it does nothing else. A percussive musical instrument, or a stringed instrument, also produces pulsations in the air and it does nothing else; although the stringed instrument goes about its job in a very roundabout manner. Yet it does not occur to anyone to regard a musical instrument as a piece of machinery; if it did, we should soon have better musical instruments than we now have.

The historical development of the bowed instruments has been presented in great detail again and again. The reasons for the successive changes in these instruments and what has been gained thereby, if anything, has been less frequently considered. This is as might have been expected, just as chroniclers are more numerous than writers on the philosophy of history. To consult the records and set down in chronological order what is recorded therein is one thing; to look beneath the events and determine their significance is quite another. To enumerate the changes that have been made in the bow instruments is a much easier task than to estimate the value of those changes. Why these instruments have assumed their present forms, whether those forms are the best possible, and whether further changes can advantageously be made, are questions which can be answered only in the light of a thorough understanding of the essential nature of the instruments and of the methods by which they accomplish the results they are designed to produce. And an understanding of the action of the bow instruments is enormously difficult.

Of all musical instruments the bowed are, with the sole exception of the human voice, the most indirect and complicated in their method of tone production. In the brass instruments, of which the horn may be taken as a type, the production of tone is comparatively straightforward and simple. The lips of the player are so compressed and stretched as to allow air to escape into the instrument only in a series of puffs. These puffs travel from the mouthpiece of the horn to the bell and enter the atmosphere in which we live immersed, producing a succession of pulsations which the ear interprets as sound. This process is easy to understand. In the reed instruments, of which the clarinet is an example, a reed flutters back and forth between the air cavity of the mouth and that in the instrument, likewise compelling the air to escape in puffs. This again is easy to understand. But now consider the process by which the violin, as a type of the bow instruments, goes about its job of producing atmospheric pulsations. A rosined bow is drawn across a taut string pulling it away from its position of straightness between bridge and nut. When the string has been drawn far enough so that the pull of the string against the bow is greater than the rosin can withstand, then the string escapes from the hold of the bow and flies back toward its original position. Whether the string recedes entirely to its initial position or stops short of it or goes beyond it is, I believe, not yet definitely known. It must be remembered that the bow is all the time seeking again to lay hold of the string and stop its retreat. When the bow does finally get hold of the string, the little drama begins all over again. It is evident to my mind that the bow, because of its constant clutching at the string, does not permit it to recede quite to its position of rest although this latter is not the orthodox view. But it is certain that neither the progress nor the recession of the string is at a uniform rate; its rate of motion varies continuously. That this is the case is shown clearly and conclusively by graphs of the sound the string makes.

But if an understanding of the string's motion is not easy, that of the bridge is difficult indeed. Is the bridge pulled back and forth in its own plane by the action of the string, does it jump up and down on the belly, or does it move forward toward the neck and backward toward the tail-piece? All these questions are in dispute and entirely unsettled. So far as the vertical motion is concerned, it is known that the right foot of the bridge is less free to move than the left. The view most generally accepted seems to be that the right foot is approximately stationary while the left foot pounds up and down on the belly like a hammer, but without ever entirely leaving it. To me this view appears incomplete at least, if not fantastic. I am convinced that the amount of motion communicated to the atmosphere by the motion of the bridge toward and from the neck is greatly underestimated. The effect of a mute on the tone of a violin would tend to indicate to any reflective mind that the bridge is pretty nearly the whole show. Yet few students of the subject seem to have grasped the importance of the forward and backward motion of the bridge.

It is generally believed that by far the major portion of the string's motion is communicated to the atmosphere by way of the belly. I am willing to concede that the portion so communicated is large; but the effect of the mute, like a troublesome ghost, will not permit me to rest content in entire acceptance of the conventional view. But, be the amount greater or smaller, it is obvious that whatever motion the belly has it receives through the two feet of the bridge. As Savart has shown conclusively, by mechanically clamping first one foot of the bridge and then the other, the motion received from the right foot is small indeed. This is, of course, due to its proximity to the sound-post which serves to damp its motion almost completely.

And with the sound-post we arrive at "the soul" of the violin, as the French call it. But whether "l'ame" is a beneficent spirit or an evil one does not so easily appear. The removal of the sound-post does, indeed, greatly impair the tone of the instrument; but this proves only that it serves *some* useful purpose. What that purpose is, and whether it might not be much better served by some other means, is not at all established thereby. It is usually assumed, rather hastily it would seem, that the function of the sound-post is to communicate motion to the back of the violin. This view does not at all commend itself to the writer. The principal duty of the sound-post is undoubtedly its most obvious one—and its most overlooked: to enable the back to assume part of the downward pressure of the bridge upon the belly. This downward pressure varies considerably for different instruments and with different strings, but is usually somewhere in the neighborhood of fifteen pounds—too much to be borne continuously by the belly alone. The sound-post transfers part of this pressure to the violin's back. Would some other form of support permit greater freedom of motion by the right foot of the bridge? Would a treble-bar, for instance, provide adequate belly support and still allow as great freedom of motion to the right foot as the base-bar allows to the left—or even greater? Or would some other type of strut between belly and back give better results? Or, again, should the ribs be tied together for the belly to rest upon like a roof and the belly bear the whole pressure without other assistance except possibly some additional thickening? The problem is essentially one for a civil engineer, not for a musician. This much, however, is approximately certain: whatever method of belly support will permit the greatest freedom of motion to the bridge will give the most satisfactory tone. Nor must it be forgotten that the strings are tied indirectly to the ribs of the violin through the neck at one end and the tail-piece and button at the other, and that a small portion of the string's motion is therefore contributed to the atmosphere by way of the ribs.

It will have been noted that the influence of the varnish, that subject so dear to the heart of the violin connoisseur, has not been enlarged upon to any great length. This for the reason that the vast accumulation of doctrine about the tonal importance of the varnish is largely unadulterated superstition. So far as I am aware no one advocates the varnishing of the inside of the violin; yet whatever *tonal* reason exists for varnishing the outside calls with equal force for a similar treatment of the inside.

With all these matters of fundamental importance regarding the manner in which the violin essentially behaves still in doubt, with the precise function of each of its constituent parts as yet unknown, how can any sober-minded person not entirely devoid of fiddle knowledge assert that the violin has reached a state of perfection? To do so is arrant nonsense. Have all the steps by which the bow instruments have reached their present status been taken in the wisest possible direction; and has the last step been taken? No one has enough positive knowledge on the subject to warrant our being disturbed for a single moment by his answers to these questions, be he an "authority" or not. Any expression of opinion on the matter is a statement of faith pure and simple and not of knowledge actually possessed. My confession of faith with respect to the violin runs counter to the one conventionally accepted: I believe the violin, together with the rest of the bow instruments, can be improved and that materially.

It might be well to note some of the defects of the violin persistently ignored by those for whom Cremona is the holy city. In the first place the tone of the violin is inexcusably weak. When twenty-four first violins are necessary to balance one first flute, one first oboe, one first clarinet, something is wrong. A musical instrument is a machine for producing periodic pulsations in the atmosphere. Its efficiency is measured by the degree of success with which it accomplishes this end. No method is at present known of determining what portion of the bowing energy is actually communicated to the atmosphere to produce pulsations, but the fraction is probably small. It is also more than likely that the efficiency of bowed instruments can be materially increased. And if anyone thinks their tone quality would necessarily be impaired by increasing their volume, let him listen to the playing of a string quartet amplified by present-day methods almost to the sonority of a concert band. So far from losing in quality, the tone gains if anything.

And the violin possesses "wolf-tones," notes so objectionable both in quality and volume that they would be considered inexcusable if found in the voice of a first-rate singer. The wolf is due to the fact that the machine, for some reason, almost completely fails of its purpose so far as the production of this particular note or notes is concerned. The failure is, of course, due to defective structure of which three varieties are already known: faulty placement of the sound-post, faulty construction or position of the bass-bar, and faulty graduation of the belly's thickness. That a wolf may be caused in each of these ways is shown by the fact that the wolf has been removed by treatment in each of these three directions.

A third fault of the violin is that the open tones differ from the stopped ones, both in quality and volume, to such an extent that the evenness of the scale is seriously impaired. The cause of the discrepancy is not far to seek: for stopped notes the string is terminated by the soft finger-end while for open notes it is terminated by the hard nut. The result is that the open notes are much more resonant and brilliant in quality than the stopped ones. Of course this discrepancy can be more or less concealed by avoiding the use of open notes; but it would vanish entirely if either the nut were soft like the finger-end, or the finger-ends were hard like the nut.

The defects of the violin can be remedied; but, as has been stated, it is a problem for an engineer not for a musician. Put a violin in the hands of an able civil engineer—one capable of designing a suspension bridge—furnish him with a moderate amount of fundamental information about sound, tell him to improve the instrument, and in a year or so he will turn out such a violin as Stradivarius dreamed of all his life but never succeeded in building. If this be blasphemy, make the most of it.

And if the violin can be improved, so too can the viola, the 'cello and the double bass. Especially is this true of the viola, which is a comparative failure because its size is inadequate to the tessitura assigned to it by composers. Playing a fifth lower than the violin, the length of the viola should be just a half greater than that of the violin; but of course a viola of this size could no longer be played on the arm, it would have to become a *viola da gamba* instead of a *viola da bracchio* and be held on the knees in playing.

Will the bow instruments ever be improved? Not if dealers in old violins can prevent it. A merchant whose shelves are filled with instruments for which he hopes to receive from $500 to $60,000 each can hardly be expected to welcome innovations which might at any time render his stock worthless. And if you assume that he will not employ every possible means to avoid such a contingency you will be disappointed. The dealer is on the long side of the market in old violins and must protect his interests. But in one respect at least his position is very strong; for the customer's child-like faith in the dealer in old violins is something beautiful to witness—from behind the counter. It is a question whether such phenomenal credulity has ever been equalled in the whole history of human gullibility. According to the dealer there never has been, there never can be, any merchandise to equal the goods he has for sale; he himself says it. Your only means of verifying any of his statements is to call in one of his confederates as referee; and you are to stand and deliver, open mouthed but mute, whatever price he may choose to ask you. The interests of the public are diametrically opposed to those of the dealer in old instruments; the public would like to see better instruments produced if possible, the dealer is opposed to this. It remains to be seen whose interests shall determine the trend of developments.

I suppose everyone has his own little galaxy of saints to whom he does reverence; I know I have mine, Sir Isaac Newton, Theobald Boehm, Charles Steinmetz, Luther Burbank, Thomas Edison, a few others perhaps. As I name them over I note that they have all been men of indefatigable industry whose labors have greatly contributed to human welfare. Some of them have been adequately rewarded in some way or other, some of them have been rewarded not at all. None of them gave much thought to the matter of reward; the work itself was the thing, rather than any reward it might or might not bring.

In the first decade of the nineteenth century there was a certain goldsmith's apprentice in Munich who spent his days mastering his craft and his evenings teaching himself to play the one-keyed flute. By the time he was sixteen years old he had become a good enough mechanic that, having become dissatisfied with his old flute, he sold it to his chum, borrowed from a friend a four-keyed flute to serve as a model, and made himself a new instrument. His playing of the new instrument so annoyed a professional flutist of the neighborhood that the latter in self-defense offered to furnish him systematic instruction upon it. The young mechanic showed such improvement that at the end of two years he was able to secure a regular position in a theatre orchestra of the city. He was still dissatisfied with his instrument, however, and constructed for himself and for others copies of all the best flutes available, but incorporating in them many improvements of his own. The remaining seventy years of his life he gave almost exclusively toward constructing a flute that should satisfy him, but never quite succeeded in doing so.

When Theobald Boehm died in 1881 at the age of eighty-eight there was little left of the flute to identify the instrument with which he began. The instrument, which theretofore had been constructed of wood, was changed into one of silver. The bore of the instrument, which had been conical, increasing in diameter from the lower end to the upper, he changed so that it became cylindrical. The inside dimensions of the head-joint he completely revolutionized, and he changed the distance of the blow-hole from the end plug. He changed the height and design of the posts which support the keys, and improved the screws entering the posts as well as the method of fastening the springs to the body. He so revolutionized the system of fingering used in playing the instrument that flutists had to learn to play all over again. He changed the manner of blowing the flute, and the character of tone produced by it. Indeed the only feature of the flute I can think of that Theobald Boehm did *not* change was the position in which it was held to be played.

Boehm never made a flute that entirely satisfied him, but the instrument he produced was such a vast improvement over the old one that the Boehm flute is now used by every professional flute player the world over. While the flute is not without its faults, it probably approximates more nearly the possibilities of which it is capable than does any other musical instrument. Its tone-quality and intonation will probably never be materially improved, it is as beautiful to look at as a Cremona violin, and as a piece of machinery it is as well constructed as a high grade watch. It has been at the same time the inspiration of all the improvements since made in other woodwind instruments, and the despair of the makers of other woodwinds because they have not been able to equal it. While Theobald Boehm did not attain his ideal, he probably established an ideal for other wind instrument makers for all time.

Boehm was the first man to make a musical instrument according to scientific principles; and since him there have been but two others, D. J. Blaikley and Victor Mahillon, the latter dead, the former retired. Arriving at the conclusion, at the age of fifty-two, that he would never be able to produce the instrument he wished without the aid of scientific knowledge, Boehm gave two whole years to the study of sound under Professor von Schafhautl of the University of Munich. At the end of those two years he turned out his flute in its definitive acoustical form; his later improvements were confined to matters of mechanism. And withal he was one of the most modest, unostentatious individuals imaginable. After giving seventy years of his lifetime to a labor of love for the benefit of his fellowmen, he was reluctant to permit even a brief biography of himself to be appended to his explanation of the improved instrument. I wish there were more persons like him.

Why do I regard the flute as approximately a perfect instrument? Every musical instrument has its own inherent defects peculiar to itself which can never be overcome; but, after all these are taken into account, every musical instrument of whatever kind should possess these three characteristics: (1) its scale should be sufficiently correct that it shall not be offensive to the most discriminating musical ear because of faulty intonation; (2) notes a half-tone apart should be nearly enough alike in tone quality that they can not be identified because of their tone quality alone; (3) throughout its compass the instrument should furnish a reasonale facility of execution in all signatures. The instrument which lacks any one of these three qualifications is an instrument upon which there is yet work to be done before it can be regarded as reasonably perfect. The instrument which possesses all of these characteristics is an instrument which may be looked upon as completed.

The flute is an instrument which possesses all three of these characteristics. Its intonation in the first two octaves is entirely satisfactory; the intonation of the highest octave leaves something to be desired, but this probably can not be overcome. The tone quality of chromatically adjacent notes can not be distinguished, and its facility in different signatures throughout its compass is very nearly equal. No other instrument of the orchestra possesses to the same degree all three of these characteristics, and, for that reason, no other orchestral instrument is as nearly perfect as the flute.

Of the remaining woodwinds, the oboe probably most nearly approaches the flute in possessing all these characteristics. Its intonation of course depends much upon the player, as is true of all the woodwinds; but the intonation of the oboe itself, as distinguished from that of the player, may be said to be satisfactory. The same is true of the tone quality of chromatically adjacent notes; no two are sufficiently different in tone quality to be distinguished because of that alone. Its system of fingering, moreover, is such that the player is able to feel very much at home in any signature throughout the compass of the instrument.

As much can not be said for either the clarinet or the bassoon. Both of these instruments badly need a complete overhauling such as Boehm gave the flute. The intonation of the clarinet is so faulty that clarinetists have come resignedly to accept the claim of clarinet makers that it is impossible to construct a clarinet that shall be in tune. The solo clarinetist of the United States Marine Band once said to me, "There never was a clarinet that was in tune"; and his view is representative of the opinion of professional clarinetists in general. When the clarinetist needs a new instrument he tries out clarinets by the score until finally he finds one that he can force into tune by "lipping," and this one he purchases.

In the matter of evenness of scale the clarinet is as faulty as it is with respect to intonation. Of the twenty-five tone holes of the clarinet there are only about half a dozen whose notes can not be positively identified through tone-quality alone by a person familiar with the particular clarinet being played. The bell notes, for example, are much fuller, rounder, less reedy, than the notes a half-tone above them. D in the lower register is probably the best note of the entire register; it is rich, round, full and glorious. C♯ just below it is abominable: fuzzy, choked and anaemic. All the throat notes from E to B♭ are unmusical except G♯ and A. The F♯ and B♭, however, will be good notes if made with the side keys. In the lower joint both the G and the A speak with difficulty, seeming inclined rather to stick in the instrument than to emerge freely from it; and the same is true of the notes produced by the same holes in the upper register, D and E.

From the standpoint of facility in different key-signatures the so-called "Boehm" clarinet (with which, however, Boehm never had anything to do) is quite satisfactory, although it might be improved slightly in one or two respects. But its key mechanism is atrocious when compared with that of the flute. So noisy are the keys that I have heard the clarinets of a large concert band rattle distinctly enough during the playing of a program to be heard plainly backstage. Nothing of that sort would be at all possible with flutes. One of the reasons why one never hears a clarinet solo as one does flute solos is that the rattling of the key mechanism would be distinctly audible in a pianissimo passage. Another reason is that many notes of the clarinet are so poor in quality that the soloist would have to change frequently during his solo to a clarinet in another key in order that the bad notes might be avoided, as the clarinetist now is compelled to do in the orchestra.

None of these faults of the clarinet are inherent in the instrument. The faults remain simply and solely because clarinets are not constructed with the painstaking care that is given to the construction of the flute. There is no reason whatever why the intonation of the clarinet in the lower and middle registers can not be psychologically perfect, i. e., accurate enough that the most discriminating of musical ears will not be able to tell whether a given note is too sharp or too flat. There is also no reason why the scale of the clarinet can not be even enough in tone quality that adjacent notes can not be qualitatively distinguished except at the point where the notes change from the lower register to the upper, or vice versa. There is furthermore no reason why the mechanism of the clarinet can not be as silent in its operation and as beautiful in its appearance as that of the flute. When someone does for the clarinet what Boehm did for the flute he will deserve equal credit with Boehm except for the fact that Boehm broke out the pathway which the feet of the clarinet reformer will have to follow.

It would be ungracious indeed to underrate the work of Savary, Jancourt, Triebert, Buffet, and Heckel toward the improvement of the bassoon. But it would also be an ignoring of patent facts if we failed to recognize that the bassoon is still in most unsatisfactory condition. The intonation of the bassoon is worse, if possible, than that of the clarinet. Indeed the intonation of the bassoon is so bad that the bassoonist can not play any bassoon in tune except his own. Moreover the key mechanism of the bassoon is such that the notes belonging to the sixth from bottom B♭ up to G on the first line of the bass clef can only be played when detached from one another, and even so they must be played quite slowly. But these are precisely the notes for which the woodwinds make chief dependence upon the bassoon, and for the lower four of these notes the bassoon is the woodwind's sole dependence.

Someone should set himself the task of devising a key mechanism for the notes of this lower sixth on the bassoon which would make it possible to slur from any one of these notes to any other one of them. The problem should not be beyond solution; there are nine notes to be fingered from B♭ up to G, and there are two thumbs and two little fingers available with which to finger them. The two little fingers already finger four notes on the clarinet, or even five notes if the instrument happens to have a low E♭. Surely it would not be impossible with a suitable key mechanism to finger nine notes on the bassoon with the four fingers that are available. Like so many other problems in music, this is apparently one which has merely been overlooked.

I am also convinced that the faulty intonation of the bassoon can be remedied. The difficulty respecting intonation has been overcome in the sarrusophone, and the same might perhaps be done for the bassoon by employing the same means. The defective intonation of the bassoon arises, of course, from the fact that some of its tone holes are bored through the walls obliquely, which practice makes it impossible to produce a tone hole whose length from the inside surface of the tube to the outside shall meet very precise specifications. In consequence, the pitch of the note produced through the hole is not very precisely determined, and faulty intonation is the result. If the tone holes were all bored straight through the walls, the intonation of the bassoon could be made as accurate as desired. The question naturally arises whether the tone quality would then be impaired; but I am of the opinion that this need not follow if sufficient attention be given to the determination of the proper sizes for the several tone holes. It should not be forgotten that the tone holes of the sarrusophone are much larger than those of the bassoon, and that this fact is largely responsible for the difference in the tone qualities of these two instruments.

Of the brass instruments used in the orchestra the trumpets and tubas have piston valves, the horns have rotary valves, and the trombones are without valves of any kind. Each of these types of instrument has its own advantages and disadvantages. The trombones are capable of the best intonation of the three; but notes can not be slurred on the trombone without producing a portamento, hence it is necessary to play notes of different pitch slightly detached. This difficulty is of course inherent in the instrument and can never be entirely overcome; but the disadvantage in this respect is not great and is more than compensated for by the trombone's superiority of intonation. There is also another defect inherent in the trombone that can never be entirely overcome. Since the outside slide fits over the inside slides, it must necessarily be a little larger than the latter. This results in an air column whose diameter changes suddenly at the ends of the inside slides, by an amount equal to the thickness of the walls of the inside slides. When the trombone is in the "third position," producing A♭ on a B♭ tenor trombone, this discrepancy in the diameter of the air column produces a tone which is very likely to "break" if the volume of the tone is forced very much. To avoid this difficulty the inside diameters of the inside and outside slides should be as nearly equal as possible, i. e., the walls of the inside slides should be made as thin as possible. This difficulty can never be overcome entirely since it is a physical impossibility to make the walls of the inside slides of no thickness whatever, but the difficulty may be minimized by making the walls of the inside slides as thin as possible through intelligent selection of a suitable material from which to construct them.

Trumpets and tubas possess a similar defect through faulty construction of their pistons. Neighboring airway tubes through the pistons are placed so close together that their walls are indented by pressing against one another. The resulting constriction of the air column impairs the intonation of the instrument at some point in its scale by causing one or more of the open tones to be too sharp or too flat. This difficulty is entirely unnecessary and would be obviated by placing the airway tubes far enough apart that they would not indent each other. This defect well illustrates the customary insincerity of manufacturers of most wind instruments: it is a defect that is concealed and that would not be recognized as a defect by one purchaser in a thousand even if discovered; so why bother about it? A similar defect found in nearly all brass instruments of whatever type, and equally inexcusable, is the offset in the air column at the end of the mouthpiece due to unnecessary thickness of the mouthpiece at the inner end. Players of brass instruments are not aware that this impairs the musical value of their instrument, and the manufacturers either do not know or do not care; thus the defect is perpetuated.

Another unpardonable fault of brass instruments with piston valves is the leaking of air between the pistons and their casings. Almost never does one find a brass instrument with piston valves through whose pistons air can not be blown with the greatest ease. No brass player would accept an instrument with a pin-hole somewhere in its tubing, because it would make the instrument hard to blow. It does not occur to him that leaky pistons have precisely the same effect on the playing of the instrument. One wonders what would happen to the manufacturer of an automobile engine whose cylinders leaked as badly as do the cylinders of a piston valve instrument.

French horns are usually made with rotary instead of piston valves; but whichever type of valve is to be used they should be air-tight if an easy blowing instrument is to be secured. It ought to be better understood by players of brass instruments that the conditions necessary for an easy blowing instrument are an air column with walls that are absolutely air-tight and as smooth as glass; that the conditions securing correct intonation are an air column unconstricted throughout its entire length by anything in the nature of a dent or an offset, and bows for each of the three valves that are the correct length; and that the quality of tone, so far as the instrument itself is concerned, is determined solely by the taper of the air column from the player's lips to the outside edge of the bell. All these contentions will be immediately apparent to the thoughtful player, with the possible exception of the claim that the walls containing the air column should be as smooth as glass. As smooth as ice would perhaps have been more appropriate phraseology, since the whole air column must be propelled back and forth like a piston several hundred times a second by the lips of the player. When this fact is taken into consideration it will become obvious that the smoother the walls containing the air column the smaller the amount of the lip's energy that will be lost because of friction and, in consequence, the easier the instrument will blow.

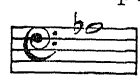
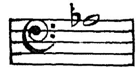
It was intimated in the latter part of Chapter 4 that the tuning of the valve instruments is a very difficult matter, and that their perfect tuning is impossible with less than six valves. A bowing acquaintance with the difficulty involved should perhaps be made at this point. The length of the air column in the B♭ euphonium is about 100 inches. Since the frequency of B♭ is ⅛ greater than that of A♭ (in the key of E♭), then the length of the air column for A♭

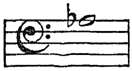
should be $\frac{1}{8}$ greater than for B ♭ (100 inches), or 112.5 inches. A bow 12.5 inches in length for the first valve will therefore produce a correct A ♭. Since the frequency for B ♭ is $\frac{1}{5}$ more than for G (in the same key of E ♭), therefore the air column for G will have to be $\frac{1}{5}$ longer than for B ♭ (100 inches), or 120 inches, and we will need a bow for the third valve 20 inches in length to add that amount to the air column when G is produced. If now we use both the first and the third valves to produce F, then we will have an air column of 132.5 inches to produce F. But the frequency of B ♭ is $\frac{1}{3}$ greater than for F (in the same key of E ♭), and the length of the air column for F should therefore be $\frac{1}{3}$ more than for B ♭ (100 inches), or $133\frac{1}{3}$ inches, instead of 132.5 inches which we get by the use of the first and third valves; i. e., our air column is $\frac{5}{6}$ of an inch too short to produce a correct F, and the note produced is therefore too sharp. Thus if we make the bows for the first and third valves of the proper length to produce notes of correct intonation when each valve is used alone, then the note produced when the two valves are used together is too sharp. And the same is likewise true when valves one and two, or valves two and three, are used together; and it is still worse when all three valves are used at the same time.

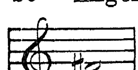
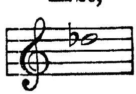
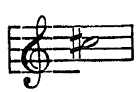
The solution of the difficulty is complicated. It consists in making each of the bows too long by such respective amounts as will equalize as nearly as possible all the errors arising from using each valve alone and in all the possible combinations with each and all of the remaining valves. But, in solving the problem, it can not be assumed that the open notes of the instrument will be correctly pitched; for this is seldom the case. The first step in tuning a valve instrument is to determine the actual pitches of the open notes as produced by the instrument under consideration. When these pitches have been accurately determined then the tuner is ready for the solution of the mathematical puzzle involved, as merely outlined above.

The tuning of a valve instrument is the most complicated tuning problem ever encountered by the manufacturer of a musical instrument. It need hardly be added that the problem is not often solved by the manufacturer. He is quite satisfied if he can produce an instrument on which it is possible to play with tolerable intonation in a few nearly related keys, leaving the unfortunate player to "lip" his instrument into tune as best he may when called upon to play in other keys. The problem of tuning a valve instrument so that it may be played in all the fifteen signatures from seven sharps to seven flats is not impossible, but it involves a more exhaustive knowledge of the musical scale than is often possessed by manufacturers of brass instruments. But that, too, time will remedy.

The only purpose of valves is to bridge the gaps between the open tones of the brass instruments. Since the French horn and trumpet in F utilize open tones lying higher in the harmonic series than the other brass instruments, their open tones are therefore closer together, the gaps to be bridged are smaller, and the number of valves necessary for perfect bridging of the gaps is consequently smaller on the horn and F trumpet than on the other brass instruments. The largest gap between open tones on the horn and F trumpet is that of a fourth, requiring a bridge of four half-tones, while the largest gap on the other brass instruments is a fifth, requiring a bridge of six half-tones.

Since the notes produced by the use of any combination of two or more valves is imperfect because the note produced is too sharp, therefore for a perfect bridging of the gaps the horn and F trumpets should have four valves and the other brass instruments should have six. However, there is only one note on the horn and F trumpet which requires a bridge of four half-tones, the note  All the other gaps may be filled with a bridge of three half-tones. With the single exception of this note, then, every note on the horn and F trumpet may be produced in perfect intonation without combining any two of the instrument's three valves. The note  being slightly too sharp, must be "lipped" a little bit flat. But if less than six valves are employed on the B♭ trumpet, the cornet, the fluegel horn, the euphonium, or the tubas, two or more valves must at times be combined to bridge the gaps, and the notes produced by combining valves are in consequence too sharp.

The tuning of the French horn and the trumpet in F is therefore a much easier matter than the tuning of the other valve instruments, for the reason that the bow for each of the valves on the horn and F trumpet may be made of the correct theoretical length and the resulting scale, *produced always without combining any valves,* will be a scale that is perfectly even tempered except for the one note  which will be slightly too sharp. But on the other brass instruments with valves, the B♭ trumpet, the cornet, the fluegel horn, the euphonium, and the tubas, it is impossible to avoid the combining of valves in bridging some of the gaps. This gives rise to the difficult problem of tempering the scale of these valve brasses by the manufacturer as sketched above, and of overcoming the inaccuracies of the valves temperament by the player of those instruments.

At least this much should be known about valve brass temperament by every player of the B♭ trumpet, the cornet, the fluegel horn, the euphonium, or the tubas, who would like to escape criticism of his playing because of faulty intonation: (1) any note produced by a combination of valves will be sharper than the same note produced with one valve or produced open, and the greater the length of tubing that is combined to produce a note the greater the inaccuracy due to excessive sharpness; (2) in choosing between a larger and a smaller number of valves for the production of enharmonic notes, the smaller number of valves should be chosen to produce the note if the signature of the note is flat and the larger number of valves should be chosen if its signature is sharp: e. g.,  should be fingered with the second valve whereas  should be fingered with a combination of the first, second, and third valves; likewise,  should be fingered with the third valve while  should be fingered with a combination of the first, second, and third valves. Conductors who wish to be scrupulous in the matter of intonation would make no mistake in assuring themselves that enharmonic notes are being correctly fingered by their brass players, for the latter are not always aware of these discrepancies in the tuning of their instruments; indeed the players can hardly be expected to know about them when the manufacturers of the instruments themselves are not aware of them. And composers who wish to be sure that their intentions with respect to intonation will be faithfully carried out would be justified in even marking the fingerings intended for the enharmonic notes of valve brasses other than the horn and trumpet in F.

The writer's knowledge of the construction of most percussion instruments is insufficient to enable him to discuss their mechanical defects with much profit to the reader. He has the general impression that the manufacture of percussion instruments, whether of skin, wood or metal, and whether of definite or indefinite intonation, has been very efficiently conducted especially by the better American manufacturers. Those most commonly used in the symphony orchestra are of course the drums, both the timpani and the drums of indefinite intonation. It may very well be that the drums are quite as capable of improvement as are the string or wind instruments of the orchestra; but if so the discussion of these matters must for the present be left to someone whose knowledge of them is more intimate than the present writer's.

The saxophone is not in as good condition as it can be. Its voice should be that of the natural horn made from the horn of an animal, a tone color of remarkable richness and beauty at present possessed by no instrument of the orchestra. If the tone of the saxophone throughout were made as good as its best notes, and the instrument were furnished with a key mechanism a little less crude and bunglesome, it would prove a welcome addition to the symphony orchestra instead of remaining the outcast it now is.

The situation with respect to the harp well illustrates the ideal attitude of a manufacturer toward his instrument. A certain harp manufacturer undertook the improvement of the harp with the avowed intention of making it the best instrument that unlimited time and money could produce. He succeeded in greatly improving the instrument and, as a consequence, today enjoys a practical monopoly of the market for harps. However, the pedal action of the harp is still far too noisy and should have some further work on it to make it all that it should be.

CHAPTER XV

DEVELOPING NEW INSTRUMENTS

TRUSTWORTHY history of musical instruments does not extend nearly so far back as dynastic and military history. But so far as we have reliable information regarding the development of new musical instruments they have almost always arisen by making some modification of an already existing instrument; it has been a process of small accretions. The origin of the violin is more or less obscure, but by the beginning of the sixteenth century it has assumed fairly definite form, developing by slight successive modifications of a primitive string played by rubbing it with a bow string. The piano arose in the early eighteenth century by giving to the dulcimer a mechanism enabling the player to strike as many strings simultaneously as he had fingers instead of being limited to striking a string for each of his two hands. The clarinet arose about the same time by adding to the chalumeau a speaker key, thus enabling the player to extend with ease the compass of the instrument an octave or more above what it had been. The application of the stop-cock principle to the air tube of brass instruments produced the valve and made possible the instantaneous connection of any one of as many different crooks as the instrument had valves, thus transposing the instrument to any desired key. The origin of the saxophone is undecided; but it arose either from giving a single-reed mouthpiece to a brass instrument such as the keyed bugle or the ophicleid, or by giving the clarinet a conical bore. The cup mouthpiece instruments, such as the trumpet and horn, were expanded by Wieprecht and Sax into a complete family of brasses from the soprano to the contrabass. Wagner wished to extend the tone quality of the horn an octave lower, and the Wagner tuba (not to be confused with the ordinary tuba) is the result. Richard Strauss called upon Wilhelm Heckel to furnish him an oboe pitched an octave lower than usual, and the heckelphone was brought into being. Theobald Boehm introduced the principle of overstringing the piano, but someone else ran away with the idea because Boehm lacked the financial resources to develop it. Jonas Chickering gave the piano an iron frame. Strauss constructed an immense drum of one head by stretching a piece of elephant's hide on a square, timber frame, and called it a "thunder-machine." The list might be almost indefinitely extended, but always we see the same principle at work: an old instrument is modified in some mechanical respect, and a new instrument is the result.

Of course this process of development has not yet reached its end. It is hardly complimentary to the musical mind that it should seem necessary to record this last remark; and it would be unnecessary if the musical public thought about musical instrument in a sane and rational manner, as mechanical devices for the production of sounds of various kinds, instead of regarding them with childish and superstitious awe. Just as the mechanical modification of a relatively primitive musical instrument in some slight respect, for the purpose of increasing its efficiency as a piece of musical machinery, is the process by which new musical instruments have always been developed, so too will it always hereafter be the chief means by which further new musical instruments will be brought into existence. Some of the more obvious future modifications of existing musical instruments, either in the direction of a desirable extension of the instrument's compass or in increasing its efficiency in the production of sound or both, will now be noted.

In the family of the bowed instruments the gap between the violin and the 'cello is so great and so inadequately filled by the viola that it would be highly desirable to have the situation relieved. As was noted in the preceding chapter the viola, playing a fifth below the violin and therefore producing atmospheric pulsations a half longer than the latter instrument, should be constructed just a half longer than the violin to enable it to produce its notes as efficiently as the violin. The viola could be thus increased in size provided it were rested on the knees while it was being played, but a viola so constructed would be entirely too long to be played along the arm by any person of ordinary stature. And even if the viola were to have these dimensions, the gap between it and the 'cello would yet be a whole octave, and it would still probably be advisable to have an instrument pitched half way between the viola and the 'cello, playing just an octave below the violin. The dimensions of such an instrument should be just two thirds those of the 'cello and twice those of the violin. With additional little 'cellos such as these, and with violas of the dimensions here suggested added to violins, 'cellos and string basses of the present dimensions, the effect of the string family would be materially improved through the strengthening of its middle parts.

Practically every manufacturer of high grade flutes from the time of Theobald Boehm onward has entertained ambitions to extend the lower compass of the flute family down to C on the bass staff; and a few such bass flutes in C have been constructed. Those who have heard these instruments speak highly of them, and it would no doubt be desirable to have such instruments. The difficulty is not that of constructing such instruments, but in playing them after they have been constructed; they are too long to be held transversely in playing without undue fatigue. The application of the principle of the slide trombone to the flute would make it possible to extend the lower compass of the flute family downward even to the lowest C of the 'cello without any difficulty whatever. The San Francisco whistle is already a primitive soprano slide-flute of this type and, conventional notions aside, it is not so very primitive either in the hands of an efficient player. The capabilities of any instrument should not be judged by its performance in the hands of a beginner; so judged, even the violin would fare rather badly. A U-shaped tube as long as the arm with a blow hole at the end of one branch and the end of the other branch closed, and with a slide to be manipulated by the player just as on the trombone, would produce a complete chromatic scale of at least two octaves and a half extending from C below the bass staff up, by the use of the same seven arm positions now employed on the trombone. By constructing the instrument with double slides, so that there would be four branches instead of two, an instrument could be produced with a compass extending still another octave lower—to the second C below the bass staff. Of course such instruments would permit no such agility of execution as the flute with lateral tone holes, but it would be equal in this respect to the trombone.

The alto and bass clarinets at present in use are valuable instruments of their family in every respect except one: they can not be played. For example, the notes belonging to the lower half-octave in the middle register, notes which must be constantly employed, are so difficult to produce that they are impossible even to most professional clarinetists with years of experience; and, again, the poor clarinetist blames himself instead of censuring the manufacturer of the instrument, as he should. This defect is due simply and solely to lack of information on the part of the manufacturer of these instruments, and the fault can be easily overcome. Indeed the larger sized clarinets can be so constructed that they may be played with less difficulty than the saxophones. When this has been done it is entirely possible that the larger clarinets will rival the saxophones in popular favor. It is also most desirable that a contrabass clarinet in E♭, an octave below the alto clarinet in E♭, should come into general use. Its lowest note would be the same as the lowest note on the four-string bass if the contrabass clarinet were constructed with a C♯ foot, and its size would not make it unwieldy; its length would be just about the same as that of the baritone saxophone, but its weight would be much less than that of the latter instrument because of its smaller tubes and less bunglesome key mechanism. It is not at all improbable that this clarinet would become a very popular contrabass instrument for general purposes, being much less unwieldy both to carry and to play than either the string bass or the BB♭ tuba.

There can be no question of the desirability of a contra bass trombone in BB♭, having the same compass as the BB♭ tuba but constructed with a smaller bore so as to provide the trombone tone quality. Built with double slides this trombone would require precisely the same arm reach for the seven positions utilized in its manipulation that are now employed on the B♭ tenor trombone, so that the player of a tenor trombone could change to the contrabass trombone by merely acquiring a new embouchure for the larger mouthpiece. If the instrument were built with a helicon bell rising at an angle of about 45°, above and to the left of the left shoulder, it would easily be the handsomest and most imposing in appearance of all the brasses, and, besides, would have the important advantage possessed by all trombones of perfect intonation; and the weight of the extended slides would not have to be born by the right arm because that weight would be counterbalanced by the weight of the bell, all of which weight would be supported upon the left shoulder.

I am also inclined to think that it would be advisable to have a trombone in F with a tube of the same bore and length as the old F trumpet which has now practically disappeared. The F trumpet was a splendid instrument musically, but its weight was too great to be easily supported in the position made necessary by its shape. The F trombone would not have this disadvantage and, if it had the same bore throughout as the old F trumpet, would supply the beautiful soprano voice of that instrument, a voice which is not provided by the B♭ trumpet and is consequently now lost to the orchestra.

Richard Wagner insisted on having the horn tone quality extended below the compass of the horn, and for this purpose had constructed what came to be known as Wagner tubas. There were two of them pitched in B♭ and F respectively a fifth and an octave below the horn in F. They had the small conical bore and deep conical mouthpiece of the horn, and were constructed with four valves so that the larger instrument extended downward to within a half-tone of the lowest note of the four-string bass. The Wagner tubas have not come into much favor outside of Germany; but Wagner's opinions on matters of instrumentation are well worth the consideration of any serious student of the subject, and the musical world will probably follow his lead in this respect sooner or later. If such instruments are to be employed, however, I should be of the decided opinion that they should be constructed in such shape that it would be possible to reach the bell so that the "stopped" effect could be produced when desired, one of the most valuable of the hornist's whole bag of tricks.

The writer is emphatically of the opinion that the percussion section of orchestras and concert bands is as yet quite undeveloped. Lully introduced the timpani into the orchestra, and they remained; but it was not until Beethovèn that they were employed for the production of as many notes as two. In the century since Beethoven's death we have increased the number of notes to be produced by the timpani to three, although Berlioz made heroic efforts to introduce them into the orchestra in larger number. If there is any occasion for timpani in the orchestra at all—and who does not believe that there is?—they should be used in larger number than three. The fact is that there should be a complete chromatic scale of timpani of from one and a half to two and a half octaves. Four players would be sufficient to manipulate them even if they were called upon for melodies or for four part harmony, and of course the four players would only occasionally all be employed at the timpani at the same time.

Rossini introduced drums of indefinite intonation into the orchestra in the face of severe ridicule, but they remained. Still there are not enough of them; we need drums of indefinite intonation, and without snares, of all sizes from the big bass down to little finger drums. I should also like to see diminutive snare drums, and I am not at all certain that bass snare drums would not be useful. I should also be glad to see complete families of Chinese gongs and Turkish cymbals from the large to the small. There is no section of the orchestra more difficult to score for than the battery, and no section more effective when its scoring has been judiciously done. Percussion is the spice of the orchestra, but, like any other spice, it should not be laid on with a trowel; nor should the composer's spice cabinet contain nothing but salt and pepper if he wishes to turn out a *chef d'œuvre*. The percussion is the most neglected section of the orchestra; and that section, together with the woodwinds, it is to be hoped, will show the greatest future development.

Wood and metal percussive instruments of definite intonation have for the most part received but slight recognition by symphonic composers. The celesta, invented by Mustel of Paris, has won an established position in symphonic music, but the xylophone, the orchestral bells, and the marimba, have as yet been excluded from the symphony orchestra. Undoubtedly they will ultimately be admitted, but they will probably have to force their entrance by way of a jazz orchestra grown to symphonic proportions. The splendid treatment of these instruments by American manufacturers within recent years calls for nothing but praise. The xylophone, the orchestral bells, and the marimba, are all splendid instruments of distinctive tone quality and great future possibilities; either one of them is much superior to the dulcimer at the time that Cristofori converted it into a piano by giving it a keyboard. Indeed Mustel, in producing the celesta, has already given a keyboard to the upper compass of the orchestral bells; but their lower compass should have a keyboard as well.

Quite recently there has been produced a modification of the orchestral bells known as the vibraphone. It is essentially a set of orchestral bells with a metal tube below each bar to serve as a resonator, and with a revolving disk in the mouth of each resonator to produce the vibrato effect. The metal bar is able to sustain its tone for a considerable time without undue diminution of its intensity, being materially superior in this respect to the piano. Upon the whole the vibraphone furnishes music of a tone quality so ethereally sweet as to quite equal our dreams of what angel voices might sound like. Give the vibraphone a keyboard with a set of piano hammers and dampers, so that the instrument might produce a tone for each of the player's fingers, and it would provide the most ravishing music ever heard from a keyboard.

But, even so, the instrument could be still further improved by producing the tones from the metal tubes sometimes used in clocks and called "Westminster chimes," instead of from the metal bars of orchestral bells. The tone quality of a metal tube struck at the proper point with the proper kind of hammer is decidedly superior to the tone of a metal bar, being of wonderful sweetness, mellowness, and sustaining power. Supply a set of eighty-eight such generating tubes with a corresponding number of resonator tubes and each resonator tube with a revolving vibrato disk, equip the generating tubes with a keyboard and a set of piano hammers and dampers, enclose all in a case similar to that of a piano, and we would have a musical instrument either for household or for concert purposes decidedly superior to the piano in several ways: the instrument would never get out of tune, the vibrato could be employed or not at the pleasure of the player, and its tone would be better sustained than that of the piano—it would have a more singing tone. Moreover, all the literature of the piano would be immediately available to be played upon it, and the cost of manufacturing the instrument would probably be materially below that of the piano.

Another class of instrument which has been splendidly developed by American manufacturers in recent years is the plectral instruments of the banjo, guitar, and mandolin type. These instruments, too, have not yet reached the symphony orchestra, but will probably arrive at that destination finally, going by way of the jazz orchestra. The banjo might well find a place there at once. Sixty players of bowed instruments in a symphony orchestra can not accomplish as much *pizzicato* effect as can four equally proficient banjoists, nor can they do it as well. Not only in comparison with some strings along a stick fastened to a cigar-box all in the horny hands of a cotton-patch colored man, from which rude beginning the banjo arose, but also in comparison with the best contemporary musical instruments of other types, the modern banjo is a magnificent product of the instrument maker's art; and for it you will pay a pretty penny—fully as much as you would for the best of violins by modern makers.

The mandolin and guitar types of instrument have both been expanded into full families ranging in size from the sopranos to the contrabasses, and comparing quite favorably in appearance with the best products of the Cremona luthiers. Among people who care more about enjoying themselves musically than they do for observing the musical conventionalities with respect to instrumentation, there will frequently be found complete choirs of each family of the plectral instruments assembled into large orchestras of players meeting regularly and sometimes presenting quite ambitious musical programs. It would be a little difficult at the present time to predict the precise limit of developments in the field of improved plectral instruments, or in the possibilities of better music for them.

There is another instrument, today but little more than a toy, which is entirely too valuable musically to be allowed to remain in its present condition—the ocarina. Its tone color is beautiful, and it has a staccato not equalled by any other instrument either wind or string. Its compass indeed is small at present, but perhaps it might be increased; the chalumeau was a poorer instrument two hundred years ago when Denner transformed it into a clarinet by giving it a speaker-key than is the ocarina of today. And possibly ocarinas of large size might be developed to strengthen the flutes in their lower compass. At least the possible gain would justify some experimental effort in the direction of improving the ocarina.

The "thunder machine" of Richard Strauss is essentially a single-headed drum of very thick skin stretched upon a strong frame, tightened by electrical heat, and played by beating upon it with drum-sticks. It is very good for percussive effects of exceptional volume. But there seems to be no reason why it might not be further utilized as an instrument of definite intonation of great power, and extending the compass of the orchestra down to the limit of the ear's ability to hear sounds. The lowest note of the orchestra at present is contrabassoon C, a major third below the lowest string of the double-bass as normally tuned, this C having about 33 pulsations per second. Dr. Seashore reports that the ear is able to hear a tone having as few as ten pulsations per second. So far as I am aware his claim in this respect has not been verified by other investigators and would extend the lower limit of audibility set by most investigators by about half an octave if admitted. But if the claim of Dr. Seashore is to be credited, then there would be approximately two octaves of musical tones the ear could hear below the lowest E of the double-bass which octaves are never heard in the orchestra except for the major third from this E down to contrabassoon C which third is occasionally furnished by the contrabassoon or by the string bass with its lowest string tuned down to C. If the skin head of the "thunder machine" were motivized by a piston whose frequency was mechanically controlled, and the instrument were played from a keyboard, we should have a powerful rumbling bass of any desired pitch in these lower two octaves and of any required volume. Of course it would be impossible to recognized pitch in this nethermost region; but the present thinness of the contrabass region would sound much richer and fuller. I should be glad of an opportunity to hear such a thunderphone in the orchestra. If some composer should call for it in his score, it could very easily be produced.

CHAPTER XVI

WHAT OF THE KEYBOARD INSTRUMENTS?

IN RESPECT to the number of notes it can simultaneously produce the keyboard instrument has a great advantage over most instruments. The keyboard instrument can produce a note for each of the player's ten fingers if necessary, while instruments without keyboards are usually limited to a much smaller number than this. Generally speaking, the string and wind instruments of the orchestra are limited to the production of a single note. The player of a cup mouthpiece instrument, such as the horn, occasionally sings one note into the horn with his vocal chords while he plays another note on the mouthpiece with his lips producing, with the differential note arising from these two, a full chord of three notes; and once in a blue moon the composer scores for such effects on the horn. But as a rule the wind instruments produce but a single note at a time. The string instruments played with a bow frequently produce two notes at a time by double stopping, and the number of notes so produced is sometimes even increased to three. Such plectral instruments as the banjo and guitar produce a note for each finger of one of the player's hands if necessary, and the harp produces a note for each finger of both hands. The percussion instruments played with hammers, like the timpani and xylophone, can produce two notes at the same time, one for each of the player's hands. But all the keyboard instruments, the piano, the organ, the celesta, the calliope, are able to produce a note for each of the player's fingers if the occasion arises for doing so, and the organ can add a couple more notes by making use of the player's feet.

This is, of course, a tremendous advantage for the keyboard instruments since it allows them unassisted to produce full harmonies, while other instruments to produce the same results must usually have assistance. The flute, the horn, the violin, can play a melody, but if it wishes to participate in music with full harmonies it must join an ensemble with other instruments to be able to do so. It was Cristofori's great contribution to music that he added enough machinery to the dulcimer to provide each string with a mechanical hammer motivized by a single finger instead of leaving it as he found it, limited in the simultaneous production of notes to a hammer held in each of the player's hands. This immediately increased the number of musical parts possible to the player from two to ten, and it was one of the great steps forward in the history of music. The principal keyboard instruments in existence before Christofori were the organ, the spinnet, and the harpsichord, and each of these had its handicaps. The organ was too large and too expensive to be available as a household instrument, and the harpsichord was unable to produce any variation in the loudness of its music. The dulcimer before Christofori was sadly inferior to the harpsichord in most respects as a musical instrument, but it possessed the single advantage of being able to play either loudly or softly depending upon the force with which the string was struck with the hammer. Christofori had the insight to recognize this inherent advantage of the dulcimer, and the courage to apply the keyboard principle in the production of a new instrument and to meet the opposition offered the innovator.

Antonius Stradivarius, Barolomeo Cristofori, Theobald Boehm, Antoine Sax, these are the names which form the great landmarks in the history of instrumental music. Without them and their collaborators in the development of new and better instruments, such men as Bach, Beethoven, and Wagner could not have existed. Take away the work of the inventors and makers of musical instruments and there never would have been a Bach, a Beethoven, a Wagner, or any of their followers. It is the custom to sneer at the inventor, yet it is he that has breathed the breath of life into all the music we know except choral music. Without the inventor of musical instruments and the craftsmen in musical instruments which follow in his wake there never would have been any musical instruments to write for. And without musical instruments to write for there would have been composed but little of the music of the past three centuries which we call great. Consider for a moment what kind of music Bach would have written if there had been no organ, no clavichord, no harpsichord, what music Beethoven would have composed without the piano and the orchestral instruments to write for, what music Wagner would have written if there had been no orchestra, what kind of music would have been produced by the disciples of these men if innovators in the production of new and better musical instruments had been unable to survive the opposition their new ideas encountered, then go confess your sins and resolve never again to sneer at the person who is trying to improve the music of the world by giving it better musical instruments. He is the one who makes possible the existence of the composer and the interpretive artist, and he is not only entitled to your profound respect but to your enthusiastic and persistent encouragement and support as well. Whatever you today enjoy in the way of music is due to some person like him at whom your spiritual progenitors sneered in like manner a few generations ago, and who did all they could to prevent his making possible the music of today.

The two great events in the history of modern music are the discovery in the early fourteenth century that the thirds and sixths were harmonious, and the invention of the pianoforte by Cristofori some four hundred years later. The first of these events produced the polyphonic and homophonic music of the past six centuries, and the second of these events put instrumental music into every home. It is not surprising that the piano became the household instrument. There is no other musical instrument on which the student can so quickly and so easily acquire the ability to provide for himself and for his friends so much in the way of musical enjoyment. Indeed the amount of piano music, of a kind, produced by those who have never given the instrument any formal study whatever would bulk surprisingly large if it could be computed—and I would be the last to deny them the privilege of so enjoying themselves; music was made for man, not man for music. Persons have even been known to become millionaires "composing" music by picking out tunes and harmonies on the piano without being able to read a note of music. And, to descend to the very depths of the ridiculous, it should not be forgotten by anyone attempting to understand the vogue of the piano that it is first of all, to the vast majority of its purchasers, a piece of household furniture. This fact is well understood by every successful manufacturer of pianos, and is never lost sight of if he remains successful.

The piano has been the iron chancellor of the musical world for the past hundred and fifty years. Most of the music composed during that period has been composed at the piano, by a pianist and usually ends by becoming music for a piano, no matter what might have been the composer's original intention with respect to its instrumentation. Music scored for the orchestra or for a vocal ensemble is too often piano music at heart. The composer who does not go to the piano to find out how his orchestral or vocal score is going to sound is more than ordinarily conscientious—or more than ordinarily intelligent possibly. Berlioz did not play the piano at all, and Wagner did not play it enough to do him any damage; but most composers have a piano in the offing when they undertake to write music. So we have music compounded of piano rhythms, piano melodies, and piano harmonies, no matter what the instrumentation that is scored for. If I were musical *duce* I suspect that I should issue a ukase that no composer or conductor could own a piano; but possibly I might be a bit lenient at first in enforcing the prohibition. Ultimately, though, I should want to have both composers and conductors entirely freed from the domination of the piano.

But in spite of the tremendous hold of the piano upon the music of the world it is a musical instrument with most serious defects. Its most obvious defect is its inability to sustain a tone. Like any other percussive instrument, the piano produces a tone reaching its maximum volume just after the moment of stroke and then beginning immediately to die away. This gives the piano a wonderful staccato, but leaves it entirely without the ability to sing. If the piano string could be made to continue its tone undiminished as long as desired the piano would be wonderfully improved. And if such a sustained piano tone could further be made to increase and diminish in volume as desired, the piano would become the most marvelous instrument ever manipulated by a single player. It would have the staccato the pipe organ lacks, and a crescendo-decrescendo superior to that of the organ in that it might be applied at pleasure to individual notes or groups of notes. Perhaps such an improvement in the piano would not be impossible to attain. The choralcello maintains the vibration of a string idefinitely and increases or decreases its volume at will by the use of an electric current to motivize the string. There seems to be no good reason why the same means might not be employed to the same end on the piano. Such an innovation might somewhat stabilize the present rather precarious condition of the piano trade.

The startling advances now being made in the reproduction of artistic piano playing is rapidly revolutionizing artistic technique. Reproducing pianos are today able to present interpretations which the recording artists themselves recognize as superior to the renditions from which the records are made. One of the greatest pianists of the present age, after listening to a record made from his own playing, despairingly exclaimed: "Why can't I play that way!" The reason he could not "play that way" is that human muscles do not always follow the promptings of the brain directing them, and the result is inaccurate as compared with the intention. No one realizes the truth of this more than the musical artist. But all such inaccuracies and imperfections can be corrected and smoothed out in detail in the record in accordance with the intention as clearly shown in its broad outline but not faithfully executed by the player's muscles. Paradoxical as it may appear it is not at all impossible that great pianistic artists will soon be taking "re-touched" records of their own playing as models to be studied and approximated as nearly as possible.

More solid, scientific investigation has been given to the pipe organ than to all other musical instruments combined. Every stop has been subjected to the most rigid scrutiny, and the most exhaustive experiments have been conducted in the several directions of "scale," voicing, materials, and shape of each pipe. Respecting these matters the writer has no suggestions to submit, preferring rather to defer to the judgment of such authorities as Audsley and

Cavaille-Col. On one point, however, constructive criticism may unhesitatingly be offered: the organ should be tuned in just intonation instead of in even temperament. No person can become intimately acquainted with sound in its relation to music without becoming at the same time entirely convinced of the unquestionable superiority of pure harmonies over tempered. The only question is as to the possibility of constructing the organ in just intonation. The conclusion reached in Chapter 4 was that thirty-five notes to the octave are necessary to produce the just scale in all the fifteen tonalities from seven sharps to seven flats, instead of the twelve notes to the octave now necessary in even temperament. Just intonation for the organ, then, becomes a matter of approximately trebling the number of pipes to a stop and of devising a means of utilizing the appropriate pipes for each tonality.

The appropriate pipes for each tonality could be selected by the player by providing a tonality-stop for each of the fifteen tonalities. The player would depress a tonality-stop when, and only when, he modulated from one tonality to another. He would, for example, depress the B♭ tonality-stop when he wished to enter the B♭ tonality. As long as he remained in that tonality the B♭ tonality-stop would remain depressed without further attention from him, and he would be connected with the pipes appropriate to that tonality. But when he wished to pass, for example, into the F tonality he would have to depress the F tonality-stop. This would disconnect any notes of the B♭ tonality which are foreign to the F tonality—there would be two of them as will be seen by referring to the table of page 51—and connect the notes of the F tonality foreign to the B♭ tonality—there would also be two of them. By such an arrangement it would be possible to play the untempered scale in all the fifteen tonalities without any change of the present keyboard. Heretofore no method for doing this has ever been devised.

Would the game be worth the candle? I doubt whether there is any way to convince a person unacquainted with sound of the desirability of such a change except by constructing an experimental stop designed along these lines and letting him listen to the music it would produce; this, I believe, would convince anyone no matter how conservative he might be. The use of justly intoned organs would be desirable not only for their own sake but for other results also which would naturally and necessarily follow. The choir singing beside a justly intoned organ would naturally sing the pure scale instead of the tempered. This would make possible an adequate *a capella* presentation of polyphonic music by these choirs, a thing now entirely impossible to a choir singing beside the tempered organ. And the use of justly intoned organs in theatres would teach the natural scale to the orchestras there employed, and thus make available to composers desiring to write in the modes orchestra players able to produce their compositions to sound as intended.

Of all the musical instruments which man employs there is no other he plays so badly as the organ. It is often almost impossible for a discriminating musician to listen to the playing of an organ, especially of a church organ. The organists in some of the larger movie theatres are less offensive in their playing, but church organists as a rule are most exasperating. Their feet usually drag along a measure or two behind their hands, they do not scruple to hold any convenient note as long as they may please while they poke stops or hunt up a new piece of music, and in general they conduct themselves as if there were no such thing as rhythm, either measured or unmeasured, in the music they play. It will not avail the church organist to contend that his music is quasi-unmeasured; his complete lack of comprehension of unmeasured music is convincingly proved whenever his choir attempts to produce a polyphonic composition. If a church organist has the good fortune to hold a part-time job in some movie house he will usually be able to pick up the rudiments of rhythm sooner or later from the jazz band employed there. Otherwise the church organist remains the sorriest example of the professional musician anywhere to be found.

It is entirely possible that the organ has become too complicated a musical machine to be managed by one player. I am not at all certain that this is not the case. It might perhaps be advisable to relieve the organist of the duty of managing stops, turning music, etc., by allowing him an assistant. Even better, in my opinion, is the plan of producing the notes of the score mechanically, as on the reproducing piano, leaving the organist entirely free to give his undivided attention to stops, tempo, dynamics, and nuance in general. The popularity of the mechanical piano subject to personal control has been surprising; the popularity of the organ constructed along similar lines should, it seems to me, be equally great. For the homes of the well-to-do, the personally controlled self-playing organ should meet with a lively demand. It is quite certain that these instruments would most effectively meet the needs of picture houses. And such a use of the organ would make it possible to hear organ music really played. The organ is the greatest of all musical instruments; but there are those who object to its being utilized merely to mutilate good music.

There is another keyboard instrument which the writer hesitates to mention because of its customary undignified associations, the calliope. Ridiculous as it may seem, the calliope is capable of becoming a really musical instrument. The calliope is essentially the flute stop of an organ; its method of tone production is identical with that of the orchestral flute, the flue pipe of the organ, and the locomotive or steamboat whistle. The calliope is always overblown because of too high wind- or steam-pressure, but this of course is unnecessary; the instrument might be so constructed that its wind-pressure could be increased or diminished at will, and its compass might be extended both upward and downward. If we are to play calliopes, let us have better ones than those at present supplied to us. Personally, I should not object to them if their wind-pressure were decreased and were put under dynamic control.

The carillon is not at present a keyboard instrument, but it should be. The energy necessary to ring the bells of a carillon is so great that it is absurd in this age of machinery to employ human energy for such a purpose. There is no reason why the bells could not be struck by hammers motivized hydraulically or by electromagnets. When we move freight trains by electromagnets, and use electric cranes for the lifting of enormous weights, it becomes silly to use the human biceps to hammer bells weighing thousands of pounds. Unfortunately, the carillon also falls short of its possibilities in other respects, and often becomes a means of most exquisite torture to persons of refined musical sensibilities. The bell produces a tone of great volume and with powerful partials. Moreover, the tone of the bell continues for a long time after the note has been struck, sometimes not dying completely away for a minute or more. Now carillon music consists of a melody with more or less of an harmonic accompaniment, and a great many notes are struck in the course of a minute of carillon playing. And the carillon has no dampers! The result is a din that is little less than pandemonium. Imagine your neighbor's piano as loud enough to be heard a mile or so and him playing like mad with the sostenuto pedal always held down, and you will have an approximation to the playing of a carillon. Of course the obvious remedy is to equip the carillon with dampers. This could be so easily and so simply accomplished that it is surprising it has not been done long since. The reason is, as might be suspected, that carillons have for a long time been constructed in the traditional manner and the makers see no traditional reason for constructing them differently. Now that carillons are becoming so numerous in America, it would not be at all unjustifiable for American legislative bodies to declare a carillon, and a set of chimes as well, to be a nuisance unless equipped with dampers, and imposing a penalty for the playing of one not so equipped. With dampers, the carillon would not longer be "sweet bells out of tune"; and heard in the distance at evening this "tower music" would furnish a real contribution to the musical life of America.

CHAPTER XVII

IMPROVING THE AUDITORIUM

THE AUDITORIUM is an acoustical device which, if not itself a musical instrument, is so intimately associated with them that it becomes necessary to consider the way it acts in connection with them. The need for more reliable information with reference to the action of auditoriums is most urgent. Undoubtedly the chief purpose of an auditorium is to enable persons there assembled to hear what occurs in it. A secondary purpose, of course, is to enable them also to see what transpires; but the very terms "audience" and "auditorium" emphasize the fact that its principal function is to enable those assembled there to hear. If an auditorium is so constructed that hearing is rendered impossible, then that auditorium is a failure. Every church, every theatre, every concert hall, every lecture room, every school or public auditorium, depends for its effectiveness upon the faithfulness with which it conforms to the laws governing the action of sound phenomena. If an auditorium is so constructed that sound pulsations in it can behave as desired, then that auditorium is good; otherwise it is bad, and the money expended in its construction is virtually wasted. Every year there are thousands of auditoriums built, and frequently the cost is great. Occasionally a great church is erected whose cost runs into millions. If, when it is completed, the communicants are unable to hear what occurs in it, that church stands as an enduring monument to the folly of its architect. What architectural beauty it possesses of course still remains, and to that extent the structure still has value. But the appeal to the eye is in all probability properly considered secondary, its chief purpose being to enable worshipers to hear the service; and if the service can not be heard, both spoken and musical, then the structure fails of its purpose.

Most auditoriums are acoustical failures, and the remaining ones are failures too if the efficiency they attain be compared with that which they might attain if we had complete knowledge of the behavior of sound within them. The architect does not understand sound, can hardly be expected to do so. The architect is first of all an artist addressing his appeal to the eye, and frequently with great success; but if a question arises where choice must be made between the visual and the auditory effectiveness of the completed structure, thumbs go down for auditory considerations without a moment's hesitation. Nor does the engineer understand sound; he has given the matter as little thought as the architect. And, usually, no one is called into consultation who does understand sound with sufficient accuracy that the acoustical efficiency of the completed auditorium can be precisely foretold. The auditorium is constructed as a woman bakes a cake—but costs more: when the cake is done she takes it from the oven, and it either "falls" or not; the event is in the hands of the gods. It would be better if she knew why it "falls" or not; it would be better if the architect also knew why his completed auditorium behaves as it does from the standpoint of hearing. He could then guard against failure—could predict the acoustical performance of the completed structure.

In the very near future there is going to be a recognized profession of acoustical engineering. When that time comes auditoriums will be constructed with as complete foreknowledge of their acoustical efficiency as the civil engineer now has of a projected bridge, or as an electrical engineer has of a dynamo designed by him. It will then be possible for the acoustical engineer to furnish specifications for an auditorium with a guarantee that every person in its audience can hear every syllable of the speaker without his voice being raised above an ordinary conversational tone.

The acoustical problem involved in the construction of an auditorium can be understood with but little thought; the solution of the problem is not so simple, but is not at all impossible. Let us suppose that a speaker occupies a given position on the platform of an auditorium, and an auditor a given position in the audience. The speaker, in the course of his speech, pronounces a syllable containing the consonant sound "k." Let us separate this "k" sound from the body of his speech and give it detailed consideration to see what happens with respect to it. If the auditor is fifty feet from the speaker, the "k" sound will reach the auditor about .05 of a second after it has been pronounced—coming in a straight line from the speaker. But sound advances from the speaker not only straight toward the hearer, but in all directions from the speaker. Travelling in one certain direction from the speaker this "k" sound will strike the ceiling and rebound like a billiard ball to the auditor's position. If the sound had to travel sixty feet going to the auditor by way of the ceiling, then it will reach the hearer about .06 of a second after it is spoken. The "k" sound reaching the hearer by one of the walls, travelling say 70 feet, will arrive .07 of a second after it is spoken. The same "k" sound going by another route will arrive in .08 of a second, another in .084 of a second, still another in .103 of a second, etc., *ad infinitum.* It must be understood that all these "k" sounds leave the speaker at the same time but reach the auditor at different times because they travel by different routes, and that all of them keep bounding around back and forth, up and down, from side to side, between walls and ceiling and floor, like very light but tremendously elastic rubber balls, until they finally at great length come approximately to rest. And in the meantime the hearer has been receiving scores, even hundreds, of "k" sounds, each reaching him at a different interval after it was spoken because each travelled a different distance to reach him, going over a different route. In consequence, the ear receives not one "k" sound from the speaker, but a very great number of "k" sounds one after another, in a kind of auditory smear of "k's."

Suppose this "k" sound occurred in the word "score," from the phrase, "Fourscore and seven years ago—." The "k" sound would be smeared along to such an extent that it would commingle with the "o" smear immediately following it, and the "r" smear following that, and so on. The words "Fourscore and seven years ago—," would ordinarily take about two seconds in being pronounced. Now it is not at all unusual for an auditorium that is acoustically bad to have a reverberatory period as great as five or six seconds, or even ten seconds when it is empty; i.e., a given sound will continue for that period of time after it is produced before it becomes entirely inaudible. It is thus apparent that, under very poor acoustic conditions, the first "F" sound of, "Fourscore and seven years ago our fathers brought forth on this continent—," might not have entirely died away until the hearer would have received the beginning of the "t" smear forming the close of the clause, and that the "F" sound would be commingled with all the phonetic elements of the clause between it and the "t" sound.

It thus appears that what we hear in a poor auditorium is not a succession of clear-cut phonetic elements, but a conglomeration of auditory smears all scrambled inextricably together. This is what makes it impossible to hear a speaker distinctly in an auditorium that is acoustically poor. What should be done to render the auditorium acoustically good for speaking purposes? The reader knows the answer as well as anyone: prevent the walls, ceiling, and floors from reflecting sound to a sufficient degree that hearing shall not be interfered with. The best method of accomplishing this without unduly impairing the architectural beauty of the auditorium is sometimes a complicated matter. The safest procedure, of course, is to call into consultation with the architect at the time the auditorium is being designed a competent authority on the subject of sound. But some of the means to be employed in solving the problem may here be indicated.

According to what has come to be known as Sabine's law, first worked out and enunciated by the late Professor W. C. Sabine of Harvard and now universally accepted, the reverberatory period of an auditorium increases with the volume of the auditorium and decreases as the power of its walls to absorb sound increases: that is, the smaller an auditorium is, and the better its walls absorb sound, the better it will be for acoustic purposes. With a large auditorium it is therefore necessary to exercise the greatest care to insure that its walls shall absorb sound instead of reflecting it. Walls of hard plaster may reflect as much as 98 per cent of a sound and walls covered with hair felt an inch thick may reflect as little as

40 per cent of a sound, according to the best experimental information at present obtainable.

Of course walls of hair felt an inch thick would be impossible because of their ugliness; but walls covered with tapestries would be very attractive, and they would attain the same end provided the pile were deep and the walls were covered with the tapestry as with wall-paper. Moreover, walls that are very rough reflect much less sound than walls that are smooth, especially if the roughness extends to the point of breaking the surface of the walls up into pockets or recesses of considerable size. The architect who makes extremely liberal use of beams and groins in the treatment of his ceiling and walls will have taken a long step toward providing an auditorium that will be acoustically effective. The more completely the walls and ceiling are broken up from a plane, smooth surface the more effective will the auditorium be. And this means of securing acoustical effectiveness can be employed at a gain of architectural beauty instead of at a loss.

The reflection of sound pulsations by walls, ceiling and floor, is less harmful to song than to speech because of the fact that in singing the enunciation of phonetic elements is less rapid than in speech, and the phonetic smearing is consequently less complete. It is sufficient even in the case of singing, however, to be seriously detrimental. And there is an additional difficulty that arises in connection with music that does not occur in the case of mere speech. A given note of a musical composition produced in an auditorium is prolonged by reverberation until it mingles with other notes following it in the score, producing the same evil that arises from playing a piano without dampers. Succeeding notes mingle with notes preceding them in a manner not at all indicated in the score, and the resulting harmonic coloring that reaches the listener's ear at a given moment is quite different from that intended by the composer. If the music is to reach the listener's ears as presented in the score, sound reverberation within the auditorium will have to be eliminated.

And this applies to instrumental music as well as to singing. Indeed the difficulty is greater in the case of instrumental music because of the fact that instrumental music usually proceeds at a much faster rate than vocal and, in consequence, the number of successive notes smeared together is correspondingly greater. When it is realized that several measures of a symphonic composition may be played within the reverberatory period of a poor auditorium, and that all the notes played within that period are more or less commingled with the notes one is trying at the moment to hear, it can be realized what a hodge-podge a poor auditorium sometimes makes of our music. Not an inconsiderable part of the charm possessed by music *intime* is due to the fact that it is presented under acoustic conditions that make it possible for the hearer's ear to receive the music approximately as the composer has set it down in the score.

Whether the auditorium is to be used for speaking, for singing, or for purely instrumental music, reverberation must be eliminated; and this will be accomplished when our knowledge of the behavior of sound within enclosures has become sufficiently exact, and when auditoriums are designed not only for architectural beauty but for acoustical efficiency as well.

CHAPTER XVIII

BETTER VOICE TRAINING

THE LACK of information about the action of the human voice, and the extent of the misinformation concerning it, is amazing; and misinformation is infinitely worse than ignorance. As long as a person remains aware of his lack of information there is hope for him; but once a vocal authority has learned something about voice action that is not true, and announces his adherence thereto as a principle of his belief, he becomes hopeless. To abandon the principle he has espoused would be to admit he has been wrong; and that the voice teacher can not do. Anyway, there are so few with positive knowledge of the matter concerning which he is in error that the probability of his being brought to account for his misinformation is slight, so he swears renewed allegiance to his error; since he will not be caught, he can not be bothered about the matter.

The number of matters of fundamental importance upon which there is divergence of views by voice teachers is enormous. As an extreme illustration of the situation existing, there has been raging through American musical journals for more than a year a discussion whether the vocal cords are necessary to voice production for singing purposes. And no one can follow the arguments that have appeared on the subject without becoming convinced that one side is just as sincere and anxious to arrive at the truth of the matter as the other; indeed, to the present observer, the side that is manifestly in error is if anything more zealous and indefatigable in its search for the truth than the side which is right. When sincere and zealous seekers after vocal truth can not agree upon a matter of such vital and fundamental importance as this, what can be expected regarding the hundred and one details of voice production which, although less momentous, are still important? There is probably not a single point with respect to the production of the singing voice upon which persons who are recognized as authorities in the singing profession are not in categorical and emphatic disagreement.

The question naturally arises why there is such diversity of opinion about matters, not of taste, but of sober, physical fact concerning phenomena occurring as frequently as the sounds of the human voice? Different conclusions can be arrived at by logical minds only if the assumptions upon which the reasoning is based are unlike. The chief cause for the diversity of opinion among vocal authorities in regard to important questions of fact about voice production is not their illogical thinking, but that the several authorities start out from different assumptions upon which to base their reasoning. The starting point for all of them, although they may be unaware of the fact, is their several conceptions as to the nature of sound. Consciously or unconsciously, a voice teacher's theory as to the nature of voice production, if he has one, will be determined in its entirety by his conception as to what precisely sound is and how it behaves. If he has no theory as to the nature of voice production, it will be because he has no definite notion as to the precise nature of sound and its behavior. If he has an erroneous theory of voice production, it will be because his conception of sound and its behavior is at fault. If he has a valid theory of voice production it will be because he has a correct understanding of the nature of sound and the way in which it acts. In a word, the diversity of opinions among vocal authorities about questions of fact regarding voice production is due either to false reasoning or to a misunderstanding of precisely what sound is and how it behaves.

Most voice teachers have no clear conception as to precisely what sound is and how it acts. If they ever think about the matter it is in terms of "sound waves" and "sound vibrations," but they do not know precisely what they mean by "sound waves" or "sound vibrations." It has for years been the writer's opinion that if an individual once gets the term "sound wave" definitely fixed in his vocabulary he will never be able to understand what sound is or how it acts. To ninety-nine persons out of a hundred who use the term it has no meaning whatever, it is a meaningless assemblage of syllables. Possibly the reader knows one person of which this statement is true. It will perhaps have been observed that, throughout this volume, the reader has never met with the term "sound wave" or "wave." The term is misleading and vicious and should be avoided. The very first step in our discussion of sound was to call attention to Newton's sage remark that "sounds can be nothing else than pulses of air" caused by a tremulous body, and by every means and device at the writer's command this idea has been elaborated and emphasized. Until this notion is firmly established in the mind there can be no chance whatever of understanding the action of the human voice or of any other musical instrument. Sound is a pulsing of the atmosphere, a kind of shivering or trembling of the air; and the recognition of this fact is the beginning of wisdom regarding musical phenomena. The pulsing may be caused in several different ways but always, as Newton says, by "a tremulous body." The tremulous body may be a string, as in the violin or piano, it may be a reed fluttering back and forth, as in the clarinet; or it may be pieces of flesh, as the human lips in playing a trombone. Let us examine these three methods of producing pulsations in order, that we may get their bearings on the process of sound production in the human voice.

The piano hammer strikes the string and sets it into vibration. As the string vibrates back and forth it causes successive condensations and rarefactions of the air on either side of the string which condensations and rarefactions travel away from the string toward the listener's ear as fast as they are produced, each condensation and rarefaction together constituting one pulsation. The reed of the clarinet flutters back and forth between the air cavity in the player's mouth and the air cavity in the clarinet producing successive condensations and rarefactions of the air in the clarinet which condensations and rarefactions emerge from the bell of the clarinet and travel away toward the listener's ear as fast as they are produced, each condensation and rarefaction together constituting one pulsation. In playing the trombone the player's lips are stretched tight, and air from the player's mouth is forced to escape from between the lips causing them to flutter back and forth producing successive condensations and rarefactions of the air within the trombone which condensations and rarefactions emerge from the bell of the trombone and travel away toward the listener's ear as fast as they are produced, each condensation and rarefaction together constituting one pulsation. In the human voice the vocal cords are drawn together, and air from the lungs is forced to escape from between the cords causing them to flutter back and forth producing successive condensations and rarefactions of the air in the mouth of the singer which condensations and rarefactions emerge from the singer's mouth and nose and travel away toward the listener's ear as fast as they are produced, each condensation and rarefaction together constituting one pulsation. The repetitive phraseology is employed, not for the purpose of carrying the reader back to his childhood days, but to emphasize the fact that all musical instruments, including the human voice, are alike in being devices for the production of successive pulsations in the atmosphere.

In either the clarinet, the trombone, or the human voice, the loudness of the tone produced depends upon the wind pressure applied to the generator of the sound, the reed of the clarinet, the lips in the trombone, or the vocal cords in the human voice. The quality of the tone produced depends, in each case, upon two factors: (1) the manner in which the generator itself, reed, lips, or vocal cords, vibrates, and (2) the shape of the air cavity constituting the resonator of the instrument. As was pointed out on page 39 with respect to the clarinet, the reed and the "lay" of the mouthpiece, together with the manner in which the instrument is blown, determines the way in which the reed shall vibrate, and constitutes one of the factors entering into the tone quality of the clarinet. The other factor is the shape of the air cavity forming the resonator of the instrument; if the inside diameter of the instrument is changed, if the size of the tone hole producing a given note is increased or diminished, if a change is made in the height by which a pad rises above its hole, or if the inside proportions of the mouthpiece is made to vary, then a new tone color is imparted to the instrument. That the manner in which the lips vibrate is an element in the tone quality of the trombone is shown by the fact that tones of the same pitch on the same trombone may be made to differ in quality by blowing them in different ways. But the tone quality of the trombone is also dependent upon the shape of the resonating air cavity within the instrument, for it is changed by any modification in (1) the shape of the mouthpiece, (2) the bore of the cylindrical part of the tube, (3) the shape of the bell, or (4) the relative lengths of the cylindrical part as compared with the bell part.

The tone quality of the human voice depends in part, no doubt, upon the manner in which the vocal cords themselves vibrate, although this is not easy to determine with certainty because of the difficulty of isolating this part of voice production for observation; it is very difficult to change the action of the vocal cords and observe them without at the same time changing the proportions of the air passages above the vocal cords. But the chief element in determining the tone quality of the human voice is the shape of the resonating air cavities above the vocal cords. Any slightest change in the position of any of the mobile walls of these air cavities produces a corresponding change in the quality of the tone produced. The voice teacher refers to this shaping of the upper air passages as "voice placement"; and the business of the teacher of "voice placement" is to train the student so to shape the upper air passages for each note within his compass that the best possible quality of tone shall be produced for each of those notes. When that point is reached in the pupil's studies where the proper shaping of the upper air passages becomes quite automatic, and can be secured by the pupil without conscious thought or effort, then the pupil's voice is properly "placed" and the student is ready to begin the study of singing itself.

The pitch of a note in the human voice could, conceivably, be attained wholly or in part in three different ways. The tightening of the vocal cords would produce a note of higher pitch, and loosening them would produce a note of lower pitch, just as with the string of a piano or violin. But, in this connection, the tightening of the vocal cords must not be confused with the tightening of the air passages above the vocal cords. The tightening of the vocal cords is a process of which the singer is entirely unaware and over which he has not the slightest possible control *from the standpoint of the throat;* so far as the control of this tightening of the vocal cords is conscious, it is conducted from the ear, and, *so far as the throat is concerned,* is entirely effortless, automatic, and takes place without knowledge of the singer. *The ear knows that a change of pitch has taken place but the throat does not.* This is what the voice teacher means when he tells the pupil to "keep everything loose" on the production of a higher note. So far as conscious knowledge of the singer is concerned everything, indeed, *is* loose; the vocal cords may have tightened at the behest of the ear, but it was without the conscious knowledge of the throat. While keeping "everything loose" does not represent the facts in the case as they actually exist, it does represent the facts so far as the singer's throat is aware, and is therefore entirely proper teaching practice; but the teacher himself, at least, should be aware of the fact that the cords themselves may have unconsciously tightened at the command of the ear.

There is another way in which the pitch of the human voice could conceivably be changed: by changing the volume of the resonating air cavity above the vocal cords. This is the method by which the pitch of a note is controlled when whistled by the lips. The writer's whistling compass is about two octaves and a half upward from middle C as a lowest note. As successive higher notes are produced above middle C, the resonating air cavity behind the whistling lips is made smaller and smaller until, when the extreme topmost note of the whistling compass is attained, the resonating air cavity has been made the smallest possible. How the whistling tone itself is produced by the lips I do not understand, nor have I ever discovered anyone who did; but the pitch of notes whistled by the lips is dependent largely upon the volume of the resonating air cavity behind the lips. Now the pitch of the notes of the human voice could likewise be controlled, by varying the volume of the resonating air cavity above the vocal cords; this is a method of pitch control in common use on all wind instruments whether brass or woodwind, and the human voice is certainly a wind instrument.

But whether the pitch of the human voice *is* so controlled as a matter of fact, I do not know; a view either for or against this supposition presents difficulties.

The resonating air cavity of a flute producing middle C is about twelve cubic inches. It is perhaps not impossible that the maximum volume of the resonating air cavity back of the whistling lips might be twelve cubic inches. To produce a note two octaves and a half above middle C the air capacity should be one-sixth of this, or two cubic inches. And it is perhaps not impossible that the minimum volume of the resonating air cavity behind the whistling lips might be two cubic inches. Now the lowest note of the writer's singing voice is about an octave and a half below middle C, and its highest note about a half octave above middle C. Assuming all conditions to remain the same as in whistling, the resonance cavity for the production of this lowest singing note should be about three times that for middle C, twelve cubic inches, or thirty-six cubic inches; and the resonance cavity for the production of the highest singing note, two octaves above, should then be one-fourth of this thirty-six cubic inches, or nine cubic inches. Again it is perhaps possible that thirty-six cubic inches and nine cubic inches might be respectively the maximum and minimum capacities of the resonating air chambers above the vocal cords for singing purposes. So that it is perhaps not impossible, from this point of view, that the pitch of the singing voice might be controlled, like other wind instruments, by the volume of the resonating air cavities employed in singing.

On the other hand it is certain that, in singing, the air chambers below the vocal cords pulsate in precisely the same manner as the resonating air cavities above the vocal cords, but in reverse order; i. e., a condensation above the vocal cords occurs simultaneously with a rarefaction below them, and a rarefaction above the vocal cords occurs simultaneously with a condensation below them, so that the upper and lower parts of a pulsation constitute its opposite halves which are separated from each other by the vocal cords. Now what effect the volume of the air cavity below the cords would have upon the volume above them in determining the pitch of a note, provided that pitch is considered as being determined by the volume of the resonating air cavities, is not at all easy to see in the present state of our ignorance upon the whole subject. Upon the whole, then, it is difficult to say whether the human voice, like other wind instruments, has the pitch of its notes controlled entirely or in part by the volume of its resonating air cavities.

There is also a third method by which the pitch of a note of the human voice might be influenced to at least some extent, although perhaps not entirely: by making the orifices larger or smaller by which the tone pulsation escapes to the outside atmosphere. This is a method of pitch control utilized on all woodwind instruments. If on the flute or any reed instrument the orifice by which a tone pulsation escapes to the outside atmosphere is enlarged, then the pitch of that note is raised; if on the other hand that orifice is made smaller, then the pitch of that note is lowered. Thus if a tone hole on any of these instruments is enlarged the pitch of the corresponding tone is sharpened, and if the tone hole is made smaller then the pitch of that tone is flattened. But this principle applies not only to the lateral tone holes, it applies to the bore of these instruments as well. Thus the oboe and the clarinet are approximately of the same length; but, since the bore of the oboe increases from reed to bell thereby permitting an easier and quicker escape of the pulsation, the pitch of the oboe is raised about a fourth above that of a clarinet of equal length, the clarinet having a cylindrical bore throughout most of its length. Likewise the pitch of a saxophone is about a fourth higher than that of a clarinet of the same length, because the pulsation escapes more easily and therefore more quickly on account of the saxophone's conical bore. The common statement in textbooks of physics and in treatises on musical acoustics to the effect that an instrument with conical bore is pitched an octave higher than a cylindrical instrument of the same length is not borne out by the fact; the difference in pitch depends upon the rapidity with which the conical bore increases its diameter, and probably never exceeds a fifth. In the ocarina the ascending scale of the instrument is secured solely by opening a larger and larger number of orifices by which the pulsation may escape, thus making it easier for the pulsation to get out, and reducing the amount of time necessary for it to escape, thereby raising the pitch of the tone produced.

This method of pitch control may, perhaps, be utilized in determining the pitch of a note produced by the voice. There are two points at which the facility with which a voice pulsation escapes to the outer atmosphere may be augmented or diminished by enlarging or making smaller the orifices by which the escape is made: the uvula may be raised or lowered to make the orifice between the pharynx and the mouth larger or smaller, and the lips of the singer may be opened wider or closed more to enlarge or make smaller the orifice between the mouth and the outer atmosphere. The use of either of these two means of controlling the size of the orifices by which the pulsation escapes would sharpen the pitch of the note as the orifices were made larger or flatten its pitch as the orifices were made smaller. The pitch would be somewhat stabilized, however, so far as this means of control is concerned, by the fact that the nose orifices always remain approximately of the same size, and the degree of pitch control by this means would therefore be less than if there were no nose orifices. This method of pitch control is a possible means which might conceivably be utilized by the voice; but whether this means of pitch control is actually utilized in singing, I do not believe we are at present in a position to say because of our profound ignorance regarding all these matters at the present time.

We see, then, that there are three possible means by which the pitch of the human voice could conceivably be controlled either entirely or in part: (1) by varying the tension of the vocal cords, (2) by varying the capacity of the resonating air cavities, or (3) by varying the size of the orifices by which the tone pulsation is permitted to escape from the resonating air cavities to the outer atmosphere. Which of these methods, or what combination of them, is actually used in singing to control the pitch of the tones sung? Is the pitch of a note by the human voice controlled entirely by the tension of the cords, by the size of the resonating air cavities, by the size of the openings between the air cavities and the outside atmosphere, by a combination of two of them, by a combination of all of them; and if by a combination of these methods, then to what extent does each method entering into the combination contribute to the resulting control of the pitch?

At the present time we have very few well established facts upon which to base answers to these questions. There is the greatest possible need for serious scientific investigation of these matters. It might possibly be inquired if voice teachers have not been investigating these questions ever since the day of Manuel Garcia *fils,* and before. That is undoubtedly true; but voice teachers are too uncritical in their thinking to make the conclusions reached by them trustworthy. A voice teacher always insists jealously that every successful singer he has taught attained success because of his own teaching no matter how many other teachers he may have had, but never lays any claim to those of his pupils who failed as singers; and the same kind of reasoning is employed with respect to the methods he uses and the vocal theories he holds. The logic employed by the vocal teacher, unfortunately, is too often like that of the cock which believed the sun came up because of his crowing. Not that the logic of the scientist is always entirely above question, but the scientist does at least record evidence both for and against the hypothesis he is investigating.

There is another matter with respect to the pitch of the human voice that should receive consideration: the difference of pitch between the male and the female voice. It is usually stated that the male voice is pitched an octave lower than the female voice; and so it is when they both sing the same melody. But at other times the statement is only a very rough approximation to the truth. The tessitura of one male voice is not at all the same as that of another male voice, nor are the tessituras of female voices the same by any manner of means. The tessituras of either male or female voices may vary by perhaps as much as a full octave; so that the lowest male voice may be pitched almost or quite two whole octaves below the tessitura of the highest female voice. Moreover, some male voices are pitched higher than some female voices. Upon the whole, then, the statement that the male voice is pitched an octave lower than the female should not be taken in any literal sense. A more accurate statement of the facts would be that the male voice is *usually* pitched lower than the female, and that the difference in pitch between the male and female voice may be any interval up to perhaps two octaves.

What is the reason for the difference in pitch between male and female voices? There are almost certainly two reasons for the situation: the male vocal cords are longer and thicker, and the resonance cavities are larger than in the female. Arising from these two reasons there is what might be regarded as a third reason for the difference in pitch: the male voice usually employs its fundamental notes in singing, while the female voice usually sings on an upper harmonic note of the voice instead of on its fundamental. This statement will perhaps need some slight explanation before it will be understood.

When the air stream impinging upon the edge of a flute blow hole is stiffened a bit by harder blowing, the pitch of the note jumps an octave. Still a little harder blowing will cause the pitch to jump a fifth more. Both of these latter, higher notes are upper harmonics of the lowest or fundamental note. If the reed of a bassoon is pinched the proper respective amounts by the lips of the player, the pitch of the note will likewise jump first an octave and then an additional fifth, to the first and second harmonics of the lowest or fundamental note. If the lips of the trombone player are tightened by the proper respective amounts, the pitch of the trombone will in like manner jump from the fundamental note to the first and second harmonics, first an octave and then a fifth higher than the octave.

The same phenomenon occurs with the male voice. If the male vocal cords are tightened by the proper amount—of course the tightening occurs without conscious effort of the throat—the pitch of the voice will jump an octave, from the "chest" or fundamental tone of the resonance cavity then in use to the first harmonic of that same cavity, producing a tone which is ignorantly called "falsetto." Of course there is nothing whatever "false" about this tone, and it is unfortunate that the term "falsetto" has crept into vocal phraseology. These harmonic tones of the male voice are only occasionally employed by basses, baritones, and tenors, but are regularly employed by male sopranos, yodlers, and female impersonators. The former emasculation of boys for the purpose of producing adult male sopranos is an amazing testimonial to vocal ignorance in the land of "bel canto" at a time when that art was supposed to be at the height of its development. Practically any adult male can learn to sing soprano as well as a female if he will devote to the production of these tones the same amount of study that a woman gives them.

And this leads to the next point: the female voices employ these harmonic tones exclusively, and never sings on the fundamental note. This is the reason a woman is supposed to have no "falsetto" voice. As a matter of fact her voice is all "falsetto"—she has no other kind of voice. Occasionally, it is true, a female voice will be found that is able to produce these fundamental tones; such a voice is usually referred to by some such term as a "female baritone," but they are sometimes called contraltos provided the notes are not too big.

The female voice is not the only musical instrument which finds it very difficult or impossible to produce its fundamental notes. It is very difficult indeed to produce the fundamental notes of the French horn, and is quite impossible unless the mouthpiece is exceptionally large. And the same is true of the trumpet in F. The production of the fundamental notes on the piccolo, too, is not very satisfactory or easy; and on a very short instrument of the flute type known as the pico pipe it is entirely out of the question.

The reason most female voices are unable to produce the fundamental notes of their resonance cavities is that the female vocal cords are too short for that purpose as compared with the size of the resonance cavities; the male vocal cords are longer in comparison with their resonance cavities than are the female cords in comparison with theirs. From another standpoint it might be said that the female resonance cavities are too large for the vocal cords to produce the fundamental notes of those cavities. The facility with which some coloratura sopranos sing almost to the top of the keyboard is explained by the fact that their vocal cords are unusually short and they are able to sing upon higher harmonics of their resonance cavities than most sopranos.

The voice of the pre-adolescent male is due to the underdeveloped size of his larynx as compared with his resonance cavities which are almost fully developed. The head of the boy increases much less in size as he approaches maturity than the rest of his anatomy; the head and resonance cavities are nearly as large as they will ever be, while the larynx is in comparison small and the vocal cords short. The shortness of the vocal chords makes it impossible for him to produce the fundamental notes of his resonance cavities, and he therefore speaks and sings upon the harmonic notes of those cavities like a woman. As he nears adolescence his larynx increases in size more than his resonance cavities, there comes a time when his larynx has attained sufficient size and his vocal cords sufficient length that it is equally easy for him to produce either the fundamental notes or the first harmonic notes, and his voice "breaks." At this period it is difficult for him to control the pitch of his speaking voice, since the tension of the vocal cords is determined chiefly by the unconscious domination of the ear through the sense of pitch and not by conscious muscular effort of the throat, and his voice wobbles willynilly between the voice of a man and the voice of a boy, to the infinite embarrassment of the youthful speaker. As his growth proceeds still further, the size of his larynx and the length of his vocal cords increases still more in comparison with the size of his resonance chambers, and he finally speaks with confidence and assurance in the voice of a man, to his immense relief. The throat and larynx of the female never attains the size that it does with the male, and, in consequence, she seldom acquires the ability to speak or sing with her fundamental notes; her voice does not "break" during adolescence as does the voice of the male.

There is an ignorant superstition on the part of some persons that the use of the voice at the time that it is "breaking" is dangerous, and the boy is in consequence sometimes forbidden the use of his voice for singing purposes at that time under penalty of complete loss of his singing voice. In view of the facts as here presented, it can be seen that there is not the slightest possible danger to be incurred by the use of the singing voice at this time. And if the boy continued singing as a soprano throughout the "breaking" period, he would carry over into adult manhood all the soprano singing ability acquired during his youth, and could remain a soprano all his life—probably superior to most female sopranos because of the greater size of the male resonance chambers as compared with those of the female. His continued use of his soprano voice would have nothing whatever to do with his acquisition of an additional male voice as a bass, baritone, or tenor, either for or against. He would, of course, know little about voice production with respect to his male voice and, if he wished to acquire also a male singing voice, he would have to study the "placement" of the fundamental male notes of that voice in precisely the same way that would be necessary if he were to drop his soprano voice in favor of his male voice. If he acquired a male singing voice also, and continued the use of his boy's voice as well, he would, throughout his adult manhood, be the possessor of two distinct singing voices: his original soprano or contralto boy's voice, somewhat enriched in tone quality because of the lengthened vocal cords, not quite so "white" in color as during boyhood, and also whatever male voice he might subsequently develop whether bass, baritone, or tenor. The use of his soprano or contralto voice by the adult male would be a question of taste to be determined by each individual singer as might suit his personal inclination; but I am inclined to believe that adult male sopranos and contraltos would, generally speaking, be superior to female sopranos and contraltos because of their greater resonance and their more "dramatic" tone quality. Coloratura male sopranos would probably be rare, but males with "dramatic soprano" voices would be common. The writer is, of course, aware that this is revolutionary vocal doctrine, but he is merely reporting the facts as they exist with respect to the human voice as a musical instrument.

The greatest need of the vocal profession today is more extensive, more intensive, and more dependable, information respecting the action of the human voice as a musical instrument. It will be readily conceded that the maker of a flute, a clarinet, a trombone, a violin, or an auditorium, must know the proper proportions for his instrument if he is to produce the best result possible to the skill of his craft, and that exhaustive laboratory investigation would be contributory to that end. It is not so generally recognized that the same principle applies to the voice builder; but such is undoubtedly the case. A flute or a violin comes to the player as a finished, completed instrument ready to be played. It is not at all so with the voice. The prospective singer receives his instrument in a very rough and incomplete state, far short of a finished and perfected instrument ready for his use—"knocked down," the violin maker would say of a violin in a similar state of incompletion. Before the prospective singer can use his unfinished instrument he must take it to the vocal instrument maker—a voice teacher—to have it completed. And it is only after a tedious process of finishing and polishing that the vocal instrument is put into fit condition to be used for singing.

Of all musical instrument makers the voice builder is in greatest need for exhaustive and exact information about the instrument he makes, for the reason that the voice is of all musical instruments the most complicated in its method of tone production. Of all artificial musical instruments the violin is the most complicated in method of tone production; but the violin is less complicated in its action than the voice. And to the extent that the voice is the more complicated instrument, to that extent it is necessary for its builder to have the more exhaustive and exact information concerning its action. Two flutes from the same maker can be approximately alike; no two voices from the same voice builder can by any possibility be alike. In the case of two flutes, both of sterling silver as nearly uniform as it is possible to compound the alloy, both of as nearly the same bore as it is possible to draw the bodies, with walls as nearly as may be of the same thickness, with holes as nearly of the same size and location, and with hole caps as nearly of the same rise, it is possible to build the flutes approximately alike. But the vocal cords and air passages of any two singers differ so widely that their voices are entirely different instruments. Voices are more distinctive even than faces; it is more easy to mistake a face than a voice. The almost unerring vocal identification of individuals by the blind is illustrative of this. No one could possibly mistake a Caruso record for one by McCormack, even though both sang the same simple melody. A flute maker does not have to deal with adenoids, tonsils, long and short palates, recalcitrant muscles, and tissues that change in size and shape daily and almost hourly; a voice maker does. It is these conditions, in part, that makes the task of the voice builder so tremendously complicated and difficult.

It was said above that the greatest need of the vocal profession is more information regarding the action of the human voice as a musical instrument. The particular direction in which this information should be sought is in the laying of a broader and deeper foundation for the career of voice building. It should be realized by the vocal teacher that the human voice is but one of many musical instruments all of which are very closely related, and that every musical instrument has as its sole excuse for existence the production of periodic atmospheric pulsations. The preparation of the vocal teacher should therefore begin with a thorough study of sound in general and of musical sound in particular. The nature of musical sound and the manner in which it behaves should be thoroughly investigated, so that he will understand precisely what characteristics of atmospheric pulsations correspond to differences of pitch, differences of tone quality, and differences of tone intensity. And these matters should be understood as concrete atmospheric facts, not as mere verbal formulas to be mouthed over meaninglessly. When he comprehends the nature and behavior of musical sound, the prospective voice teacher should then proceed to a study of the methods by which these musical sounds are produced by various musical instruments. In studying the action of musical instruments he should lay especial stress upon the wind instruments because of the fact that the human voice is a wind instrument. But he should not neglect the study of the string instruments also; for he can learn about singing from them, to paraphrase Kipling. When he has acquired a thorough comprehension of the ways in which the various wind instruments produce musical sounds, he may begin a study of the human voice and may reasonably entertain a hope of coming into a real understanding of its idiosyncrasies and foibles. When all this is finished he is then ready to begin the study of voice placement, to be followed ultimately by a study of singing itself and finally of the interpretation of vocal scores.

Of course this is not the program by which the voice teacher is now trained. His preparation never includes any of these items except the last three, with heavy interest upon the last. He builds the dome of his structure with not the slightest interest whether it shall have any foundations or intervening stories whatever. Well informed voice teachers are quite aware that but little is positively known about the action of the voice in singing. The teacher's lack of information is usually camouflaged by high-sounding phrases frequently signifying nothing to the teacher using them, and almost never meaning anything to the student. Patient laboratory investigation would replace the present-day vast accumulation of pseudo-information about voice action by a solid foundation of facts, and would obviate the enormous current waste of vocal talent due to ignorant teaching—a wastage hardly less than criminal. It is not meant that there could ever be devised *a* method of voice production in the sense of a set of cut-and-dried rules applicable to all voices, the religious following of which would make a singer of every pupil possessing a voice. Voices differ too much for that. But, although no cut-and-dried method could ever be found, more definite information would make more definiteness of method possible, and would obviate the present categorical and emphatic disagreement of vocal authorities upon the most elementary and fundamental points of vocal action. It is to be hoped that vocal talent in the future will be much more economically conserved and efficiently developed than is done at present; and more extensive, more intensive, and more dependable, information about voice action will be the chief means to that end.

CHAPTER XIX

REFORMING THE ORCHESTRA

FROM Monteverde to the time of Wagner the orchestra remained essentially an aggregation of strings with a few woodwinds and brasses added for use in solo passages to relieve the monotony of the strings. But it was well understood by all concerned that the woodwinds and brasses were the stepchildren of the family; they could speak only when they were spoken to. It remained for Wagner, influenced in a measure by Berlioz, to recognize the genuine merits of the brasses and to incorporate them into the orchestra as legitimate and integral members of it. There they will always remain; their value is too great and too obvious ever to be sacrificed.

But the woodwinds have had no Wagner; they are yet stepchildren. Utilized frequently but briefly for solos, they are sunk without a trace in a tutti passage. To introduce woodwinds into the orchestra in sufficient numbers to secure tonal balance will perhaps require another Wagner; and Wagners are distressingly infrequent.

A reasonable canon for balance in the orchestra is that in a tutti passage no choir shall be entirely submerged. This does not mean that every individual instrument shall be heard, nor that each separate part must be audible even when played by several instruments. It does mean, however, that each family of instruments shall make an appreciable contribution to the tone color of the ensemble in a fortissimo passage. It follows as a consequence that strings, woodwinds and brasses must be approximately equal in volume when the whole band is playing fortissimo.

It is hardly necessary to state that balance of this kind has never been attained in the orchestra since Beethoven. Such balance would multiply many times the number of tone colors on the palette of the orchestral composer. Under the present negligible status of the woodwinds, relatively few tone colors arising from different dynamic combinations are possible. For example, if we assume that there are three different dynamic degrees, loud, medium and soft, then only seven tone colors arising from different dynamic combinations are possible: (1) strings and brass of equal volume; (2) strings loud, brass medium; (3) strings loud, brass soft; (4) strings medium, brass loud; (5) strings medium, brass soft; (6) strings soft, brass loud; and (7) strings soft, brass medium. But if the woodwind choir were raised to a dynamic importance equal to that of the strings and brasses, then twenty-five tone colors arising from different dynamic combinations would be found possible. And if we recognize a greater number of different dynamic degrees than three, then the color disparity in favor of the balanced orchestra becomes even greater.

How many woodwinds are necessary to secure tonal balance in the orchestra? A reliable answer to this question is not easy to arrive at. So far as I am aware only two writers on instrumentation, Rimsky-Korsakov and Clappé, have attempted even to estimate the dynamic values of the various orchestral instruments; and the values given by them are obviously mere guesses. We are grateful to them, however, for raising the question and for their laudable attempts to find an answer to it. The difficulty arises from the lack of a simple, effective method of measuring sound intensity. And such a measurement is most imperatively needed. How much does the addition of four more violins to a first violin section of twenty add to the tone volume of the section? Do twenty violins produce twenty times as much volume as one violin? How many violins does it take to equal in volume one 'cello, one clarinet, one flute, one horn, one trombone? It is all guess work at the present time. Yet, in these days of large deficits for the orchestral season, the question cries aloud for answer. If business men on the directorates of symphony orchestras applied the same efficient methods of economical management to the orchestra that they employ as directors of business corporations, they would insist that someone secure this important information for them.

Perhaps the most reliable evidence now available can be drawn from the combined instrumentation of the leading concert bands and symphony orchestras. As between strings and brasses, the consensus of opinion among orchestral conductors seems to favor about three times as many strings as brasses. As between woodwinds and brasses, the opinion of leading band conductors appears to sanction about two-thirds as many brasses as woodwinds. Upon the basis of these ratios, the instrumentation of an orchestra of a hundred and fourteen pieces would be: sixty strings, thirty woodwinds, twenty brasses, four percussion.

Within the string choir of the symphony orchestra the balance of violins, violas, 'cellos and basses may be accepted as approximately correct. The present orchestral assignment of instruments in the brass choir also secures a fairly satisfactory degree of balance within that choir. However, some slight modifications of brass instrumentation will be suggested below.

Now what should be the distribution of the thirty woodwind voices in an orchestra of this size? In the first place, eight flutes are necessary for the upper portion of the woodwind keyboard—enough to make themselves heard among the other altissima voices of the orchestra, the violins. Two of the flautists should double on flutes in high G, and two on flutes in low G, thus forming with the four remaining flutes in C a double flute quartet. It is impossible for anyone who has not had the privilege of listening to a flute club to form an adequate conception of the beautiful effects possible in such an ensemble. It supplies a tonal fabric as delicate in its traceries as the sheerest lace.

Then there is need for a complete family of clarinets: two in E♭ (or D), two first B♭'s (or A's), two second B♭'s (or A's), two bassett-horns in F, and two bass clarinets in B♭ (or A). The purpose of the E♭ clarinet is not to squeal to the top of the keyboard *à la* "Til Eulen-spiegel," but to extend a few notes higher the beautiful chalumeau register of the clarinet choir. Indeed, it is a mistake ever to score for the clarinet above its thrice lined C. Higher than that the clarinet ceases to be a musical instrument, except for the greatest of artists, and becomes a demoniacal perversion of its prototype, the quill squawker. The organ-like effect of the complete clarinet choir, mellow and melting yet sonorous, is at present quite unattainable in the orchestra but most desirable.

The double-reed choir, too, should be augmented and rounded out so as to include a first and second oboe, an English horn, a heckelphone, a first and second bassoon, a contrabassoon, and a contrabass sarrusophone. It is sometimes thought by those not thoroughly familiar with woodwind instruments that the bassoon is essentially a bass oboe. This is erronous. The bassoon, in fact, is quite a different instrument than the bass oboe, differently constructed and with a materially different tone color. The bassoon has a conical bore, the bore of the oboe flares like a bell. Moreover the inside diameter of the oboe increases, from reed to bell, much faster than that of the bassoon. In consequence the oboe and the bassoon have quite different qualities of tone. The bassoon is not the proper bass for the oboe. Its natural bass is the heckelphone, pitched an octave below the oboe and an authentic oboe in every respect. The tone of the heckelphone is of the genuine oboe quality, and beautiful from top to bottom. Two oboes, an English horn, and a heckelphone form a true oboe quartet homogeneous in tone color and most useful in the orchestra. Likewise two bassoons, a contrabassoon, and a contrabass sarrusophone supply a true bassoon quartet, for the sarrusophone is really a contrabassoon constructed of metal.

It is surprising that the double-reed instruments have been so little utilized for harmonies among themselves. True their harmonies would be rough, weird and wild; but it is precisely because of this fact that they should on proper occasion make a strong appeal to the composer, supplying as they would an entirely new orchestral effect. It would be very interesting to see what a competent composer would be able to do with a bagpipe pibroch scoring it in free counterpoint for a double-reed choir such as that suggested above. With a proper complement of drums employed in the highland manner, the result should be most effective.

Finally, there is need in the orchestra for a quartet of saxophones, soprano, alto, tenor, and baritone. It is only supercilious conservatism that now proscribes their use in the symphony orchestra, and sooner or later they will be admitted. There are too many people who regard the saxophone voice as beautiful for it to be laughed summarily out of the court. In the hand of an amateur its tone is execrable, it is admitted; but the same is true also of the violin. The real artist on the saxophone is quite as capable of eliciting from his instrument tones of delicate beauty as are players of other orchestral instruments.

The variety of tone colors obtainable by different combinations of the thirty instruments in the above woodwind choir is almost infinite, and the composer who fails to utilize them is needlessly circumscribing his own possibilities and ruthlessly barring his audiences from sources of musical beauty to which they are fully entitled.

One or two slight modifications of the brass choir are desirable. The mellow voiced horns and tubas are at present without a soprano voice. The fluegel horn serves this purpose perfectly, and with its addition to the orchestra the family of the mellow voiced brasses would be complete. On the other hand, the brilliantly voiced brass family of trumpets and trombones lacks a contrabass. The logical candidate for this position is the BB♭ contrabass trombone, and it should be included in the orchestra. With double slides the contrabass trombone in BB♭ would require precisely the same arm-reach as the tenor trombone, and the player of the tenor trombone who wished to change to the contrabass would be able to do so by simply acquiring an embouchure suitable to the larger mouthpiece. Perhaps an alto trombone in F should also be employed to replace the vanished trumpet in F. The F trumpet was a splendid instrument musically, but was too heavy to hold in the position made necessary by its shape. The F trombone would be free of this objection, and would fill a rather wide gap between the B♭ trumpets and the tenor trombones. And if the F trombone were constructed with the same bore as the old F trumpet, it would supply a soprano voice for the trombones satisfactory in every respect and not subject to the faulty intonation of the valve brasses.

The practice of requiring players to double on nearly related instruments is a simple, logical expedient for greatly extending the tonal resources of the orchestra without unduly increasing the number of players employed. This is already established practice for symphonic flautists, who play either the flute in C, the piccolo in C, or the contralto flute in G, as occasion demands. In jazz organizations the practice has been greatly extended so that the single-reed artist plays any of the clarinets and any of the saxophones as demanded, and plays them well. Symphonic conductors might wisely emulate the example of their more unconventional brothers by requiring their own musicians to do likewise. Not only should the flautist play any of the flutes, but the single-reed player should play any of the clarinets or saxophones, and double-reed players should play any of the oboes or bassoons. I should even go so far as to say that players of the trumpet and fluegel horn should play either of the brass sopranos. With such doubling on nearly related instruments established as recognized practice, the resources of the orchestra would be enormously increased without a corresponding increase in the cost of maintaining it.

I am quite aware that the proposal for orchestral players to double on nearly related instruments will meet with vigorous opposition from symphonic musicians. I am the less disturbed by this opposition because of the fact that symphonic musicians have for the past hundred years insisted that every new technical demand made upon them by composers and conductors was quite impossible of execution, and then have proceeded in the most matter-of-fact way to meet the new demands. Furthermore jazz musicians are, with entirely adequate artistry, already doing all the things here suggested for symphonic musicians. Competent, disinterested critics, I believe, would agree that the professional superciliousness of the symphonic musician is without adequate foundation. There is probably no wind instrument in the jazz orchestra that is not better played by jazz artists than by symphonic musicians. It would be indiscreet to disclose how great is the percentage of symphonic musicians who would willingly desert the symphony for jazz if they were able to meet the technical requirements of the latter organization. The doubling or trebling of one's salary is a powerful argument even if one is an artist.

The percussion, too, is a much neglected field; particularly is this true of the drums. I am decidedly of the opinion that drums of indefinite intonation might well be used much more liberally than they now are. Indeed the increasing importance of rhythm in contemporary music makes this almost imperative. When Rossini introduced drums into the orchestra, as distinguished from timpani, he was ridiculed and nicknamed "Tamburossini" (from *tambur*, drum); but drums have remained, and their use will increase. There should be an adequate complement of all sizes of big and little drums without snares, drums with snares, tom-toms, tambourines and castanets, and of gongs and cymbals of all sizes from large to small.

And why should the timpani be limited to three notes of the scale? If there is any excuse for admitting the timpani to the orchestra, and I certainly believe there is, then there is equal justification for enabling them to emit more than the three notes now possible. The timpani should be present in sufficient number to furnish, without tuning in the midst of a performance, a complete chromatic scale of *at least* an octave and a half, i. e., twenty timpani. Four percussion players would be ample to manage them even if harmonized melodies should be required of them. As a soft harmonic background for an incidental solo on a string or woodwind instrument the timpani would probably be found useful. It can even be imagined that the fortissimo use of several timpani, either for harmonies or dissonance, would be desirable in certain passages of a composition like the "Alpine Symphony." And why should not some composer write a concerto for percussion along some such lines as the elaborate African drum ceremonial of greeting to the new moon? In the effective use of drums and rhythms we yet have much of value to learn from the tribes of Africa.

Such are the possibilities of the orchestra. The probabilities; there's the rub! The conservative will contend that whatever is is good enough; the progressive will want to make things better. It would indeed be unfortunate if the native conservatism of the orchestra should prevent changes which would materially increase its usefulness.

CHAPTER XX

CHAMBER MUSIC POSSIBILITIES

BROADLY speaking, chamber music may be said to have begun with the appearance of Haydn's first string quartet in 1755. The seventy-seven quartets due to him, the twenty-six of Mozart, and the sixteen by Beethoven, furnished the foundation for the superstructure which we today call chamber music.

During the three quarters of a century from Haydn's first quartet to the death of Beethoven the only instruments of the orchestra which could be called at all satisfactory were the bow instruments. Boehm's first improvements on the flute appeared in 1832, but it was a score of years more before the instrument attained its present approximate perfection. The first so-called "Boehm" clarinet, really due to August Buffet and Hyacinthe Klose, was exhibited by Buffet in 1839. It was the following year that Triebert brought out "System No. 3" of the oboe, which system serves as the foundation of the present-day instrument. The task of bringing the bassoon to whatever degree of facility it today possesses was accomplished chiefly through the labors of Jancourt between 1845 and 1875. It is not overstating to say that the improvements on all these instruments were inspired by Boehm's work on the flute. The valve now used on the horn was devised by Blumel in 1827, the year in which Beethoven died; it was several years more, however, before valves for the horn reached their present state of efficiency.

Quite otherwise was the situation with respect to the bow instruments. The Cremona school of luthiers had reached its culmination in Stradivarius, and the hand of that master had already been stilled for more than a century before Haydn wrote his first quartet. Under such circumstances, with excellent bow instruments and quite inferior wind instruments to write for, it is not surprising that the string instruments should have won the allegiance of composers for small instrumental ensembles. The influence of the mechanical development of musical instruments upon the history of musical composition has never received the consideration which is its due. This is most curious since the choice of instruments for which a composer shall write is determined solely by the comparative musical status of the instruments employed in his day. It is the instrument maker who has always wielded the whip over the composer and determined what kind of music he shall write.

The improvements in wind instruments in the past century renders it no longer necessary for composers of chamber music to confine themselves to the bow instruments. And this is true even if he wishes to write for a quartet of instruments of a single genus; for it is at present possible to assemble an effective quartet either of flutes, clarinets, or double-reed instruments. Besides the orchestral flute in C, which is the one generally employed, flutes pitched in G a fourth lower are now becoming quite common; and a flute in G a fifth higher than the C flute is available, at least in America. Two flutes in C and one each in high and low G form a very satisfactory quartet, although the compass does not extend quite as low as might be desired for the bass. A plenitude of clarinets is ready to hand for the composer. From the lowest to the highest they include the bass, the alto, the bassett-horn, the B ♭, and the E ♭. Two B ♭ clarinets, a bassett-horn and a bass clarinet, provide a most engaging clarinet quartet. In the double-reeds, an oboe, an English horn, a heckelphone, and a bassoon, constitute a quartet of a weirdness that should appeal strongly to the composer for certain purposes.

The composer of a quartet who today wishes to confine himself to instruments of a single family is thus at liberty to choose either strings, flutes, clarinets, double-reeds, or brass. In either medium he will find at his disposal ample tonal material for an interesting composition. The strings will allow him a great range in compass, dynamics, and in flexibility of melodic line. The flutes will furnish him almost equal melodic flexibility, but they will be more limited in compass and in dynamic range. In respect to compass, the clarinets will provide him with notes of about the same gravity as the strings, but the upper range of the clarinets will be considerably less than that of the strings unless he substitutes an E♭ clarinet for one of his B♭'s. But, in either case, he will find the compass of the clarinets entirely adequate for a satisfactory quartet; and in flexibility and dynamic range the clarinets will be approximately equal to the strings. The double-reeds offer about the same compass as the clarinets, but in point of flexibility and dynamic range are decidedly inferior to either the strings, the flutes, or the clarinets. A quartet of horns, or of trumpets and horns, would provide sufficient compass and dynamic range, but would be decidedly inferior to the string quartet or to either of the woodwind quartets in point of flexibility. The brasses would undoubtedly offer greater variety of tone color than the string quartet or than either of the woodwind quartets confined to a single family. In variety of tone color the quartets other than brass would probably rank in the following order: clarinets, strings, flutes, double-reeds. The unique esteem in which the strings are conventionally held for quartet purposes is undoubtedly historic in its origin, and is quite certainly largely extrinsic.

If the composer for chamber groups wishes to mix his colors, the variety of combinations available is almost infinite. To discuss properly all the color combinations possible would require a volume. It may be permissible, however, to raise the question as to the most satisfactory woodwind quartet. Undoubtedly the logical candidate for the position of high voice in such a quartet is the flute. Its extremely high range and its exceptional flexibility fit it preëminently for that position. The part of the low voice should perhaps be assigned to the bassoon. The only objection to it is the fact that its lower half-octave can speak only detached notes, and those rather slowly. The upper middle voice should undoubtedly be the B♭ clarinet. The lower middle voice must be given either to the bassett-horn or to the heckelphone; there is no other woodwind instrument whose compass has a suitable lower limit. Both the bassett-horn and the heckelphone are instruments with voices of remarkable beauty, and it is unfortunate that composers are not better acquainted with them. They fill a most urgent need both in the woodwind quartet and the woodwind choir. It is probably not over stating to say that the bassett-horn is the most valuable of the clarinets, and the heckelphone is certainly of equal merit with the oboe or the bassoon. With the two upper parts given to the flute and the B ♭ clarinet, the lower parts could be assigned either to the bassett-horn and the bassoon, or to the heckelphone and the bass clarinet; either of these combinations would provide a very satisfactory woodwind quartet.

It is surprising that the harp is not more used in chamber music ensembles—as surprising as that the piano is so used. With a harp added to the above woodwind quartet, it would be difficult to imagine any combination of five instruments offering to the composer so much in variety of tone color without losing the necessary homogeneity and without departing from that refinement of utterance which is essential to chamber music. The undoubted leaning toward monotony inherent in the string quartet would be obviated, and the virtues of the string combination would not be unduly sacrificed. If a greater homogeneity of color among the woodwinds of such a quintet is desired, the harp, two flutes in C and low G, with a bass clarinet, and with a bassett-horn or B ♭ clarinet as the fifth instrument, will attain the result nicely. For a trio, a flute, a B ♭ clarinet and a harp, or a flute in low G, a bassett-horn and a harp, could hardly be improved upon. During the latter part of his life Theobald Boehm played the low G flute by preference, and to the exclusion of any other. Surely this is praise from Sir Hubert for that instrument. For the rôle of a polyphonic instrument in a chamber music ensemble the harp is unquestionably superior to the piano. Its character is in every respect in perfect keeping with the chamber music genius, while the piano is entirely too much of a boor to fit into polite chamber music society.

The cultivation of chamber music for the woodwinds is receiving increasing attention on every hand. At the present time there seem to be permanently organized and active societies confining themselves exclusively to the cultivation and presentation of woodwind chamber music in the cities of Buenos Ayres, Amsterdam, The Hague, Rome, Madrid, Malmo, and Boston, with two such societies each in Paris and New York.

Perhaps the most striking chamber music development of the past generation is the quite exceptional popularity of the chamber orchestra. This is undoubtedly due to two influences: (1) the increasing cost of maintaining orchestras of modern symphonic proportions, and (2) the loss of orchestral balance between the strings and brasses of the symphony orchestra, on the one hand, and its woodwinds on the other. As shown in the preceding chapter, the introduction of a larger number of brasses into the orchestra by Wagner was followed logically by an increase in the number of strings; but, illogically, the number of woodwinds remained practically unchanged. In consequence the woodwinds are submerged in the modern symphonic orchestra except in solo passages. It was further shown that to restore balance between the string, woodwind and brass choirs would necessitate the use of not less than thirty woodwinds in an orchestra of one hundred and fourteen.

Such a method of restoring balance to the orchestra has its advantages. But it possesses also the disadvantage of being expensive. An alternative method of restoring balance, and one not involving increased expense, is that of reducing the number of strings and brasses. I speak of "restoring" the balance of the orchestra because of the fact that in the days of Haydn, Mozart, and Beethoven, the number of strings and brasses was not sufficient to submerge the woodwinds. From the reduction of the number of strings and brasses in the orchestra there has arisen the modern chamber orchestra or "little symphony" as it is sometimes very appropriately called.

The prospect for the future of the chamber orchestra is most alluring. It so easily meets the musical needs of so many of the parties concerned. Composer, instrumentalists, and public here find a common ground not beyond their abilities to attain. That this is true becomes clear when we consider the personnel necessary to the establishment of a chamber orchestra. It is probably impossible to establish a definite maximum limit to the chamber orchestra, but it is at least safe to say that it should be much smaller than the symphony orchestra. Perhaps one might be safe in stating that the chamber orchestra need never employ more than the following twenty-five players: five for strings, four each for flutes, clarinets, double-reeds and brass, a harp, and three for percussion. The five strings are the usual string quartet with a string bass; the quartets of flutes, clarinets, double-reeds, and brass are those suggested above. As for percussion, the writer is of the opinion that the use of percussive instruments is only in its infancy and, as indicated in the preceding chapter, would favor a widely extended use of both skin and metal percussion instruments of both definite and indefinite intonation; not alone for use in climaxes, but for pianissimo effects as well—say, for example, muted trumpets and stopped horns against a roll on the Chinese gong as a background. All these percussive instruments, together with a full chromatic scale of timpani for at least an octave and a half, could be manipulated by three percussion players, for they would never all be in use at the same time.

Moreover the whole twenty-five players enumerated above would perhaps never appear in the rendition of any one composition. Probably the number of instrumentalists used in a whole program would be not more than a dozen. But a dozen players in a chamber music concert, as against a hundred players in a concert of symphonic music, reduces the financial risk of the undertaking in the ratio of eight to one. The city not large enough to support a symphony orchestra could undertake a season of chamber music with fair assurance of success.

The possibilities in this direction are already beginning to dawn upon enterprising communities. Kansas City not long ago organized a chamber music society of sixteen instrumentalists, and conducted a successful season extending over a period of thirty-two weeks. The experiment seems to have been satisfactory to all concerned. That many other cities which find a symphony orchestra beyond their purses will profit by the worthy example of Kansas City would seem to be a foregone conclusion. And in doing so they will put within reach of their respective communities a musical literature quite the equal of that for the larger orchestra, although of a somewhat different character and not so well known.

And, especially for smaller cities, how well this plan meets the needs of all. The public is assured of an opportunity to hear music of the highest possible character, orchestral musicians are offered occasional respite from the stifling tedium of daily theatre and other commercial playing, and composers of chamber music are given additional opportunities of having their compositions performed.

Whatever may be the explanation of the situation, the fact certainly is that composers are addressing their efforts more and more in the direction of chamber music. Perhaps the conventions surrounding the composer of chamber music are less fixed than in other fields of composition and thus allow him a greater degree of freedom to follow his bent; perhaps the competition is as yet less keen than in the fields of symphonic and operatic composition; at any rate, the field of chamber music composition is today being cultivated with astonishing assiduity. And this is gratifying. One wishes, however, that the modern composer's sense of humor did not so frequently desert him, or that he possessed greater confidence in his ability to succeed along legitimate musical lines instead of striving flapperwise to attract attention by becoming bizarre. After all, to do something entirely unheard of is not so easy as might at first thought appear. Ravel, for example, probably would not have scored a cat fight for soprano and tenor voices if he had been aware that Krieger, in 1667, had already done the thing as a fugue for four voices, and with a Teutonic thoroughness impossible to the Frenchman of today.

CHAPTER XXI

THE SYMPHONY BAND

IT MUST have occurred to all observers of musical progress that the wind band is gradually assuming a position of commanding importance as a musical organization. That it has not yet attained the dignity of the symphony orchestra is undoubtedly true however. Why it has not reached that respectable eminence, and whether it ever will do so, are questions of considerable interest.

There are three reasons why the wind band is as yet inferior to the orchestra: the band is about two hundred years younger than the orchestra, composers of the first rank do not write for it, and its instrumentation is even less effective than that of the orchestra.

Any brief statement must necessarily be inaccurate; but, if we agree to regard the orchestra as beginning with Monteverde, then it will have been in existence for about three hundred years. The band, on the other hand, is certainly less than a hundred years old. The foundation of the wind band is the tuba. Just as there could be no orchestra until there was a string bass, so the wind band could not antedate the wind bass; the tuba brought the wind band into existence. True there were trombones three hundred years ago with a compass as low as that of the tuba, and they could have become the foundation for a wind band; but for some reason they did not. And no other instrument of those days was an adequate bass for the wind band.

In the last analysis it was the invention of the valve by Clagget, Blumel and Stolzel, 1788 to 1827, that produced the wind band. First applied to the horn and trumpet, the valve was, by 1828, adapted to the larger brass instruments including the tuba. But the valve remained little more than a curiosity until the mechanical genius of Antoine Sax popularized the whole family of the valve brasses from the soprano to the contrabass.

More immediately, Sax and Wieprecht are the founders of the wind band; and which of these contributed more to its development is not easy to say. Sax may dispute with Theobald Boehm and Antonio Stradivarius the distinction of being the greatest maker of musical instruments who ever lived. Sax was certainly the most prolific of the three—and the most piratical; Boehm was just as surely the most scientific; and Stradivarius was undoubtedly the most fortunately situated. It was neither as an inventor nor as an instrument maker that Wieprecht contributed most to the world's musical welfare, but rather as one crying in the wilderness the gospel of a new kind of music—that of the wind band. Wieprecht was a civilian bandmaster of Prussia who, by 1828, had interested the Prussians in his idea to such an extent that he was able to conduct a band concert in Berlin which was participated in by thirty-two army bands with twelve hundred players. He also did valiant service in the way of transcribing orchestral music for the wind band. In 1845 French military bands were reorganized along the new lines; by the middle of the century Austria, Italy, Spain, Russia and England had fallen in line with the new idea. Since 1850 there has been but little change in the military band situation of Europe.

The greatest development in band music since the middle of the nineteenth century has been in connection with civilian bands. Of these bands there may be said to be two classes, the amateur and the professional, an amateur bandsman being understood as one who has another vocation than music. In America nearly every town of a thousand inhabitants has an amateur band, and the larger city may have scores of them. In England amateur concert bands are even more numerous. The two counties of Yorkshire and Lancashire alone are said to have over 4000 such bands with 60,000 bandsmen. And some of these English amateur bands attain a degree of musical proficiency that is indeed astonishing.

The professional concert band has become an established institution in America. The great precursor of these was the Patrick S. Gilmore band of a generation ago; the Sousa and Goldman bands are well known contemporary examples of this type of band. But not only is the professional concert band indigenous to America, it is quite certain to reach here its highest development; for the multiplicity of military bands in European countries operates there to the disadvantage of the professional concert band.

Of the reasons why the wind band is yet inferior to the symphony orchestra, the one already given is that the band is much the younger of the two organizations. A second reason is that composers of the first rank do not write for it. If, for example, Richard Strauss wishes to compose, it never occurs to him to write for the wind band; he writes for the orchestra as a matter of course. And quite naturally; the European composer is not familiar with non-military wind bands of the excellence of the American professional concert band. And as for American composers, they have not declared their independence of European leadership. Perhaps, too, the inherent advantages of the wind band as an instrument for musical expression have not yet presented themselves to composers.

Everything considered, the wind band probably has more to offer the composer as a means by which he may express himself than any other instrument or ensemble of instruments. Let us consider this claim. Why should a composer write for an ensemble rather than for a single instrument, or for one ensemble rather than for another? He does so to avail himself of a more suitable compass, more appropriate volume, a more desirable tone color, or more fitting technique, than he otherwise would have. And what, from the composer's standpoint, are the several advantages and disadvantages possessed by various instruments and ensembles of instruments?

The human voice, at its best, possesses a tone color of unparalleled beauty, but it has no staccato and its effective singing compass is only about an octave and a half or, possibly, two octaves. Its volume is greatly inferior to many of the artificial instruments, the brasses for example, and its flexibility is not great as compared with an instrument such as the violin or flute. The vocal choir furnishes a somewhat greater volume, and extends the compass to three, perhaps four, octaves. But the only respect in which the chorus can possibly compete with the band or orchestra is in delicacy of dynamic shading and in refinement of tone color. In other respects the vocal ensemble is inferior to the band or orchestra.

Of course no individual orchestral instrument can compete with the whole orchestra either in compass, volume, tone color, or technique. This fact is so obvious as to need no elaboration. Nevertheless each instrument of the orchestra has its own advantages and disadvantages. These were discussed more or less in detail in the preceding chapter and need not be repeated here. The composer for a single instrument or for a small group of instruments will be guided in his choice of instruments by their suitability for the particular message he has in mind.

The piano possesses a greater compass than the band or orchestra, but it is vastly more limited in tone color and volume; and its percussive character, which makes it impossible to sustain a tone or to modify its intensity after production, tremendously circumscribes its technical possibilities. The organ surpasses the band or orchestra in compass and volume, and possibly almost equals it in tone color. But its technical possibilities are much inferior to them; the band or orchestra has an artist for each voice, and a super-artist to direct the artist players, while the organ has but one artist for the whole ensemble. Moreover, the organ has no staccato, nor can it control the dynamics of an individual voice or of separate choirs of voices.

Upon the whole, then, no single instrument nor combination of instruments either human or artificial can vie with the band or orchestra as a means of musical expression. It remains to compare the resources of the band and orchestra with each other. In compass and technique the band and orchestra are approximately equal. The band is undoubtedly capable of producing greater volume than the orchestra, but the strings of the orchestra may possibly be able to play more softly than the band. It is possible, however, that the band through its clarinets in the lower register and its flutes in the higher register may be able to play almost as softly as the orchestra. It is probably within the facts to say that the band has the greater fortissimo, the orchestra the greater pianissimo, and that the dynamic range of the two ensembles is about equal with a possible advantage in favor of the band.

In point of tone color the orchestra has the greater possibilities, but the band perhaps has the greater probabilities. As was shown in the second preceding chapter, to secure proper tonal balance in the orchestra the woodwinds should be about half as many as the strings, and the brasses about two-thirds as many as the woodwinds. An orchestra of one hundred and fourteen divided into sixty strings, thirty woodwinds, twenty brasses and four percussionists would provide these ratios, secure excellent tonal balance, and be nearly ideal in variety of tone color. In a word, such an orchestra would be superior in the matter of tone color to any possible instrumentation of the band because of the latter's lack of strings. These are the possibilities of the orchestra, but not the probabilities. The orchestra is perhaps too firmly fixed in the string tradition for any such radical change to occur within the reasonably near future, no matter how desirable the change may be.

But the instrumentation of the band is still in a plastic state, its tradition is yet to form, and the composer is here at liberty to follow the promptings of his artistic inclinations. The greatest defect of the wind band as at present constituted is its ineffective instrumentation. It is as lacking in balance as would be a symphony orchestra having first and second violins and brass only. Indeed that is the present condition of the professional concert band. The theory is that the strings of the orchestra should be replaced in the band by the clarinets. And the parts which in an orchestra would be given to the first and second violins are, indeed, assigned to the B *b* clarinets. But that there are in the orchestra such instruments as violas, 'cellos, and string basses, seems to be entirely forgotten by transcribers of orchestral music for the wind band.

What should be done, of course, is to include alto, bass and contrabass clarinets in the band in about the same ratios that the violas, 'cellos, and string basses bear to the violins of the orchestra. The clarinet choir should possess the same balance between its soprano, alto, tenor, bass and contrabass voices as does the string choir of the orchestra. Without this tonal balance in the band's principal choir, there can be no symphony band; with it there can. Upon this basis the instrumentation of the clarinet choir should be about as follows: twelve first B ♭ clarinets, twelve second B ♭ clarinets, eight bassett-horns in F (or alto clarinets in E ♭), eight bass clarinets in B ♭, and six contrabass clarinets in E ♭—forty-six clarinets in all. When the mellow, organ-like effects of this clarinet choir are considered, it is difficult to conceive that a composer's hand would not itch to write for it.

But clarinets and brass will not furnish a balanced band any more than strings and brass form a balanced orchestra. Flutes, double-reeds, and saxophones are as necessary to the band as to the orchestra. The flutes should be eight in number, as in the orchestra, two flautists doubling on flutes in high A ♭ and two on flutes in low A ♭, to form a double flute quartet when desired. Since the band uses instruments in flat signatures, the flutes for the band should be pitched in D ♭, high A ♭, and low A ♭, instead of in C, high G, and low G, as in the orchestra. At first thought it might be supposed that eight flutes would be lost among so many clarinets; but when it is considered that the flutes would play in unison in tutti passages, and usually an octave above the clarinets, it will be agreed that eight are enough.

Of the double-reeds there is need for fourteen: two first oboes, two second oboes, two English horns, two heckelphones, two first bassoons, two second bassoons, and two contrabass sarrusophones. Again, such a comparatively small number of double-reeds might seem inadequate to balance forty-six clarinets. But the penetrating tone-quality of the double-reeds is quite capable of making their presence known. As one writer on instrumentation puts it, "nothing should be written for the oboe that is not intended to be heard." Of saxophones there should be a double quartet: two sopranos, two altos, two tenors, and two baritones. The saxophones do not play high on the band keyboard like the flutes, nor is their tone-quality so penetrating as that of the double-reeds; but their voices are so sonorous that eight of them will be found quite sufficient for balance.

The soprano brass instruments should be six in number: two trumpets, two cornets, and two fluegel horns. Just as the brilliantly voiced trumpets are needed as sopranos for the trombones, so the fluegel horns are necessary to supply the mellow high voice for the

French horns, euphoniums, and tubas. The six brass sopranos all playing in unison would form a composite tone-color approximately equal to that of the cornet—neither excessively brilliant nor unduly mellow. But the players of the soprano brasses should double on all of the brass sopranos so that, as occasion demanded, all six players could be concentrated on trumpets, cornets, or fluegel horns. There should be a quartet of French horns, two alto trombones in F, four tenor trombones, two euphoniums, two E♭ tubas, two BB♭ tubas, and two BB♭ contrabass trombones.

With four players for percussion instruments, of the same character and variety as suggested for the orchestra in the preceding chapter but one, this would constitute a symphony band of one hundred and four members. From every point of view this organization would equal the present symphony orchestra as a musical instrument, and would surpass it in volume of tone and in variety of tone color; in a word, such a symphony band would be the superior of the symphony orchestra as at present constituted.

But the symphony band should appeal to the composer not only because when properly instrumented it is superior to the orchestra as a musical instrument, but for another reason which addresses itself to the needs of the composer with peculiar intimacy and force. One of the greatest obstacles encountered by the symphonic composer is that of getting his compositions produced. The supply of musical literature for the orchestra is so immense and so rich that the composer with a new work to produce is subjected to a competition that is keen to the point of unfairness. To secure a hearing he must bid against the writings for the past two hundred years of the world's greatest musical geniuses, and must displace from the program a composition by some one of the giants. It is a battle in which victory is not to the strong but to the strongly intrenched. Unless he is able to measure swords with the greatest of these, not on a fair field but assailing them in their strongholds, he is forthwith eliminated as one of the unfit.

But if a composer writes for the band instead of for the orchestra, the competition he encounters in securing a hearing is precisely *nil*. There are no great compositions for the band. Except for transcriptions of orchestral compositions, the wind band would be reduced to the playing of quicksteps. Compositions of the slightest merit written directly for the symphony band would secure an immediate and eager hearing. Conductors of concert bands would, with the greatest avidity, seize upon anything offered them by a competent composer. Moreover composer and conductor alike would be contributing materially to the sum total of the world's happiness, and to our general "respite from the cussedness of things."

The symphony orchestra has perhaps reached a higher state of development in America than anywhere else. But the possibilities for further development inherent in the wind band, the great popularity it has attained in less than a hundred years, and the tremendous present interest in the cultivation of bands and band music, all point unmistakably to the conclusion that the wind band in the comparatively near future will reach a position of musical respectability and artistic excellence at least equal to the symphony orchestra and perhaps superior to it.

CHAPTER XXII

THE LABORATORY STUDY OF MUSIC

As announced in the foreword, the purpose of the present volume is twofold: to establish that there is a science of music, and to persuade that the study of that science is important. This purpose has at all times been kept constantly in view, and it is to be hoped that something has been accomplished in the way of insinuating the writer's belief into the viewpoint of the reader. If the reader is not already convinced, it is too late to do that now; but it is perhaps not unreasonable to suspect he is fairly well persuaded that the two main contentions of the writer are valid. It will therefore be assumed that the reader and the writer now occupy common ground regarding the importance of cultivating the scientific study of music, and they may next consider ways and means of providing an opportunity for the pursuit of that study.

Of course there are no musical laboratories, either in connection with schools of music or with the laboratory systems of universities. The investigator today who wishes to study any of the multitudinous problems that press for solution in the field of musical science is compelled to provide his own laboratory. The situation thus becomes a bit difficult; for laboratory equipment and laboratory rent are expensive, and the researcher unfortunately is too often not well-to-do. He is therefore compelled to accept one horn or the other of an unpleasant dilemma: he must abandon his investigations, or he must undertake them with inadequate equipment and under unpropitious working conditions. Usually he does the "sensible" thing, and reluctantly foregoes pursuit of the elusive and fugitive fact; but, if the temptation is too strong for him to resist, he enters the pursuit burdened with handicaps that seriously compromise his chances of success. If his interests were in any other field of science, the doors of a hundred laboratories would be thrown wide to welcome him; but, since his interests are in those questions which lie at the foundations of music, all laboratories remain closed to him because they have no facilities for the investigation of his problems.

There should be at least one laboratory in the world where the fundamental facts of music could be investigated under conditions reasonably conducive to success. The interest in music is so widespread and intense, its appeal so intimate and poignant, and its significance for mankind so potent and profound, that it becomes unwise not to devote some portion of the enormous outlay for music to research in its fundamental questions. "Millions for superficial adornment, not one cent for strengthening the foundations of our musical structure," can hardly be expected much longer to remain the guiding principle of our action. If even an occasional crumb from the banquet of music could be gathered up and kept for the support of musical science, the banqueters would find that it would soon return to them increased a hundred fold.

Music is an art which could scarcely exist without its patrons, and it has never had to suffer long from lack of those willing to furnish it sustenance. But for the generous and intelligent interest of the well-to-do, the music of the modern world could not have come into being, nor could it otherwise continue to endure. The states of Europe have reached sufficient maturity to recognize the wisdom of extending governmental support to musical institutions. America is yet too young, perhaps, to take this point of view; possibly the attitude of American governments toward music is one inherent in democracy. At any rate, it is the wealthy private patron that makes possible the splendid orchestras and the magnificent musical foundations of America. Upon him it is that American music must depend for its support, and to him it must look for whatever advances are yet to be made toward its improvement. Clark, Coolidge, Curtis, Eastman, Flagler, Guggenheim, Higginson, Julliard, Kahn, Mackay, McCormick, these are the names to which America must do honor for the admirable music it enjoys; and it is from these, and others like them yet to come, that America must receive whatever of music it shall hereafter have. It is just as well to face the facts: it will not be for many years, if ever, that American legislators will become sufficiently broad-visioned to vote governmental funds for the support of musical institutions; in the meantime, it is to those who wish to contribute from their private abundance that American music must be indebted.

There is no other musical activity in which a modest sum from some patron of music would show such large returns in advancing the art of music as would result from providing the laboratory equipment for a study of musical science in connection with some representative university together with a sufficient annual budget for the support of perhaps a dozen scholarships and fellowships in musical science with one or two teachers to direct their studies. There is no other end to which a large amount of money could be dedicated which would so profoundly influence the music of the world for its betterment as would the creation of an endowment for the permanent establishment of a school of musical science in connection with some university, the endowment to provide for the erection and equipment of a building to house the school and for a sufficient annual budget to maintain it comfortably, with sufficient scholarships, fellowships, and professorships to assure adequate talent for a successful prosecution of the work of the school.

As compared with the endowment of an additional musical foundation providing for the instruction of interpretive artists, the endowment of a school for musical science should commend itself most strongly to the patron of music seeking a field of music in which his benefaction would secure the greatest possible returns toward musical betterment. It is easily within the facts to say that there is in America today an over supply of vocalists, pianists, and violinists. A business man would not by preference choose a line of industry where the article he would produce is already a drug on the market, but would enter a line instead where the demand was lively and the supply inadequate; that was the procedure by which he accumulated his fortune, and is it the way in which he should disburse it as a benefaction; yet that is precisely what the philanthropist is not doing who today establishes a school for the production of additional vocalists, violinists, and pianists. If, on the other hand, the musical philanthropist establishes an institution for the production of conductors and composers, or for the improvement of musical instruments and music itself through research in the fundamentals of music, then he is entering a field where the harvest is great and the laborers are few. The question of marginal returns should engage the attention of the philanthropist seeking an outlet for the placing of his musical benefactions in precisely the same way as it engaged his attention in the days when he was accumulating his fortune through business. And if patrons of music thus take into account the question of the comparative returns to be realized from placing their benefactions, the establishment of a musical laboratory will not have long to wait before some philanthropist will give to it the breath of life.

I am in no position to speak authoritatively as to the motives of the philanthropsit; but it seems reasonable to presume that the purpose he has in view is first to contribute to the happiness of mankind in some wholesome way, and second to secure for himself the credit to which he is justly entitled for having made such contribution. And, if these are his motives, how could he better accomplish his purpose than by establishing in some university a musical laboratory bearing his name? That music is a powerful influence in adding wholesome happiness to the lives of men is everywhere conceded; perhaps it might even be said that music is today the most powerful influence for good to which human beings are subjected. The person who contributes, according to his ability, to the improvement of the world's music has in all probability chosen the most profitable field for the expenditure of his efforts for human betterment; and, within the field of music, the most fertile spot to cultivate, as we believe we have succeeded in showing, is the scientific study of music in the laboratory. The person who improves the music of the world puts mankind under obligation to him to such a degree that he can never be repaid; and the persons who will hereafter most improve the music of the world will be those who give their lives to the scientific study of it, and those who make that scientific study possible through the establishment of a musical laboratory in which such studies may be pursued.

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A NOTE ON THE TYPE IN WHICH THIS BOOK IS SET

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This book is set on the Linotype in DeVinne, a Modern type face. The Modern types are sharply drawn with an almost mathematical exactness and were first made about 1790 and, becoming immensely popular, were soon grossly distorted. It was not until late in the nineteenth century that the Modern type was brought back to a useful sanity of design, largely through the influence of the great American printer Theodore Low DeVinne, in whose honor this type face was named.

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