four hundred and fifty to four hundred and fifty-two, the beats will occur twice in a second, and so on.

**197.** Beats are not due only to differences between fundamental notes, or to imperfect unisons. Dr. Pole (1877) thus writes: "Beats may arise (1) from two fundamental sounds that are nearly in unison: this kind may be called the *unison beat;* or (2) from two fundamental sounds which lie wider apart but the overtones [partials] of which approach each other within beating distance: this kind may be called the *overtone beat.* . . . There is, however, a third kind of beat which was pointed out by Dr. Smith of Cambridge, in his learned work on Harmonics published in 1749 [(1749 and 1759)] and was afterwards further explained by Mr. De Morgan in the Cambridge Philosophical Transactions for 1858. It differs from the first mentioned kind of beat, in that it arises from the imperfection, not of unisons, but of wide-apart consonances, such as the third, fourth, fifth, sixth and octave. It has been called the *beat of imperfect consonances.* It is well-known, practically, to organ-tuners, and is appreciable to any musical ear. . . . The theory of the consonance beat as explained by Smith and De Morgan, is too complicated to be given here, but it may be said in general terms to be a beat of the second order, depending, not like the unison beat, on a cycle of differing periods, but on a cycle of differing cycles."

**198.** Notwithstanding the disagreeable effect of beats on the ear, they have been of immense service to the cause of music, for they are proved to be the only satisfactory tests of intonation, as will be seen in chapter IX. Mr. Ellis has written a masterly and exhaustive treatise on this subject (1880B), a copy of which he was kind enough to present to me, and which I have found exceedingly useful.

# CHAPTER VI.

## ON QUALITY OF TONE, AND THE CAUSES OF ITS VARIETY.



**199. General View of Quality of Tone.** The plain English expression, quality of tone, will be used, throughout this work, to express those peculiar characteristics of musical sound, by means of which we are enabled, not only to distinguish the tones of different voices and instruments of music from one another, but to appreciate the finer and more delicate shades of variety in the tones elicited by different performers from the same instrument, and also the still more recondite differences between the sounds produced by the same performer from the same instrument at different times. The French word *timbre*, which originally meant "a bell struck on the outside by a hammer, instead of on the inside by a clapper," and which now has more meanings than letters, has lately been imported into this country as a substitute for the English term, but, as Mr. Ellis observes, it is "often odiously mispronounced, and not worth preserving." Professor Tyndall's new word "clang-tint," a not very happy translation of the German term *klangfarbe*, sound colour, hardly needs a protest.

**200.** The chief constituents of quality of tone may be thus antithetically grouped; their particular consideration will be deferred for the present.

| | | |
|---|---|---|
| Power | - - | Softness |
| Volume | - - | Thinness |
| Brilliancy | - - | Dulness |
| Sweetness | - - | Harshness. |
| Clearness | - - | Impureness. |
| Acuteness | - - | Gravity. |

It will now be useful to examine some of the opinions of well-known writers on the supposed causes of qualitative variety of tone, beginning with the consideration of a simple sound, that is to say, as far as we are able to consider that which may be assumed to have no separate existence.

**201. Quality of Simple Sound.** Until the last forty-five years the quality of simple sound was generally regarded as a mystery, and notwithstanding recent positive assertions to the contrary, supported by some astute arguments not often disputed, there are good reasons for thinking that a mystery it will long remain. Many and ingenious have been the suggested solutions of this difficult question, in earlier times, though some of the best men have passed it by altogether.

**202.** Chladni (1809, §31) modestly and guardedly says that the "differences of quality seem to be caused by small noises mixed with the appreciable tone; for example, during singing we hear, besides the vibrations of the air, the friction of this fluid on the organs of the voice; on the violin, besides the vibrations of the strings, we hear the friction of the bow on the strings. . . . Perhaps the different species of noise and of quality consist in the unequal movements of the molecules of the sonorous body."

At §240 of the same work, we read: "The different qualities of tone and its articulations are amongst the most remarkable



objects of the sense of hearing. They do not appear to depend on the manner of the vibrations, and very little, if at all, on the form of the sonorous body, but rather on the matter of the sonorous body and on that of the body by which it is rubbed or struck, as also on the nature of the medium of transmission. We have not the least idea of the nature of these different characters of sound, nor of their propagation."

**203.** Sir Charles Wheatstone states positively that "the quality of a sound depends on the magnitude of the vibrating corpuscles."

**204.** The more recent theory is that simple sounds are the result of pendular vibration only, and that this being the only possible form of their vibrations, there can be no variety in their quality.

**205.** Dr. G. S. Ohm (1843, 1844, 1853) is considered to have been the originator of this theory, and he certainly worked it out with admirable skill, though he thus acknowledged frankly the difficulties he might have had in doing so, but for the celebrated "Fourier's theorem": "Fourier spread light in our darkness when he brought out his '*Experiments on the diffusion of heat in bodies*,' and so enabled theoretical mechanics to solve the most difficult problems of physics with unparalleled ease." This theorem has been thus rendered by Professor Helmholtz and Mr. Ellis (1885): "Any given regular periodic form of vibration can always be produced by the addition of simple vibrations, having vibrational numbers which are once, twice, thrice, four times, etc., as great as the vibrational numbers of the given motion." Again, "Any given regularly periodic motion can always be exhibited in one single way, and in no other way whatever, as the sum of a certain number of pendular vibrations. The law, which Dr. Ohm deduced from the above theorem, is thus rendered by the same writers: "Every motion of the air which corresponds to a complete mass of musical tones, is capable of being analysed into a sum of simple pendular vibrations, and to each such single simple vibration corresponds a simple tone, sensible to the ear, and having a pitch determined by the periodic time of the corresponding motion of the air."

**206.** All this seems so clear and categorical that one would hesitate to refuse entire acceptance of the theory, were it not that some very distinguished mathematicians and acousticians have disputed its correctness, and, as it appears, with success. The chief assailant is Herr Seebeck (1843, 1844). Apart from the question of whether or not a simple tone can have a separate existence, his contention is that simple tones differ amongst themselves, other forms of vibrations, besides the pendular, having the power to cause the sensations of simple tones of varying quality: and he not only brings his great mathematical knowledge to bear upon his adversary, but he appeals to common sense and reason in these terms: "How can the question as to what belongs to a tone be decided except by the ear? We may realize the motion [by other means], but the ear alone distinguishes this motion as tone."

**207.** Professor Helmholtz has adopted the theory of Ohm in its entirety, and, concerning the tones produced "by blowing over the mouths of bottles," he asks us to believe that "if we disregard the friction of the air, the proper musical quality of such tones is really the same as that produced by tuning-forks" (1885 p. 70). Now, in the first place, we have no right to disregard the friction of the air, which, as pointed out by Chladni and others, has an important effect on quality of tone; in the next place, if we do so disregard it and compare the sounds of the bottle and the fork, we find but a very slight resemblance between them. It may be difficult to prove this, because it is simply a question of acuteness of aural faculty, and we know not what may constitute the difference between the two sounds, but that there is a difference must be manifest to any trained ear.

**208. Influence of the Partials on Quality of Tone.** We have now to consider one of the most interesting questions of



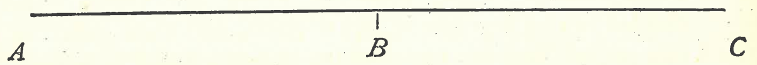
musical acoustics: the influence of the partials of a composite sound on its quality of tone. It is the custom, among recent authors, to attribute the merit of the discovery of this influence to Professor Helmholtz, but it seems absolutely beyond belief that philosophers, as well as experts, from the time of Aristotle down to our own, should have been aware of the compound nature of tone, and yet have failed to draw the simple and obvious deduction, that the nature, number and proportions of the component parts of a musical sound must necessarily influence the quality of the whole. We may therefore take it for granted that the conclusion was generally considered to be so transparently evident that it was unnecessary to invite particular attention to it, and it will be seen, as we proceed, that although Professor Helmholtz did great service by his careful analysis of composite tone, he certainly did not discover the influence of the partials. It will also be seen that he exaggerated greatly this influence, though not to the same extent as did Rameau and Estève.

**209.** Organ builders and organists must always have been familiar with the effect of the combination, with the chief sound, of others an octave higher or an octave lower; also with the effect of the *twelfth* and *fifteenth* stops, and the proportion to the general sound in which they were agreeable or otherwise. The well-known *mixture* stops can have been invented for no other purpose than to increase the power and brilliancy of the tone by the addition of artificial partials to those of nature. No one with a well-cultivated ear can ever have compared the sounds of an open and a stopped organ-pipe without having been aware that the sound of the upper octave was distinctly present in the one and absent from the other, and that the presence or the absence of the octave caused an undeniable difference in the tone. The recent application of the word *timbre* probably arose from the knowledge that the combination of the various sounds of a bell, influenced the quality of its tone.

**210.** The following brief extracts from some of the most noteworthy writings of the last two centuries and a half, on the influence of the partials on quality of tone, may prove interesting and instructive.

**211.** Mersenne (1636). "There are many amongst the possible conjunctions [of the twenty-two organ-stops, the combinations of which he was describing] that are not agreeable, and from which result bad effects."

**212.** Dr. Wallis (1677). "The same string as *A C*, being struck in the midst at *B*, (each part being in unison to the




other) will give no clear sound at all; but very confused. And not only so (which others also have observed, that a string doth not sound clear if struck in the midst:) but also if *A D* be struck at *B* or *C*, where one part is an octave


to the other; . . . . and so in other like consonant divisions: but still the less remarkable as the number of divisions increaseth. This and the former I judge to depend upon one and the same cause; *viz.*, the contemporary vibrations of the several Unison parts, which make the one tremble at the motion of the other: but when struck at the respective points of division, the sound is incongruous, by reason that the point is disturbed which should be at rest."

Perrault (1680). See quotations in §181.

**213.** Sauveur (1702). "The organ only imitates, by the combinations of its stops, the natural harmony of sonorous bodies."

**214.** Rameau (1737, 1750). The exaggerated ideas of this author, with regard to the influence of partials, have been mentioned in §172.



**215.** Dr. Thomas Young (1800), in allusion to his experiment rendering visible the vibrations of a string by means of a ray of light, mentioned in §30, says that "according to the various modes of applying the bow, an immense variety of figures of the orbits are produced; more than enough to account for all the difference of tone in different performers."

**216.** The same author (1807, Lecture XXII). "It is not, however, invariably true that the fundamental sound must always be accompanied by all the harmonics of which the chord is susceptible; for I have found that by inflecting the chord exactly at any point in which the chord might be divided into a number of equal parts, and then suffering it to vibrate, we lose the effect of the corresponding harmonic." It will be seen that this discovery was anticipated by Dr. Wallis and others, but it is generally mentioned as "Young's law."

**217.** Chladni (1809). "It seems that the harmonics of violoncello or violin strings are sweeter than the same sounds produced in the ordinary manner because they are unmixed with others."

**218.** Sir Charles Wheatstone (1823). "The richness or volume of sound depends on the number of co-existing vibrations. . . . It has often been thought necessary to admit the existence of more minute motions than the sensible oscillations, in order to account for many phenomena in the production of sound. . . . . . Chladni thinks their existence necessary to account for the varieties of quality."

**219.** Johannes Mueller (1840). "We are able to distinguish the sounds of a particular instrument in a full orchestra, partly because of the different qualities of their sounds, which are rendered remarkable by reason of their accessory vibrations."

**220.** Professor Helmholtz (1863, 1885). "The enquiry how far differences in quality of tone depend on the differing force or loudness of the upper partials, will be found to give a means of clearing up our conceptions of what has been hitherto a perfect enigma."

**221.** "We are able to lay down the important law that differences in musical quality of tone depend solely on the presence and strength of partial tones, and in no respect on the difference of phase under which these partial tones enter into composition." By the term "difference of phase," he explains that he means "the relative amount of horizontal displacement of the wave curves."

**222.** "Simple tones, like those of tuning-forks applied to resonance chambers, and wide stopped organ-pipes, have a very soft, pleasant sound, free from all roughness, but wanting in power, and dull at low pitches."

**223.** "Musical tones which are accompanied by a moderately loud series of the lower partial tones, up to about the sixth partial, are more harmonious and musical. Compared with simple tones they are rich and splendid, while they are at the same time perfectly sweet and soft if the higher partials are absent. To these belong the musical tones of the human voice and of the French horn. The last named tones form the transition to musical tones with higher partials; while the tones of flutes and of pipes on the flute stops of organs with a low pressure of wind, approach to simple tones."

**224.** "If only the unevenly numbered partials [counting the fundamental as 1] are present (as in narrow stopped organ pipes, pianoforte strings struck in their middle points, and clarionets) the quality of tone is *hollow*, and, when a large number of partials are present, *nasal*. When the prime tone predominates, the quality of tone is *rich;* but when the prime tone is not sufficiently superior in strength to the partials, the quality of tone is *poor*."

**225.** "When partial tones, higher than the sixth or seventh, are very distinct, the quality of tone is *cutting* and *rough*. The reason for this will be seen hereafter to lie in the dissonances which they form with one another."

**226.** (Dr. Koenig (1881). "The [supposed] fact that a stopped organ-pipe can only produce the isolated partials that



respond to the uneven numbers, [counting the fundamental as 1,] does not exclude the possibility of the existence of harmonics which would be owing to an undulating movement of the air different from the pendular movement . . . . . . The sound of a closed tube giving $c''$, . . . . being analysed by means of resonators, proved the presence of $c'''$, very weak; $c''''$ was much more pronounced, $g''''$ nearly as much; $c'''''$ was hardly perceptible . . . . These sounds varied with change of pressure and with the length and diameter of the tube."

**227.** A very important and convincing paper, by the same author (1881), is too long and too abstruse to be presented entire to the general reader, and to extract portions from it might be misleading. The following may be taken as a fair summary of the paper. Had Dr. Koenig been able to accept the theory, attributing the cause of variety in quality of tone solely to the combination of the partials with the prime tone, there would have been no occasion for his investigations, but, not being satisfied with the theory propounded, he did investigate the matter, and his experiments proved conclusively that, although variety of quality depends in a great measure upon the influence of the partials, these are not the sole cause of that variety, difference of phase being a factor much too important to be left out of consideration.

**228. Influence of the Lower Attendant Sounds on Quality of Tone.** Whatever may be the influence of partials, for good or for ill, on the quality of tone, there can be no doubt that the audible presence of the lower attendants (see §§192-3) is always objectionable, even when only single, detached notes are played, but in playing passages in which the harmonics form the chief sounds, the lower attendants and the partials are sometimes so prominent that the effect of consecutive octaves and fifths, so abhorred by musicians, is painfully obtrusive. Further allusions to these most disagreeable sounds will be found in Parts II. and III.

**229. The Chief Constituents of Quality of Tone, analyti-**

**cally and antithetically considered.** It will be now convenient to examine the various constituents of quality, each of which may, in some sense, be in itself regarded as a quality, of course leaving out of the question certain recondite and indefinable properties of simple tones. The subjoined list, as given in §200, is repeated here for convenience of reference.

*Constituents of Quality.*

| | | |
|---|---|---|
| Power | - - | Softness. |
| Volume | - - | Thinness. |
| Brilliancy | - - | Dulness. |
| Sweetness | - - | Harshness. |
| Clearness | - - | Impureness. |
| Acuteness | - - | Gravity. |

Penetrativeness is not included in the above list, as it cannot be pronounced a distinct constituent of quality: it is but the result of power, brilliancy, clearness or acuteness, or of the combination of any of these.

**230.** *Power: Softness.* Power, or intensity, depends on the general amplitude of all or any of the components of a sound: it may be combined with all the other constituents of quality except its own antithesis, softness, and will serve to intensify most of them. Excess of power is destructive to all musical tone, and causes it to degenerate into noise. The delightful element, softness, being simply the opposite of power, requires no explanation.

**231.** *Volume: Thinness.* Volume, or fulness, is due to excessive amplitude of the vibrations of the chief sound, whether fundamental or harmonic, compared with that of the partial vibrations. Extreme volume is the cause of dulness, or hollowness. Insufficient prominence of the chief sound causes thinness, or poorness, such as we observe in what is technically called a "wiry tone."

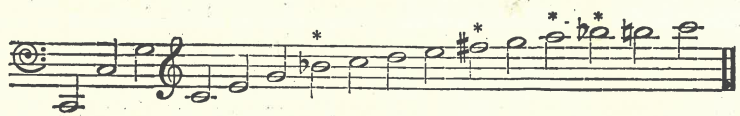
**232.** *Brilliancy: Dulness.* Brilliancy, the rich, sparkling property so much admired, depends in a great measure on the



due admixture of the sounds of the lower partials, notably the octave, in certain proportions to the chief sound. There are probably no more brilliant sounds than those of the lowest octave of the flute, and in these the octave partials are decidedly prominent, whatever may be said to the contrary. Mr. Hermann Smith (1874c) thinks that "a diapason pipe is never so strong and so brilliant as when it is just verging on the transmutation of fundamental to octave." This mixture of the octave may, however, be carried too far, and general excess of prominence in the partials will cause hardness and inflexibilty, as well as the thinness before mentioned and a spurious kind of brilliancy which is often, but not justly, admired. Insufficient prominence of [illegible] particularly of the octave, causes the tone to be d[illegible]w, through excess of volume: yet the clarionet ha[illegible]arly charming tone, not by any means without br[illegible]hile we know that the octave partials are almost ab[illegible] its sounds. The *twelfth*, however, is particularly pr[illegible] and this may in some measure account for the re[illegible]haracter of the tone of that instrument.

[illegible]*eetness: Harshness.* Sweetness, or smoothness, may be [illegible] as a happy medium between brilliancy and dulness. [illegible] sounds the partials can only be present in a very [illegible]egree, and the higher ones are not audible. Softness is [illegible]ement of sweetness. Carried to excess, sweetness degenerates into hollowness, and the tone becomes vapid and characterless. Harshness, or roughness, is often due to the excessive prominence of the higher partials. In order that this may be understood, it is necessary to present a more extended series of harmonics than that given in §46.

*Table of the higher Harmonics.*



* * * * These four sounds do not belong to the recognised

musical scale, but they are approximately as indicated above.

It will be at once apparent that the effect of sounding all these higher notes at once would be similar to that caused by placing one's arm on the keyboard of an organ. Happily the intensity of the higher partials diminishes as they rise, nevertheless they are often sufficiently powerful to produce an exceedingly disagreeable effect. The tones of the flute and the clarionet are remarkably free from them; in the hautboy they are apt to be too prominent, but skilful performers obtain exquisite tones from the instrument notwithstanding this peculiarity. My valued friend, the late Alfred Nicholson, discoursed from it music as sweet and as eloquent as it is possible to conceive. The hautboy, in such hands, has no trace of harshness, but the penetrativeness of its sounds, in proportion to their volume and acuteness, is unsurpassed.

**234.** There is a redundancy of the higher partials in the sounds of all stringed instruments, especially in the violin and the violoncello, which may account for the fact that some delicately organised persons are unable to admire the tone of these instruments. The discovery of the effects of the dissonant partials is generally attributed to Professor Helmholtz, but the subject was clearly shadowed forth by Des Cartes (1618); elaborately and exhaustively treated by Estève (1750), and mentioned by many other writers, including Rousseau (1764, article *Consonnance*).

**235.** *Clearness: Impureness.* Clearness, or pureness, of tone may be set down simply as freedom from extraneous noise; impureness being, of course, the reverse. Clearness is an essential element of brilliancy and sweetness, and even power is marred by impureness. Clearness is not incompatible with any other constituent of quality but harshness and its own antithesis, which are akin. The "jarring, scratching, soughing, whizzing hissing" noises mentioned by Professor Helmholtz, to which may be added the spitting sound peculiar to a certain school of flute-players, all detract from brilliancy, sweetness and clearness



of tone, consequently they may be classed amongst the contributors to impureness.

**236.** *Acuteness: Gravity.* I must now ask for the impartial judgment of any scientific man who may honour me by reading my book, for I am about to fly in the face of Professor Helmholtz; of all his disciples, and of some of his predecessors. No law has ever been laid down with more decision than this: "quality is independent of pitch." It may seem odd that the learned Professor himself, should have accidentally refuted this, but it is the plain fact that he has done so. These are his own words, as translated by Mr. Ellis, and already quoted in §222: "Simple tones . . . have a very soft, pleasant sound, . . . wanting in power, and dull at low pitches." (1885, p. 118). Now, if it is necessary to say that certain tones are dull at low pitches, it can only be because they are admittedly less dull at higher pitches, which is really an indisputable fact, therefore we must infer that lowness of pitch is the cause of their dulness. *Cadit quæstio:* the four unguarded words "dull at low pitches" have conceded the whole argument, and we may now be allowed to say that acuteness is conducive to brilliancy, while gravity is conducive to dulness, and how anybody could ever have doubted either proposition passes comprehension.

Acuteness, without sweetness and clearness, is liable to become shrillness, a form of harshness peculiar to high notes. Acuteness is always a cause of penetrativeness.

**237.** Gravity without brilliancy may be the cause of sounds becoming completely unmusical (see chapter I.), thus, gravity, a cause of dulness, requires sometimes the corrective, acuteness, an aid to brilliancy. The old lutists, before mentioned, gave practical proof of their knowledge of this, and there is other evidence of the fact, constantly under the eyes and ears of orchestral musicians and musical instrument makers, of which no one appears to have taken notice, yet it is hard to believe that the author of the appliance of which I am about to speak, whoever he may have been, was ignorant of the nature of his improvement. Neither the bore nor the reed of that magnificent instrument, the bassoon, is adapted for the production of fine low notes without the artificial combination of certain partials. This combination is effected by the opening of a very small hole in the upper part of the instrument, called the crook, which, determining the necessary partials, answers the same purpose as the higher strings of the lute, and thus the desirable brilliancy is given to the tone.

**238.** Pitch is also, in another sense, a fruitful source of variety of quality, as there is no greater aid to smoothness or roughness than perfect or imperfect intonation, the beats caused by the latter, giving rise to an amount of roughness which may be intolerable.

**239. Synthesis of Tones.** The recent attempts to imitate the sounds of various instruments, by the artificial combination of simple tones, were not likely to prove particularly successful, and, as a matter of fact, they have not so proved, though many persons seem to have deluded themselves into the belief that perfect success has been achieved. The difficulty, if not impossibility, of obtaining simple sounds with which to work, renders very doubtful the prospect of effecting anything approaching to a close imitation of the natural sound of a musical instrument by artificial means. It is all very well to strike two tuning-forks, and to say that they produce a tone similar to that of a flute or a clarionet: the question is, will the trained ear of a musician endorse such an opinion? I think not. Spurious imitations can always be detected by careful experts, and even the most casual observer often requires, like the "Marchioness" of Charles Dickens, to "make believe very much" before he can induce himself to think that they bear any resemblance to what they pretend to be. In the category of spurious and easily detected imitations must be placed the "synthesis of tones."

**240. Occult Causes of Variety in Quality of Tone.** In the absence of more definite proofs than have been adduced to the contrary, it may be well to believe that the indefinable and particular charm that should be possessed by each voice and



each instrument, is due, in a great measure, to causes so subtle and remote as to be beyond the scope of scientific investigation. By means of the sense of hearing alone we are able to appreciate the loveliness or the unpleasantness of a sound, as by means of our other senses we are able to appreciate the objects of sight, smell, taste and touch, and this power of appreciation must be exercised, not only by the separate examination of component parts, but by an intelligent judgment of the object as a whole. The ear, then, being indisputably the responsible agent for the appreciation of sound, we may enquire whether there is, or is not, a final court of appeal, before which its judgment may be arraigned? We cannot doubt that there is. We know that music and noise cannot always be distinguished, one from the other, except by the light of taste, and by the light of æsthetic culture alone must quality of tone be also regarded and finally judged.