THE ATTRIBUTES OF SOUND[1]

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My special interest in the attributes of sound began, I think, in 1903, when, through association with Professor Max F. Meyer, I became familar with his important work in audition. Up to this time I had accepted the traditional account of the attributes of sensation as being four in number: quality, intensity, extensity, and duration. When applied to sound this view identified pitch with quality, while extensity was represented by a vague concept of volume. Meyer in his paper 'On the Attributes of Sensation'[2] impressed me with the notion that there need be no *a priori* assumption that all sensations should have the same formal attributes. I also learned at this time of Meyer's distinction between *quality* and *pitch*. The former he referred to *height*, in the sense that every sound has its characteristic place in a progression, best described as a variation from mellowness (lowness) to shrillness (highness). A sound may also have pitch, *i. e.*, musical relatedness. In this case it is a *tone*. The attributes of sound, as given by Meyer, were four in number: duration, intensity, quality, and pitch. Extensity disappears. Whatever there may be of voluminosity is absorbed in quality. But Meyer's attributes are not the independently variable aspects of a sensory content. Rather, they are like atoms of consciousness that can be judged or compared with the aid of attention. Noise lacks pitch altogether, for it cannot be used musically. Objection can here be raised because pitch as so described is a *meaning*: it is musical significance, what else it may be does not appear.

Meyer stated in his paper that 'the average psychologist

[1] Paper read before the American Psychological Association at Pittsburgh, Dec. 27, 1917.

[2] PSYCHOL. REV., 1904, 11, 83–103.

takes . . . little interest in auditory sensation.' This seems to have been true, for Meyer's contribution to the scientific description of sound exerted but slight influence upon psychologists until they were confronted with the more startling results of Köhler, Révész and Jaensch. Then, at last, such an interest began to awaken. Révész[1] in particular discovered a remarkable pathological condition in the hearing of his friend and collaborator v. Liebermann. The latter proved to be unable to judge fusions and musical relations correctly in certain regions of the scale, although his sense of interval-distance was unimpaired. This led Révész to a distinction in the pitch attribute analogous to that which Meyer tells us he got from Stumpf, and made public as early as 1898. But Révész reverses the terms: quality becomes his designation for musical relatedness and fusion, while pitch becomes brightness-height or dullness-depth. In the interest of a uniform terminology, Meyer[2] has recently suggested that the first attribute be called *tonality* and the second *vocality*. But these terms, as we shall see, embrace too much. Besides they are still open to the objection that they incorporate meanings into the structure of sensation.

Watt has now subjected the whole matter to a critical review that culminates in the presentation of a comprehensive theory of the psychology of sound. This he incorporates in a recently published volume.[3]

Watt returns to the traditional classification of the attributes and attempts to establish a uniform list applicable to each of the senses. It is through integrations of these attributes, he believes, that all conscious processes arise. By way of certain uniformities we arrive at the unity of consciousness in which the various sense modalities figure. The attributes he suggests are quality, intensity, 'systemic order,' extensity, temporal order and durance. Quality signifies the essential nature of the sensation, as cold, warm, red, bitter. In the realm of sound there is but one quality,

[1] *Zsch. f. Psychol.*, 1912, 63, 263ff., 325ff.
[2] *Zsch. f. Psychol.*, 1914, 68, 115ff.
[3] H. J. Watt, 'The Psychology of Sound.' Cambridge, The University Press, 1917.

though there are three important integrations: tone, noise and vowel. Intensity requires no special comment as to its meaning. 'Systemic order' underlies all localizations and positions. In sound it is what we call pitch. Extension is the attribute of 'spreadoutness;' in sound this is volume. Temporal order is the basis for comparison of units in time, as evidenced in rhythm, while durance is mere protensity, or the temporal spread of sound.[1]

With regard to tone, Watt urges that this is always a massive phenomenon. The volume of a tone embraces a number of 'systemic orders,' one of which, rising to prominence, marks its pitch. The rise of this predominant order, together with the others included in the volumic whole, measures the tone's intensity. The 'systemic orders' incorporated in a sound are of great importance in determining fusion and sequential integrations. It is in this way that Watt explains musical effects. The predominant order, or pitch, is normally central to the tone's volumic outline. Volumes decrease regularly in size as pitch increases in height. Hence, when two tones in the octave relation are simultaneously sounded, the upper tone will fall entirely within the volumic outline of the lower tone. Furthermore, the order of the higher tone's pitch predominance will be such that it occurs midway between the lower tone's predominance and the upper limiting order of its volumic outline. The upper limiting orders of volume for all tones coincide, because two tones simultaneously heard never stand apart, but always interpenetrate. In the case of the octave "only one natural pattern offers itself as obvious: that in which the extreme order included in the volume of the higher tone on its lower side coincides exactly with the predominant order of the lower tone."[2] On this ingenious foundation Watt constructs his theory of fusion and musical interval as resting upon a balance of the resultant sound mass when one sound coalesces with another. (See Fig. 1, p. 238.)

[1] "To distinguish temporal order from the order upon which localisation rests," writes Watt, "the latter may be called systemic, as it is the order that appears when a system of receptors yielding one quality is given." *L. c.*, p. 9.

[2] *L. c.*, p. 64.

Coming to Watt's interpretation of v. Liebermann's case, we find him suggesting that the pathological condition is in reality a shifting of the pitch predominance away from its normal central position in the volumic mass. Hence, the fusional balance is destroyed, although the volumic outlines remain as usual. V. Liebermann judges his distances correctly. He knows that the octave span is greater than that of the fifth, yet he cannot always detect a fusional difference between them.

Although adequate experimental evidence for Watt's theory is lacking, it must be noted that such results as we have are rather in line with his proposals. Dr. G. J. Rich, for instance, who has experimented on volume discrimination, finds it to follow the geometrical progression of Weber's Law. His recent investigation with pure tones, which I am privileged to cite, indicate the limen to be approximately 6 vib. in the region of 275; 12 in the region of 550, and 24 in the region of 1,100. The fractional increment is thus about .02. This uniformity suggests that the volumes of tones in octaves are halved in size as one proceeds upwards in the scale, which is the conclusion Watt reaches on theoretical grounds.

The difficulty of Watt's theory does not rest on an assumption of volumic coincidence so much as in the 'symmetry' and 'balance' inferred in the case of all fusions. This is his explanation of fusion: that two tones fuse when the volumic pattern of the higher one balances with, or is symmetrically placed within, the volumic pattern of the lower. For such emplacement the decisive factors are the terminal limits of the two volumes, but these limiting orders must be consciously and physiologically negligible. Strictly speaking symmetry is only found in the octave, and a true balance only in the fifth. Other fusions seem to rest upon accommodations resulting from a sense of proportionality with regard to the intervals employed. Note, for instance, the graph of the *fourth* in Fig. 1. The balance is here disturbed because the predominant order of the higher tone is twice as far removed as is its lower limiting order from the predominant order of the lower tone.

My own reaction to this matter is determined by a different point of view. While Watt attempts to overcome the difficulties of a purely structural psychology by working out an elaborate system of integrations among the attributes of sensation, I am disposed to a functional interpretation, in which I accept mental acts as distinct from mental contents. The attributes that constitute a sensation are basic facts upon which the mind operates, but the operations themselves are not inherent in the attributes. Neither fusion nor musical relatedness, I think, can be adequately accounted for without reference to an *attitude*. The attitude is dispositional and embodies tendencies to conscious response: directions and determinations that have their origin apart from the attributive nature of the tones fused or related.

The revision of the attributes of sound that I am about to suggest is based upon this functional point of view. Since I leave much to *cognition* as a function, I do not find it necessary to incorporate among the attributes all that Watt deems requisite. Nor do I find it theoretically important that a uniform set of attributes should be equally applicable to all the sense modalities. Yet mental functions can operate in the first instance only upon what the sensations offer. If mental acts are capable of creating mental contents, as I believe them to be, such contents are of a different order, namely, the thought contents. While thought is qualitatively distinct from sensation, as a complex of attributes within a certain modality, still it is from comparisons instituted among the attributes that these derived contents of thought or meaning come into existence. Hence their creation does not occur in a world apart from that of sensory experience. They are founded in it and upon it.

The attributes of sound as I find them are not primarily determined with a view to system, but are describable facts of consciousness. In this instance my findings have been largely gained from participation as an observer in the experiments performed last year in the Cornell Psychological Laboratory by Dr. Rich. But I hasten to add that the interpretation I place upon my own experiences, as well as upon

the general results of the experiment which Dr. Rich kindly placed at my disposal, is my own, and in no way implies concurrence on the part of Dr. Rich.

In listening to a pure tone I was impressed by the pitch predominance of which Watt speaks, and also by the surrounding aura of volume. I also felt that I could detect differences in *emergence* of the pitch salient from its surrounding volume. This latter effect I designate as *brightness*. These seem to me to constitute three attributes of sound: pitch, volume and brightness. In addition, intensity is clearly attributive, as is also durance. Of these, brightness finds no place in Watt's list, and I must admit that I have no evidence of a correlative uniformity in vibrational frequency, as I have in the case of pitch and volume. How brightness is dependent on frequency and amplitude I do not know. In the main, brightness increases with rise of pitch and decrease of volume, it therefore seems to depend on these two attributes; but intensity may also be involved. Pending further investigation, I am content to accept it provisionally among the attributes because of its descriptive differentiation from the rest. As for Watt's two temporal attributes, one suffices me, because I regard temporal order as a functional effect, partly meaningful, in which kinesthesis probably plays an important rôle.

The attributes of sound here advocated are, then, pitch, volume, intensity, duration, and, tentatively, brightness. A graphic representation will perhaps aid in distinguishing these. (See Fig. 2.) In this minaret-shaped solid the pitch is indicated by the salient peak, while the volumic spread is suggested by the solid form as a whole. The rise of the total mass from its circular base represents intensity. Brightness is the emergence of the salient from the volumic mass. Another figure (see Fig. 3) gives two forms representing like pitch, volume and intensity, but varying brightness. In the first form the salient emerges more clearly than it does in the second. Duration, finally, is mere persistence of the sound in time; dependent upon fluctuations of the stimulus, the physiological response and the attention, providing the basis for rhythms, periods and the like.

Watt also includes quality as an attribute, though he admits but one invariable quality of sound. If a sensation is the sum of its attributes, then quality must be one of them, even at the expense of independent variability. But I prefer to regard the substantial essence of sensation as a fundamental class or modality, rather than as an attribute. I agree with Watt that there are three kinds of sound: tone, noise and vowel, but while he regards these as results of integration, I would refer them to functional interrelationships. Although the attributive nature of the sound determines to a large extent whether it shall be regarded as a tone, noise or vowel, intrinsically it is lacking in any such definition. The act of relationship introduces order. By comparison I determine one pitch to be higher than another, one volume to be greater than another, one tone brighter than another, more intense, or of longer duration. I prefer, then, to speak of three *characteristics* of sound: tonality, vocality and noisiness, rather than of three integrations, or of three attributive qualities.

Tonality is a characteristic of those sounds that can be fused or musically related. It rests primarily upon pitch and volume. As pitch varies from high to low it affords a means of comparison with respect to serial order. But it is not pitch alone that gives rise to musical order. Very high sounds, even when produced by regular periodic vibrations, are notably lacking in tonality. Although differences in height are still evident, volume differences are so vague, owing to their smallness, that they cannot be readily compared. In the lowest range of sound we meet with a similar difficulty, but the reason is not the same. Here volume dominates, and pitch does not emerge sufficiently to define the tone. As all high sounds are too bright, so all low sounds are too dull to lend them the characteristic of tonality. The mind can act in certain ways upon sounds whose pitch and volume are defined. This activity of the mind is musical, and it depends upon the definition of tones. Hence tonality is a characteristic of sounds only when they imply a musical setting. This activity rests chiefly, I believe, on two principles of

correlation. The first is the principle of harmonic interval, and the second that of equal interval, or proportional division.

By *interval* I mean the distinction of two tones whose pitch and volume are both clearly differentiated. This is tonal definition. It is introspectively evident that pitch difference alone does not constitute an interval. Pitch distinction is possible with less than one vibration difference in the stimuli of two tones. As is well known, the liminal increment tends to follow an arithmetical series. One may distinguish with equal ease tones of 250 and 251 vibrations, and tones of 500 and 501 vibrations. Rich has shown[1] that this is not the case with volume. Volume distinctions are not so fine, and they follow a geometrical progression of vibrational frequencies. Thus while the octave of 250 to 500 vibrations would contain more than 250 discriminable differences of pitch, it would contain, from Rich's estimates, but 25 to 50 discriminable volumes. Furthermore, with slight variations of pitch we note no change of tonality. Only when a clear volumic difference is evident does an interval seem to occur.

As regards the origin of the principles upon which tonality may be said to rest, that of harmonic interval obviously suggests the series of partial tones. The common musical setting of the octave is in part due, I think, to the dominance of this interval among the audible partials. The fundamental dominates its overtones. The first interval in the series, as well as the one most frequent among the partials, is the octave. Hence the octave as a special function of relationship may be said to obtain prominence because of the frequency with which the ear must act upon this relation of tones. It may be objected that there are tones in which the even-numbered partials are not conspicuous, but these are rather unusual. A more serious objection is made by Stumpf, who does not admit that frequent association can produce so fundamental an effect. Answering this we have the results of Moore[2] and Valentine[3] to show that adaptation does facili-

[1] Cf. J. of Exper. Psychol., 1916, 1, pp. 13ff.

[2] Psychol. Monog., 1914, 17, no. 73.

[3] *Brit. J. of Psychol.*, 1913, 6, pp. 190ff.

tate functioning. It appears that one can readily learn to change the effect of a not too dissonant into a consonant interval. Still one must rely on something more fundamental than musical practice to explain fusion. I have therefore previously suggested that racial adaptation is also probable.[1] Assuming a certain ease of functioning in the case of the harmonic intervals, it is possible to understand the readiness with which one might be able to detect the differences of timbre that characterize the more significant noises, voices, and clangs of nature. Hence, the most frequent intervals of the partial series may have a certain survival value, because facility in their functioning would thus open a way for recognition of constituents that are not readily fused. V. Hornbostel[2] has sharply criticized my views on the ground that among primitive peoples noises and inharmonic intervals are much more prevalent than tones. But I do not see that this need prevent a gradual evolution in refinement of adjustment and judgment. The facility of harmonic intervals might be of use in perception long before it became a basis for music. Furthermore, we have not one sole principle of tonal order, but two to reckon with. In addition to harmony, there remains the capacity for proportional divisioning of which primitives, especially, make great use.

Granted the octave, however it be founded, the question of smaller intervals is solved in two ways. One is by the harmonic principle in accordance with which other conspicuous intervals of the partial series are the important bases of division: thus, the fifth and the fourth, particularly, lead to the diatonic scale of whole and half tone intervals. The other is the principle of proportional division whereby the octave is divided into a certain number of *equal* intervals, irrespective of harmonics. Hence we find such scales as those of Siam and Java, the first with seven, the second with five equal intervals. Stumpf's investigations[3] leave us with no doubt as to the natural origin of these scales. Even

[1] PSYCHOL. BULL., 1909, 6, pp. 297ff.
[2] *Zsch. f. Psychol.*, 1912, 61, p. 70f.
[3] *Bericht v. d. IV. Kongress f. exper. Psychol.* Leipzig: Barth, 1911, pp. 256ff.

though the divisioning may have been originally influenced by the dominance of the fourth and fifth, as Watt thinks probable,[1] this would only explain the number of steps to be provided in the octave, for these scales have evidently been worked out with a careful regard for equally tempered intervals throughout.

Thus we see that certain Oriental music is more intent upon equal than it is upon harmonic intervals. And this is quite possible, because equal proportions and their multiples are as readily distinguishable as are harmonic intervals. So long as music remains essentially a melodic sequence without musical accompaniment, the harmonic intervals, which alone permit fusion, are not requisite. The melodies of equally tempered scales are atonic, but although they lose the tonic dominance of harmonic organization, they gain freedom in transposibility. It is difficult for us with our very different traditions and usages to appreciate such music, yet I think it quite certain that those who are familiar only with naturally tempered scales find real and logical delight in the employment of intervals that are based upon simple multiples of a common unit.

It seems evident that this principle of proportionality has its origin in the proportional decrease of volumes. Yet it would be incorrect to regard pitch as negligible, for pitch secures to the tone its characteristic salient, and thus contributes expressly to its definition. Volume alone defines the interval in an atonic, no more than it does in a diatonic sequence. While volume difference makes intervals possible, it remains for the mind to choose appropriate functions in determining a specific tonality or musical setting. The main choice is between dominance by the 'harmonic chord of nature,' the partial tone series, or by a simple division of the octave into any small number of equal parts. In either

[1] *Cf.* l. c., pp. 135ff. The interval of three whole tones in the Siamese scale is $514\frac{2}{7}$ 'cents,' as compared with 498 'cents' for the true interval of the fourth. Four whole tones in this scale give $685\frac{5}{7}$ 'cents,' as compared with 702 'cents' for the true fifth. The discrepancy in each case is $16\frac{2}{7}$ 'cents.' Comparisons between similar intervals of the Javanese scale show discrepancies in each case of 18 'cents.' The greatest discrepancy between notes of the tempered diatonic scale and those of the scale in just intonation occurs with the sixth, where it is 16 'cents.'

case the octave furnishes the framework, the basic attitude or disposition, upon which these functions must operate. Wherever there is tonality, there is read into the tone an octave setting.

While I have advocated the theory that the octave owes its origin in part to the harmonic series, I am not sure that this is its sole foundation. Although I have criticized Watt's theory of 'balance' as an explanation of all music, I think it not unlikely that the proportional decrease in volume by halves with octave frequencies may be of fundamental importance in lending to this particular interval its outstanding position. Goebel,[1] too, has advanced a theory that bears upon this matter. It is to the effect that in sounding any tone with sufficient intensity, another that is an octave below it is also involved. He believes that portions of the same resonator in the ear act together in producing the two sounds. Hence octaves are subjectively inherent in tones. However this may be, the fact is at least evident that octaves are the most fundamental of intervals, and all effects of tonality relate to them.

While tonality results from the fusion and musical relatedness of intervals, vocality is that characteristic of sounds which defines vowels. As the investigations of Jaensch have shown,[2] vowels are sounds of *regional*, but not of salient pitch. A number of vibrational frequencies varying but slightly from one another unite to occasion the sound we call a vowel. The researches of Köhler,[3] Miller,[4] and others have shown that the chief vowel sounds (continental usage) fall in the order *u*, *o*, *a*, *e*, *i*, each being characterized by a regional pitch beginning around 264 v.d. for *u*, and proceeding upwards by octave steps for each of the others. The significance of these special regions for the outstanding vowel sounds leads Stumpf[5] to suggest the possibility of specially marked *C*-

[1] *Zsch. f. Sinnesphysiol.*, 1911, 45, pp. 109ff.

[2] *Zsch. f. Sinnesphysiol.*, 1913, 47, pp. 219ff.

[3] *Zsch. f. Psychol.*, 1910, 58, pp. 59ff.

[4] D. C. Miller, 'The Science of Musical Sounds.' New York: Macmillan, 1916, pp. 215ff.

[5] *Bericht v. d. VI. Kongress f. exper. Psychol.* Leipzig: Barth, 1914, p. 322f.

Fig I

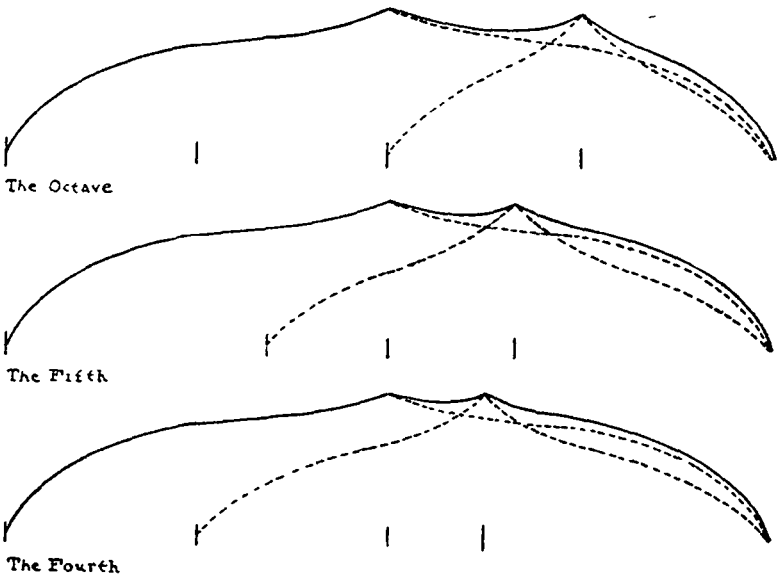

Fig. II

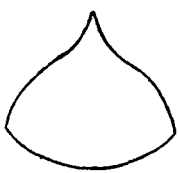

Fig III

Fig IV

Fig. V

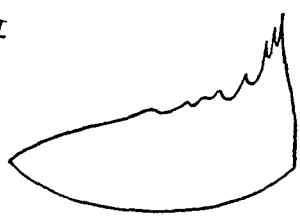

FIG. 1. Watt's Conception of Fusion.
FIG. 2. Graphic Representation of a Tone.
FIG. 3. Graphic Comparison of two Tones differing in Brightness.
FIG. 4. Graphic Representation of a Vowel.
FIG. 5. Graphic Representation of a Noise.

qualities in the tonal series. Watt,[1] however, remarks that if we but assume some special facility in the articulation of a single regional pitch of this series, the rest would be likely to follow in this order because of the dominating influence of the octave law.

The graphic form of the vowel is indicated in Fig. 4. Pitch is not altogether lacking, but it has no salient of brightness. The sound of the vowel is smooth, for pitch is submerged in the volume. Comparatively, pitch is still distinguishable as an average or regional effect, and, optimally, is that pitch which would be central to this volume if it had a marked salient. The true vowel is not necessarily the only element in a vowel utterance, for Miller has shown[2] that with the higher vowels, *e* and *i*, a pitch predominance of a lo ver order may be present in even greater intensity than is the region of resonance characteristic of the vowel. Yet when the upper region is eliminated, the sound changes to that vowel characterized by the lower region of resonance.

Noisiness, finally, is the characteristic of sounds in which neither a definite salient nor a regional pitch is in evidence. Noises are irregular sound phenomena, and the occasions of such irregularities are numerous. If one increases unduly the range of adjacent frequencies employed to produce a vowel, the sound will gradually take on the character of a noise. If one does not increase the range enough, the sound remains a tone. The ability to bring together adjacent pitches into a definite regional or vowel effect is therefore limited to a certain range of adjacent frequencies. But noise may also occur through the combination of several tones of outstanding pitch. This happens when the combined tones cannot be ordered in accordance with the harmonic principle, *i. e.*, when the constituents do not fuse. Eight notes in the sequence of the major chord fuse into a tonal effect, but eight adjacent notes of an octave, when simultaneously struck, are noisy. In addition we have the noisy effect of incomplete vibrations whose periodicity is confused. Sudden changes

[1] *Brit. J. of Psychol.*, 1914, 7, p. 12f.

[2] *L. c.*, p. 223f.

in intensity, brightness, duration and volume also contribute to such confusion. Indeed, any irregularity that the mind is incapable of mastering by its usual functions of harmonic fusion is an occasion for noise. This includes the noisiness of very high and very low sounds, even though their vibrational frequencies are quite regular. A graphic representation of this condition is offered for comparison with those already given, though it suggests but one among numerous types of noise. (See Fig. 5.)

Although indefiniteness of either pitch or volume is the occasion of noise, Köhler has pointed out[1] that sounds of the high and low regions are not lacking in individuality. For it is here that we find certain of the consonants: *m* sounds are characteristic of the low, and *f*, *s* and *ch* sounds of the high regions. It is also probable that definite blendings of the attributes are responsible for all the other consonants, as well as for a wide range of characteristic and easily recognizable noises.

My conclusion is, then, that within the modality of sound there are to be found the following attributes: pitch, volume, intensity, duration, and probably brightness. With the aid of appropriate mental acts, or functions, the presence of these variables in a sound leads to certain orderly arrangements and usages, resulting in the characterization of sounds as tones, vowels, and noises. While the attributes are revealed from the standpoint of a detached description of structural content, tonality, vocality and noisiness are meaningful implications of reciprocal interactions between mental functions and conscious structures. Lack of functional capacity explains *amusia*, and also some forms of speech deafness. Music, oral speech, and significant noise are all results of comparison and judgment, in which the structural elements of sensory content furnish the basic data.

When the sound possesses a dominant pitch and a definite volume it may be fused and related with other sounds of like nature. It thus acquires the character of tonality. When it possesses regional pitch and regular volumic proportions,

[1] *Zsch. f. Psychol.*, 1913, 64, pp. 92ff.

but no salient, it becomes a vowel. Because the larynx and mouth cavity are capable of producing such regular and characteristic sounds, they have been seized upon as important elements in vocal language. When, finally, the sound is irregular as to pitch and volume, it is described as a noise. But although noises cannot be treated in the octave setting, they are often capable of reduction to characteristic units, recognizable by their individuality as significant vocalizations —the consonants—and likewise as familiar objects of nature.