THE TELEPHONE THEORY.*

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In the time at my disposal to-night it is impossible to discuss fully the telephone theory. I will, therefore, limit myself to a brief review of the main reasons why the supporters of this hypothesis prefer it to the more generally accepted piano or resonance theory.

In the present state of our knowledge with regard to tone perception one is justified in supporting that hypothesis which best explains the known facts in regard to tone perception; which is least in disagreement with the recognized facts of anatomy, physiology and physics; and which at the same time gives the best basis for progressive investigation. This is what is claimed for the telephone theory.

Under the name telephone theory are grouped various shades of hypotheses in regard to tone perception, all of which unite in rejecting the Helmholtz piano or resonance theory as unsatisfactory and all of which agree in these two essentials:

(1) That the membrana basilaris or the membrana tectoria vibrates as a whole.

(2) That while a certain amount of analysis is peripheral, the ultimate analysis is in the cerebrum.

The telephone theory has the support of many of the best physiologists, for instance, Ewald, who has done more than any other physiologist to elucidate the physiology of the ear; of Waller, one of the most distinguished English physiologists. It has the support of some of the best neurologists, for instance, Mott, one of the greatest living neuro-pathologists, and Hardesty, one of the best neurologists in this country. This theory received its first great support, if not its birth, from the work of my old professor of physiology, Rutherford. Since that time it has lost many of its non-essentials and still to-day influences the investigations of some of our best physiologists.

It is agreed that the auditory impulses are conveyed in the acoustic nerve by means of the hair cells of the organ of Corti, probably through the agency of the hairs. That these hairs are not themselves capable of producing suitable vibrations would appear from the fact that their length and arrangement seems to be such as to

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preclude their acting as suitable vibrating structures. Such being the case, we have to seek for some mechanism which will produce suitable vibration of the nerve endings, which are so closely attached to these hair cells, and so offer a reasonable explanation of tone perception.

In order to get a clear idea of what the telephone theory implies it seems best to give the conception of it presented by two of its most prominent exponents. Ewald[1] states it thus: a tone sets the whole basilar membrane into vibration and is analyzed into a series of waves. The totality of these waves (the sound-picture, Schallbild) produces in the brain the tone perception. Each tone corresponds to a characteristic sound-picture. Waller's[2] interpretation of it is very similar: "The basilar membrane vibrates in its entire area to all sounds, though more in some parts than in others, giving what we may designate as acoustic pressure patterns between the membrana tectoria and the subjacent field of hair-cells. So the varying combinations of sound give varying pressure-patterns comparable to the varying retinal images of external objects." Hardesty's[3] conception corresponds to these, applied, however, not to the basilar membrane, but to the tectorial membrane.

The main reasons I would present to you for rejecting the resonance theory as applied to the basilar membrane may be briefly put as follows:—

(1) It is doubtful if this membrane is composed at all of independent fibers. It appears to partake more of the nature of a felt-work of interwoven fibers comparable to what appears in a thin flat tendon.

(2) The radial fibers which do appear are so weighted that they cannot act as resonators.

(3) The resonance theory demands that the cells of the organ of Corti must be capable of moving separately, but it would appear that these cells are intertwined and interwedged so firmly as to be impossible of so acting. (Hardesty[7]).

(4) Physiologically no resonance theory is capable of explaining the phenomenon of tone-perception without suppositions in general physics which have not appealed to some of our best physiologists and physicists. The difficulty in regard to beats has been explained away by assuming that each tone stimulates not one but several neighboring radial fibers—assuming these fibers to be capable of acting as resonators; but no adequate explanation has been offered for what are known as combination tones. The supposition that these

combination tones are due to some formation in the tympanic membrane or the incus-malleus joint is not regarded by many physiologists as satisfactory.

The upbuilding of a theory of resonance with the basilar membrane as the resonating structure has proved so unsatisfactory that the attempt has been made to replace it by the tectorial membrane. To me the objections to the tectorial membrane are even more serious than those which can be applied to the basilar membrane. Passing over the physiological arguments that can be raised against any resonance theory, we have the following fatal objections:

(1) It is obvious that in order to discuss the physiology of a body we must know its anatomical structure. So far anatomists have not been able to offer such information in regard to the tectorial membrane, but differ widely in regard to its formation and its attachments. It is a structure of such supreme delicacy that it offers great barriers to ordinary methods of study; methods of fixation at present at our disposal appear worse than useless.

(2) Physicists declare that even granting those disputed characters which the supporters of this phase of the resonator theory claim to be present in the tectorial membrane, this membrane does not appear capable of acting as a resonator and is not comparable to any resonator known to physics.

It will be noted that these objections to the tectorial membrane are to a certain extent based on a want of definite anatomical knowledge in regard to its structure. Such knowledge is gradually increasing, and to this end the work of Shambaugh has been that of a pioneer. Further investigation may therefore be looked for to confirm or refute these objections; but at present we must note their existence.

The objections which have been made to the basilar membrane as a resonating structure do not apply to the basilar membrane as a vibrating structure. Take each of the above anatomical objections, which I believe to carry the most weight against the resonance theory, not one can be successfully urged against the basilar membrane as a vibrating structure. In short, it is acknowledged to be a structure capable of vibrating.

The principal argument that has been urged against the telephone theory is that it leaves the exceedingly elaborate structure of the organ of Corti out of account (McKendrick[4]). It has always seemed to me that this objection loses much of its force when one considers that the hypotheses of Ewald and of Waller demand such a peripheral mechanism in order to translate the complex sound

waves into corresponding nerve impulses. The physical properties of sound are so totally different from what the physico-chemical properties of nerve impulses appear to be that in order to get the complexities of the sound waves adequately interpreted by the corresponding nerve impulses an intermediary mechanism of considerable complexity must be employed. If the relatively simple sensations of pressure or taste require an elaborate peripheral mechanism to translate the physical or chemical stimulus into a corresponding nerve impulse, how much more elaborate must be the mechanism which translates the complex wave motions of an orchestra into corresponding nerve impulses. Accordingly, the statement that the telephone theory offers no explanation of the organ of Corti seems based on an inadequate conception of the full significance of the hypothesis. At this point one must clearly recognize that the assigning of a degree of peripheral analysis to a vibrating structure is a totally different thing from assuming that the vibrating structure is acting in a manner comparable to a resonator.

In regard to the ultimate analysis of sound, the evidence seems to me to point to its being central. It is a matter of everyday experience that tone perception varies greatly in individuals and is largely a matter of education and imitation. This does not appear to be easily explained, if we assume a constant peripheral non-nervous mechanism for the elaborate differentiation of sound which the resonance theory presupposes. Involved in this question is the difficult and as yet undecided physiological problem of the specificity of nerves—that is, that a nerve fiber only transmits impulses producing one kind of effect. This is a question of vital importance to both the resonance theory and the telephone theory. It appears to me that the modern trend of physiology is towards the belief that the nerve fiber is capable of transmitting not one, but several varieties of nerve impulses. Thus in taste, for example, it would be assumed that there is not one nerve for sweet and another for bitter, but that according to the kind of peripheral irritation at the taste bud, so is the central interpretation which is produced through the medium of the nerve. (Nagel[5]). To go one step further, sugar produces sensations of sweetness, salt of saltness, but a mixture of sugar and salt produces a sensation totally different from either sweetness or salt. (Nagel[6]). Similar interpretations are also applied to the other senses.

I do not claim that with our present knowledge the telephone hypothesis explains everything physiological and pathological, but I do claim that it offers a sounder basis from which to attack the

complex difficulties of the physiology and the pathology of the auditory nerve than does the resonance theory.

1. EWALD: Nagel's Handbuch der Physiologie des Menschen. Braunschweig, 1905. Bd. 3, p. 571.
2. WALLER: Halliburton's Handbook of Physiology. Philadelphia, 1904. p. 749
3. HARDESTY: *The American Journal of Anatomy*, 1908-9. Vol. VIII. p. 109.
4. MCKENDRICK: Schaeffer's Textbook of Physiology. Edinburgh, 1900. Vol. 2, p. 1192.
5. NAGEL: Handbuch der Physiologie des Menschen. Braunschweig, 1905. Bd. 3, p. 641.
6. NAGEL: loc. cit., p. 643.
7. HARDESTY: loc. cit. p. 156-7.

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Cholelithiasis and Pancreatitis. C. N. SMITH. *Journal A. M. A.*, June 5th, 1906.

The writer states that the prevalence of cholelithiasis and of infections of the biliary tract as the essential feature in the production of pancreatitis demands thoughtful consideration. He enumerates the early symptoms: Pain, shortness of breath, liver tenderness, chills simulating malaria, etc. There is frequently a history of previous typhoid fever. The one great stumbling block in the way of an early diagnosis of gallstone disease, he says, is the allurement of jaundice, which seems to have bewitched the judgment of so many medical men, in that they demand its evidence before admitting the presence of gallstones. Jaundice, however, is an infrequent and inconstant event in gallstone disease, and when present is as a terminal rather than as an inaugural one. Too frequently, indeed, does jaundice announce the advanced stage of a secondary chronic pancreatitis. It is high time that the medical profession should break away from the fetish of jaundice; that it should recognize the presence of gallstones by their inaugural symptoms; that it should appreciate the gravity of gallstone complications and sequels and that it should forestall such complications and sequels by the institution of operative procedures immediately following the establishment of a diagnosis.