II.

AN ANALYTIC STUDY OF THE RINNE AND OTHER TUNING FORK TESTS.*

FIRST COMMUNICATION CONCERNING PERCEPTION DEAFNESS.

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I.

In a paper published in 1855, Rinné¹ claimed that a vibrating tuning fork is stronger and longer heard by bone conduction than by air conduction in diseases of the middle ear, and vice versa in diseases of the perception apparatus. The test did not come into general use until 1887, when Lucae² called attention to its great importance and elaborated many rules to govern its application, as likewise did Bezold.³ An interesting résumé of the earlier controversies concerning the test was given by Turnbull and Reed⁴ in 1888. From then to date contributions to the literature of the subject have been numerous.

It would be hardly possible to doubt the diagnostic value of the Rinné experiment in testing hearing, and yet there is no statement so misleading as the average textbook instructions concerning the method of comparing bone and air conduction. Nine out of ten authors describe the test as being made by holding the tuning fork over the mastoid until the patient says it is no longer heard, when it is then quickly transferred to the front of the auricle, and if the patient says that it is again heard, the test is positive, and the lesion, if one exists, is probably in the sound perceiving apparatus; if the tuning fork is not heard by air conduction, the Rinné is negative, and

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the deafness is conductive in character. The method of making the test may also be reversed.

By the Rinné experiment we should attempt to determine:

- (1) Whether or not air conduction is normal.
- (2) Whether or not bone conduction is normal.
- (3) In which course of sound conveyance lies the defect, or the greater defect, in hearing.

Under the first proposition we test all those structures which have to do with the conveyance of sonorous vibrations until they are perceived as sound. Under the second proposition we test those intralabyrinthine structures which have to do with the conversion of the mechanical vibrations into a nerve stimulus and the conveyance of this stimulus to the higher centers. The Rinné test should be made, therefore, as recommended by the Eighth International Otological Congress (Budapest, 1909), by a separate test of air and bone conduction, and the result recorded accordingly.

II.

In the first analysis we must consider sound with all its phenomena in terms of physical vibrations which would exist as a part of kinematics or mechanics, even if we did not have the sense of hearing. The ears convey and properly transpose, but they do not create, the vibrations which the brain recognizes as sound; therefore, to a large extent, hearing is governed by physical and anatomic properties rather than by physiologic or psychologic hypotheses. The vibrations set up in the air by any sonorous impulse—for example, a tuning fork—are taken up by the drum membrane as vibrations, and are conducted by the ossicular chain to be transmitted by the footplate of the stapes to the perilymph of the scala vestibuli; these vibrations continue around the helicotrema into the scala tympani to impinge, if there be sufficient force, against the membrane closing the foramen rotunda. During the course of the vibrations through the perilymph of the scala vestibuli they are transferred to the endolymph of the ductus cochlearis, probably by the law of physical resonance stimulating into vibration certain analytic areas in the membrana tectoria. As the result of the interaction between the membrana tectoria and the hair cells of the organ of Corti the vibrations are con-

verted into a nerve stimulus, and this is transmitted by the cochlea branch of the eighth nerve to the cerebral centers in the temporosphenoidal lobes of the brain, and recognized, in the case of our example, as the sound of a tuning fork.*

From the foregoing it must be obvious that up to the point where the vibrations are converted into a nerve stimulus, hearing must be governed by the same laws governing physical vibrations. Elementary physics teaches that the pitch of a sound is due to the number of vibrations to the second set up by the initial shock, and that it is constant as long as the sound can be perceived; the intensity, or loudness, however, depends on the amplitude of the vibrations, and decreases from second to second until the oscillations are too small to be taken up and conveyed by the conduction apparatus, and then our perception of sound ceases. The conduction apparatus of the normal ear can convey sonorous shocks as slow as sixteen double vibrations to the second, and as rapid as thirty thousand or more, if the intensity is sufficient. All vibrations within this range are capable of setting up resonance in the tectorial membrane, to be taken up by the interacting hair cells of the organ of Corti and converted into a nerve stimulus and recognized as sound. Hence, hearing may be said to be measurable by the ability of the conductive apparatus to transmit and the nervous apparatus to perceive vibrations of any rapidity within the normal range under what is estimated to be a minimum intensity as compared to the normal minimum intensity. Therefore, it is not sufficient to determine that a tuning fork is "heard," for such a determination may only mask a degree of deafness which may be of diagnostic importance; likewise, the fact that a tuning fork is "not heard" may only mean that we are below that intensity necessary to set a defective conduction apparatus into vibration, or to stimulate a diseased nerve ending, or even to create a

*Without entering into the mechanical action of the ossicles, this is the simplest physiologic explanation of the conveyance, the reception and the perception of sound vibration. It is the Helmholtz theory augmented by the investigations of Shambaugh,⁵ who has anatomically demonstrated the impossibility of the basilar membrane being the vibrating structure, whereas the tectorial membrane apparently can and does fulfill this rôle. This theory is much more logical than the speculative "telephone theory" of Rutherford, and it will be dogmatically accepted throughout this paper.

nerve impulse powerful enough to "get through" a true "nerve block."

III.

With a tuning fork we have a means of obtaining a musical tone of constant pitch with a prolonged intensity which decreases in definite retrogression until its vibrations can no longer be conveyed or perceived as sound. It is necessary that we make the attempt to determine the intensity under which a fork is heard, and, with all its faulty factors, our best index of this is the difference between the faulty duration of perception and the normal duration of perception; for it is the only practical way that we have of determining the vibrations of the smallest amplitude capable of setting up similar vibrations which can be conveyed and perceived as sound. Unfortunately, the decrement of the vibrations of a tuning fork is not uniform from second to second, but is much more rapid at the beginning than near the end, for the reason that the amplitude decreases by geometric progression; that is to say, the decrement in intensity from one step to the next takes place by a division of the initial and the succeeding amplitudes by a constant quantity. This constant quantity varies with each and every tuning fork, and otology is greatly indebted to Dundas Grant⁶ for the methods and formulæ necessary to determine it. Though the problems involved almost prohibit the scientific estimation in everyday work of the actual percentage value of the hearing of the tuning forks, the law of decrement is unalterable, and the practical significance is as follows:

In all tests with all tuning forks the duration of the perception, both abnormal and normal, must be determined and noted, and the difference in time between defective and normal perception of the duration of the vibrations, and not the duration of perception itself, taken as the factor of importance and the one which must serve as the index of defective audition. (See Figures 1 and 2.)

The normal duration of perception will vary greatly, as it is practically impossible to obtain a standard initial intensity with the various forks, or even with the same fork at different times, though many methods have been tried, notably by Gradenigo,⁷ whose investigations should be carefully studied,

but the abnormal hearing will also vary in approximately the same proportion.*

IV.

Hearing by air conduction is physiologic, the mechanical perfection of the ossicular chain making it possible for us to interpret vibrations of very low intensity. Up to the point where the vibrations are transferred by resonance to the tectorial membrane, hearing is purely a question of sound wave conduction; beyond this point hearing becomes truly perceptive in character. In diagnosis it is important that we be able to locate the situation of a lesion causing deafness, and this becomes possible because a vibrating tuning fork placed upon any portion of the cranium can be perceived without the waves being conducted through the ossicular portion of the conduction apparatus.†

The normal duration of perception for a tuning fork by bone conduction is much less than the normal duration of perception by air conduction.‡ It seems to be generally assumed that this is so for the reason that sound vibrations are not transmitted as well through a solid as through the air. Without qualification, this is a makeshift and unscientific explanation, for sound vibrations are imparted to and conducted for some distance through solids without appreciable loss in the intensity. How then may an inch of porous bone, form-

*In *The Laryngoscope* for September, 1914, I published the description of "An Apparatus Designed to Give an Approximately Accurate Quantitative Hearing Test." The instrument was constructed with the purpose of obtaining a tuning fork stimulation of uniform value, and hence a sound of constant intensity. The apparatus is more or less of a failure in this respect, but after hundreds of trials I have found that the proportion between abnormal and normal hearing is strikingly preserved, though the duration of perception may vary considerable.

†Bezold and Henson claimed that the oscillations were first taken up by the tympanic membrane and ossicles, and that bone conduction was due to what was termed cranio-ossicular transmission. That this theory is erroneous is proved by the fact that bone conduction is increased, if altered at all, after the mastoidotympanal exenteration.

‡Eitelberg⁸ showed that the normal duration of perception for the C² (512 d. v. s.) tuning fork on the various parts of the cranium was as follows: Mastoid, 30 seconds; forehead, 18 seconds; occiput, 20 seconds; teeth, 15 seconds. The normal duration of the same fork by air conduction being 58 seconds.

ing almost a tubular conductor, reduce the normal hearing by bone conduction to a minimum percentage value of the same sound conducted through the medium of the drum head and the ossicles?

A tuning fork placed on any part of the cranium imparts its vibrations to the bone, and these vibrations are distributed to all parts of the head. Why then may we not consider hearing by bone conduction as simply the result of "sympathetic vibration," especially since Shambaugh's investigations have anatomically enhanced the Helmholtz theory of hearing? We know that we can create vibrations in a stable tuning fork by bringing a vibrating one of its own pitch in proximity or by touching a stand on which the quiet fork rests with vibrating fork. These induced vibrations will be of less intensity than those of the exciting force and, consequently, shortened in duration or perception, for there is a leakage of energy through friction or wave emission, so that the forced vibrations only increase up to the point at which leakage of energy balances the energy put in by the applied force; therefore, in resonance there is always a loss of energy, and the amplitude only increases until the loss is balanced by the gain from the work done by the applied force. If there were no dissipation of energy, the vibrations would increase indefinitely when the periods coincided. Why then may we not postulate the following explanation of bone conduction?

With a vibrating tuning fork held on the mastoid, or on any part of the cranium, we hear its vibrations through the creation of "sympathetic vibration" in that area of the tectorial membrane tuned to respond to the pitch of the fork used. The sound is reduced in intensity, and, therefore, in duration of perception because the tectorial membrane can only vibrate up to a point where the leakage of energy balances the energy put in by the fork on the mastoid.

SUMMARY.

The whole matter may be summarized as follows:

1. By both air and bone conduction it is necessary that we have some index which will indicate the intensity under which a tuning fork is heard, and the simplest way to obtain a factor of this description is by comparing the abnormal duration of

perception with the normal duration of perception and taking the difference between the two as the significant indicator.

2. As the energy necessary to make a tuning fork heard by bone conduction is markedly greater than the energy necessary by air conduction, the normal duration of perception of each is different; therefore, we may not directly compare the one with the other, but we must make separate tests of each course of sound conveyance.

V.

The tuning fork tests being wholly and purely subjective, we have been led to doubt, not only the results of others, but our own findings as well, and for this reason so many qualifications and exceptions have crept into acceptance that each individual seems to have a system of his own, and the original tests are almost worse than useless. If we can bring ourselves to postulate dogmatically one rule, and working from that prove or disprove the whole, our results will assume a different aspect. Accepting resonance as the chief factor governing bone conduction, I consider that a shortening of ten seconds or more by bone conduction is abnormal, especially if it is unilateral, the other ear being normal, and if contraaudition has been prevented by the use of the "noise apparatus."

The older investigators were hampered and confused by the impossibility of excluding one ear while the other was being tested, as the occurrence of contraaudition, the bone conduction from the mastoid of one ear to the opposite ear, prevented a true determination of the duration of perception by bone conduction, and this was the reason so many restrictions were placed on the use of the Rinné test by such scientists as Hartman, Bezold, Lucae and others, and the discrediting of the Schwabach test. The introduction by Bárány of the noise apparatus has made it possible to diagnose total unilateral deafness, and, what is more important, to determine the duration of perception of the sound of a tuning fork by bone conduction in each ear separately. The use of the noise apparatus and the possibilities of original work along this line has not, to my mind, been sufficiently investigated. We are inclined to think that the instrument is only of value to exclude one ear in testing for total deafness. As a matter of fact it

should be used whenever bone conduction is tested, and there is no reason why we may not be able to test restricted areas of the tectorial membrane by the use of a scientifically constructed suppression apparatus.*

VI.

In the use of the tuning forks of different pitch it must be remembered that the amplitude of the forks of low pitch is wide, the time rate of decrement slow, and the intensity weak; therefore, a slightly defective conduction apparatus will fail to convey these vibrations when the normal ear will still transmit and perceive them for a long time afterwards. With the forks of high pitch the amplitude of the vibrations is short, the time rate of decrement very rapid, and the intensity very strong; hence, the difference between defective perception and the normal perception of the duration of the vibrations may be so short that it is immeasurable. (Figure 3.)

By the use of three tuning forks, the C (128 d. v. s.), the C² (512 d. v. s.), and the C⁵ (4096 d. v. s.), the useful range of hearing may be covered, and my routine examination is made in the following order and manner:

- (1) The Weber test.
- (2) The Schwabach test, the duration of the perception by bone conduction for the C² fork as compared to the normal. The noise apparatus tuned to cut out this fork is used to exclude the ear not being tested.
- (3) The duration of perception for the C² fork by air conduction as compared to the normal. (The method to be described later.)
- (4) The duration of perception for the C fork by air conduction as compared to the normal. (The method to be described later.)

*Francis R. White exhibited before the Ninth International Otolological Congress, Boston, 1912, a noise apparatus which is simple and inexpensive, and yet is the most useful and adaptable of all these instruments whose requirements he summed up as follows:

- "(1) The sound must effectually exclude all other sounds.
- "(2) The sound must not be transmitted to the other ear.
- "(3) The sound apparatus must be regulated for varied hearing.
- "(4) The use of the apparatus must not be disagreeable to the person being examined."

The White and the Neumann instrument fulfill all these requirements. The Bárány instrument cannot be regulated, and is disagreeably loud.

(5) The duration of perception for the C⁵ fork by air conduction as compared to the normal. The noise apparatus tuned to great intensity is used to exclude the ear not being tested.

All these trials are timed with a stop watch, and the result of each is written in the form of a fraction the numerator of which denotes the patient's hearing and the denominator my own hearing. If there is a difference in our hearing in any test it is noted minus or plus, and this is the important factor that indicates the defect in the patient's hearing.

The Weber test, when properly explained to the patient, is usually accurate; it may be verified with the noise apparatus, but when the fork is not heard from the forehead or the teeth it is indicative of perception deafness. The Schwabach test should be made in the original way, by transferring the fork from the patient's mastoid to one's own, or vice versa.* The normal perception duration of a tuning fork is much more constant and much easier for the patient to determine by bone conduction than by air conduction, and the noise apparatus increases the ability to say when the fork is no longer heard. In estimating the duration of perception by air conduction it is not always easy for the patient or the examiner to determine when the vibrations can no longer be perceived; this is probably due to interference with the sound waves, reflections, etc., unless the fork is held in exactly the right position in front of the auricle. To avoid these factors I make use of a small stethoscope (Figure 4) upon which I rest the handle of the tuning fork, one tube being in the patient's ear the other in my own. The method is good for any fork below the C³ (1024 d. v. s.), and has been advised in various forms by several aurists. For the routine bone conduction test the C² (512 d. v. s.) has proven the most valuable in my hands; it is heard and not felt, and it tests the central portion of the tectorial membrane. I look upon the tests with the various forks named

*Years ago Kayser used a tuning fork mounted in the middle of a wooden bar, one end of which was placed on the patient's mastoid, the other on his own. Bárány suggests the use of an otoscopic tube. I find by this method that the physician's duration of perception is less than normal and that the tube creates a Weber reaction in the patient's ear. Wanner proved that the electrically stimulated forks were unnecessary, and that the test could be made as accurately by the older method.

as giving me a "field of hearing" the variations of which furnish the basis of differential diagnosis.

The classification to be given presupposes that bone conduction when properly estimated is an infallible indication of the condition of the auditory nervous apparatus, that the C fork is the lowest in the key of C allowing an approximately accurate estimation of the intensity under which this note may be heard and not felt, and that the C⁵ fork should be heard, under its minimum intensity, in all cases of conductive deafness.

VII.

(A) Conduction deafness, including affections of the eustachian tube, when:

(1) The Weber reaction is referred to the ear complained of or said to be the deafer.

(2) The bone conduction for the C² fork is equal to or greater than the normal in duration of perception.

(3) The air conduction for the C² fork is reduced in duration of perception as compared to the normal. (Rinné showing all deafness to be by air conduction.)

(4) The air conduction for the C fork is reduced in duration of perception as compared to the normal, and to a greater degree than for the C² fork.

(5) The air conduction for the C⁵ fork is normal in duration of perception.

Case I.—K. S. is a patient who has had the radical operation and retained good hearing, distinguishing the whisper at four and conversation at ten feet. Bone conduction for the C² fork + 5" (40"/35"). Her duration of perception for the tuning forks as compared to the normal shows that her hearing is purely a question of faulty conduction.

C—49" (16"/65")

C¹—27" (13"/40")

C²—30" (30"/60")

C³—10" (15"/25")

C⁴— 3" (18"/21")

C⁵— 1" (9"/10")

If this patient is accepted as a control case, and I feel justified in presenting her record as such, the record of her hearing

can be taken as a demonstration of the physical properties of audition which have heretofore been described. Theoretically this girl has a form of deafness which, if we had an instrument of absolute precision as to intensity, could be shown to be actually the same for all these forks. That is to say, that a reduction of forty-nine seconds for the C fork does not indicate any greater degree of deafness than a reduction of one second for the C⁵.

The case has been given to show that in pure conduction deafness the results of the tuning fork examination will follow the physical laws governing the same. There are exceptions, but these exceptions are often important, especially in the diagnosis of otosclerosis. If the bone conduction is increased, normal or slightly decreased (five to ten seconds) in duration of perception for the C² tuning fork, with a decrease by air conduction for the same fork which is equal to or greater than the decrease in the duration of perception for the C fork, one should be guarded in prognosis, for with a normal drum head, a patent eustachian tube, and the complaint of tinnitus, one is probably dealing with a beginning ankylosis of the footplate of the stapes. The explanation of this defect in hearing has puzzled me until the appearance in the ANNALS OF OTOLGY, RHINOLOGY AND LARYNGOLOGY for December, 1915, of an article by G. M. McBean, of Chicago, entitled "Theories Concerning Paracusis Willisii," in which this pertinent inquiry is advanced: "Is there any longer a sound conduction apparatus when its most important link, namely, the fenestro-stapedial articulation, has become ossified? The sound conduction has then ceased to exist as a specialized mechanism."

In making air conduction tests by means of the stethoscopic method, the sound waves are conducted directly against the drum head without interference; therefore, the vibrations from the C fork probably act in the same way as the jolting under which paracusis Willisii becomes a symptom. With the C² fork this element of jolting is by no means so marked, and we must actually hear these vibrations through the action of the ossicles. When the footplate of the stapes is free there remains a flexibility which prevents the sensation of vibration (pallesthesia), though the vibrations may not be transposed and transmitted as well. When ankylosis begins, the ossicular

chain takes on the characteristics of a solid connecting bar between the drum head and the cochlea, rather than a perfect conducting medium; therefore, the vibrations of the C fork are felt under the law of "deep sensibility," whereas the vibrations of the C² fork are not suited to reach the sensorium by this route, and we lose in duration of perception for the C² fork to a greater degree than for the C fork. As the ankylosis progresses the hearing tests take on the characteristics of a simple conduction deafness of marked degree.

Case 2.—Otosclerosis. Mrs. C., aged thirty-five years. Complains of deafness slow in onset but progressive in character. Drum heads and tubes normal.

Right.		Weber not referred.		Left.	
B.C. -12" (20/30)	A.C. -74" (15/89)	C ² -54" (35/89)	A.C. -N (30/30)	B.C.	
	A.C. -39" (15/54)	C -36" (25/61)	A.C.		
	A.C. N. (9/9)	C ⁵ N. (10/10)	A.C.		

Case 3.—Conduction deafness, right; labyrinthine deafness, left. Miss K. H., aged twenty-eight years. Complains of deafness in the right ear which has grown worse within a few weeks. Left ear deaf for years. History of many recurrent attacks of earache when a child.

Right.		Weber referred to right.		Left.				
B.C.	-5" (20/25)	A.C.	-28" (15/42)	C ²	(Neg. /50)	A.C.	-22" (10/32)	B.C.
		A.C.	-45" (15/60)	C	(Neg. /55)	A.C.		
		A.C.	-1" (9/10)	C ⁵	(Neg. /10)	A.C.		

Ear drums: Right markedly retracted in anterior segment. Handle indrawn. Left retracted, but not so markedly as right; scarred. This patient had an acute eustachian catarrh in the right ear, which quickly responded to treatment. No attempt was made to treat the left ear.

If the "fields of hearing" are contrasted in these cases, it will be noted that although the deafness for the C fork is much greater in Case 3 than in Case 2, the deafness for the C² fork in Case 3 is also much less than in Case 2. In Case 2 the greater degree of deafness is for the C² fork. In Case 3 the deafness is more marked for the C fork. In Case 3 the left ear is, for all practical purposes, totally deaf. Made in the ordinary way, Rin would have been called negative because contraudition was marked. With the noise apparatus it was a simple matter to determine the nervous element in the case.

VIII.

(B) Perception deafness may be considered complete when the field of hearing is as follows, assuming that the lesion is unilateral:

- (1) The Weber reaction is referred to the better ear.
- (2) The bone conduction for the C² fork is negative, the good ear being suppressed with the noise apparatus.
- (3) The air conduction for the C² fork is negative, the good ear being suppressed with the noise apparatus, and the C² fork, stimulated to its greatest intensity, is not heard by the stethoscope method.

(4) The air conduction for the C² fork is negative under the conditions just described (3).

(5) The air conduction for the C⁵ fork is negative. With this fork it is particularly needful that the noise apparatus be used.

Robert Bing, in his most valuable "Compendium of Regional Diagnosis in Affections of the Brain and Spinal Cord (second edition, page 134), has this to say: "Between nerve deafness—namely, that due to lesions of the cochlea nerve or its supranuclear tracts and that due to lesion of percipient structure in the cochlea—no symptomatologic distinctions can be drawn. From the neurologic point of view, therefore, the regional diagnosis of lesions of the auditory mechanism must be regarded as wanting in precision." As a matter of fact, the question of differentiation, though presenting problems of baffling complexity, is by no means beyond the realm of possibility. Gradenigo, to whom we owe so much along the line of acoumetry, has shown that it is possible, and Hollinger,⁹ among others, has reported most convincing cases.

Accepting the theory that tone analysis takes place in the labyrinth, and that the cochlea branch of the auditory nerve serves but to convey all tones to the higher centers, we may assume certain things:

Labyrinth—

(1) If the intralabyrinthine structures are completely involved, we will have total deafness, both by bone and air conduction.

(2) If the intralabyrinthine structures, excluding the nervous elements, are but partially involved, we will find deafness by bone and air conduction, but, as a rule, the degree of deaf-

ness will be greater by air conduction than by bone conduction.

Nerve—

(3) If the nerve itself is involved, the deafness will be total in high degree of neuritis, both by air and bone conduction.

(4) In partial acoustic neuritis the bone conduction will be reduced out of all proportion to the air conduction.

Total perception deafness must be either labyrinthine or nerve, but we should look upon certain labyrinthine forms as conductive perception deafness, remembering that there is a sound conduction function to the labyrinth, and that only actual nerve involvement, peripheral or distal, constitutes true perception deafness. A massive effusion into the labyrinth would cause a total labyrinthine deafness simply because sound vibrations could no longer be conveyed from the footplate of the stapes—the nerve, however, might remain perfectly normal. A partial effusion into the labyrinth might only involve the vestibule or the first turn of the cochlea: in such a case sound vibrations could not continue their course when heard by ossiculoperilymphic transmission; therefore, air conduction would show a greater reduction in duration of perception than bone conduction, though the latter would also be reduced. Bone conduction, we assume, is due to resonance created by the vibrations taken up by the skull, and, therefore, if the areas of the tectorial membrane which responds to a certain tone is not greatly involved, bone conduction will be better than air conduction. In other words, the vibrations by air conduction must make their way through an obstructed passage; by bone conduction they are directly received in an area specifically suited to respond by indirect transmission. In such a case the energy exerted by the vibrations upon the tectorial membrane is greater by bone conduction than by air conduction.

If the auditory nerve is involved and the labyrinthine structures are intact, the vibrations follow more closely the normal physical laws. That is to say, that the energy exerted by the vibrations is much greater by air conduction than by bone conduction. Vibrations conveyed by ossiculoperilymphic transmission would get through a partial "nerve block," whereas, the weaker vibrations of bone conduction, created

by resonance, would have no effect; and so, bone conduction would be much reduced in duration of perception, whereas air conduction might be, in slight cases of nerve involvement, almost normal.

To attempt to draw hard and fast rules along this line is, of course, impossible; the exceptions occur more often than the rule. As a question for study, however, I make the following classifications in cases of partial perception deafness:

(C) Partial labyrinthine deafness.

(1) The Weber usually referred to the better ear. At times to the bad ear in cases showing but slight reduction in bone conduction.

(2) The bone conduction for the C² fork reduced at least ten seconds in duration of perception, usually from one-half to two-thirds the normal duration.

(3) The air conduction for the C² fork negative or markedly reduced in duration of perception.

(4) The air conduction for the C fork negative.

(5) The air conduction for the C⁵ fork negative.

(D) Partial nerve deafness.

(1) The Weber referred to the better ear.

(2) The bone conduction for the C² fork greatly reduced or negative in duration of perception.

(3) The air conduction for the C² fork better in duration of perception, or reduced to the same extent as the bone conduction for the C² fork.

(4) The air conduction for the C fork of good perception duration in recent cases, reduced markedly in old cases, but never negative.

(5) The air conduction for the C⁵ fork reduced in duration of perception, or negative.

The basis of such a classification is the study of forty cases* of perception deafness which I have been able to make in the last year in my ear clinic at the Baltimore Eye, Ear and Throat Hospital, and in the Department of Neuro-Otology, which through the interest of Dr. Harry Friedenwald and with the cooperation of Dr. A. C. Gillis, we have been able to estab-

*This number has been increased since the paper was written, without change in result.

lish at the Mercy Hospital. In a later communication we hope to be able to show the importance of the hearing tests in conjunction with the vestibular tests of Bárány. In this paper I shall only speak of the examination of the cochlea branch of the eighth nerve.

Case 4.—Partial labyrinthine deafness. Wm. A. D., aged twenty-one years (B. E. E. T. H. 102,924), was examined May 20, 1916. He complained that he had been almost totally deaf since February. Gradual onset. The patient was so deaf that all questions had to be written.

Ear drums.—Right: Thickened and congested. Bulging in posterior portion. Middle ear seemed filled with thick secretion. Left: Presented the same appearance.

The patient had had no pain, no nausea, no vertigo. Denied lues. He had, however, been a patient at the Maryland Tuberculosis Sanatorium from January 3 to January 27, 1916, and was pronounced by Dr. V. C. Cullen "a progressive case of tuberculosis with an absolutely bad outlook." Dr. Hirshman, who examined the man in May, was of the same opinion. The hearing tests gave the following results:

HEARING TESTS BY AIR CONDUCTION.

The Weber was referred uncertainly to the right. The air conduction was negative for the C, the C¹, the C² and the C³ tuning forks under their maximum intensity. The C⁴ showed —22" (3/25) in the right ear, but was negative /25" in the left. The C⁵ fork was negative /10" in both ears. The Galton was heard at three turns in the right and at five turns in the left.

Here undoubtedly was a case of serous labyrinthitis of tubercular origin. The deafness was of the conduction type, but labyrinthine as well as middle ear. The bone conduction tests are of great interest and were as follows:

HEARING TESTS BY BONE CONDUCTION.

Right.		Left.
Negative /35	C ²	—25" (5/30)
—8" (7/15)	C ¹	— 6" (9/15)

A paracentesis was done on both drums, which was followed by a thick, nonpurulent discharge that continued for some weeks. On June 7, 1916, his bone conduction had im-

proved for the C² fork, and he could hear the C fork for a few seconds by air conduction.

Right.		Left.
B. C. —23" (7/30)	C ²	—18" (12/30) B. C.
A. C. —84" (6/90)	C	—78" (12/90) A. C.

The discharge ceased and the drums resumed a partially normal appearance, and by October 9, 1916, he could hear a loud conversational tone. The bone conduction for the C² fork had increased to 35/35 in both ears. The air conduction for the C fork had increased to right, —50" (25/75); left, —30" (30/60). He still could not hear the C⁵ in either ear, and this was interesting from the standpoint that although bone conduction was normal for the C² fork, the C³ and C⁴ showed a decrease of —20" and —18" respectively. The tests of the vestibular apparatus, both by rotation and the caloric reaction, were of interest, and confirmed the labyrinthine affection. It is not the purpose of this paper, however, to go into that side of the question. The man's blood showed a negative Wassermann on two examinations.

Concerning tuberculosis of the middle ear, H. B. Graham¹⁰ has this to say: "In functional testing of cases of tuberculosis of the middle ear, one is nearly always struck with the disharmony between the remarkable deafness and the length of time and the severity of the attack. The reduced perception for the voice and the low tone is, of course, the most marked factor, but the perception quantitatively for all tuning forks is also markedly and rapidly reduced, so that one is reminded of the luetic cases he sees following salvarsan, suggesting that there may be some similar toxic effect in the labyrinth as well as a disturbance of conduction. In the later stages a complete deafness may occur without vestibular symptoms having developed, and on sectioning the labyrinth we find a complete replacement of the labyrinth by a caseous organized mass." The case (Case 4) which I have just reported follows closely certain cases reported by Graham. One is borne out then by the pathologic findings in assuming from the hearing tests that the lesion is purely labyrinthine and that it is not a toxic neuritis in the true sense of the word. On the other hand, nerve deafness due to lues is truly an eighth-nerve involvement, and the results of the hearing tests in a case of partial percep-

tion deafness due to syphilis, when compared to labyrinthine case (Case 4) just quoted, will, I think, bear out the differential diagnostic points to which I have called attention.

Case 5.—L. S., aged forty-four years, was seen at the Baltimore Eye, Ear and Throat Hospital, June 12, 1916. He complained of poor vision and failing hearing; the patient thought this had been progressing for about six months. He admitted lues of twenty-five years' duration. Treatment only during the first six months following the chancre. To report his general condition as briefly as possible, the man is a tabetic with partial optic atrophy, the vision of the right eye being 18/30, of the left 18/50 at the first examination. His pupils are unequal, the left being the larger, and the response to light is sluggish. Ophthalmoscopically the optic discs show atrophy to the temporal side, more marked in the left eye. The visual fields are contracted for form and colors, and there is a small central scotoma for red in the left eye. His patellar reflexes are absent. His hearing tests with the tuning forks are as follows, his tympanic membranes being normal in appearance:

June 12, 1916.			
Right.	← Weber.		Left.
B.C. —5" (30/35)	A.C. —2" (73/95)	C ² —15" (47/62)	A.C. —25" (10/35) B.C.
	A.C. —10" (40/50)	C —10" (50/60)	A.C.
	A.C. —3" (7/10)	C ⁵ —5" (5/10)	A.C.

Note that in the left ear the Rinné shows a marked reduction by bone conduction as compared to air conduction. That the C fork is practically normal in duration of perception, but that the C⁵ fork shows a reduction of five seconds, which with this fork indicates a marked degree of deafness for a tone of this pitch. This is the characteristic hearing defect found in syphilitic cases.

In recent years there has been a considerable study of the syphilitic affections of the internal ear, and the chief diagnostic point brought out by all authors is that there is a shortening of the bone conduction out of all proportion to the shortening by air conduction, with but slight shortening, or loss, for the sound of the low forks and a tendency for the forks of high pitch to be reduced in duration of perception. One of the most interesting articles concerning this subject

was presented by George H. Wilcut¹¹ at the San Francisco meeting of the American Medical Association in 1915. In this contribution Wilcut gives a good résumé of the subject to date, besides his own valuable observations, which include a far greater number of cases than had been studied by the majority of the authors quoted. The question of the pathology of the condition is somewhat uncertain, but the indications are that the lesion is most probably "a syphilitic infection of the nerve sheath."¹² Swift and Ellis¹³ believe that syphilitic deafness should never be considered an isolated entity, but a manifestation of cerebrospinal syphilis. Whether or not there exists a syphilitic meningitis in all cases is yet to be determined, but certainly all observers agree that deafness in these cases is due to a neuritis of the eighth nerve, either toxic or caused by increased intracranial pressure.

Physically speaking, it does not seem possible that the reduction by bone conduction in hearing power could be out of all proportion to the reduction in hearing power by air conduction, for if the nerve is affected, how can sound vibrations be perceived, no matter how well they may be conveyed? This has already been explained. By bone conduction the energy necessary to create resonance in the tectorial membrane is much greater than the energy necessary in vibrations carried by air conduction; therefore, in these cases of auditory "nerve block," the weak stimulation produced by bone conduction resonance is not sufficient to get through, whereas the stimulation produced by the powerfully reinforced vibrations, received and converted into the form best suited by the drum head and the ossicular chain, is sufficient to overcome the block. Though not exactly comparable, a similar condition is seen in the reduced peripheral vision of optic neuritis, with the retention of almost normal central vision. In the Mercy Hospital Dispensary we have been able to follow a creditable number of cases of acoustic neuritis accompanying tabes, cerebrospinal syphilis, and other syphilitic central nervous system lesions which we hope later will furnish observations worthy of report.

In conclusion, my apology for presenting many well known facts is simply that the question of perception deafness and the use of the tuning forks is, generally speaking, in rather a

chaotic condition, regardless of the fact that many contributions to the subject are worthy of deep consideration. There is absolutely no standardization in the use of the tuning forks, each man using them as he pleases. Why should we persistently speak of "hearing" or "not hearing" a tuning fork, when a moment's thought will convince us that unless we know the intensity under which any sound is heard, its value as a measure of auditory power is useless? Why should we persist in the use of terms "negative" and "positive" Rinne, when we know that a "negative" is often found in perception deafness and a "positive" in conduction deafness? Why should we persist in comparing bone conduction and air conduction by a method that is most inaccurate, especially when by the use of the "noise apparatus" we may definitely determine the true bone conduction of each ear separately? And may not all these inaccuracies account for the report of but eight cases of internal ear disease out of seventeen hundred and fifty-three cases of ear disease (I take these figures from the report of one of the largest special hospitals in the South)? And yet no less an authority than Politzer says that the eighth nerve is oftener affected than any cranial nerve! I have no doubt that my paper is open to criticism. I make no claim for originality. Much that I have said has been said before, and better said. The work itself has required a great deal of patience, but as otologists we can do no better than to accept the opinion of Gradenigo: "That the proof based on the duration of perception of tuning fork sound furnishes, in pathologic cases, a deformed likeness of the hearing power; real progress of otology can only be reached when rigorous and exact methods in physical regard become established."

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The bibliography of the subject is, of course, exceedingly extensive. The author has made no attempt to give exact references except when it seemed necessary. The object has been to gather together into a workable whole those facts which are far enough removed from the hypothetical to be practical.

FIGURE 4.

FIGURE 1.

The incorrect impression of the decrement of the vibrations of a tuning fork.

The correct way in which decrement takes place.

FIGURE 2.

The normal ear can hear this fork for 25". Supposing that the abnormal one can only hear it for 15"—noted so —10" (15"/25").

At the next test the abnormal ear will hear the vibrations for 20", apparently an improvement, but if the normal is increased to 30", the degree of deafness will be the same as at the first test, viz.: —10" (20"/30").

The duration of perception is immaterial. It is the difference between abnormal and normal perception which is the important factor.

FIGURE 3.