On some points in the physiology of the tympanum : read before the the [sic] Section on Physiology of the Medical Society of London / by George Pilcher.

ON SOME POINTS

IN THE

PHYSIOLOGY OF THE TYMPANUM;

READ BEFORE THE THE SECTION ON PHYSIOLOGY

OF

The Medical Society of London.

BY

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&c. &c. &c.

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NOTICE.

The following pages have been printed at the desire of several Fellows of the Medical Society of London, who had not an opportunity of hearing the Paper read; and in the hope that the attention of Physiologists being directed to the subject, the views contained therein may either be confirmed or refuted.

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ON THE

PHYSIOLOGY OF THE TYMPANUM.

READ BEFORE THE PHYSIOLOGICAL SECTION OF THE MEDICAL SOCIETY OF LONDON, ON THE 13TH FEBRUARY, 1854.

In selecting the subject, "A few points connected with the Physiology of the Tympanum," for our evening's discussion, my object is to elicit the views and opinions of the Fellows of the Society in reference to certain conditions and functions still debatable and at the present moment debated. I purposely avoid all reference to the influence of the external ear upon sound, and likewise to the effect of the undulations of the aqua labyrinthi upon the expansion of the auditory nerve, confining my observations, as strictly as perspicuity will admit, to the mode of action or influence of the middle ear, or the tympanum, including under that term the structures bounded externally by the membrana tympani, and internally by the membrano-osseous wall, forming the outer boundary of the internal ear or labyrinth: thus we have to consider briefly the functions of the membrane of the tympanum—of the

ossicles with their ligaments and muscles—of the membrane of the fenestra ovalis—of that of the fenestra rotunda or membrana tympani secundaria—of the eustachian tube—of the mastoid cells—and of the cavity (improperly so called) of the tympanum itself.

On the very threshold of our inquiries we cannot but be struck with the interesting fact of the existence and purpose of a tympanum being confined to the modification or influence of ærial sounds; and that though we find it in aquatic mammalians, and in reptiles alike aquatic and terrestial, and in amphibians; in all these its structure is so modified for its protection and occlusion when in the watery element as then most probably to be closed from all action or function, so that the Physiologist is justified in the conclusion that a tympanum, including its appendages, is in its function peculiar to air-breathing, and consequently air-hearing animals; and that it is in direct association with the medium conveying the sound, or, more correctly speaking, producing that effect upon the organ by its undulations or vibrations, as it may be, which we term *sound*. Yet the inquirer recognises that a tympanum is not only in association with the ærial medium conveying sound, but that it becomes importantly modified in the different orders of terrestial beings in correspondence with the development of the brain, and consequently of the intelligence; thus its complexity and perfection are gradually advanced through the orders of animals till it reaches its supposed perfection in man. We are thus led to the conclusion, and I anticipate that the sequel will confirm that conclusion, that the great

end and intention of the tympanum is so to extend and multiply the modifications and variations of sound as to give rise to that infinite variety of impressions upon the mind which we recognise as articulate language. It is no sufficient argument to the contrary that the *passeres*, that most beautiful and all-delighting section of creation, are capable of warbling hymns of praise, and to sing in language readily comprehended by their mates, distinctly expressing their joys and griefs, their hopes and alarms, with a tympanum no more elaborately organized than the amphibian with its hoarse croak, or the higher reptile with its almost single expression of alarm or of rage: these great differences in the capacity of appreciating voice are due to corresponding differences in the peculiarities of mental development, suiting each class of beings to its especial uses and habits. The same objection, if urged at all, might be more forcibly urged upon comparison of the range of voice and hearing in the nightingale and the rook, the anatomy of whose organs, both of hearing and of voice, are exactly corresponding, modified only in relation to their relative size, and perhaps to the muscular power in correspondence to their peculiar function. Nor is it a sufficient argument to the contrary of the proposition that the use of the tympanum is to so modify the sound falling upon it as to produce that incomprehensible variety of undulations in the water of the labyrinth which occasions a corresponding variety of impressions upon the sensorium, the appreciation of which constitutes recognised language, whether spoken or sung, that this

great effect is in many instances but little impaired by the loss—even it may be complete—of the entire structure as an organ of audition; it usually happens, and it may be regarded as a general law, subject however to many exceptions, that the loss of function is in the ratio to the loss or disease of structure; but I have frequently seen the contrary to obtain, a slight hypertrophy of the membrana to occasion a serious amount of deafness, and on the other hand, the complete loss of the membrana and ossicula, including even the stapes, to be unattended with ordinarily appreciable loss or diminution of hearing. This fact, which at first sight seems irreconcilable with the recognised law, that "function cannot take place without structure," is proved by ample experience. I have *seen* the exposed membrane of the fenestra ovalis, have had the stapes of that ear, as well as the other ossicles, in my hand, and yet the sense was so perfect that the patient did not consider himself deaf upon that side. It is a common occurrence to find the whole of the tympanic contents, except the stapes, including the membrane, the malleus, the incus, and the orbicular bone, and the entire mucous lining, to be lost by disease, leaving the promontory very marked, the head of the stapes just perceived in the situation of the oval opening, the outline of the round opening well recognised, and all merely covered by the healthy periosteum, and yet the extent of hearing remaining to a very considerable degree, and in some —nay, many—instances its diminution being hardly perceptible. But who would argue from this that the

tympanum is of little importance or useless in the economy of audition? Yet it proves among other conditions that it is simply an appendage to more important structures, and that the loss of its function can be supplied by an exaltation in the function of the essential part of the organ, the nerve in its expansion in the labyrinth; a conclusion borne out by the fact that this happy result occurs only when the destructive disease has taken place in childhood, the period when, by use and education, the susceptibilities of the nerves of sense may be greatly augmented; and what is of much more moment, the mental perceptions may, by the same means, be so much increased in power, and the appreciation of external impressions so much enlarged, that the fainter impressions conveyed through the abnormal organ, which would be lost to the less specially educated nerve and brain, are duly perceived and acted upon.

I am tempted to tax the patience of the Society here by committing a digression unconnected with my subject, in stating my almost conviction, that if this principle were applied to the deaf-dumb arising from malformation of the labyrinth, which malformation is generally a partial deficiency of development, many unfortunate cases would experience such an amount of improvement as to be so capable of the enjoyment of hearing, as to ensure its necessary accompaniment, speech. See *Appendix* I.

It will be more convenient to adopt the ordinary method in considering the physiology of this interesting structure; that is, in the course in which it is

influenced by sound; which leads us first to the membrana tympani; of the structure of which I wish to say no more than is requisite for the due consideration of its function, which, however, renders some observations absolutely necessary. I need merely allude to its oblique position from above downwards and inwards, as being important to the performance of its office; to its being beautifully set in a ring of bone, with the exception of the upper part where the bone is deficient; to its general form of an ovoid, its broader extremity being above, its longer diameter, which is usually rather less than half-an-inch, or about two-fifths of an inch in extent, being perpendicular; to its outer surface, which inclines also a little forwards, forming with the floor of the auditory canal an angle of about 45°; to its *general* concavity without and convexity within. I say *general* emphatically, for it does not form a pure concavo-convexity, it is especially depressed a little below the centre, where the extremity of the handle of the malleus is attached; its upper part is divided into an anterior and posterior portion by the malleus, which also thus constitutes a lower division; it is interesting to notice that though the manubrium of the malleus, as seen shining through the membrane, usually passes *backwards* in its descent to the central external depression and internal elevation, yet it occasionally runs *forwards*, and sometimes does not occupy the upper half of the entire membrane; a circumstance pointing to the fact that though the obliquity of the membrane and bone is important, the precise direction of that obli-

quity is unimportant, for these variations occur in normal ears with perfect hearing. It is further interesting to remark that each of these divisions does not partake singly of the concave depression, but regarded alone, is rather a flat surface, as Mr. WILDE has described, particularly the inferior and anterior, which circumstance may improve the vibratibility of those surfaces. I have occasionally seen the upper part of the superior posterior division more diaphanous than the rest of the membrane, the lower border of this transparent part being semilunar and well defined, as though the true membrane became there deficient, the part being eked out by the external and internal dermoid structures; this, I expect, constitutes the "membrana flaccida" of SHARPNELL, and which, I have no doubt, is a congenital deficiency in the membrane, and from its slighter resistance often becoming protuberant, and more readily giving way to disease or accident. I am induced to regard this membrana flaccida—if such I may still call it, though SHARPNELL was evidently incorrect in naming it and regarding it as a normal arrangement—as a deficient development from the facts, that it is only occasionally seen, and then in delicate persons, and mostly in women; and that, as in most other, if not in all other, malformations, it is an approach to the normal condition in some lower animals.

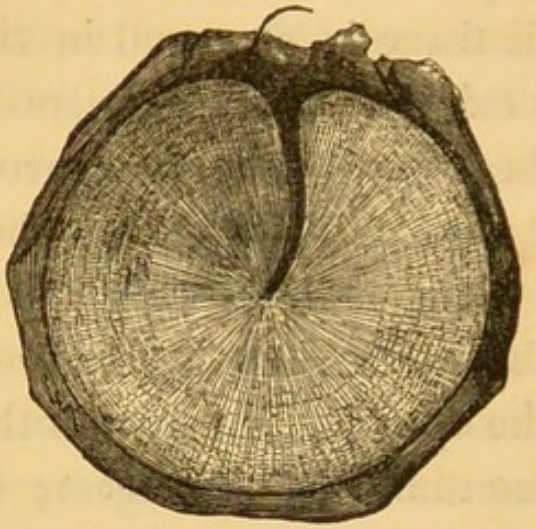
It does not appear to be generally known that many of the mammalia, and perhaps even all, have a large aperture, bounded by a well-defined margin, of an oval shape, the lower border often being con-

cave, while the upper is convex, at the upper and back part of the membrane, just behind the neck and superior part of the handle of the malleus, through which there is a free communication with the interior of the cavity of the tympanum. My friend Mr. LANE has invariably found it in the cat, in the ox, in the horse. (*Appendix* 2.) I am anxious the Fellows of the Society should bear this circumstance in remembrance, as it must materially influence our conceptions of the action of the membrana.

Though thin, delicate, and transparent in structure, the membrana tympani is compound, being a dermo-fibro-mucous membrane. That the outer surface is covered by a continuation of the cuticular lining of the meatus is clearly proved, both by anatomy and pathology; but my friend and colleague Mr. BLENKIENS, from his very careful microscopical investigations, concludes that its epithelium is considerably modified, not presenting the usual epithelial cells, and never perforated by hairs, which are abundantly seen in the same structure of the meatus close to the membrane. Mr. TOYNBEE has lately endeavoured to prove that the true skin is likewise continued or reflected over the membrane proper, and does not, as is supposed by many Anatomists, form the membrane by a modification of its own structure; with what success I must refer my auditors to Mr. TOYNBEE'S well considered paper for their determination. The mucous membrane of the tympanic cavity, here remarkably thin, yet firm and compact, is doubtless reflected upon the inner surface of the membrane, and

pretty certainly also with its epidermoid or epethelial layer. An unassisted eye-view presents the whole structure when healthy, as one layer thin, delicate, and transparent, but aided by the microscope the cuticle is readily removable, and a fibrous tissue is evidenced; this tissue is arranged in two layers; the *external* more extensive and universally spread out over the membrane, proceeds from every part of the circumference, most probably from the surrounding framework of bone, and is attached by its centric extremity to the entire length of the manubrium of the malleus; the fibres inserted into the apex, being the most numerous and the strongest; those attached to the upper part, proceeding from the sides, where the osseous ring is complete, and crossing more or less laterally towards the centre, so that few, if any fibres are seen to proceed from the upper part of the tympanum where the bone is deficient; it follows, of necessity, that minute as are these fibres, every one must vary in length, their periphery being circular, or nearly so, and their centre being elongated, and that in varying degrees; I must also observe that their curves must vary in relation to the concavo-concavity of the membrane. It has long occurred to me, and almost at the same time to a late inestimable and intelligent friend, upon physiological reasoning, rather than upon anatomical demonstration, it must be confessed, that the probability was great that the fibres, as they must vary in length, might also differ in thickness and size, and perhaps also in density The *internal* layer of fibres is less uniformly spread

over the membrane; it is circular, and much more abundant at the circumference, and does not appear to reach the malleus, with the exception of a few fibres at the apex.



A diagram, copied from a microscopic drawing of the membrana tympani exhibiting the radiating and circular fibres, the dermoid structures being removed.

Mr. TOYNBEE has described these two layers of fibres as continuations from the periosteum of the surrounding bone; the external radiating of that of the osseous portion of the outer meatus, and the internal circular continued from that of the walls of the tympanum; it seems certain, and I am not aware that it has been ever disputed, that the proper fibrous membrane is intimately attached to the surrounding periosteum, and is consequently continuous with it; but *continuity* of structure by no means necessitates *identity* of structure; for example, the tendon of a muscle, or the ligament of a joint, though continuous, cannot be regarded as identical with the periosteum; and Mr. BLENKIENS, who is an authority upon such mat-

ters, regards this tissue as differing from all others; certainly very unlike the common white fibrous tissue, of which the periosteum is an example. As the function of these fibres is mechanical, it matters but little to the physiologist with what surrounding structure they are identified, the mechanical arrangement being the important question; for I presume that Sir EVERARD HOME'S dogma that they are muscular is now not at all entertained. It is unnecessary here even to allude to the organization of these structures; in a perfectly healthy condition the membrane does not appear to convey red blood, or rather the quantity is so small in the minute vessels as to be insufficient to reflect the red colour, yet the vascularity is very great, as seen by the readiness with which it becomes injected upon the slightest stimulation. The same excitement renders it often inordinately sensitive, it being frequently the subject of neuralgia, and ulceration takes place in it very rapidly.

It is generally described that the malleus is firmly and compactly united to the inner surface of the membrana tympani between the two layers of the true membrane, which, however, may be fairly doubted; at all events, it is so securely fixed by the mucous membrane and its epithelium, as of necessity, to accurately follow every movement or vibration of the membrane, and to almost, if not quite, preclude the possibility of separation, except as a consequence of disease; a connexion which leads to the legitimate conclusion that one great use, if not the chief use, of the membrane, is to communicate its vibrations to the

malleus, which we shall perceive are extended onwards through the chain of bones to the membrana fenestræ ovalis. If, therefore, this last-named membrane be the only or the chief means of exciting the undulations of the aqua labyrinthi, the movements or vibrations of the membrana tympani become of extreme interest.

All-absorbing as are the doctrines of the vibrations of solid bodies, as illustrated and demonstrated by mathematical science, the limits of this paper would not allow me to allude to them, even if I possessed the inclination and the ability. I can do no more than recall to your remembrance a few obvious facts as connected with the vibrations of membranes, of which that of the tympanum I offer as a good example; 1st, That it vibrates rapidly in proportion to its tensity; however, according to the experiments of Savart, Willis, Wheatstone, and others, there appears to be a limit to the vibratibility of a membrane, that it may be rendered so very tense as to be incapable of further motion, even of vibration. 2nd, That it vibrates rapidly in proportion to its thinness, the condensation of its material, or its tenuity or resistance. 3rd, That the entire membrane does not necessarily vibrate at the same time, that one portion may be in a state of rest while others are actively moving. 4th, That in all instances, when the whole extent is said to be in agitation, it is vibrating in lines with intervening spaces at rest, and that these lines will be determined by their density and tension, these interstices at rest constituting the *nodal points*. 5th, That these lines

themselves must necessarily vary in their capability of vibration, as they differ in their length, in their tenseness, in their solidity or density; in fact, though so arranged together as to constitute a membrane, each line or fibre is moving in obedience to the same laws which regulate a vibrating musical chord: a vibrating membrane being but a series of vibrating chords. 6th, That a line or chord, whether consituting a part of a membrane, or stretched out alone as a string, may vibrate throughout its entire length, or in separate and distinct portions, and either at the same time or at different intervals; when vibrating in different portions or lengths, the intervening spaces form the nodal points. 7th, That exactly in reverse proportion to the *rapidity* of vibration will be the *extent* to which the fibres will move in the surrounding medium. 8th; And that thus the highest or most acute note proceeds from a string, or chord, or line, at the same time the most tense, most dense, smallest, shortest, and vibrating through, or in the most limited space; a chord vibrating under the reverse of these conditions will produce the lowest or deepest note or sound. Upon applying these principles, and from the experiments of CHALDNI and others, and more especially of SAVART, it was found, as might be anticipated, that the membrana tympani fulfilled all these indications, and that the lowest note or sound audible to an ordinary healthy human ear was occasioned by a vibration occupying the sixteenth part of a moment or thereabouts; that the sonorous waves of the atmosphere, which were capable of exciting sixteen vibra-

tions of the membrane in a moment, could be appreciated as sound by the sensorium. On the other hand, that the highest appreciable note occupied the twenty-four thousandth part of a second in its vibration; that is, when the tympanic membrane was thrown by the sonorous undulations falling upon it into a state of 24,000 vibrations in a moment of time, sound could be perceived; thus, that the extent and rapidity of vibrations varied from sixteen times to 24,000 times in a second, of course the intermediate numbers are those which are best recognised. My limits do not permit me to allude to the interesting experiments of M. SAVART, and to the regular, and beautiful, and mathematical shapes which light sand or powder scattered upon a vibrating membrane invariably and of necessity assumes; which, however, is of less importance, as they are amply detailed in most treatises upon natural and experimental philosophy, as well as in our works on physiology.

When considering this subject some years ago, while preparing the Essay to which your council kindly awarded the Fothergillian Medal, I was led to conclude that, as the fibres of the membrane of the tympanum certainly differ in length, and probably in density and thickness, and are regulated in tensity by muscular action (yet to be mentioned), so each fibre, delicate as it is, possesses its own special degree of vibratibility; and that, therefore, though many or all may vibrate at the same instant and from the same cause, each will vibrate with its own intensity, or to its own special extent; and that thus it is possible,

nay, probable, that in the human membrana tympani there is a chord capable of vibrating in concert with every sound known to the human mind: a sympathetic chord, producing a sympathetic note in unison with a corresponding note, though issuing from a different instrument; and which note the musical world so well know passes over every string not in unison with it till it meets with that in its sympathy, and in which it excites a corresponding musical sound.

This doctrine appears to be capable of explaining several phenomena, which otherwise are inexplicable to my mind, such as the circumstance of persons, with otherwise normal hearing, and a healthy organ, being congenitally deaf to certain sounds, either completely or partially,—a lady without disease of the ear never heard a canary bird, though one was singing in her room; and deep sounds of good intensity are inaudible, or nearly so, to some persons:—some cases of thickening, or other diseases of the tympanal membrane being attended with the loss of certain sounds in particular, others being fairly perceived:—the circumstance that in cases of sudden and loud sound, or of condensation of the air, as by a bawling unexpectedly in the ear, or a sudden box on the ear, will be attended with rupture, sometimes of one portion of the membrane, sometimes of another:—the restoration of all the usual appreciations only upon the restoration of health to the organ:—perhaps I may say the lessened capability of distinguishing the direction or the distance of sounds:—especially the

power of distinguishing one particular sound from among many even louder :—and often of hearing that sound to the exclusion of the others :—and in a peculiar manner the ready capability of uniting into one harmonious whole the various sounds proceeding from many instruments of different pitch and quality when playing the same music : thus in a concert, the music of each instrument is distinctly appreciated, occasioning to the musically educated ear and mind, pleasure or annoyance, as the sounds may be harmonious or discordant :—the instant recognition by the musician of a wrong or discordant note in a piece of otherwise well-played music. I am fully aware that many of these phenomena are attributable to the operations of the mind, yet I think there exists fair reason to conclude that the sounds are thus prepared by the external organ, and by this membrane in particular, for their due appreciation by the intellect.

Thus, then, I infer that the membrana tympani, and that in man more especially, is a compound musical instrument, made up of innumerable strings or chords, each possessing its own peculiar note, and in concert with a corresponding external sound, and probably with that only, capable of being, and often being, tightened or relaxed to concert pitch with the external note ; and that, as we shall see anon, both voluntarily and involuntarily.

Let me recall to mind the admirable adaptation of the membrane from its situation, and position, and attachment, to receive upon some part or parts, or the whole of its surface, the sonorous undulations

modified in their transit along the external meatus; no less admirably adapted is it to transmit its own vibrations directly to the manubrium of the malleus, thence through its head to the body of the incus, down the long crus of which to the orbicular bone, onwards to the stapes, thus reaching the membrane of the fenestra ovalis.

We must observe upon, though very briefly, the beautiful arrangement of this chain of bones; the head of the malleus is placed above, and therefore free from the direct action of, the membrane of the tympanum, and hence is free to oscillate in its tympanic sinus; by its short process, and extremity of its handle, it is somewhat poised, as it were, upon two especial points of attachment to the membrane, whereby its varied rotations or other movements must be augmented; it is protected in these movements, and they are limited to their just proportions, by the attachment of the long crus to the anterior part of the bony ring. The junction, in the upper part of the cavity of the tympanum, of the head of the malleus and body of the incus, is well formed, not only for the transmission of oscillation, but also for its increase, the joint, which is very perfect, much resembles that formed by the ulnar and humerus, being rather a ginglymoid than an enarthrodial articulation, yet, no doubt, possessing considerable lateral motion, it may be correctly described as a double-hinge joint; this articulation is so arranged as to determine the centre of motion rather through the body and short crus of the incus, which being tied by its ligament to the

edge of the mastoid cells, is well adapted to secure the bone in its attachment; thus the long crus hanging downwards, at the same time a little forwards and inwards diverges from the malleus, and oscillates like a pendulum, but from the nature of the articulation most probably in the double direction inwards and outwards, forwards and backwards, but chiefly in the former direction; it does not appear capable of rotation. The button-like extremity of the long process projecting inwards is articulated nearly at a right angle with the orbicular bone, with which it is more frequently than otherwise inseparably united. This ossicle forms a well-marked ball and socket joint with the head of stapes, by which means the latter bone stands in almost at a right angle with the extremity of the incus; its base exactly corresponding with the margin of the fenestra ovalis, and with the membrane occupying it, to which it is united by a strong lubricated ligament; but whether a true synovial membrane, or a reflection of the mucous membrane, is not decided; most probably the former. The ossicles necessarily constitute, in consequence of their peculiar mode of union, an elastic and rapidly-acting spring; and as the inner end is fixed, excepting so far as the membrane of the oval opening is capable of yielding, and the outer extremity more moveable, it must first act from without inwards, springing back to its condition of rest when the operating cause is removed; besides this movement inwards and outwards, the oscillations forwards and backwards, must be very considerable, and as rapid as the vibrations of

the membrana tympani itself; with the important addition that their extent must be increased in proportion to the leverage formed by the processes of the bones, and by their articulations. Thus, then, the vibrations of the comparatively large membrana tympani, or of so much of it as may be in action, are importantly augmented, as well as modified, in their transmission through the osseous chain, and become concentrated upon the comparatively small membrana fenestræ ovalis.

But, furthermore, these little bones modify and regulate the action of the membrana tympani itself through the medium of the muscular action with which they are furnished. We cannot speak certainly of more than two muscles attached to and working these interesting ossicles, and through them the membrane at their either extremity: viz. the Tensor Tympani, or Malleus Internus, is an undoubted and very powerful muscle, and in the ox appears to threaten the very integrity of the membrane from its great strength; it is so arranged by running along a canal and passing round the margin as over a pulley, to become attached to the upper part of the manubrium of the malleus, as to draw the bone inwards, and thus to tighten the membrane, increasing its vibratibility, shortening and compressing the osseous spring, and forcing the membrane of the oval opening in upon the vestibule: most likely the great power of the muscle is, besides the above uses, to tense the membrane to a degree beyond the vibratile capacity, and by this means to prevent the undue effect of otherwise over-

whelming sound upon the auditory nerve. Is it possible that the spasmodic and violent contraction of the muscle, upon the sudden and unexpected application of a loud, intense, and harsh sound, may be so great as to rupture the membrane? such instances of rupture, I know from experience, do occur, though the so called "broken drum," from loud and discordant sounds, is usually a misnomer, the unhappy condition being generally a paralysed nerve. The uniform presence of the Stapedius muscle is certain, though, indeed, CLOQUET has denied it; passing from the mastoid cells, through the canal in the eminentia pyramidalis, its strong round tendon—in which is often found a Sesamoid bone, especially in the neat-animals—becomes attached to the back part of the neck of the stapes. Its action must also be to force the stapes with some degree inwards, compressing the fluid of the labyrinth, and in so doing, still further to draw inwards the membrana tympani, thus assisting the tensor tympani; it must also roll the stapes upon its axis, and probably possesses a more important influence upon the undulations of the aqua than we suspect. In addition to these two muscles there are described the Laxator tympani, or Anterior mallei, and the Levator tympani, or Laxator minor, both which muscles, if they existed, would relax the membrana tympani, by drawing the malleus outwards, the laxator would likewise carry it forwards, and the levator raise it upwards; it is pretty certain that the levator does not exist, and the laxator, in the majority of instances, more resembles a piece of fibrous tissue than muscle;

and if the view we have taken of the arrangement and operations of the bones be correct, we can hardly imagine the necessity for additional means of restoring the membrana to its equilibrium, or of relaxing it.

Upon careful examination it is found that the tympanic muscles are supplied freely with nerves from various sources,—from the Portio Dura largely, thus being directly in association with the brain they become muscles of volition, furnishing us with the power to will or otherwise their action,—from the Otic, or Auricular Ganglion, both immediately and mediately; and I would particularly mention one large branch to the tensor tympani, thus they possess, in a large degree, involuntary power or action—from the Tympanic Plexus, and by its medium again from the sympathetic, the otic ganglion, chorda tympani, and probably also from the portio dura, glosso-pharyngeus, and the fifth cerebral. I allude thus to these nerves to point to the compound use of the muscles; they are of the mixed class, as indeed the excito-motory system of nerves, in conjunction with the volition nerves, combines all the so-called voluntary muscles; but as these muscles are in an especial manner supplied from the excito-motory system, so it is fair to conclude that there does exist a corresponding especial action, which involuntary action is called into full operation by the excitement of a loud or discordant, and otherwise dangerous sound; I expect it is by this agency that the organ is protected, in a general manner assisting our voluntary contractions, and in an especial manner when volition is not directed to the

muscular action, a circumstance so constantly occurring and so familiar, as not to require any examples for illustration. Thus we are empowered at will to bring the tympanum into concert with the external sound or note; and probably by the varying pressure upon the membrane of the labyrinth to adapt the internal ear also to the sounds about to influence it; thus also, independently of, and it may be in opposition to our will, the organ is protected against the baneful effects of impressions too powerful or too sudden for their healthy reception; yet the sonorous undulations may reach the tympanum so intensely, so suddenly, so unexpectedly, as to find it off its guard, and hence be productive of serious, of fatal mischief, either to the tympanum, or to the auditory nerve, or even to both. In these actions we recognise a close resemblance, as the intellectual ARNOLD has remarked, with the functions of the iris, the involuntary controller of the quantity of light to be admitted to the retina, yet sometimes the fatal flash of lighting occasions its paralysing effects before the pupil has an opportunity to contract.

We have hitherto argued upon the functions of the tympanum *per se;* the tympanum, however, is an atmospheric chamber, furnished with diverticula for enlargement; importantly influencing and influenced by the actions already described, nay more than importantly, actually permitting their performance, and probably the air performs some functions peculiar to itself. I need not furnish arguments to prove the necessity of a membrane, or any solid body, being

suspended between layers or strata of the same material for the purpose of its due vibration; in the instance under discussion of the membrana tympani being placed between layers of air of the same elasticity, the same temperature, consequently the same density, that it shall *per force* vibrate in exact accordance with the external impressions, and transmit similar impressions to the air and other contents of the chamber. I need only also allude to the fact that it appears proved that, highly elastic as the air is known to be, and readily moving as the particles do upon each other when influenced by the slightest agent, that elasticity and that mobility are insufficient to permit the correct vibration of a membrane, or to restore it to rest, when the volumes of air on the two sides materially differ. It is surely in strict obedience to this law that the musical instruments are constructed with a communication between the interior and the exterior, so that the air within a drum is only a layer, or a part of that which surrounds it, and possesses all its qualities; the vibrations of the drum-head, whether excited by the blows of the musician, or by waves of the atmosphere playing over its surface, can only produce undulations of the contained air in consequence of its recession to and fro through the aperture in the walls of the instrument. This recession, however, may be in some degree supplied by the vibration of a membrane, similar in structure and opposite in position to that thrown into motion, as in the double-headed-drum, in contradistinction to the kettle-drum, but then the vibrations are always imperfect, the

imperfection corresponding to the smaller extent of motion of the drum-head, which, of course, is regulated by the size of the instrument. It is asserted by MULLER, and Mr. TONYBEE quotes Mr. C. BROOKE to have stated, that a small drum does not require such an orifice, which is only requisite where the air is considerably displaced; I am informed, by one well acquainted with the subject, that even then the effect is imperfect, and the instrument unmusical.

I do not expect to meet with a dissentient from the opinion that the air in the tympanic cavity is essential to assist in poising and maintaining the membrane and the ossicles in their required positions, to allow them freely to vibrate and oscillate, to assist in restoring them to a state of repose from their movements; but there will exist differences of opinion as to these being its only uses, and to the manner in which its functions are brought about. I cannot withhold my belief that the above are the main influences of the atmosphere in the tympanum; and that it probably also aids the oscillations of the bones by the undulations which it receives from the membrane. Many, perhaps the majority of, Physiologists consider that the air directly communicates its undulations to the membrane of the fenestra rotunda,—termed the membrana tympani secundaria, from its supposed allied function by this office to the proper membrane,—the vibrations of which being transmitted to the aqua labyrinthi in the scala tympani excite undulations which influence at least the nervous expansion in that part of the cochlea. I know that atmospheric undu-

lations are sufficient to excite vibrations in the membranes of the fenestræ capable of producing good hearing, as I have already noticed that, contrary to the general opinion, and to a recent declaration of Mr. TONYBEE'S, I have several times seen the *stapes* lost, with the other ossicles, and of course the entire membrane, the membranes of the fenestræ remaining, yet with the enjoyment of a very useful amount of audition, and in one instance the sense was so nearly normal that the patient, a physician, was not aware of any imperfection. But though nature, by education of the remainder of a partially lost organ, is capable of supplying an important deficiency, it by no means follows that the new mode of action is natural or normal, but it rather proves the abundant resources naturally possessed to vicariously supply necessary or useful function. I rather adopt the opinion, which I first learnt from the late Sir CHARLES BELL, and which, I believe, originated from that accomplished physiologist, that in a healthy organ the undulations of the aqua are wholly excited by the movements of the stapes upon its membrane, and running through the windings of the labyrinth they impinge upon the inner surface of the membrane of the round opening, which recedes or bulges out towards the tympanum in exact correspondence to the projection inwards of that of the oval opening; the air most likely reacts upon the membrane of the round hole, and thus arise the requisite undulations of the fluid between the two fenestræ; in this manner the air influences both tympanic membranes alike. This view is borne out

by the impossibility of an inelastic fluid undulating in a completely filled tube without some means of recession; also by the position of both membranes being admirably contrived for the offices now described, whereas that of the round fenestra is inconveniently placed to receive the atmospheric undulations. It is true that if the membranous labyrinth were not accurately filled with the water, but partly occupied by elastic air or gas, undulations might take place without the aid of a receding membrane, and which would then, more readily than I am now able to do, account for the arrangement of the cupola or dome of the cochlea, which would serve as a nodal point, where the undulations proceeding in opposite directions from the two fenestræ would meet, and neutralizing each other, become at rest. (*Appendix* 3.)

If the doctrine of the insufficiency of the elasticity of the tympanic air to permit the vibrations of the membrane, the oscillations of the bones, and its own undulations, be correct; and if it be true that air retained for a long while in a closed chamber undergoes such alterations as to unfit it for undulations and the support of surrounding structures, to a greater extent than at present can be accounted for by its rarefaction, we can readily comprehend that the uses of the eustachian tube are to admit a constantly renewed supply of fresh atmosphere into the cavity, and to afford an opportunity to the air to advance and recede into and from the tympanic aperture during its undulations. Mr. Wharton Jones has published his belief that the eustachian tube is generally closed;

and Mr. TOYNBEE has more lately controverted the generally received opinion, stating that the tympanum is necessarily for its function a closed cavity; that the guttural extremity of the Eustachian tube is naturally shut, being opened only occasionally by the action of the Levator Palati Mollis and Circumflexus Palati muscles, and that only during the act of deglutition, for the purpose of allowing mucus to escape, and the ingress and egress of air; and the chief reasons adduced are, that during the act of swallowing with the nose and mouth closed a feeling of fulness or distension in the tympana is produced, to be relieved only by another similar effort; and that when descending in a diving-bell, the unpleasant, or even painful, sensation in the ears is instantly removed by the act of swallowing, allowing the condensed air in the bell to enter the tympanum and support the membrane, by counterbalancing the outer pressure.

The operations of the pharyngeal muscles upon the tube admit of doubt not only in man, but in the lower animals, therefore the dogma laid down that they open it must be regarded as far from being proved. This theory is ingenious and well argued, as is every opinion issuing from a mind so talented and industrious as my friend's, yet several objections and difficulties occur to my mind which forbid my present acquiescence in the opinion. 1st, It is certainly not *requisite* that the tympanum be a closed chamber; we see apertures through the membrane arising from accident, and unaccompanied by other læsion, without producing the slightest deafness. 2nd, In the cat,

tiger, ox, and perhaps all the mammalia, an aperture in the upper part of the membrane normally exists, doubtless for the purpose of maintaining a constant equilibrium between the external and internal air. I am aware that it may be objected, that in these animals the nice appreciations of varied sound are not required for the purposes of articulate language, and that a less extensive range of vibration is better suited to their economy, which is thus provided for. 3rd, The air, in many cases, constantly flowing outwards from the tympanum through an aperture, becomes one cause of tinnitus aurium, occasioned by the vibrations of the lips of the opening, which necessitates its continued entrance by the eustachian tube; for it is hardly to be imagined that it flows inwards through the same aperture, in which case the opposing currents would neutralize each other; and if it be asserted that the air flows inwards from the outer ear, the same difficulty will maintain, for it must then leave the cavity by the eustachian tube. 4th, In my experience, the more complete closure of an aperture in the ulcerated membrane, by Mr. TOYNBEE'S artificial membrane, has not been attended with such useful results as the imperfect closure by the wetted cotton introduced by Mr. YEARSLEY. 5th, The unpleasant, sometimes painful, sensation upon every inspiration, without deglutition, when a resisting piece of hardened wax lays against the membrane, evidently occasioned by the prevention of its slight movement, and the instant relief upon the removal of the foreign body. 6th, The fact that when the eustachian tube

is closed by contraction, or by pressure of an enlarged tonsil—both conditions of extremely rare occurrence—deafness is the result, and removable by re-opening the tube. 7th, The circumstance that in a case of obliteration of the tube from ulceration of the fauces producing deafness, the sense was in a fair degree restored, while the catheter remained in the tube. 8th, The case of a child, William Lee, being instantly restored from deaf-dumbness, of four years' duration, upon catheterizing the eustachian tubes, by which I expect a globule of inspissated mucus was displaced from the tympanic end of the tube; the child requiring no further treatment than subsequent education. 9th, In cases of mucous accumulation in the cavity, the immediate and very complete restoration from extreme deafness, often temporary, but sometimes permanent, upon catheterism, which can hardly be solely attributed to the removal of the fluid. I feel, however, that this fact may almost equally apply to the opposite argument. 10th, That the same "sensation of fulness and pressure is experienced in the tympanic cavity" by pressing the finger into the outer meatus, as is produced by an act of deglutition; and in both instances, in consequence of the condensation of the air upon the membrane, though, of course, upon the opposite surfaces. 11th, That it is of necessity that the effect of deglutition, the nose and mouth being closed, must condense the air in the cavity through the patent tube. 12th, That a more remarkable condensation takes place, sometimes even to rupture the membrane, in consequence of a forced

expiration, without any probable action of the muscles of deglutition, as is not infrequently seen in cases of hooping.cough, or other spasmodic respirations. 13th, The great improvement in hearing in some cases of deafness from loss of nervous functions upon gaping merely, as was well exhibited in an interesting case this morning. 14th, That the attachments of the two muscles, the Levator palati and Circumflexus palati, to the cartilaginous portion of the eustachian tube, inasmuch as a muscle always contracts from its both extremities, seem destined to close rather than to open the tube. I speak here with some diffidence, knowing that the best Anatomists hold diverse opinions upon this subject. (See *Appendix* 4.) 15th, In birds the arrangement of these tubes is peculiar, for the purpose of allowing them to respire freely, and to catch and swallow their food during their rapid flight through the air, and the free communications which exist between their tympana and the large air receptacles will allow with impunity a longer closure of these tubes. In many mammalia, particularly in the cetacea, the structure is also peculiarly modified for adaptation to especial habits. 16th, The generally received opinion, that all the openings,—including those of the eustachian tubes,—into the pharynx, are usually patent, becoming closed during the act of swallowing, by the expansion and elevation of the soft palate, is more in accordance with the acknowledged process of deglutition. 17th, Were it otherwise, the tubes would be opened only at a moment the most inconvenient for the admission of air, when

they were closed towards the respiratory organs, and must then be supplied through the nares; and 18th, The circumstance that in many persons labouring under a thickened condition of the mucous membrane of the tympanum, very complete deafness occurs during mastication and deglutition, partly occasioned doubtless by the imperfect admission of air through the eustachian tubes. I have not alluded to Mr. Toynbee's statement of the readiness with which the unpleasant sensation in the ears, arising from the pressure of the condensed air when descending in a diving-bell, may be removed by the act of deglutition, as I have not yet had an opportunity to verify the fact, and am not aware upon what data it is founded.

[See *Appendix* 5.

APPENDIX.

1. It is not usual for the congenitally deaf mute to be *entirely* deprived of the sense of hearing, such an unhappy consequence more commonly resulting from acquired disorganization; in the congenital affection the sense is ordinarily insufficient to permit the acquirement of articulation, yet it may be so increased by education in the less severe cases as to admit the patient to acquire an useful amount of speech: in one interesting case I was much gratified by such a happy result.

2. The Meatus Auditorius in the neat animals is so very long, the membrana tympani consequently so deeply seated, that it is more difficult than would be expected to expose the membrane from without; it is easier to open the cavity of the tympanum, and view the membrane from within.

3. Some Physiologists retain the opinion, that the undulations of the air in the tympanic cavity, and the oscillations of the bones, take place in the direction opposite to those I have described: namely, that the undulations of the air excited by the vibrations of the membrana tympani, impinge upon the membrane of the fenestra rotunda, the vibrations of which are communicated to the aqua labyrinthi and alone excite the required undulations of that fluid; and that the necessary recession is allowed by the yielding from within outwards of the membrane of the fenestra ovalis, and which thus forces the chain of bones, commencing with the stapes and ending with the malleus, against the membrana tympani, by which it is either restored to rest, or to a condition to receive a renewal of external impressions. I repeat my dissent from this doctrine for the reasons already stated; and, furthermore, that it is in more natural accordance that the important effects should be produced through a solid, rather than an ærial medium, that being so much more powerful a conductor of sonorous vibrations.

4. In recently dissecting these muscles in the human subject, (the Levator Palati Mollis, and Circumflexus Palati,) assisted by two Anatomists, one of whom previously declared his conviction that they closed the eustachian tube in their action, and the other that they opened it, we arrived at the unanimous conclusion that the muscles exerted no direct effort whatever upon the Cartilago-fibrous mouth of the tube; but by expanding the Velum Palati, and drawing it upwards and backwards, they carried it against the opening of the tube, and thus indirectly closed it.

5. I learn from the diver at the Polytechnic Institution, that when he gradually and slowly descends under the water, he does not require to make an effort of swallowing or otherwise, the uncomfortable sensation not occurring in his ears; but when he descends suddenly and rapidly, loading himself heavily for that purpose, the feeling of pressure, or *stuffing*, is proportionally great, and he makes the effort which removes it. This fact appears to conclusively confirm my opinion, that a certain length of time is required for the condensed air of the Bell to enter by the eustachian tube, though open, and displace the residual air contained in the tympanum, which change is expedited by the pressure of the Velum Palati against the mouth of the tube, just in the same manner as the pressure of the finger upon the outer meatus, condenses the air upon the external surface of the membrana tympani, giving rise to a similar feeling. This explanation is perfectly in accordance with the gradual manner in which the atmosphere reaches the air-cells in respiration.