up a fragment of pottery. [This fragment was exhibited when the paper was read.] Having been found at a depth of 39 feet, it would seem to be a true record of the existence of man 13,371 years before A.D. 1854, reckoning by the before-mentioned rate of increase of $3\frac{1}{2}$ inches in a century; 11,517 years before the Christian era; and 7625 years before the beginning assigned by Lepsius to the reign of Menes, the founder of Memphis; of man, moreover, in a state of civilization, so far, at least, as to be able to fashion clay into vessels, and to know how to harden them by the action of a strong heat.

February 18, 1858.

LEONARD HORNER, Esq., Vice-President, in the Chair.

In accordance with notice given at last Meeting, the Lord Talbot de Malahide was balloted for and duly elected a Fellow of the Society.

The following communication was read:—

"On the Functions of the Tympanum." By JAMES JAGO, A.B. Cantab., M.B. Oxon., Physician to the Royal Cornwall Infirmary. Communicated by Prof. STOKES, Sec. R. S. Received January 23, 1858.

(Abstract.)

As in my present effort to obtain further light upon some of the still obscure points in the physiology of the ear I have been *primarily* guided by observations made upon my own ears, I should premise that both are very efficient for hearing; but that they differ from each other in the important particular that the faucial orifice of the right Eustachian tube closes much less tightly than that of the left, insomuch that there are times when the former becomes quite patent, with no disposition to collapse. Again, having lately been troubled for above five weeks with a *tympanic* deafness, I carefully registered a series of auditory phenomena resulting therefrom, and

found them exceedingly noteworthy. Lastly, I have made certain experiments upon the external auditory canals of the sound ears.

I compare, then, with one another, the phenomena yielded by a normal ear, an ear with an open Eustachian tube, an ear with the drum impaired in a particular manner, and an ear whose external meatus is in a known altered condition; calling in facts from other sources in aid; and, finally, endeavour to determine the uses to be assigned to the several structures of the drum in order to embrace all the phenomena*.

I assure myself that my Eustachian tubes are ordinarily shut, by the difficulty (greater for my left one) of forcing the breath into the drums when I stop my mouth and nose, and the hinderment to its escape till I swallow or eructate, showing that those acts open the tubes. If we mark the sinking-in of the lachrymal sac when we swallow with the mouth and nose stopped, we may see that the naso-guttural cavity *enlarges* as the glottis is closed in that act, *producing a partial vacuum* in the drums, and therefore from the greater barometric pressure a feeling of tightness upon the membrana tympani, whilst from loss of usual pressure the Eustachian tubes thereupon close more firmly, and the faucial parts swell and stick together.

I can readily distinguish the act of opening the Eustachian tube from all other guttural ones, both by hearing and feeling. A tearing sound, or an irregular run of clicks, marks a slower, a sharp click a quicker opening of the tube, a *souffle* the rush of air through the patent tube, and a small crack the displacement of the membrana tympani. I frequently perceive these phenomena in deglutition, though, owing to the strong pressure of the current of ejected air in the fauces, more especially in eructation. Sometimes also in yawning, showing that a sundering contraction of the muscles of the pharynx and palate attends the opening of the tube.

With the tube patent I feel the membrana tympani, as expiration and inspiration alternate the greater amount of pressure in its two surfaces, oscillating from outwards to inwards, as the inner canthus of the eye, as reached by the nasal duct, may be seen to do. In violent explosive expirations, the strength of the membrane is

* A note shows, that though I speak particularly from these sources, the results rest on much broader grounds; and mentions how far anything like any portion of this paper has been previously published by myself or others.

severely tested ; the mildest speaking, coughing, or sneezing even, is always disagreeably felt thereon.

But to pass to the attendant sonorous phenomena :—the rippling of the air in the tube at each elevation and depression of the ribs expresses itself by a *souffle,* and every word I utter is taken to the labyrinth directly through the tube with a force that proves annoying ;—observations which plainly evince why the Eustachians are usually impervious, and why they almost never open except at that instant of deglutition, or of the reverse act, eructation, which occludes the glottis.

From numberless observations, I am able to affirm that the faculty of audition is not at all deteriorated by patency of the tubes, however the ordinary use of the ear may be perplexed by sounds entering the tube. Nor does stretching the membrana tympani, by augmenting or diminishing the aërial pressure on its inner surface, enfeeble hearing.

I will now turn to observations made upon my left ear when it was deafened. I show that the external meatus was unaffected ; and if I rubbed my finger over the skin covering the bone behind the ear, or carried the ticking of a watch to the bottom of the meatus by means of a metallic probe, and then did the like to the other ear, I heard well, and as well upon one as the other. Hence the labyrinth and acoustic nerve remained healthy, and the drum alone was affected. Singing noises in the head had been developed just to the same extent as hearing had been blunted,—phenomena that for three weeks before an instantaneous cure remained *quite unchanged.*

The noises were caused by the circulation of the blood about the drum, for they rose and fell as the circulation was quick or otherwise. And I was led to the belief that these noises were not created by any morbid change of local circulation, *but that, by a morbid change in the acoustic properties of the tympanum, ordinary movements of the blood thereabouts were heard in a multiplied manner* ; for the click and souffle from air entering the Eustachian tube, as heard in the healthy ear, were wonderfully magnified in the deaf one. The louder souffle, that of eructation, normally but very weak, even when the intruding air strongly forces outwards the membrana tympani, in the deaf ear was always a very pronounced *bruit.* And a couple of other sounds from distinct sources generated within the

site of the membrane are described, which, hardly audible in a normal ear, are loud in an ear thus diseased.

Thus a group of phenomena beckon to the inference, that this deafness had so modified the acoustic properties of the drum, as *both* to render all sonorous vibrations affecting the air within it by far more audible than before, and all those entering the meatus auditorius externus as much less audible than before. What physical cause can bring about these *inverse* effects?

1. If the fenestra rotunda be the chief portal for sound, no change at it could render one set of sounds more audible without doing so for the other also.

2. If sound be mainly conveyed to the labyrinth by undulatory displacements of the membrana tympani, causing *bodily* oscillation of the ossicles, the membrane could not be rendered more responsive to aërial waves falling upon one side of it without becoming equally so for those falling upon its other.

3. If the fenestra rotunda chiefly afford passage to sound, and the membrana tympani has acquired an abnormally high reflecting power, repelling vibrations that would heretofore have escaped through it from the drum back upon this fenestra, and those that fall upon its outer surface back through the meatus, effects of an *inverse* kind do result. This hypothesis, therefore, cannot be rejected without a careful consideration.

Let us inquire, then, what influence the existence of a membrana tympani would, under this supposition, exert on hearing. Sonorous vibrations impressed upon the walls of the head, that is, of the external meatus, are heard more loudly when we anyhow cover this canal so as to close it, as any cavity when closed resounds like an open one of greater size (J. Müller). In again testing this principle, I have used various materials for closing the meatus, have plugged the entrance, and laid the thing over it, and observe always that the smallest orifice in the occluding body detracts from the resonance; which I know to occur in the confined air, and not in the parietes of the canal, for my deafened ear was deaf to it. Such experiments, however, do not evince that the membrane aids *hearing* by resonance, but the contrary. Dealing with vibrations already existing in the walls of the cavity insulating the air, they do not at all imitate the case of vibrations passing into the tympanum *through a*

medium,—the membrane. As no substance can be applied over the meatus, however it be done, which does not hinder our hearing of external sounds just as much as it occasions resonance of parietal ones, the membrane on this supposition must in some degree or other be a positive detriment to the auditory function. Besides, were hearing aided by resonance within the drum, a patent Eustachian tube by allowing vibrations to disperse must impair hearing, which I know *not* to be the case. Again, if we assume the membrane to but slightly arrest the transition of sound from the outer to the tympanic air, to be, in short, an unavoidable impediment to hearing, fulfilling some non-acoustic purpose, the loss of it would not prove at once, as it does, a serious detriment to hearing rather than some benefit. I may append too, that were it but a trifling obstacle, the group of sounds occurring within it, so described, should be augmented by resonance in the external meatus, on its outlet being stopped; yet I can detect nothing of the sort. Further, I squeezed a plug of chewed brown paper, and one of dry paper, firmly into the bottom of the meatus of the healthy ear, against the membrane, covered the membrane with a stratum of wax, and filled the meatus with water; but in not one of these experiments were the said group of sounds rendered louder. So that it appears that the application to the membrane of even a highly reflecting surface fails to intercept and cause to return intra-tympanic sounds, which can only be because the membrane is difficult for such sound to pass through. But if the membrane highly resists the transition of aërial vibrations, it (the fenestra rotunda being the chief portal) is a serious detriment to hearing. Hence this fenestra cannot be of this acoustic consequence. And we must have recourse to the only other theory which suggests itself, which is—

4. *That the membrane and ossicles form the essential path for sonorous vibrations, which traverse it by the mode of condensation and rarefaction; that aërial ones impinging upon the outer surface of the membrane easily impress themselves upon its substance, and pass into the ossicles, whilst the inner surface presents a great obstacle to their escape into the air in the drum, and equally repels vibrations that fall upon it from this air.* Thus, when disease nullifies the great reflecting qualities of the inner surface, much of the sound from without passes into the drum and is wasted, or deafness re-

sults; whilst much of that in the drum enters the membrane, and some of it finds its way along the ossicles, and noises in the head are engendered.

Now I find that the cutaneous surface of the drum-head admits vibrations from air with very much greater facility than water does, that is, readily; for on filling the external meatus of the sound ear with water, and then letting it leak out again, I remarked that for more than half an hour afterwards septa of water were constantly forming themselves across the canal and producing much deafness, and then breaking again with a loud noise, and the deafness vanishing. After some evaporation the following instructive effects alone took place:—the membrane would attract a film of water over its surface, and deafness ensue; but on a gust of air plunging into the drum through the Eustachian tube, the membrane springing outwards with a smart smack, would throw off the fluid, and the hearing as *instantaneously* be restored. This would *gradually* wane away again by the re-attraction of the water, to be instantaneously regained again, and so on. But since the transition is easy between the membrane's outer surface and air, what has been said above shows that it must be difficult between the inner surface and air, and the statement in (4.) is demonstrated.

Accordingly the external layer of the membrane is formed of skin, a dry tissue of loose texture, penetrable by air, and coming into intimate relation with it; whilst the mucous membrane of the drum is, as it were, unparalleled not only for tenuity, but compactness and high vascularity, though it is barely possible to verify the presence of mucous exudation upon it, affording a glassy surface which is a formidable barrier to the passage of vibrations from it to air, and *vice versâ*; and this is so reflected, that the membrane and ossicles leading to the labyrinth lie *without* it, confining useful vibrations to their destined path, and excluding hurtful ones from it; and the mastoid cells help to further stifle such vibrations as by any accident intrude upon the air in the drum. The membrane of the fenestra rotunda, by its elasticity, protects the acoustic nerve from undue compression, &c. The membrana tympani avails acoustically by its *area*, whilst its flexibility, the joints in the ossicular chain, &c., are mere machinery for conveying, under all contingencies, vibrations to the fenestra ovalis, and provision against mechanical accidents. The

structure of the labyrinth admits of explanation, in a great degree, upon like principles.

The personal case of deafness studied in this paper was from a cold draught on the ear, a mere inflammation of the mucous lining of the drum, ultimately forming a layer of dried mucus upon the membrana tympani, which originally involving much air-bubbles, remained very permeable by air, and assimilated acoustically the inner face of the membrane to the cuticular outer one. The instantaneous dispersion of the noises and deafness was caused by the sudden peeling off of this false cuticle; whilst a film of water upon the cuticular face assimilates that to the inner one, when the ear excludes both tympanic and outer sounds from the labyrinth. Deafness produced by disease in the external meatus only yields noises when it propagates irritation so as to excite secretion of mucus on the inner face of the drum-head. Simple perforation of the drum-head only deafens in proportion to the extent of surface removed. If there co-exist a more or less fluid discharge from the drum, this spoils hearing by covering the cuticular surface of the membrane, though it may not deviate so much acoustically from that lined by mucous membrane as to very materially damage it. To remedy such deafness mechanically, we should first essay to rescue the cuticular face from the fluid by placing some material to draw off the discharge from it, so as to keep the membrane fit for its duties, and still exposed to aërial vibrations. If the mischief is so extensive that we are obliged to employ some disc to rest against the remaining ossicles as a substitute for the true membrane, we should try to form one with surfaces acoustically imitating those of the membrane itself.

The paper concludes by pointing out how the various injuries which have been known to occur by disease or otherwise to the different parts of the tympanum, are readily accounted for by the functional hypothesis here submitted.