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A CONTRIBUTION TO THE

ANATOMY OF THE ELEPHANT'S EAR

BY

ALBERT H. BUCK, M. D.,

Clinical Professor of the Diseases of the Ear, College of Physicians and Surgeons, New York.

presented by the author.

[Re-printed from The Transactions of the AMERICAN OTOLOGICAL SOCIETY, 1888.]

With the author's compliments.

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A CONTRIBUTION TO THE ANATOMY OF THE ELEPHANT'S EAR.

By Albert H. Buck, M. D., *New York, N. Y.*

The specimens which I am about to describe were very kindly sent to me for dissection by Prof. Burt G. Wilder, M. D., of Cornell University. The largest of the three represents the greater part of the right temporal bone of the large show elephant, Alice, the mate of the famous Jumbo. It had been sawed out from the skull in such a manner as to show four plane and two uneven surfaces. The plane surfaces are: a horizontal one, which is situated just above the level of the external auditory canal and middle ear, leaving both of them intact, but traversing many of the large air cells which surround these parts; an anterior transverse vertical section, which bisects the anterior end of the middle ear a short distance back of the point where it merges into the Eustachian tube; a posterior transverse vertical section which passes through a communicating system of air cells;[1] and, finally, a median antero-posterior vertical section which leaves one condyle of the occipital part of the occipito-vertebral articulation attached to the specimen. The outer and the lower faces of the specimen represent the natural surfaces of the skull as they appear after the soft parts have been entirely removed. The second specimen contains the entire Eustachian tube of the right side, from its pharyngeal orifice to its termination in the narrowed anterior end of the middle ear. The third specimen consists of the membranous portion of the left

[1]The planes of these two sections form a sharply acute angle with each other, as will be seen by an examination of Fig. 1.

Eustachian tube, divided transversely at a point about five inches from its pharyngeal orifice, and slit up longitudinally throughout a large part of its length. All the specimens are preserved in alcohol.

The external auditory canal.—The auricle had been cut away as close to the skull as possible, and all that remains of the cartilaginous portion of the canal is represented by two overlapping, funnel-shaped gutters of cartilage, which together form a complete conical framework around the skin-lined orifice of the external auditory canal. This orifice, which is nearly circular in shape, measures 9 millimeters in diameter. It enters the skull in a direction nearly parallel with the plane of the horizontal section. At a distance of about 2 centimeters from the orifice, the canal begins to bend downward in its course, and at the same

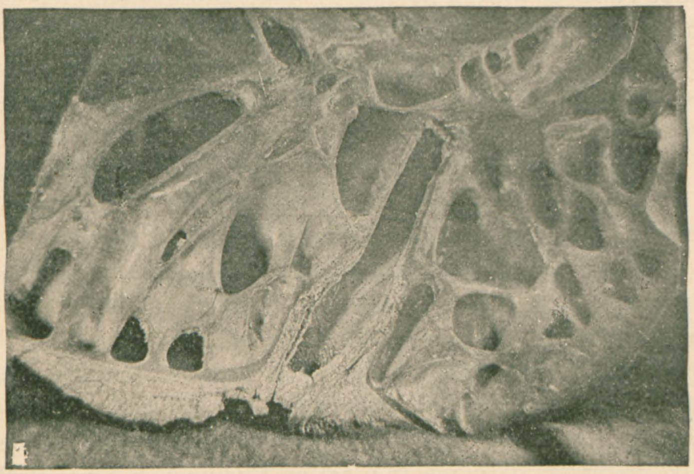

Fig. 1. Horizontal section of the skull, a little above the level of the external auditory canal. To expose the latter throughout the greater part of its course, the upper wall of the bony cylinder has been chiseled away. (Reduced to one-third of the natural size of the parts.)

time its calibre becomes considerably larger. At a distance of 7 centimeters from the external orifice it measures

15 millimeters in diameter. In the vicinity of the membrana tympani the calibre of the canal again diminishes in size—to 9 or 10 millimeters, as nearly as I could ascertain. The ring of cartilage, representing, so to speak, the insertion of the auricle, loses itself in the cutaneous lining of the canal at a distance of about 5½ centimeters from the outer orifice.[1] The entire length of the canal from the external orifice to the membrana tympani, measures 16½ centimeters, or about 6½ inches. The skin lining the canal, for a distance of about 2 centimeters (¾ inch) from the orifice, presents a finely corrugated appearance, the folds running in a direction parallel with the long axis of the canal. From this point inward, as far as to the drum-membrane, it presents a smooth, almost polished appearance.

As may be seen in the figure, which represents the parts reduced to one-third of their natural size, the cylinder of bone containing the external auditory canal lies in the midst of a labyrinth of inter-communicating cells or chambers of varying size and shape. About midway between the drum-membrane and the outer orifice this bony cylinder lies in front of a cavity of unusual size How far this cavity extends posteriorly I am unable to determine, as the back part of the skull is not before me; but that part of the cavity which is visible in the specimen measures a little over 11 centimeters (4½ inches) in its transverse, and at least 15 centimeters (6 inches) in its antero-posterior diameter; this latter measurement extending from the surface of the section (posterior transverse vertical section) to the anterior limits of that portion of the cavity which lies in

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[1] In this particular specimen the canal was found to be filled throughout its entire length with a semi-solid material which looked like an admixture of cerumen and cast-off epidermis scales. The natural inference was, that the sedentary life and the unwholesome diet (candies, peanuts, etc.) to which show elephants are almost necessarily subjected, had produced this condition of what, in a human being, would be termed eczema.

front of and above the bony cylinder. All these (presumably) air chambers communicate freely with each other, sometimes by very broad openings. So far as I am able to find out by careful exploration with a probe and by forcing smoke through different channels, these cavities do not communicate with the tympanum proper, but, as will be seen farther on, they do communicate at one point with what I have termed the subsidiary tympanic cavity. On the other hand, they apparently communicate directly with the nasal system of cavities. In the human being the mastoid cells do not communicate with the cavities belonging to the nasal system except through the Eustachian tube. In this respect, therefore, the mastoid cells[1] of the elephant differ materially from those of man.

The *Eustachian tube*, from its pharyngeal[2] or nasal orifice to the point where it emerges into the tympanic system of cavities, measures 11 centimeters ($4\frac{3}{8}$ inches). Its nasal orifice, in the present specimen, is more or less mutilated; but it is evident that in its general features and size it resembles very closely the pharyngeal end of the human Eustachian tube. The latter is perhaps a trifle larger, and it stands out more prominently from the surrounding surface

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[1] In the human being pneumatic cells are found not only in the mastoid process, but also above the dense cylinder of bone which immediately surrounds the calibre of the external auditory canal,—that is, in the very same locality as that occupied by the cells here under consideration. Hyrtl, in his "Anatomische Untersuchungen über das Gehörorgan des Menschen und der Säugethiere" (Prag, 1845), says that "the pars mastoidea of the temporal bone is, according to Köstlin, wanting in the hippopotamus, the elephant, and the rhinoceros." But this statement probably has reference merely to the absence of a visible bony prominence behind and below the orifice of the external auditory canal, and is not to be interpreted as signifying that these three animals lack the system of communicating pneumatic cells which constitutes the essential feature of the mastoid process.

[2] The specimen is too fragmentary in character to warrant me in drawing any conclusion whatever in regard to the relations of the peripheral end of the Eustachian tube to the nasal and pharyngeal cavities. It is for this reason that I employ the terms pharyngeal and nasal indifferently.

of the mucous membrane. Toward the tympanum the tube ends in a nicely rounded orifice, one side of which apparently corresponds with the termination of the long and thick cartilaginous cylinder, around which the tube is curved, gutter-like. As the specimen had been preserved in alcohol for two or three months I was not able to make out satisfactorily, by simple naked-eye inspection, the exact relations of the different tissues of the tube to each other. At the two orifices the calibre appeared to be small, *i. e.*, simply large enough to admit easily a large-sized probe. A section near the middle portion of the tube revealed at first no calibre whatever, the opposite walls being apparently in perfect contact at all points. By manipulating the specimen, however, these closely applied walls could be made to separate, thus revealing to view a calibre large enough to admit the little and perhaps even the third finger. The top part of a question mark represents fairly well the cross section of the calibre of the tube, when in a state of rest, at a point about half-way between the two orifices. Toward the tympanum the tube does not open directly into the tympanic cavity proper, but into an elongated air chamber, which lies at a somewhat higher level than this cavity, and opens into it through an elongated slit-shaped opening. This chamber commences as a *cul-de-sac* at the orifice of the tube, and gradually increases in height and slightly in breadth, throughout a length of between 4 and 5 centimeters (about 2 inches). Like all the air chambers thus far mentioned, its walls consist of thin bone lined with a smooth mucous membrane. The height of the cavity, at a distance of $3\frac{1}{2}$ centimeters from the orifice of the tube, measures nearly three centimeters ($1\frac{1}{8}$ inch); the breadth varies but does not exceed $1\frac{1}{2}$ centimeter ($\frac{5}{8}$ inch) at any part. The opening from this chamber into the tympanum proper is an elongated slit and presents one or two peculiarities. The edge of the opening, on the side toward the median line (*i. e.*, toward the promontory), is provided with two odd-looking osteophytes, one resembling a cock's comb, the other a padded drum-stick, such as is used in beating a big bass drum. The slender handle of this miniature drum-stick is perhaps 4 millimeters long and scarcely half a millimeter thick, and at the end of it is a well rounded knob, fully two millimeters in length and about a millimeter and a half in thickness.[1]

Fig. 2. View of the membrana tympani and arched roof of the passage leading from the tympanum proper to the Eustachian tube. The sharp-edged ridge running along the middle of the arched roof and dividing it into two subordinate shallow inverted grooves or arches, may be seen in the picture. (About one-third natural size.)

Still another peculiarity is observable at the opening which leads from the Eustachian vestibule, if I may so call it, into the tympanum proper. A little below the opening the floor of the vestibule becomes sharply grooved — very much like the groove of bone which, in the human being, holds the belly of the tensor tympani muscle — and runs slightly upward, backward, and inward to the anterior and

[1] Hyrtl says nothing about the occurrence of these osteophytes in the elephant in particular, but he refers to their existence in some animals in the following words: "In certain animals possessing a roomy tympanic cavity there are found, either in the middle ear proper or in some of the cavities which communicate with it, bony outgrowths of characteristic shape. As these objects are found, with rare exceptions, to be always of about the same size and to occupy relatively the same positions, the inference is permissible that they are not mere accidental formations, but probably possess some functional importance. * * * * * * * In the posterior segment of the bulla [tympanica] of the lion these curious structures attain their highest degree of development, and may be seen here in the form of pear- and other-shaped bodies springing by a slender (sometimes hair-like) stem from the floor of this cavity." From this description, and also from the pictorial representations which he gives of these bodies, it is clear that they are identical with those which I have described above.

upper portion of what should probably be termed the annulus tympanicus. As the groove emerges from the opening it becomes a sharply projecting gutter (like those placed under the eaves of houses), and continues as such close up to the top of the membrana tympani. (See Fig. 2.) The roof of the cavity immediately above this gutter, and running parallel with it, is arched, like a second inverted gutter. A low but sharply defined ridge runs along the middle of the arch, dividing it into two minor grooves or arches. The outer one of these two grooves—that is, the one lying farthest from the free cavity of the tympanum proper—is smooth and free from openings throughout its entire length, while the inner one displays three openings—two oval in shape and one nearly circular—which lead into adjacent air chambers. These chambers have no communication one with another, nor with any of the neighboring cavities. The height of the space between the grooved incline and the arched roof is 21 millimeters (nearly $\frac{7}{8}$ inch). The breadth of the grooved floor, opposite the osteophytes, is 1 centimeter ($\frac{3}{8}$ inch).

The tympanic cavity proper.—Looked at from in front, the posterior end of this cavity is shaped very much like that of the human being; all the dimensions being, of course, very much larger. From its anterior portion there branches off, in a posterior direction, a much larger cavity, the long axis of which forms with the long axis of the tympanic cavity a slightly acute angle. The junction of these two cavities converts the promontory into a bold projecting angle of bone.

The roof common to both these cavities presents no features of special interest.

The height of the tympanic cavity, directly abreast of the membrana tympani, is 27 millimeters ($1\frac{1}{16}$ inch) and its average breadth, 25 millimeters (about 1 inch). Its length could not be accurately ascertained, but it must have been at least 50 millimeters (2 inches).

The outer wall is made up of the grooved structures which I have described above, and of the *membrana tympani*. This latter membrane, which is shown fairly well in Figs. 2 and 4, is decidedly conical in shape, as seen from

Fig. 3. View of the tympanic cavity from above and in front, showing (distinctly in the photograph but very faintly in the engraving) the stall-like openings under the floor of the tympanum, a part of the jagged wall surrounding the mouth of the well-like excavation, the two osteophytes and the grooved floor of the passage-way leading from the tympanum to the Eustachian tube. (Slightly reduced in size.)*

the side of the tympanum, while the surface of the membrane on the side toward the external auditory canal presents scarcely any hollowing-out at all,—barely enough to justify the use of the expression, a shallow cone. This lack of agreement between the two surfaces is due apparently to two facts: the marked curving inward of the tip end of the manubrium mallei, and the great thickness of the soft parts in the vicinity of the umbo of the membrane. From the great resistance which the latter offers to pressure made at any point of its surface I should infer that its thickness is at no point less than one millimeter. As a

*The difficulties encountered in photographing the middle ear from different points of view were found to be very great, and as a consequence the half-tone pictures which accompany this article leave very much to be desired in the way of clear definition.

whole the membrane is nearly circular in shape and measures fully two centimeters ($\frac{3}{4}$ inch) in diameter.

Posteriorly the tympanic cavity terminates in a *cul-de-sac* composed of soft tissues, which form a thick diaphragm separating the tympanum proper from a second, much smaller cavity containing the head of the hammer, all of the anvil, and presumably the stirrup. From the lower part of this *cul-de-sac* the chorda tympani nerve passes outward and forward, in the form of a strong rounded cord, across the inner aspect of the neck of the hammer, at right angles to the manubrium. There is apparently no trace whatever of a tensor tympani muscle.

The comparatively small area of bone surface constituting the inner wall of the tympanic cavity, presents, directly opposite the umbo of the drum-membrane, a rounded eminence in which no openings are visible. This is probably the analogue of the promontory in the human being. Below it, and situated more posteriorly, is a rounded ridge of bone which terminates in a hooded opening or niche, suggesting the niche for the fenestra rotunda; but a careful exploration with the probe fails to detect any break in the hard, bony surface at the bottom of the niche.[1] Furthermore, this niche faces forward and inward, whereas that of the fenestra rotunda in the human being faces backward and outward.

The mere use of a probe is not sufficient to determine this question satisfactorily, and I must, therefore, leave it unsettled. The rest of the inner wall of the tympanum, up

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[1] Hyrtl (op. cit.) says that the fenestra rotunda, in the elephant, is to be found behind an angular overhanging projection of the promontory, and that the actual opening of communication between the tympanum and the scala tympani is a mere narrow slit. He quotes Cuvier as saying that the fenestra rotunda of the elephant is very small, irregular in shape, and concealed behind a projecting part of the promontory. At the same time he states that Fick (*Ueber das Labyrinth des Elephanten*, in Mueller's Archiv, 1844, p. 431) believes that this opening is the outlet of the aquæductus cochleæ, and that the elephant has no true fenestra rotunda.

to the point where it bends abruptly around the blunt anterior edge of the promontory just described, presents no features of special interest.

The floor of the tympanum, in the vicinity of the promontory, is smooth, but on a line with the anterior edge of the annulus tympanicus, it terminates abruptly in a thick, rounded edge which projects free into the air space. One might compare it to the edge of a semi-circular platform surrounding a deep pit. In this pit, directly under the platform, may be seen three sharp-edged vertical membranous septa, dividing the space into three deeply-shadowed recesses and one shallow *cul-de-sac*, all facing obliquely inward and forward. Taking them in regular order from behind forward I explored each stall with the probe, and found that the first one is a mere *cul-de-sac*, extending to only a slight depth beneath the floor of the tympanum. The second one, which presents the largest opening, has no visible floor, but the latter is found, on exploration with the probe, to lie at some distance below the lower edge of the entrance. The long axis of this stall measures 33 millimeters (1¼ inch) and it runs apparently directly underneath, and nearly in the same direction with, the external auditory canal. By withdrawing the probe a short distance and at the same time causing it to press against the anterior wall of the channel, one becomes conscious that the end of the instrument reaches the free edge of an elastic septum that divides this second stall into two subordinate channels. The long axis of this second subordinate channel measures 30 millimeters (1⅛ inch). The third stall is somewhat narrower at the entrance than the one just described. It consists apparently of a single passage without any bifurcations, and measures, from the entrance to its farther end, nearly 70 millimeters (2¾ inches). Its general direction corresponds quite accurately with that of the external auditory canal. The fourth stall has a length of 52 millimeters (2 inches), and its long axis, whose general direction is outward, forms an angle of about 40° with the axis of the external auditory canal. The floor is lacking close to the entrance, and the space is occupied by a deep excavation from which the probe passes outward and forward into a large chamber that apparently belongs to the system of nasal or frontal cells.

The pit lying in front of the stalls which I have just described, has a honeycombed floor; the comb-like structures rising up to such a height as to partially conceal the entrances to the stalls. One of them is particularly conspicuous by reason of its perfectly cylindrical shape, by the jagged character of its free upper edge, and by the depth (20 millimeters—$\frac{3}{4}$ inch) of the enclosed well, which seems to have no communication with any of the adjacent cavities.

The large cavity which I mentioned in the earlier part of this description as forming a slightly acute angle with the tympanum proper, presents few features of special interest. Its total length is approximately 50 millimeters (2

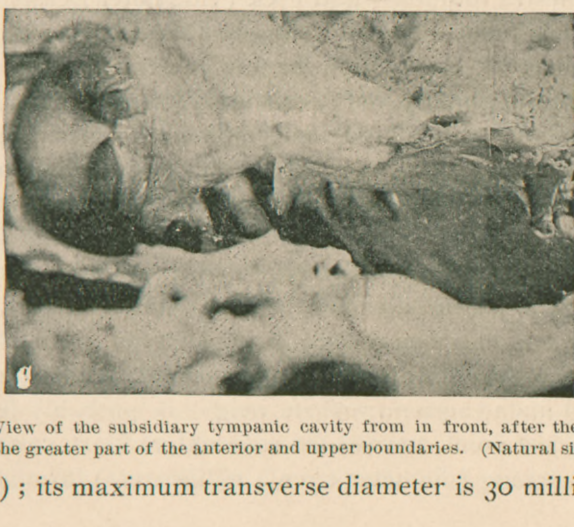

Fig. 4. View of the subsidiary tympanic cavity from in front, after the removal of the greater part of the anterior and upper boundaries. (Natural size.)

inches); its maximum transverse diameter is 30 millimeters

($1\frac{1}{8}$ inch) and the minimum 20 millimeters ($\frac{3}{4}$ inch). At the lowest point of this subsidiary tympanic cavity are two triangular openings with smoothly rounded edges. The anterior opening leads into the general system of air cells which surround the external auditory canal; the posterior opening leads into a long cavity or system of cavities which (as shown by the smoke test) do not communicate with these cells. A probe introduced into this posterior opening can be passed, in an outward and somewhat upward direction, to a distance of 85 millimeters ($3\frac{3}{8}$ inches) without encountering any resistance. Several other openings are visible along the outer wall of the subsidiary tympanic cavity, but with one exception they all lead into shallow pockets or diverticula. In this single exceptional instance a slightly curved probe can be passed in to a depth of 25 millimeters (1 inch). This small curving cavity is situated in the mass of bone which forms the angle between the tympanum proper and the larger subsidiary cavity, and its farther blind end must lie in close proximity to the cochlea. If the opening in the promontory should prove not to be the fenestra rotunda—and Fick (vide antea) casts a doubt upon this point—I would suggest this curved niche as the next most likely situation for the fenestra rotunda.

We come, finally, to the consideration of the small cavity lying above and behind the tympanum proper, the cavity containing the anvil, the body or head of the hammer, and presumably the stirrup. The plate of bone covering both this cavity and that of the tympanum proper was found to be of considerable thickness, probably at least 5 millimeters ($\frac{3}{16}$ inch) in diameter. This smaller cavity, as we have mentioned before, is entirely shut off from the tympanum proper. It is, roughly measured, about 10 millimeters ($\frac{1}{2}$ inch) square, and its height is probably less. At its highest point, toward the external auditory canal, there is an opening (diameter circa 4 millimeters) through which the probe can be passed, in an outward direction, a distance of 55 millimeters ($2\frac{1}{4}$ inches) before it encounters any obstacle. By the smoke test it appears that this cavity or channel is a closed sac, having no communication with the adjacent system of pneumatic cells, and therefore not representing, in a physiological sense, the analogue of the mastoid antrum in the human being.

The space between the tegmen tympani and the head of the hammer and body of the anvil, was found to be filled with a mass of soft connective tissue (almost like adipose tissue). Its removal disclosed to view the interlocking malleo-incudal joint. The body of the anvil slightly overtowers the head of the hammer; that is, it is a little nearer to the tegmen tympani. There is quite free play between the two ossicles, both of which, however, may be described as being very solidly anchored in their respective positions. Considerable force may be applied to the handle of the hammer near the umbo of the membrana tympani before any visible excursion of the head of this ossicle can be distinguished. The same degree of force applied to the handle of the hammer apparently fails to produce any motion whatever in the anvil. Direct pressure upon the latter must be of a very decided character before visible motion can be excited in it. A strong membranous capsule spans the space between the opposite edges of the malleo-incudal joint.

The labyrinthine structures and the relations of the stirrup to the surrounding parts were not investigated, as it was found that this could not be done without great risk of seriously injuring the specimen. If permission can be obtained to carry on the investigation, even at the expense of the total destruction of the specimen, a further report will be made in regard to these more intricate anatomical relations.