Atlas of otology : illustrating the normal and pathological anatomy of the temporal bone / by Albert A. Gray.

ATLAS OF OTOLOGY

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ATLAS OF OTOLOGY

ILLUSTRATING

THE NORMAL AND PATHOLOGICAL ANATOMY OF THE TEMPORAL BONE

BY

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PREFACE

THIS work is intended for the use of otologists, surgeons, anatomists and senior students of anatomy. It is presumed that the reader possesses an elementary knowledge of the anatomy of the temporal bone.

There is no region in the human body so difficult to grasp from the point of view of macroscopic anatomy as the temporal bone; and it is hoped that by the use of this atlas, these difficulties may, to some extent at least, be overcome.

In so far as normal structures are concerned the writer has limited himself to the macroscopic appearances, though of course, in certain of the illustrations some little magnification has been employed. In regard to the appearances found in diseased conditions this limitation has not been imposed; and a number of photographs of microscopic sections have been inserted. It is hoped that this will increase the interest of the atlas to otologists, who are curious in regard to the pathological changes which occur in otosclerosis and deaf-mutism for example.

The dissections and preparations from which the photographs are taken, have all been made by myself. The photographs also have all been taken by myself. The advantages of the stereoscopic image are obviously so great that I have made use of it in the large majority of the illustrations of the macroscopic preparations. By means of the stereoscope which is supplied with the atlas, most readers will be able to obtain the solid image at once; and with a little practice others will be able to do so. Some few individuals in whose eyes there is a considerable refractive error, will only be able to obtain the stereoscopic effect after that error has been corrected. The photographs should be examined in a very good light.

I am well aware that this work does not give a complete presentation of the subject. Even in regard to normal anatomy, limits of space necessitated the exclusion of some illustrations which I should have liked to include. And in respect to the morbid anatomy, the number of specimens procurable by any single worker must always be comparatively few. Should the present venture prove a success, a supplementary volume may be published at a later date.

Some of the illustrations have been published before in the form of half-tone or collotype plates. The great majority, however, have not appeared before.

I must express my very grateful thanks to Professor Robert Muir for the help he has given me in procuring many of the temporal bones from which I have made the preparations and dissections. The work was carried out partly in the pathological department of the Western Infirmary, Glasgow, and partly in my own house.

4 CLAIRMONT GARDENS,
GLASGOW, *30th November*, 1923.

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NORMAL ANATOMY

FIG. 1. *Stereoscopic.* $\times \frac{4}{5}$.

Viewed from the inner aspect.

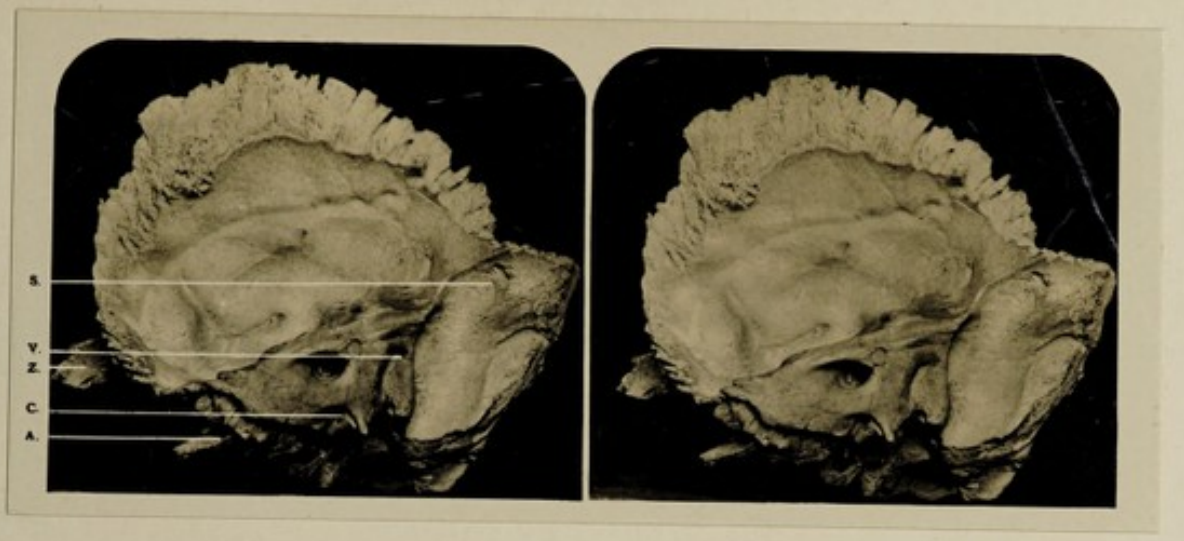
THE right temporal bone ; macerated specimen.

S. Groove for sigmoid sinus.
V. Opening of aqueduct of vestibule.
Z. Zygomatic process.
C. Opening of aqueduct of cochlea.
A. Opening of carotid canal into the cranial cavity.

FIG. 2. *Stereoscopic.* $\times \frac{3}{2}$.

THE left temporal bone *viewed from below*. The preparation shows the entrances of three canals, each of which has a stylet inserted into it. The innermost canal just behind the styloid process is that by which the facial nerve takes its exit from the skull. About two or three millimetres external to this is the canal by which Arnold's nerve leaves the skull ; the latter nerve then turns outwards and re-enters the bone by the third canal which lies between the mastoid portion of the temporal bone and the bony wall of the external auditory meatus. This last canal is frequently absent, and the nerve runs upwards in the cleft between the mastoid portion of the bone and the bony wall of the meatus. Compare this with Figs. 7, 32 and 33.

As regards the course and relations of Arnold's nerve see Gray, *Journ. of Laryngology and Otology*. Vol. XXXVII., April, 1922.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C.
A.

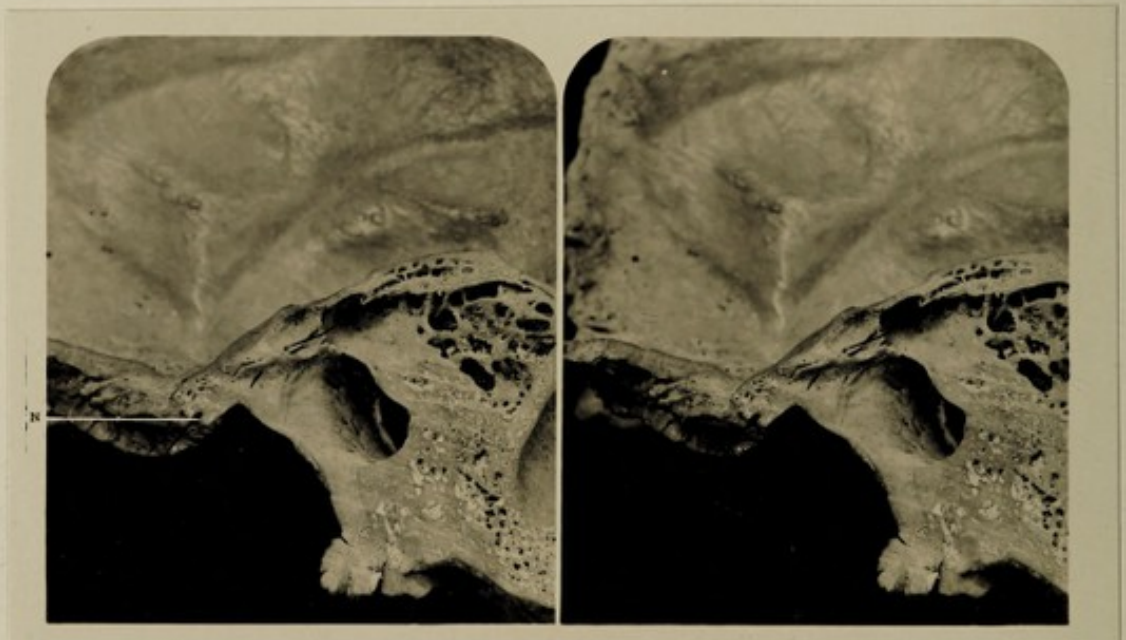


FIG. 3. *Stereoscopic.* ×2.

A PORTION of the right temporal bone *viewed from below.* A black stylet is passed through the fissure of Glaser, where the chorda tympani is supposed to leave the bone. A white stylet is passed up a little canal, and it is along this latter that the chorda tympani really passes. The chorda tympani is shown dissected out in Fig. 30.

FIG. 4. *Stereoscopic.* ×$\frac{3}{2}$.

Viewed from the inner aspect.

OUTER portion of the right temporal bone (macerated) showing the canal which transmits the anterior portion of the chorda tympani. A black stylet has been passed through the canal. It will be noticed that the stylet passes from the opening in the anterior upper region of the tympanic cavity through the canal in the temporal bone and emerges at the temporo-sphenoidal suture. The sphenoid bone is not present in this preparation, but it may be mentioned that the canal passes into it and emerges on the base of the skull, just behind the root of the spine of the sphenoid bone. Thus, the chorda tympani does not pass through the fissure of Glaser, as is usually stated in text-books of anatomy. There may be a certain proportion of subjects, in which the nerve passes through that fissure, but they are the exception rather than the rule. See Figs. 3 and 30.

N. Opening of the canal for the chorda tympani, at the temporo-sphenoidal suture.

FIG. 5. *Stereoscopic.* ×2½.

RIGHT temporal bone (macerated). The bone has been sawn through in the vertical transverse plane. The saw-cut passes through the external meatus, the middle ear, the oval window, the labyrinth and the internal auditory meatus. The posterior portion of the bone is shown *viewed from in front.*

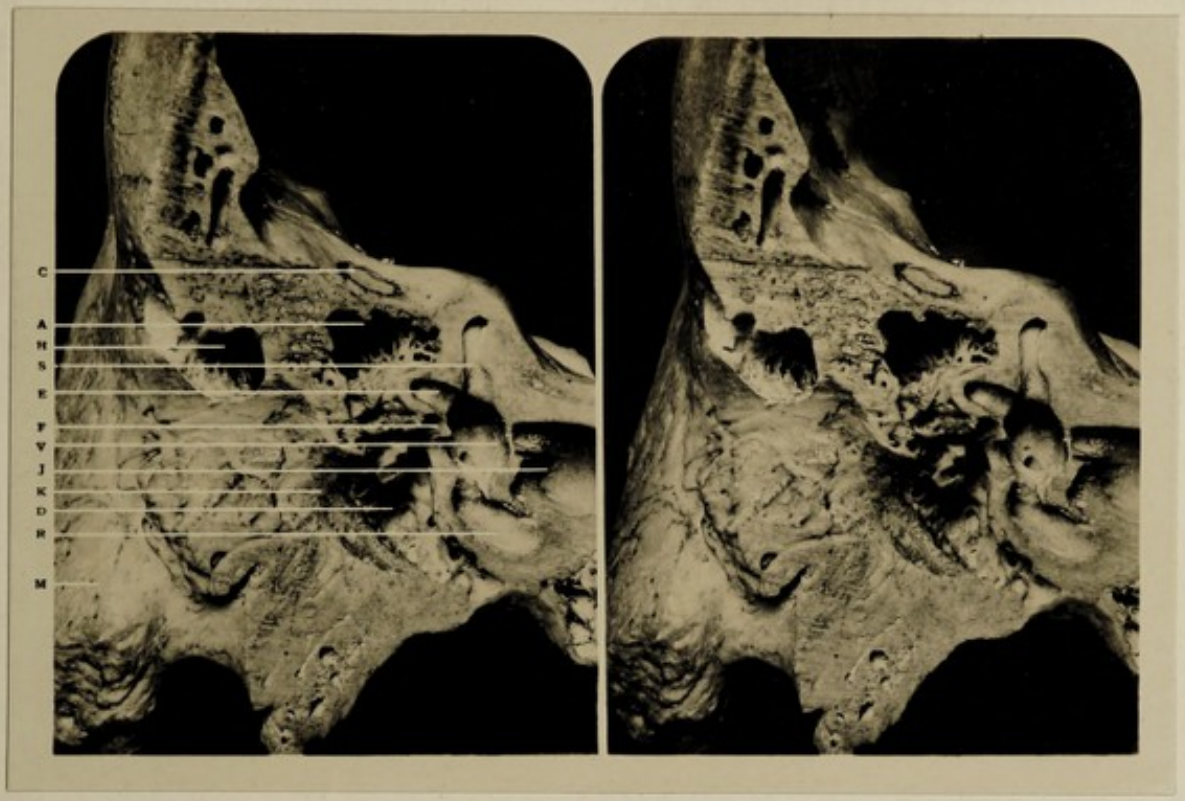
C. Oval pencil mark on the intracranial surface of the layer of bone which separates the attic of the tympanum from the middle fossa of the skull. This is a common pathway of infection leading to intracranial disease.
A. Attic of tympanum.
H. Hole bored from the upper posterior wall of external meatus into the antrum.
S. Superior semicircular canal.
E. Horizontal semicircular canal.
F. Facial canal.
V. Vestibule ; the pointer passes through the oval window, which has been sawn across.
I. Internal auditory meatus.
K. External auditory meatus.
D. Tympanic recess on posterior wall of tympanum ; this recess corresponds morphologically with the bulla of carnivora and other mammalia.
N. Lowest whorl of cochlea.
M. Mastoid process.

FIG. 6. *Stereoscopic.* ×$\frac{3}{2}$.

Viewed from the outer aspect and in front.

PREPARATION of the left temporal bone (macerated) showing the relationship of the facial canal to the structures of the middle ear. The facial canal has been laid open from the point at which it turns backward, above and in front of the oval window, to its opening at the stylo-mastoid foramen ; and a thick wire has been passed along the canal. The anterior limb of the horizontal semicircular canal has been opened and a bristle has been inserted into it ; it is seen above the horizontal portion of the facial canal. Just external to the stylo-mastoid foramen a small wire may be seen passing into a small foramen ; this is the canal which gives passage to the descending portion of Arnold's nerve ; see Fig. 33.

A. Antrum.
O. Fenestra ovalis.
R. Fenestra rotunda.
T. Eustachian tube.
M. Mastoid process.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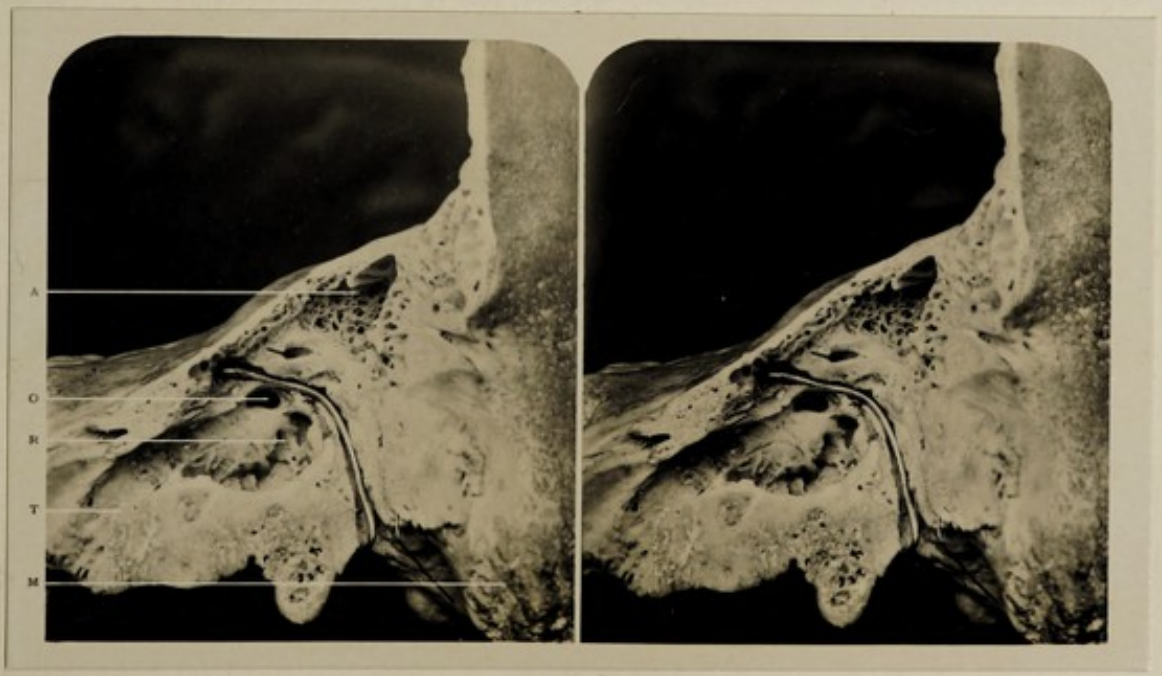

AORTM

FIG. 7. *Stereoscopic.* ×2.

Viewed from the outer aspect and in front.

PREPARATION showing the position, in the left macerated temporal bone, of the canal for the passage of the ascending portion of Arnold's nerve. The stylet shows the point of exit of the canal on the posterior wall of the meatus. The entrance to the canal on the under surface of the temporal bone is not seen in this figure, but the end of the stylet has been bent outwards and the position of the entrance of the canal can be roughly gauged. See Fig. 32.

FIG. 8. *Stereoscopic.* ×2.

Viewed from the outer aspect.

LEFT temporal bone of a child about six months old.

The mastoid process has hardly begun to develop and the mastoid antrum lies near the surface of the bone. A hole has been drilled into the antrum to show its position. The facial nerve escapes from the outer surface of the bone a little below the middle of the posterior margin of the tympanic ring. This is important to remember in operating in this region, for if the incision is carried too low the facial nerve may be cut.

FIG. 9. *Stereoscopic.* ×2.

Viewed from in front.

PARAFFIN-CELLOIDIN cast of the right temporal bone, prepared by the author's method. The ossicles, and the bone surrounding the eustachian tube, carotid canal, the anterior portion of the tympanic cavity, and the anterior and upper walls of the external meatus were all removed before preparation. The embedding media penetrate very minute cavities and the resulting cast is very complete. In this respect this method differs strikingly from that used in obtaining metal corrosion casts. The latter method gives a very misleading impression.

The photograph needs little description. Attention may be drawn, however, to the group of cells (S) lying like a shield or glove above the internal auditory meatus. I have termed these the superior petrosal cells, and it will be noticed that they are connected with the cells lining the inner wall of the antrum by a pedicle which passes outward through the arch of the superior semicircular canal. See Fig. 10. These superior petrosal cells are frequently absent.

Another large group of cells (C.) lies below the cochlea. These may be termed the inferior petrosal cells. They are sometimes infected in chronic middle-ear suppuration, and thus bring about caries or necrosis of the bony wall of the carotid canal. The author has removed a sequestrum from this region, when performing the radical mastoid operation. The case did well and the suppuration ceased in the course of a few weeks, but it was an anxious moment when the sequestrum with its rough, sharp edges was being removed.

S. Superior petrosal cells.
H. Tympanic recess.
C. Inferior petrosal cells.

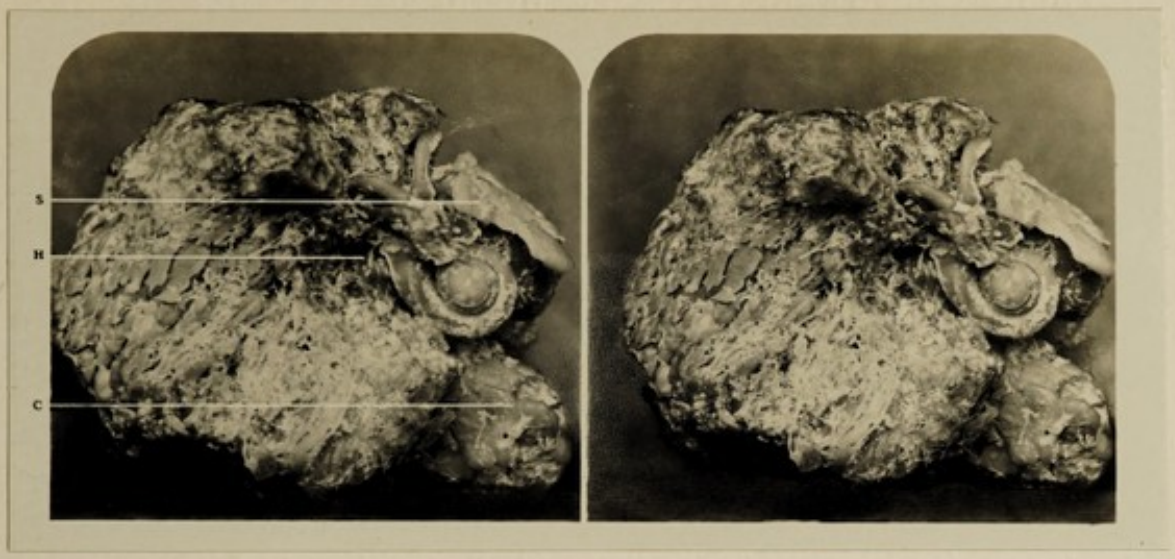
FIG. 10. *Stereoscopic.* ×2.

Viewed from above.

PARAFFIN-CELLOIDIN cast of the right temporal bone, prepared by the author's method.

The superior petrosal cells (S.S.) are well seen, as is also the peduncle which unites them to those lining the inner wall of the antrum ; they lie somewhat like a glove spread over the upper wall of the internal auditory meatus. The inferior petrosal cells are seen lying below and internal to the cochlea.

I. Inferior petrosal cells.
G. Geniculate ganglion with the facial nerve leaving it at its outer extremity. The pointer crosses the cochlea.
S.S. Superior petrosal cells.
M. Mastoid antrum ; the pointer crosses the superior semicircular canal and the peduncle of the superior petrosal cells. It will be observed that the peduncle passes under the arch of the superior semicircular canal.
N. Internal auditory meatus at its inner extremity.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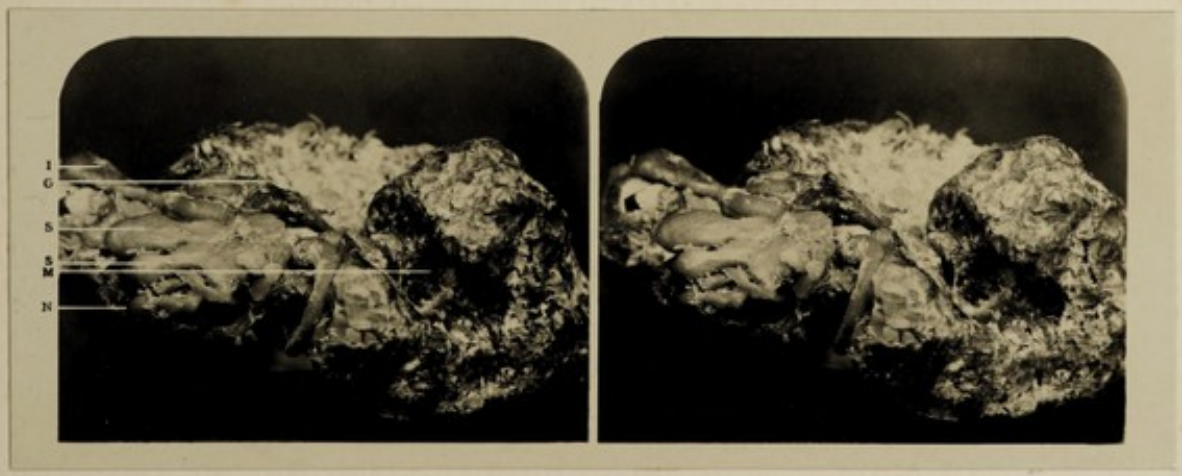
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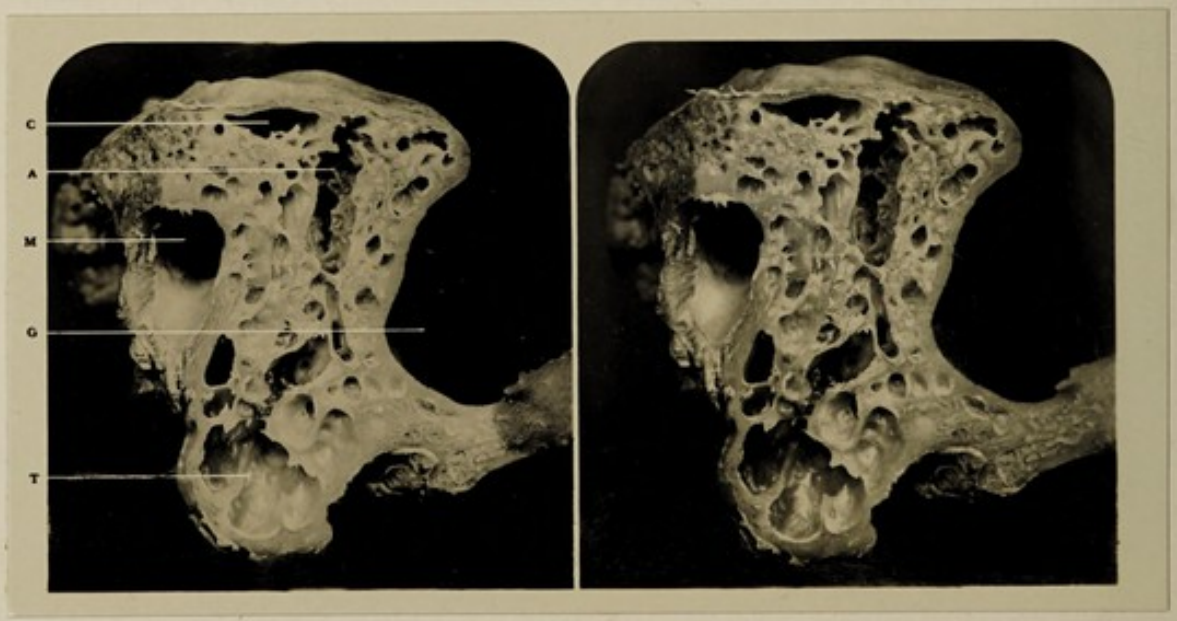
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FIG. 11. *Stereoscopic.* ×2.

PARAFFIN-CELLOIDIN cast of the right temporal bone, prepared by the author's method. *Viewed from behind.*

A considerable portion of the bone has been removed from the posterior surface in order to show the lower portion of the facial nerve, the posterior and superior semicircular canals and the internal auditory meatus.

The superior petrosal cells (P.) are shown and their peduncle which passes through the arch of the superior semicircular canal, and attaches them to the cells lying external to the labyrinth.

The cells of the mastoid process are shown (C.), and the pointer crosses the facial nerve just a little above its exit at the stylo-mastoid foramen.

P. Superior petrosal cells.
M. Internal auditory meatus.
C. Mastoid cells.
J. Jugular fossa.

FIG. 12. *Stereoscopic.* ×$\frac{3}{2}$.

Viewed from the outer aspect.

PREPARATION of left temporal bone, unmacerated. The bone has been cut through in the vertical antero-posterior plane, and the outer portion removed to show the relationship of the parts. It will be noticed that the mastoid region is of the cellular type.

C. Large air-cell separated from the cranial cavity by a thin layer of bone.
A. Mastoid antrum surrounded by air-cells.
M. External auditory meatus.
G. Groove for sigmoid sinus.
T. Large air-cell at tip of mastoid process. This large cell is important from a surgical point of view. It sometimes becomes infected in middle-ear disease and requires to be opened. It is also from this cell that Bezold's mastoiditis usually, if not always, arises. The reason for this is that the inner wall of the cell is often very thin, and the pus, finding its way through that wall, escapes into the soft tissues under the deep fascia of the neck.

FIG. 13. *Not Stereoscopic.* $\times\frac{3}{2}$.

Viewed from behind.

PREPARATION of the right temporal bone showing the cellular type of mastoid process. A vertical cut has been made through the bone in the long axis of the petrous portion.

A. Aditus ad antrum.
P. Mastoid antrum ; the antrum in this case is rather larger than usual.
M. Mastoid process showing a large number of air-cells.

FIG. 14. *Not Stereoscopic.* $\times\frac{3}{2}$.

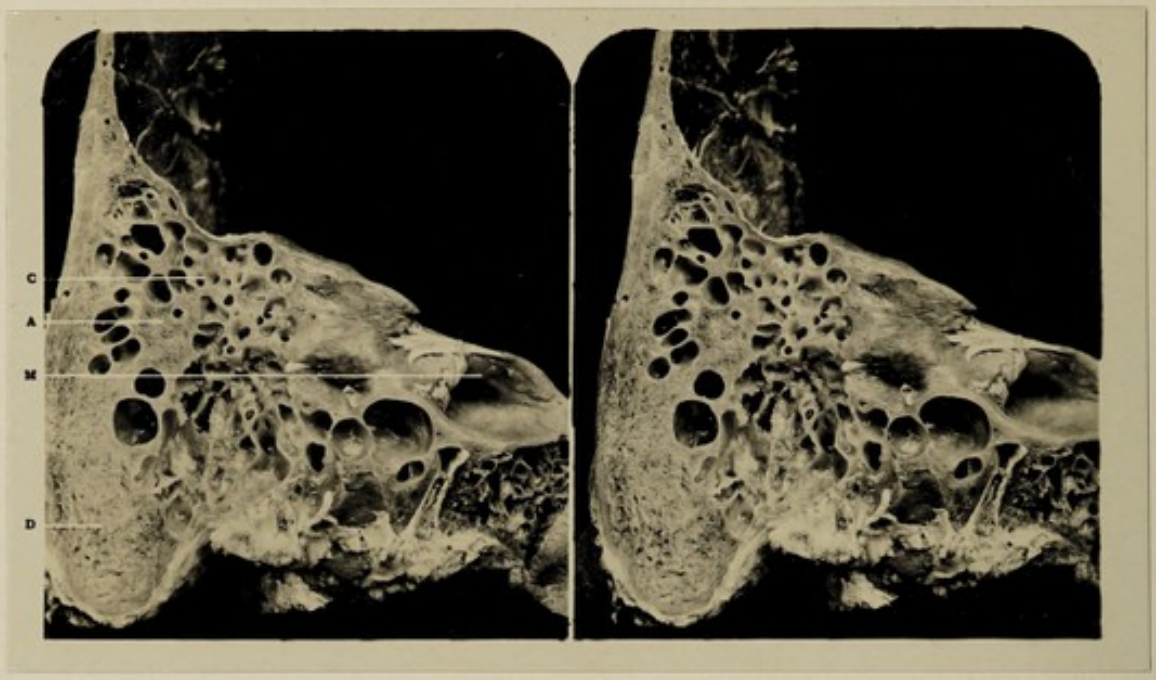
Viewed from behind.

PREPARATION of left temporal bone showing the cellular type of mastoid process. The bone has been cut vertically in the long axis of the petrous portion.

A. Aditus ad antrum.
P. Mastoid antrum.
M. Mastoid process, showing a number of large air-cells.


A
P
M


A
P
M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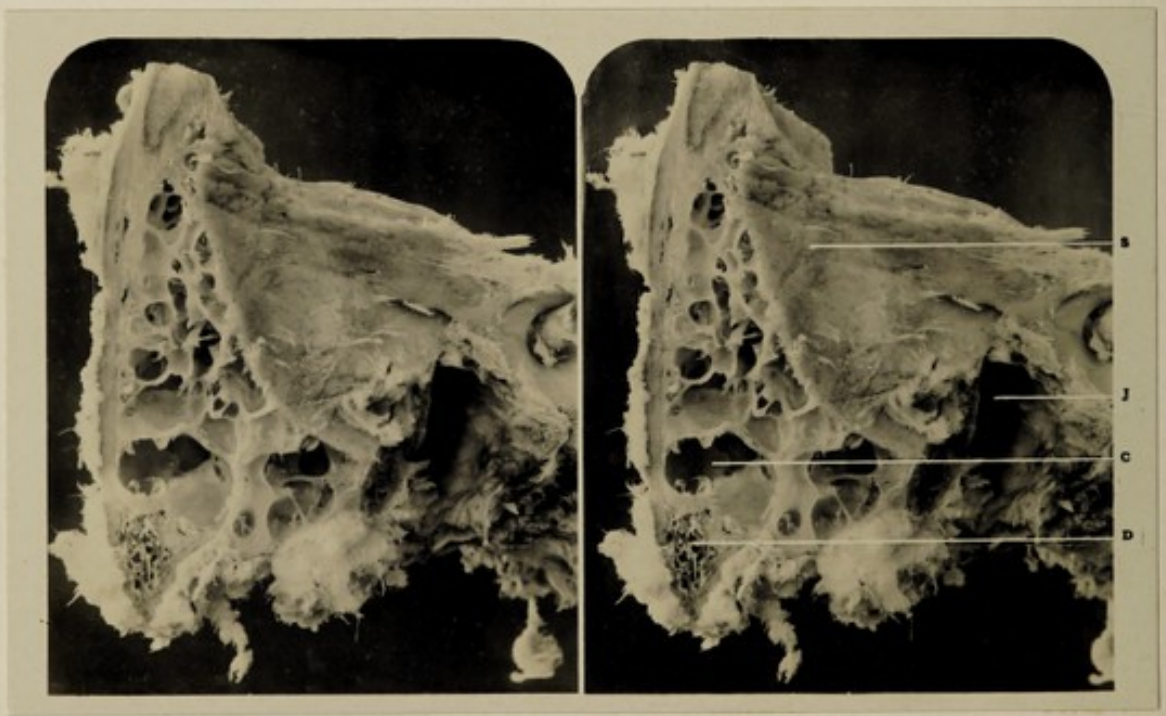
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FIG. 15. *Stereoscopic.* ×$\frac{3}{2}$.

Viewed from behind.

PREPARATION of the left temporal bone, not macerated, showing the texture of the bone. The posterior portion of the bone has been removed.

It will be seen that the lower portion of the mastoid region (D.) consists of acellular bone, while the upper portion (C.) contains numerous large air-spaces; even in this portion, however, there is a small acellular portion (A.). It should be noted that the air-cells extend deep into the bone as far as the internal auditory meatus.

C. Upper cellular region.
A. Small area of dense acellular bone surrounded by cellular type of bone.
M. Internal auditory meatus.
D. Dense acellular type of bone in mastoid process.

FIG. 16. *Stereoscopic.* ×$\frac{3}{2}$.

Viewed from behind.

PREPARATION showing posterior surface of left temporal bone (not macerated). The posterior portion of the mastoid region has been removed; and it will be observed that that region is for the most part of the cellular type. There is, however, a small portion near the tip of the mastoid process which is of the acellular type.

S. Groove for sigmoid sinus.
J. Bulb of jugular vein.
C. Large air-cell in mastoid process; other air-cells are seen higher up.
D. Acellular type of bone at the tip of mastoid process.

FIG. 17. *Not Stereoscopic.* $\times\frac{3}{2}$.

Viewed from in front.

PREPARATION of the left temporal bone showing the acellular type of mastoid process. A vertical cut has been made through the bone in the long axis of the petrous portion.

A. Aditus ad antrum ; a few air-spaces are seen external to this.
T. Tympanic cavity.
C. Carotid artery.
P. Mastoid process showing the absence of air-cells. Cf. Figs. 13 and 14.

FIG. 18. *Not Stereoscopic.* $\times\frac{3}{2}$.

Viewed from in front.

PREPARATION of the left temporal bone showing the acellular type of mastoid process. From a subject aged twelve. A vertical cut has been made in the long axis of the petrous portion of the bone.

A. Mastoid antrum ; the pointer crosses the superior semicircular canal.
T. Tympanic cavity.
C. Carotid artery.
M. Mastoid process ; the bone here is, on the whole, of the acellular type, but a few small air-spaces are seen. Cf. Figs. 13 and 14.

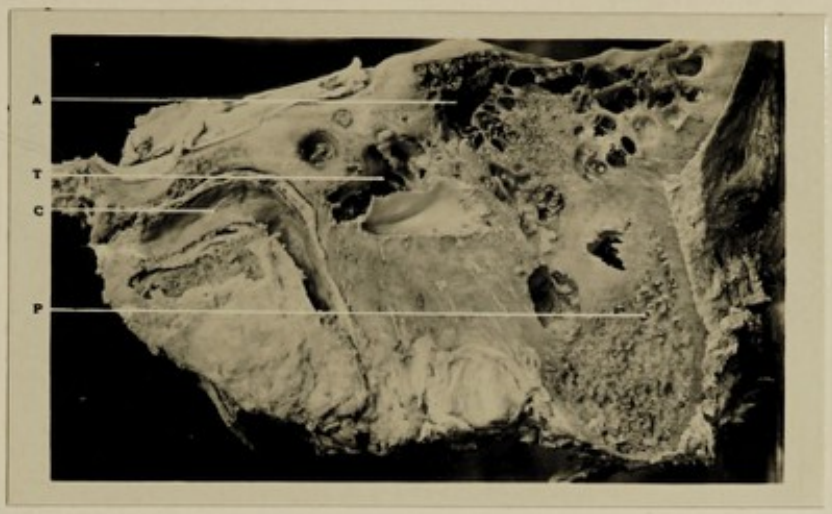
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FIG. 19. *Stereoscopic.* Natural size.

Viewed from in front.

VERTICAL transverse section through the left temporal bone (macerated).

The mastoid process is of the acellular type throughout. It is interesting to note, however, that in this specimen the bone, though acellular throughout, shows two different varieties of texture. The upper portion of the mastoid process, external to the antrum, is seen to consist of dense sclerotic bone of texture like ivory. The lower portion of the mastoid process, though also of the acellular type, consists of bone with numerous minute spaces in it, and very closely resembles the diploetic bone of the vault of the skull.

A.W. Dense ivory-like bone in outer wall of mastoid antrum.
S.C. Superior semicircular canal.
M.A. Mastoid antrum.
H.C. Horizontal semicircular canal.
F. Aqueduct of Fallopius.
C. Beginning of the lower whorl of the cochlea.
T. Tympanic cavity.
M.C. Diploetic type of bone.

For further information on the subject of the Cellular and Acellular types of the temporal bone, the reader is referred to the work of Cheatle :—*Trans. 8th Internat. Congress of Otology.* The reader is also advised to inspect Cheatle's collection of temporal bones in the Royal College of Surgeons, London. The same subject from an ethnological point of view has been investigated by Logan Turner and Porter :—*Journal of Laryngology and Otology,* March 1922, p. 115, and April 1922.

FIG. 20. *Stereoscopic.* Natural size.

PREPARATION of the right temporal bone (macerated) showing the relationship of the groove for the sigmoid sinus to the mastoid antrum. A cut has been made in the vertical plane passing from behind and outwards, forwards and inwards : the anterior portion has been removed and the preparation is *viewed from in front.* The anterior portion of the groove for the sigmoid sinus has been removed. The close proximity of the antrum to the groove for the sigmoid sinus is well seen in this specimen.

A. Antrum.
H.C. Bony covering of the horizontal semicircular canal.
F. Facial canal.
S. Opening in the apex of the pyramid for the passage of the tendon of the stapedius muscle.
L. Sigmoid sinus.

FIG. 21. *Stereoscopic.* $\times \frac{3}{2}$.

HORIZONTAL section through the left temporal bone showing the relationships of the sigmoid sinus, the external auditory meatus and the bulb of the jugular vein to one another. The section passes horizontally a short distance above the floor of the meatus, and the preparation is *viewed from above.* In this specimen the distance from the sinus to the external meatus is perhaps rather smaller than usual; but, as is well known, there are great variations in this matter in different subjects. This variation occasionally causes difficulty in performing the mastoid operations.

As regards the bulb of the jugular vein, in this preparation that structure reaches distinctly higher towards the tympanic cavity than is usual.

J. Bulb of the jugular vein.
M.M. External auditory meatus.
S. Sigmoid sinus.

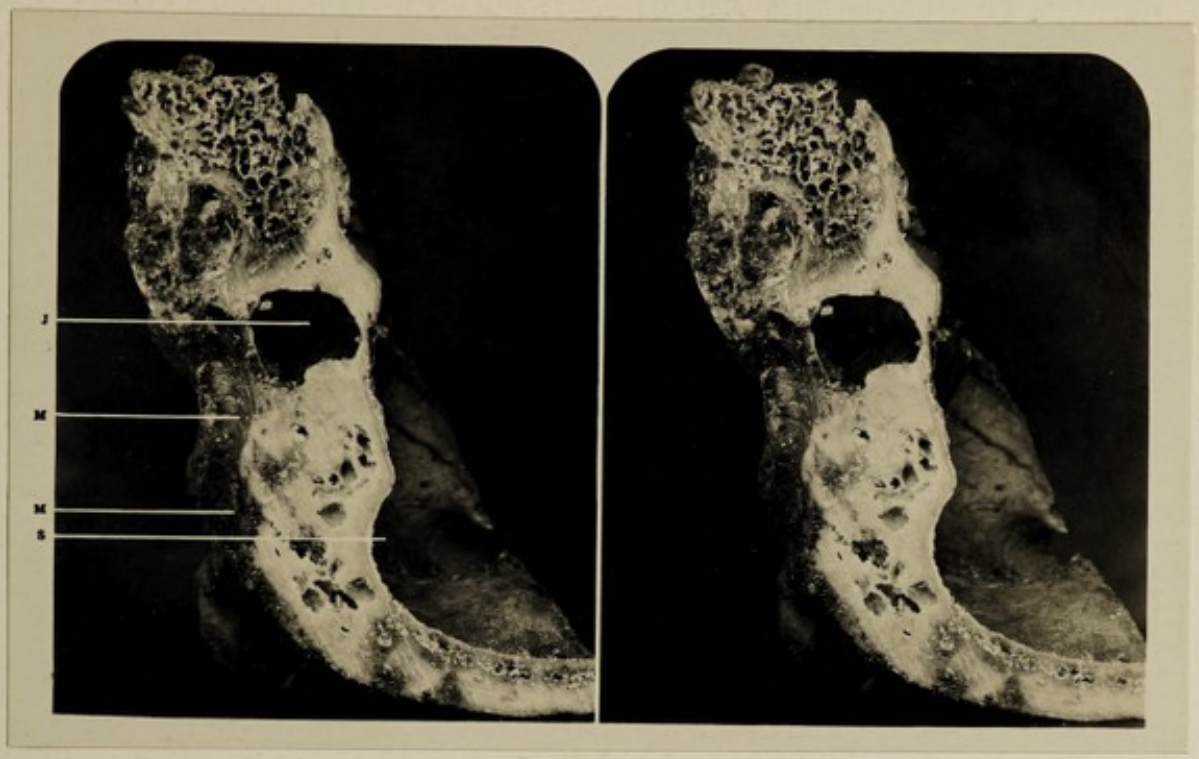
FIG. 22. *Stereoscopic.* $\times 4$.

Viewed from the inner aspect.

THE left tympanic membrane.

The head and neck of the malleus have been removed in order to show Shrapnell's membrane (S.). The posterior fold of the tympanic membrane (P.) is well developed in this specimen; usually it is not quite so broad and thick.

S. Shrapnell's membrane.
P. Posterior fold of membrane.
M. Handle of malleus.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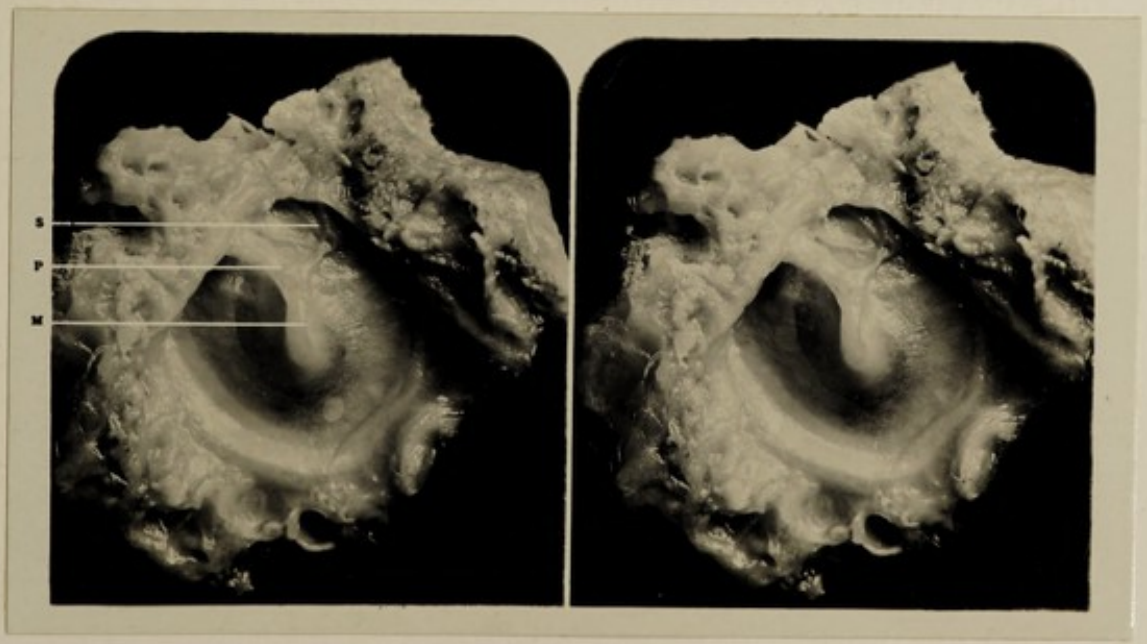
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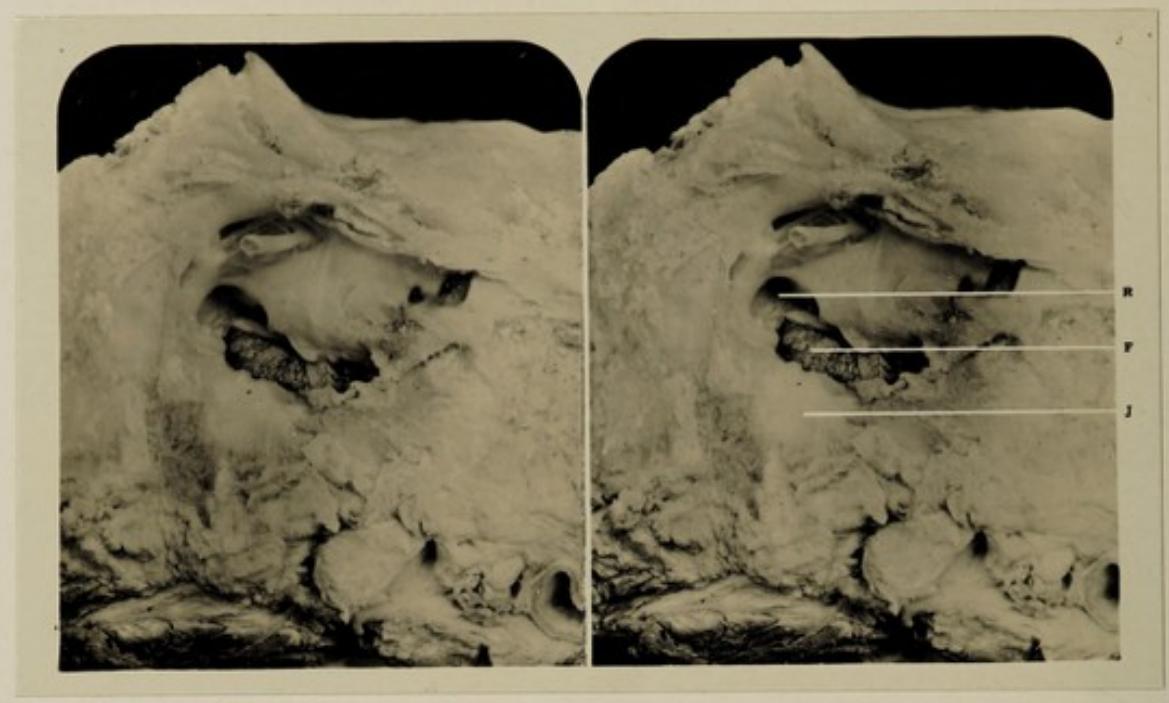
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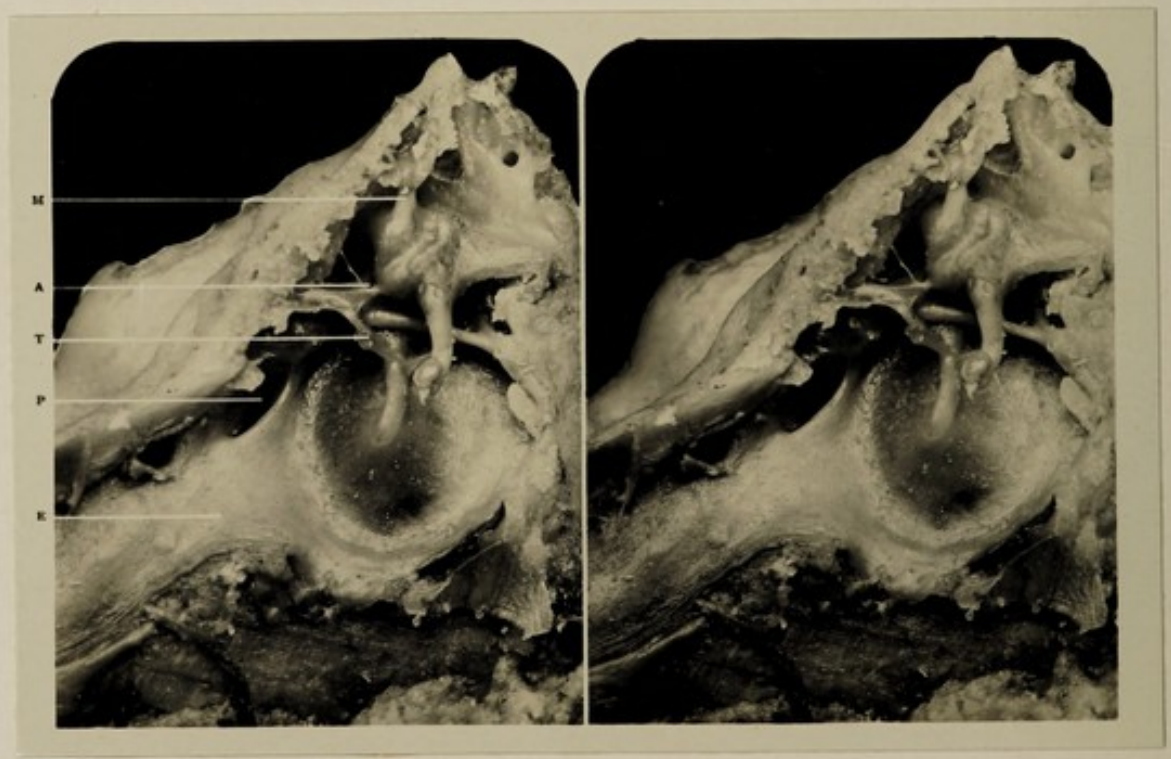
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FIG. 23. *Stereoscopic.* ×2.

Viewed from the outer aspect.

PREPARATION showing the relationship of the bulb of the jugular vein (J.) to the floor of the tympanic cavity (F.). It will be noticed how thin is the layer of bone which separates the two. The mucoperiosteum of the floor of the tympanic cavity shows engorgement of the veins. Right ear.

The tympanic recess (R.) is well shown in this preparation.

R. Tympanic recess; pointer crosses the round window.
F. Floor of tympanic cavity.
J. External wall of bulb of jugular vein.

FIG. 24. *Stereoscopic.* ×3.

Viewed from the inner aspect and slightly behind.

PREPARATION showing the outer wall of the right tympanic cavity and external portion of the eustachian tube.

M. Superior ligament of malleus. This ligament is absent in some specimens.
A. Anterior ligament of malleus.
T. Tendon of tensor tympani muscle cut short. The chorda tympani nerve passes immediately above it.
P. Pocket of eustachian tube. This little cavity has not been described before, so far as the author knows. It is absent from some specimens. It is formed in large part by folds of mucous membrane, and varies in position, being sometimes found near the floor of the eustachian tube just at the entrance of the latter into the tympanic cavity. It is probable that this pocket, like other small cavities in the middle-ear, may form a reservoir for pus and help to keep up a chronic middle-ear suppuration.
E. Eustachian tube. This structure varies considerably in calibre in its outer portion, the specimen here depicted being one in which it is much wider than usual.

FIG. 25. *Stereoscopic.* Natural size.

Viewed from in front.

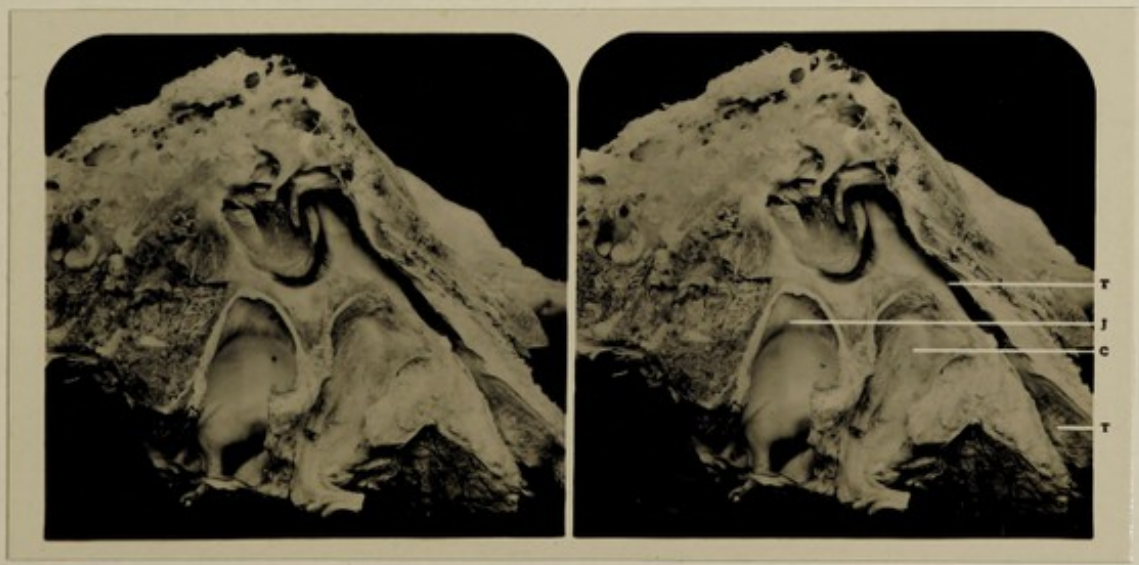
PREPARATION showing the eustachian tube, etc. Left ear. A strip from the upper portion of the anterior wall of the eustachian tube has been removed in its whole length. The roof of the tympanum and antrum have been removed, as well as the superior, anterior and inferior walls of the external meatus. A small portion of the head of the malleus is just visible. It is to be noticed that the lower portion of the anterior wall of the Eustachian tube has been left *in situ*, and is seen applied to the posterior wall of the tube.

FIG. 26. *Stereoscopic.* $\times \frac{3}{2}$.

Viewed from the inner aspect and behind.

PREPARATION showing the relationships of the bulb of the jugular vein, the tympanic cavity, the eustachian tube and the carotid artery to one another. Left ear.

J. Bulb of jugular vein.
C. Carotid artery.
T.T. Eustachian tube.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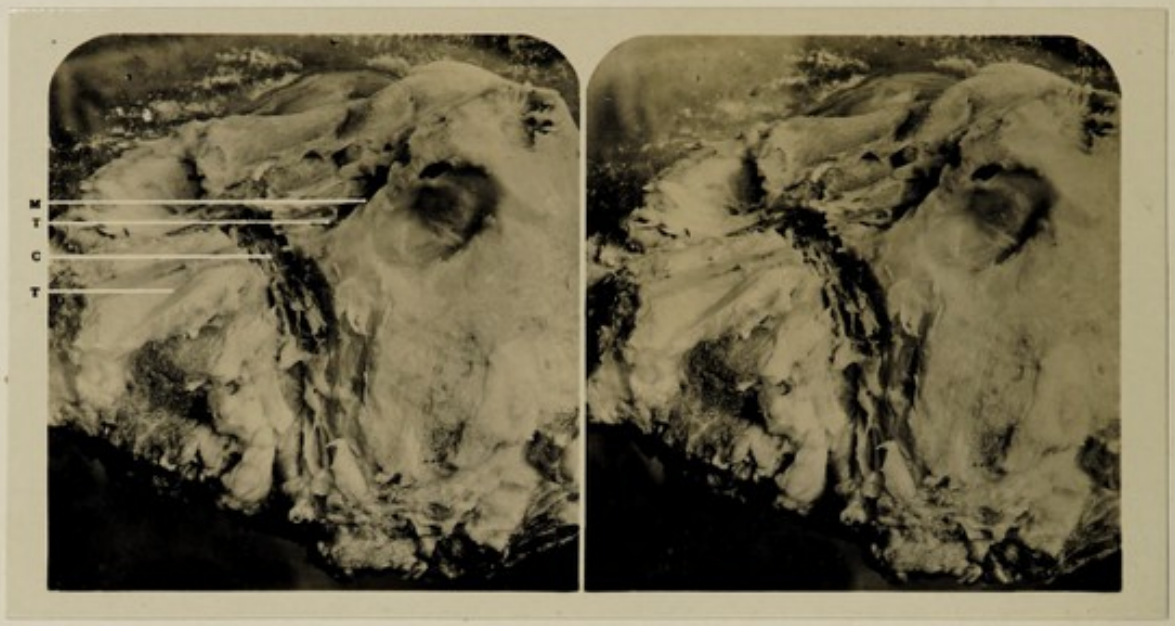
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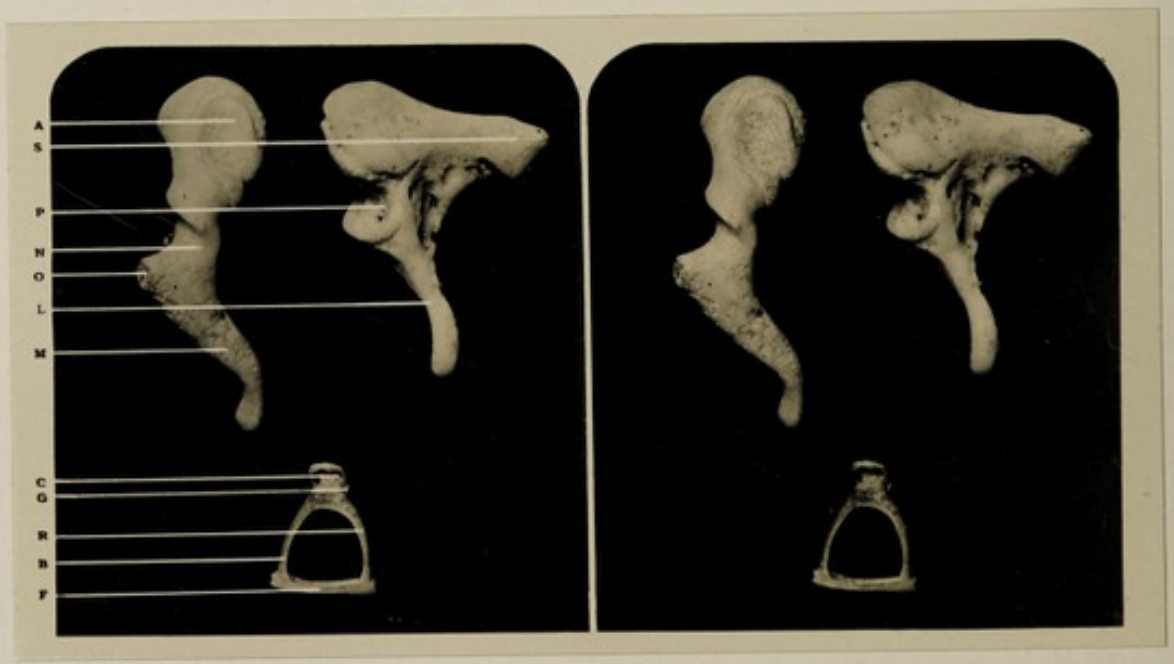
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FIG. 27. *Stereoscopic.* ×$\frac{3}{2}$.

Viewed from in front.

PREPARATION of the left temporal bone showing the relationship of the eustachian tube to the carotid artery.

The eustachian tube (T.T.) has been opened right up to the tympanic cavity and a section of the walls of the tube, at the point at which it crosses the artery, has been removed. It will be observed that the tube crosses in front of the artery at the bend of the latter, almost at right angles. The wall of bone separating the tube from the artery is very thin. This fact is important to remember in considering any surgical undertakings in this region, for the purpose of closing the eustachian tube.

An old dry perforation is present in Shrapnell's membrane.

M. Anterior portion of tympanic cavity.
T.T. Eustachian tube opened up.
C. Carotid artery.

FIG. 28. *Stereoscopic.* ×4.

THE Auditory Ossicles. The malleus (left) is *viewed from behind and outside*,—the incus (left) *from outside*, the stapes (right) *from above*.

A. Surface on head of malleus for articulation with incus.
S. Short process of incus ; the pointer crosses the body of the incus.
P. Lower portion of articular surface of incus for articulation with malleus.
N. Neck of malleus.
O. Short process of malleus.
L. Long process of incus.
M. Handle of malleus.
C. Head of stapes.
G. Surface for insertion of tendon of stapedius muscle.
R. Posterior crus of stapes.
B. Anterior crus of stapes.
F. Footplate of stapes.

FIG. 29. *Stereoscopic.* ×3.

Viewed from the inner aspect and in front.

PREPARATION showing the three ossicles in their normal relationship to one another. Left ear. The soft parts have been preserved, so that the ossicles are held together.

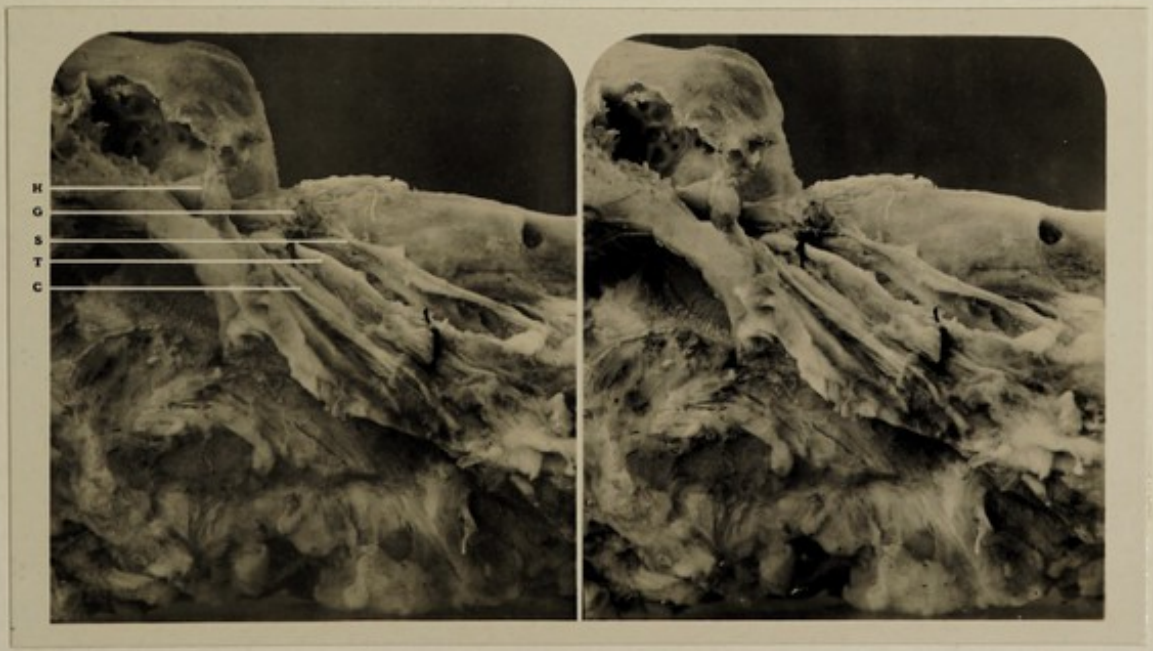
FIG. 30. *Stereoscopic.* ×$\frac{3}{2}$.

Viewed from in front.

PREPARATION showing the relationships of some of the structures in the anterior portion of the right temporal bone. Bone has been dissected away over a considerable area from the anterior and upper surfaces. One of the features of interest is the chorda tympani nerve (C.). It is hardly correct to say, as is sometimes done in anatomical text-books, that this nerve escapes by the fissure of Glaser. After leaving the tympanic cavity the nerve runs inwards and forwards through a long fine canal in the bone parallel with, and in front of, the eustachian tube. It passes across the temporo-sphenoidal suture and continues for a millimetre or two inwards through the sphenoid bone, it then turns downwards and takes its exit from the base of the skull by a minute foramen close behind the root of the spine of the sphenoid bone. In a small proportion of cases, however, it leaves its bony canal earlier in its course, and does really take its exit by the fissure of Glaser (cf. Figs. 3 and 4).

The tensor tympani muscle (T.) is shown, a black thread being tied round its inner and outer extremities. The eustachian tube is not shown, but it lies between and below the chorda tympani nerve and the tensor tympani muscle. The great superficial petrosal nerve (S.) is seen leaving the geniculate ganglion (G.), and passing inwards and forwards. The facial nerve is seen passing first outwards and forwards to the geniculate ganglion, and then backwards and outwards. The outer wall of the attic has been removed and shows the head of the malleus (H.) and the body of the incus. The upper wall of the aditus and antrum has been removed.

H. Head of malleus.
G. Geniculate ganglion.
S. Great superficial petrosal nerve.
T. Tensor tympani muscle.
C. Chorda tympani nerve.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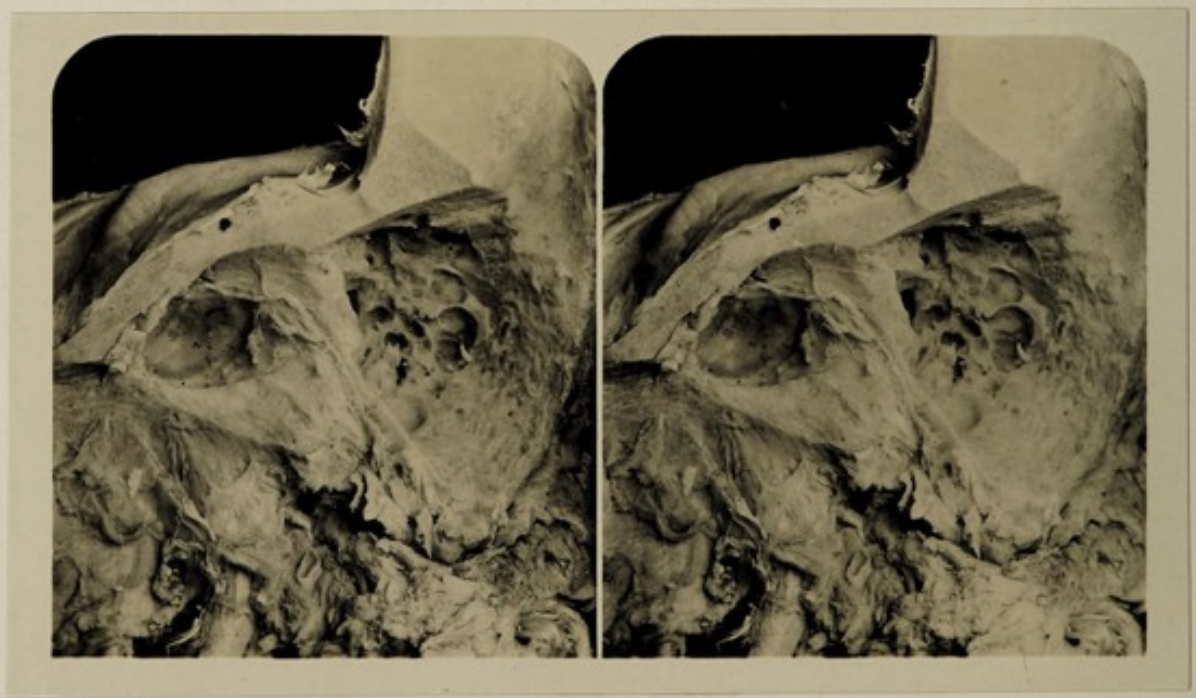

FIG. 31. *Stereoscopic.* ×⅓.

Viewed from the outer aspect and in front.

PREPARATION of the left temporal bone showing the tympanic plexus and other structures.

The nerve of Jacobson (T.) is seen entering the floor of the tympanum. At this point it gives off two small twigs (not lettered); one of these is seen running inwards and slightly upwards for one or two millimetres and disappearing into the bone; this is the carotico-tympanic branch on its way to join the carotid plexus. The other twig passes upwards and backwards and disappears over the lower portion of the bony lip of the round window; this is the nerve to the round window. Jacobson's nerve then passes upwards over the promontory and under a small bony arch; at this point it gives off a branch passing horizontally inwards for a millimetre or so and then dividing into two branches. Of these the upper one (N.) is the small deep petrosal which enters the carotid canal and joins the carotid plexus. The lower branch (S.) is the branch to the eustachian tube. Continuing upwards Jacobson's nerve (B.) enters the geniculate ganglion.

This preparation also shows the course of the facial nerve from the geniculate ganglion to the stylo-mastoid foramen; and the stapedius muscle is dissected out.

G. Geniculate ganglion.
B. Branch from tympanic plexus to geniculate ganglion.
N. Small deep petrosal nerve.
S. Branch going to the eustachian tube.
C. Inner portion of carotid canal.
T. Nerve of Jacobson entering floor of tympanum and giving off the carotico-tympanic branch to the carotid plexus inwards, and the branch to round window passing backwards.

FIG. 32. *Stereoscopic.* ×2.

Viewed from in front and from the outer aspect.

PREPARATION showing the ascending portion of Arnold's nerve. Left ear.

The anterior wall of the external meatus has been removed as well as portions of the inferior, superior and posterior walls. The outer wall of the mastoid process has been removed and the mastoid cellular spaces are shown.

The bone surrounding the canal for the transmission of Arnold's nerve has been dissected away and the nerve itself is seen from the point where it enters the bone below, to the point at which it leaves the canal on the posterior wall of the meatus above, see Fig. 7.

FIG. 33. *Not Stereoscopic.* ×8.

Viewed from behind.

THICK section of a portion of the right temporal bone cut vertically to show the relationships of Arnold's, the facial and the chorda tympani nerves. The vertical portion of the facial nerve (F.F.) is shown, and its exit at the stylo-mastoid foramen (S.). Arnold's nerve is first seen just after entering the bone from the jugular fossa. Between A. and D. Arnold's nerve is not seen as it has been removed in the section which was cut away behind that shown in the photograph. It reappears, at D., having turned slightly forwards. From D. to G. it is seen passing downwards and outwards. After that its course is not shown in the photograph, but the foramen at which it takes its exit from the skull is shown in Figs. 2 and 6. The chorda tympani (C.) is seen leaving the facial nerve and running upwards in its course to the tympanic cavity. Only the lower portion of the chorda tympani is shown, the upper portion having been removed in the section in front of that shown in the photograph. Thus Arnold's nerve passes first behind the facial nerve and then behind the chorda tympani. It communicates with the facial nerve and perhaps also with the chorda tympani. There is, however, considerable variation in the relationships of these structures, for a fuller description of which the reader is referred to a paper by the author.*

F.F. Facial nerve.
A.D.G. Arnold's nerve.
C. Chorda tympani.
S. Stylo-mastoid foramen.

* Gray, *Journal of Laryngology and Otology*. Vol. XXXVII. p. 182. April, 1922.

FIG. 34. *Stereoscopic.* ×$\frac{3}{2}$.

Viewed from behind.

PREPARATION of the right temporal bone showing the junction of the great superficial petrosal and great deep petrosal nerves to form the vidian nerve. The vidian nerve (V.) has been lifted out of its bed and drawn upwards and held in that position by a pin. The great superficial petrosal and great deep petrosal nerves are seen at M. running alongside one another just before their junction. They are also dragged upwards out of their normal position. The great superficial petrosal nerve (S.) is shown in its course from the geniculate ganglion, the latter being seen at the extreme right of the photograph. The great deep petrosal nerve is seen leaving the carotid canal at A. and running to join the great superficial petrosal at M. The upper posterior wall of the sheath of the carotid artery is seen at C.

V. Vidian nerve.
M. Great superficial and great deep petrosal nerves running alongside one another just before their junction to form the vidian nerve.
S. Great superficial petrosal nerve in its course inwards from the geniculate ganglion.
A. Great deep petrosal nerve leaving the carotid canal.
C. Upper posterior wall of the sheath of the carotid artery.


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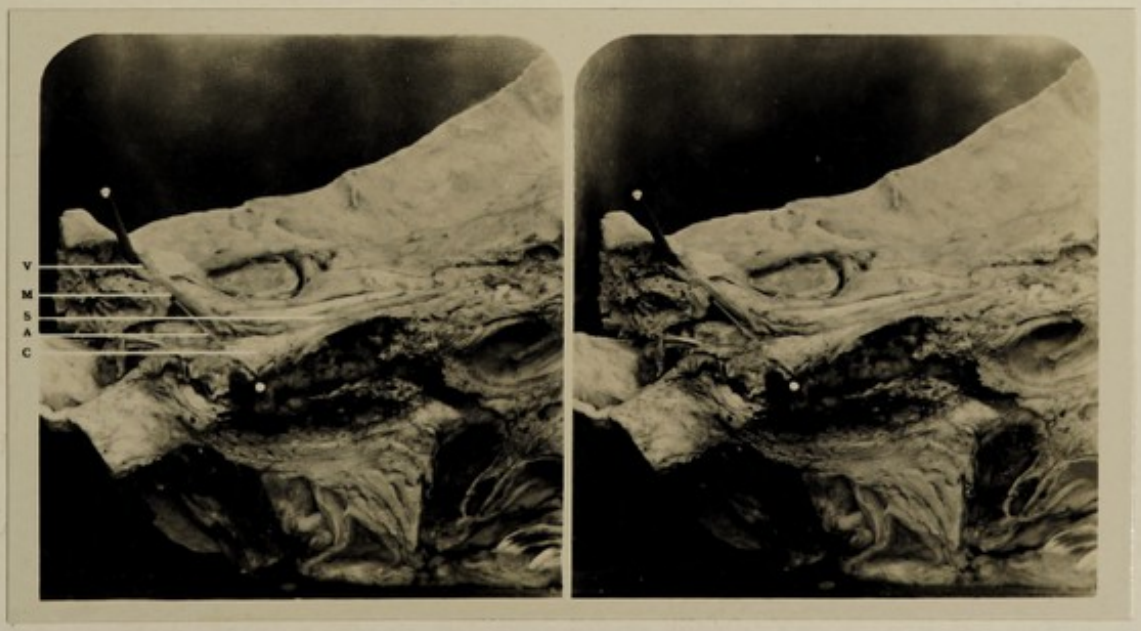
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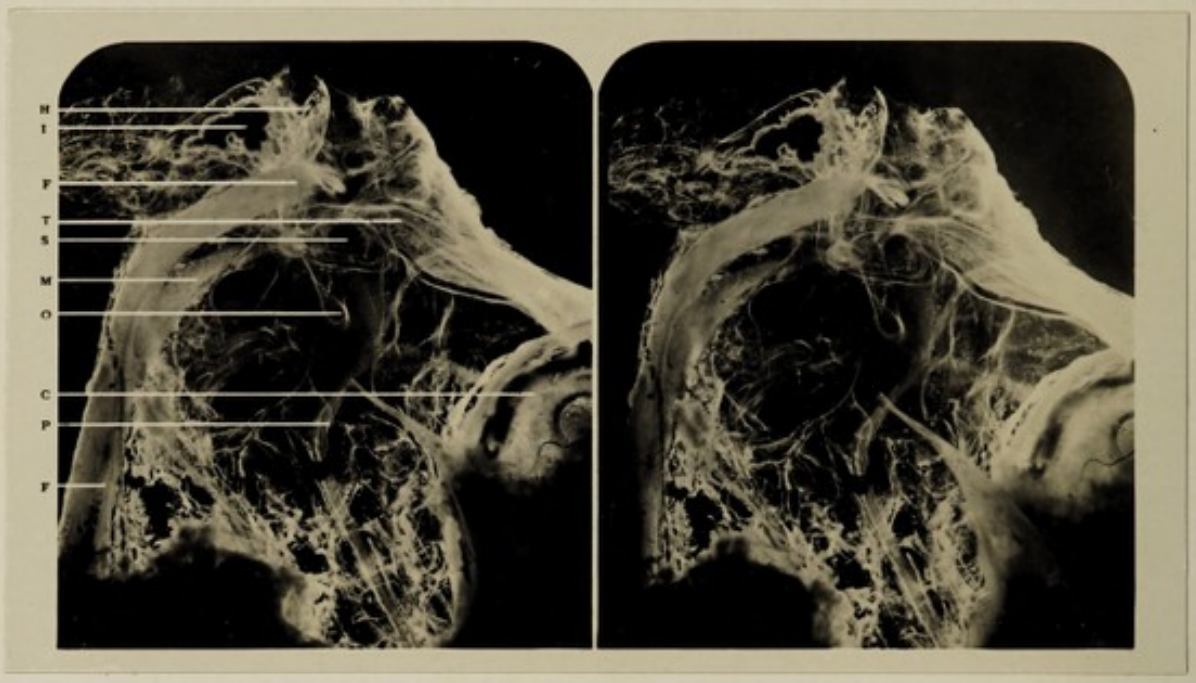
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FIG. 35. *Stereoscopic.* ×3½.

Viewed from the inner aspect and behind.

THE soft parts of the tympanum and adjacent regions. Left ear. Prepared by the author's method.* The bony tissue has been destroyed and the soft tissues left in their normal positions.

H. Head of malleus.
I. Body of incus ; a small portion of bone (black) has escaped decalcification.
F.F. Facial nerve in its horizontal and descending portions.
T. Tensor tympani muscle ; the tendon can be seen turning outwards to its insertion in the handle of the malleus.
S. Footplate of stapes in position in the oval window ; the crura and head of the bone are also shown.
M. Stapedius muscle with tendon going to insertion in the head of the stapes.
O. Tip of the handle of the malleus.
C. Carotid artery.
P. Nerve of Jacobson leading upwards to the tympanic plexus. See Fig. 31.

* Gray, *Labyrinth of Animals.* Vol. I. J. & A. Churchill. 1907.

FIG. 36. *Stereoscopic.* ×6.

PREPARATION showing the outer wall of the right vestibule as *viewed from within.*

The band of cartilaginous tissue surrounding the oval window is shown white (B.). A little foramen (V.) is seen behind the oval window ; this probably serves for the passage of a vein. Behind this foramen is seen the opening of the common crus of the superior and posterior semicircular canals.

It will be noticed that the inner surface of the footplate of the stapes (S.) does not lie quite flush with the wall of the oval window ; but that the anterior two-thirds are rotated outwards from the vestibule, while the posterior third is rotated inwards. This position is brought about by the pull of the stapedius muscle backwards upon the head of the bone. The annular ligament of the stapes is longest at the anterior margin of the oval window, rather shorter at the posterior margin, and shortest of all at the junction of the middle and posterior thirds, both above and below. Hence it follows that when the stapedius muscle contracts, the movements of the bone follow the lines of least resistance, and the footplate rotates round a vertical axis passing through the junction of the middle and posterior thirds. For a fuller account of this subject the reader is referred to a paper by the author.*

The passing of the vestibule into the scala vestibuli of the cochlea is well shown.

F. Facial nerve.
C. Upper part of vestibule just below the opening of the superior semicircular canal.
B. Band of cartilaginous tissue round the oval window.
S. Footplate of stapes.
V. Foramen.
P. Ampulla of posterior semicircular canal.
D. Lowest whorl of the cochlea.

* Gray, "On Some Anatomical Features of the Vestibule." *Proc. Roy. Soc. Med.* 1920. Vol. XIII. Section of Otology, pp. 17-22.

FIG. 37. *Stereoscopic.* $\times \frac{3}{2}$.

Viewed from above.

PREPARATION showing the origins of the great superficial petrosal and external petrosal nerves from the geniculate ganglion. Left ear. The bone has been dissected away but in the process of dissection both nerves were broken a few millimetres distant from their origin in the ganglion. The middle meningeal artery (M.) is cut across just after it has entered the cranial cavity through the foramen spinosum; and, had the external petrosal not been broken in dissection, it would have been seen continuing its course towards the foramen spinosum.

G. Geniculate ganglion.
S. Great superficial petrosal nerve.
P. External petrosal nerve.
M. Middle meningeal artery.

FIG. 38. *Stereoscopic.* $\times 4$.

Viewed from behind.

PREPARATION of the normal labyrinth, stained to show the veins. Left ear. The arteries are not seen. It will be noticed that the veins not only of the cochlea, but also, in large part at least, those of the vestibule and semicircular canals, leave the labyrinth by a main trunk in the region of the aqueduct of the cochlea.

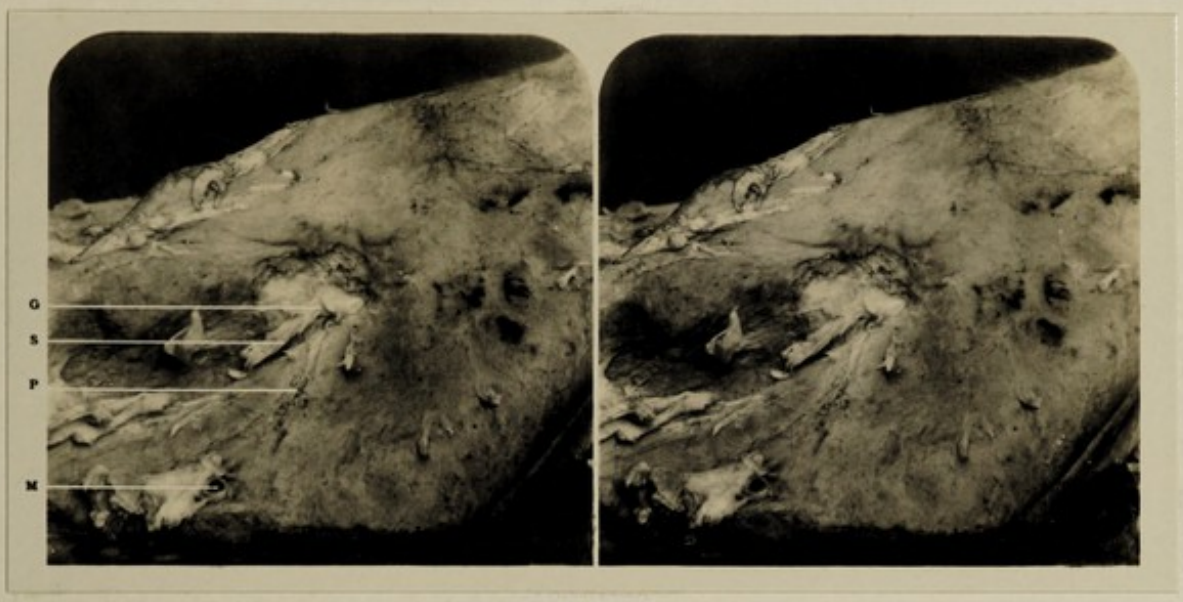
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FIG. 39. *Stereoscopic.* ×3.

PREPARATION showing the soft parts of the right middle and inner ear, *viewed from above.* The preparation was made by the author's method.*

S.C. Superior semicircular canal.
P.C. Posterior semicircular canal.
N. Seventh and eighth nerves in internal auditory meatus.
C.N. Nerve to the cochlea passing into the modiolus.
F.F. Facial nerve.
A.N. Nerve to ampullae of superior and horizontal semicircular canals.
G. Geniculate ganglion.
J. Nerve from tympanic plexus to geniculate ganglion.
T. Tensor tympani muscle ; the pointer crosses the long and short processes of the incus.
M. Head of malleus ; the pointer crosses the body of the incus.
E. Eustachian tube.
S. Muscle of Soemmering.

* *The Labyrinth of Animals.* By Albert A. Gray. 2 vols. J. & A. Churchill. 1907 and 1908.

FIG. 40. *Stereoscopic.* ×3.

Viewed from above.

HORIZONTAL slice of about one millimetre in thickness through a portion of the left temporal bone at the level of the oval window.

T. Tensor tympani muscle.
V. Nerve to vestibule ; the pointer crosses the cochlear nerve.
C.C. Chorda tympani.
F. Footplate of stapes.
M. Head of malleus.
B. Body of incus in its lowest part.
N. Facial nerve.
E. External auditory meatus.
P. Posterior semicircular canal.

FIG. 41. *Not Stereoscopic.* ×3.

Viewed from behind.

SECTION through the left temporal bone (not macerated).

The section passes in a vertical plane parallel with the long axis of the petrous portion of the temporal bone. The carotid artery is seen at the top right-hand corner of the preparation. The mastoid process is of the cellular type.

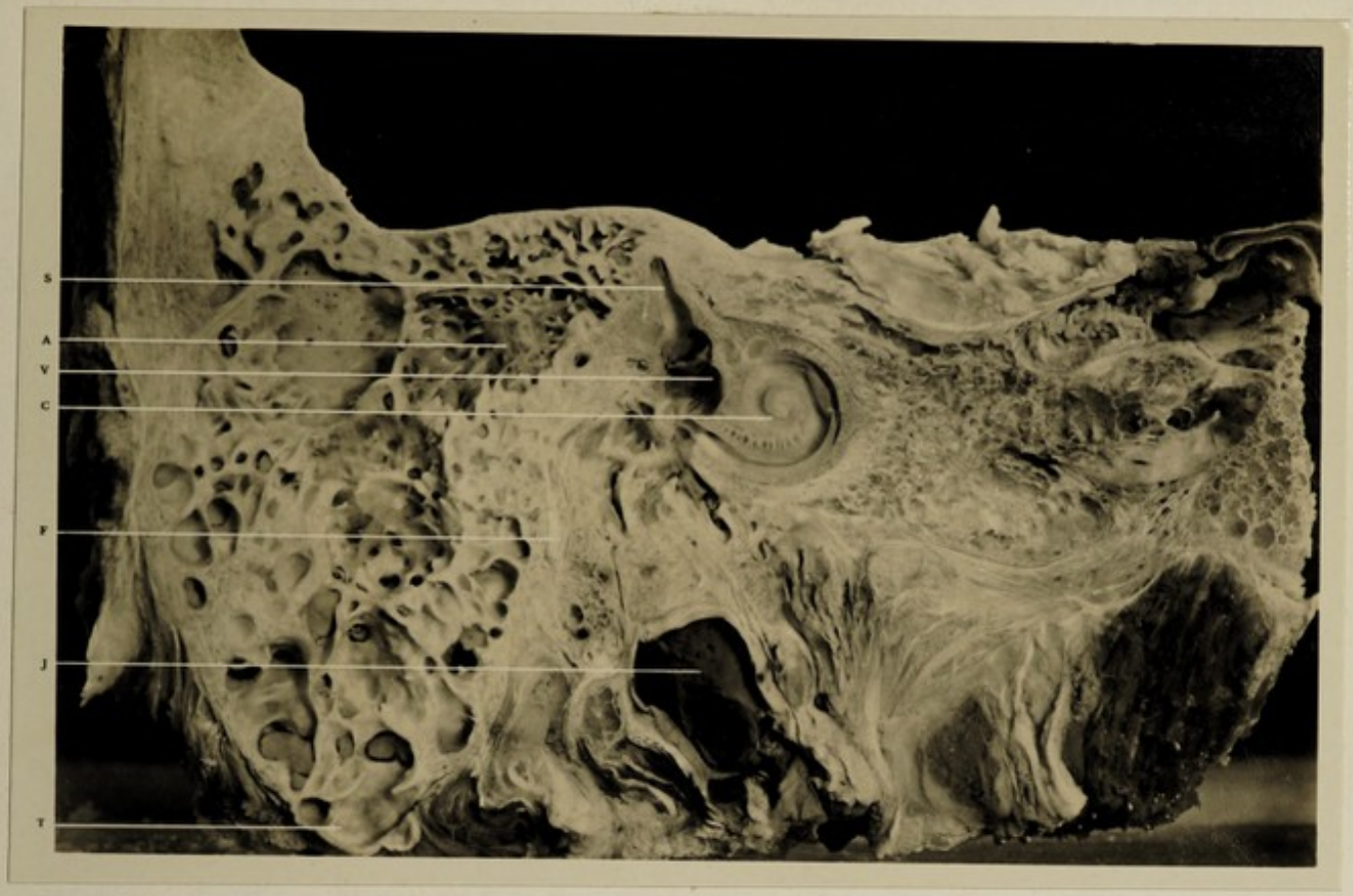
S. Superior semicircular canal.
A. Antrum.
V. Vestibule.
C. Cochlea.
F. Facial nerve.
J. Bulb of jugular vein containing post-mortem clot.
T. Tip of mastoid process.

FIG. 42. *Stereoscopic.* ×$\frac{3}{2}$.

Viewed from behind.

PREPARATION showing the superior petrosal sinus and its opening into the sigmoid sinus, which has been opened in that region. A black stylet lies along the petrosal sinus which has been opened up. Left ear.

E.S. Eminence of the superior semicircular canal.
S.P. Superior petrosal sinus opened up.
S.S. Sigmoid sinus opened in the outer part of its course.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SP
SS

FIG. 43. *Not Stereoscopic.* ×2.

Viewed from in front.

THESE four illustrations are photographs of four consecutive sections of the left temporal bone. They are cut from before backwards (and numbered 1, 2, 3, 4) in the vertical plane and in a direction almost parallel with the long axis of the petrous portion of the temporal bone. Each section is approximately one millimetre in thickness, and the sections are taken from the middle portion of the bone. Hence the anterior portions of the bone such as the eustachian tube, etc., are not shown, nor are the posterior portions such as the semicircular canals, etc., visible. The relationships of the carotid artery, the cochlea, the middle ear and ossicles, the facial nerve, the bulb of the jugular vein, the attic, the antrum and mastoid process are shown. It will be noticed that the mastoid process is of the dense acellular type.

H. Head of malleus.
T. Tensor tympani muscle.
C. Carotid artery.
M. Middle ear.
E. External auditory meatus.
A. Attic of tympanum.
D. Tip of handle of malleus.
B. Aditus ad antrum.
F. Facial nerve.
G. Upper whorl of cochlea.
J. Bulb of jugular vein.
P. Mastoid process.
N. Mastoid antrum.
O. Posterior portion of oval window.
R. Tympanic recess.

SECTION II

PATHOLOGICAL ANATOMY

FIG. 44. *Stereoscopic.* ×2½.

Viewed from the outer aspect.

LEFT ear showing a large perforation of the tympanic membrane, involving almost the whole of the membrana propria. The suppurative process had ceased a number of years before the patient's death. Only a narrow rim of the membrane is left round the margin. The handle of the malleus is indrawn but is not adherent to the promontory. The incus has been displaced at some time during or after the suppurative process, and its long process has been dragged forwards and downwards and has become adherent to the promontory. The lip of the round window has become thickened by bony deposit, so that the opening has become reduced almost to a slit. Shrapnell's membrane is still present.

L. Long process of incus.
M. Handle of malleus.

FIG. 45. *Stereoscopic.* ×2½.

Viewed from the outer aspect.

PREPARATION showing a large perforation in the lower portion of the left tympanic membrane. A considerable amount of pus was present in the middle ear, but this was removed before the photograph was taken. The short process of the malleus is seen (C.), but the manubrium is barely visible owing to the thickening of the outer layer of the membrane. The tip of the manubrium may be recognised (M.). The mucous membrane on the promontory is seen to be roughened and ulcerated.

C. Processus brevis of malleus.
M. Tip of the manubrium of malleus.
P. Promontory seen through the perforation; the mucous membrane in this region is thickened and ulcerated.


L
M


C
M
P


H
I
C
S
M


S
M

FIG. 46. *Stereoscopic.* $\times 2\frac{1}{2}$.

Viewed from the outer aspect.

PREPARATION of the right middle ear showing perforation in the tympanic membrane and adhesions resulting from a chronic middle ear suppuration which had ceased many years before the death of the patient.

A large perforation is seen in the anterior half of the membrane, and another equally large is seen in the posterior half, the latter being divided into an upper and lower portion by an adhesion in the form of a narrow band. A broad vertical strip of the tympanic membrane (M.) is seen between the perforations. The posterior margin of this strip of the membrane is adherent to the promontory. The whole of the external meatus, and the outer and upper walls of the attic have been removed.

H. Head of malleus.
I. Body of incus.
C. Chorda tympani.
S. Short process of malleus.
M. Tympanic membrane.

FIG. 47. *Stereoscopic.* $\times \frac{3}{2}$.

Viewed from the outer aspect.

PREPARATION of the right temporal bone showing the result of the eroding effects of cholesteatoma. The cholesteatoma has eroded away the outer wall of the attic with the result that the upper part of the external meatus opens direct into the attic and aditus ad antrum (S.). Shrapnell's membrane has also been destroyed, but the rest of the tympanic membrane with the handle of the malleus (M.) is still present. The preparation is dried, but not macerated. The cholesteatomatous mass was removed in order to show its eroding effects.

S. Large opening from meatus into attic and aditus.
M. Handle of malleus with all the lower portion of the tympanic membrane still present.

FIG. 48. *Stereoscopic.* ×3.

Viewed from the inner aspect.

PREPARATION showing the outer wall of the right tympanic cavity from a case in which chronic suppurative middle ear disease had previously been present. The suppurative process had ceased for many years before the death of the patient. The muco-periosteum is thickened and shows folds and adhesions. One of the latter is seen passing from the tip of the long process of the incus to the handle of the malleus. A perforation is seen in the posterior quadrant of the membrane (P.); the pointer crosses the tip of the handle of the malleus and the opening of the eustachian tube; into the latter a black stylet has been inserted.

The chief interest of this case, however, lies in the fact that a membranous diaphragm was found in the external meatus which completely occluded that passage. See Fig. 49.

P. Perforation.

C. Pocket of the eustachian tube.

FIG. 49. *Stereoscopic.* ×2.

Viewed from the outer aspect.

PREPARATION showing a membranous diaphragm completely occluding the external auditory meatus. The diaphragm is situated about 2 mm. external to the tympanic membrane, see Fig. 48. The diaphragm must have arisen as the result of an ulcerative condition in the meatus, because as will be seen in Fig. 48 there is fairly large perforation in the tympanic membrane which is clearly the result of an old middle ear suppuration which had dried up. This photograph should be compared with Fig. 48, which shows the tympanic membrane and ossicles in the same preparation.


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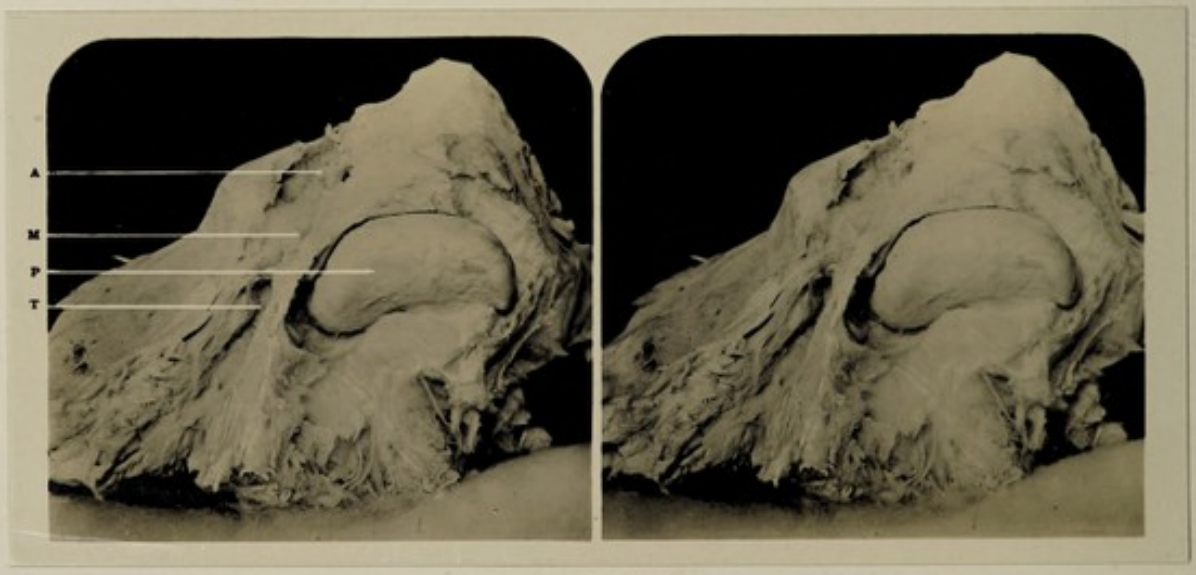
A
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T

FIG. 50. *Stereoscopic.* ×$\frac{3}{2}$.

Viewed from the outer aspect.

PREPARATION of the right ear showing the results of chronic middle ear suppuration. The suppuration produced a large perforation in the membrane. After the suppuration passed off the edges of the perforation became adherent to the inner wall of the tympanum, and a portion of the latter, including the round window and the region of the stapes became covered with epidermis instead of the normal mucous membrane. The external meatus, with the exception of the posterior and inferior walls, has been removed in order to show the parts more clearly. The ossicles are all present. The bone round the cochlea has been dissected away, but no disease of that structure was found. A small portion of the original tympanic membrane in front of the handle of the malleus still remains.

A.M. Mastoid antrum.
I. Body of incus.
S.T. Large scar of the tympanic membrane adherent to promontory, etc.
M.T. Remains of tympanic membrane.
C. Cochlea.
A.C. Posterior wall of carotid canal

FIG. 51. *Stereoscopic.* Natural size.

Viewed from in front.

POLYPUS completely filling the left external meatus. The upper, anterior and part of the lower walls of the meatus have been removed. The upper walls of the eustachian tube, middle ear, and antrum have been removed. From the same case as Fig. 60.

A. Antrum.
M. Head of malleus.
P. Polypus.
T. Eustachian tube.

FIG. 52. *Stereoscopic.* $\times \frac{2}{3}$.

Viewed from the outer aspect and in front.

INNER wall of antrum, middle ear and portion of eustachian tube from a case of acute middle ear inflammation. The pus with which the cavities were filled has been removed. Right ear.

The muco-periosteum of the antrum and middle ear are thickened and oedematous. The pelvis of the oval window is almost filled by the swollen mucous membrane, and the capsule of the incudo-stapedial articulation is thickened and the crura of the stapes are hidden. The muco-periosteum of the lip of the round window is so thickened that the entrance to the window is almost completely obliterated. The mucous membrane of the eustachian tube is much less affected than that of the middle ear or antrum.

A. Antrum.
E. Eustachian tube.
S. Incudo-stapedial articulation.
P. Promontory.

FIG. 53. *Stereoscopic.* Natural size.

Viewed from the inner aspect and behind.

(From the same case as the preparation shown in Fig. 54.)

PREPARATION of the left temporal bone showing the eustachian tube, tympanic membrane, antrum, and fistula leading into the posterior fossa of the skull, from a case of acute middle ear inflammation which resulted in cerebellar abscess. This case is of particular interest in that the tympanic membrane was not perforated. It is extremely rare to find intracranial complications of middle ear disease without perforation of the tympanic membrane.

It will be observed that the inner surface of the tympanic membrane is thickened and thrown into folds. The eustachian tube is not affected quite so much as might be expected. A white stylet has been inserted into the upper part of the antrum and a black stylet has been passed into the fistula which leads from the posterior fossa of the skull into the lower part of the antrum. It was through this fistula that infection passed and led to cerebellar abscess.

The pus which filled the middle ear, antrum and eustachian tube has been washed off in order to show the structures.


A
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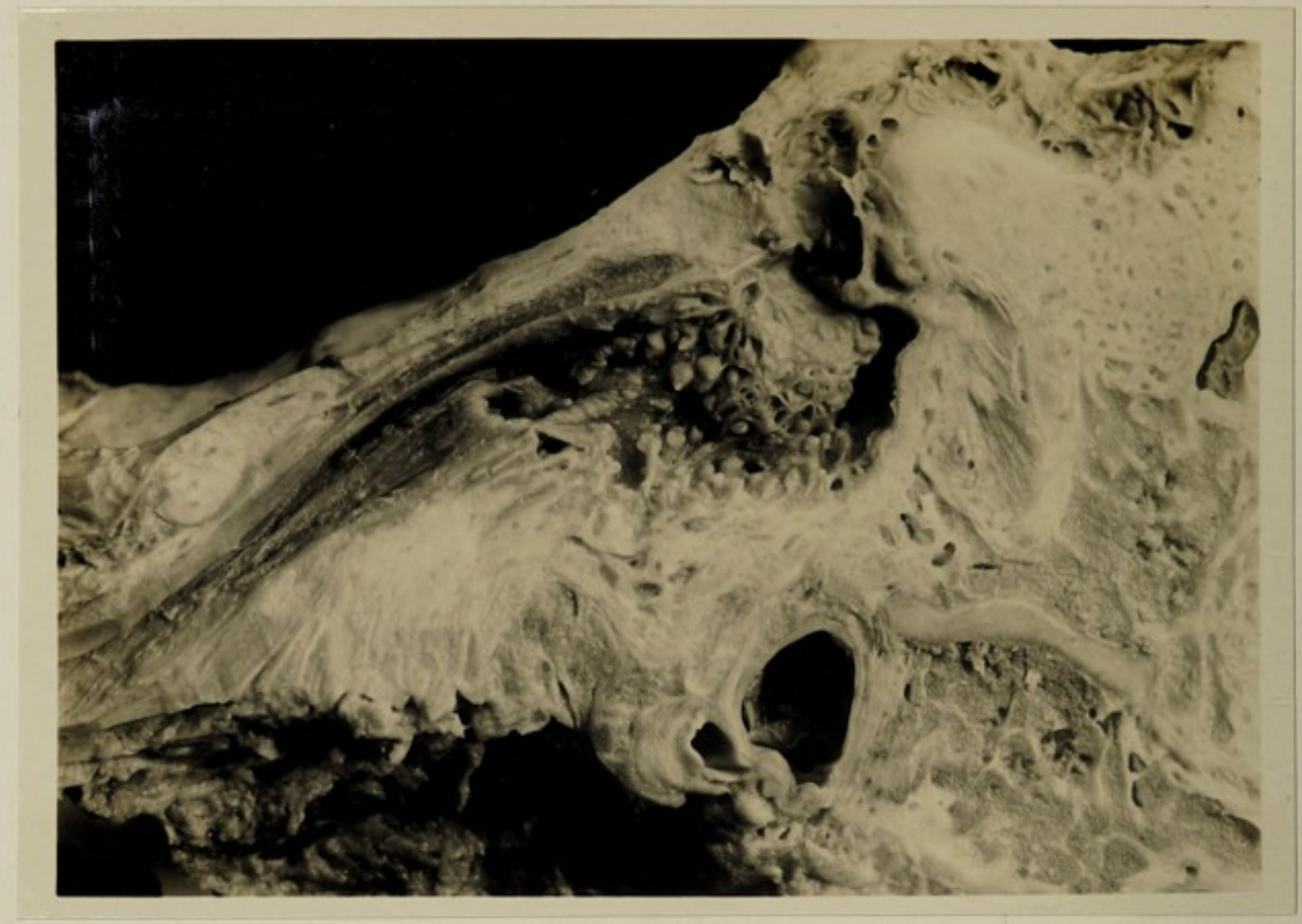
P

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M
C
C

FIG. 54. *Not Stereoscopic.* ×4.

Viewed from the outer aspect and in front.

PREPARATION of the left temporal bone showing the inner wall of the eustachian tube and middle ear, from a case of acute middle ear inflammation. From the same case as that shown in Fig. 53.

The muco-periosteum covering the promontory and middle ear generally is thickened and thrown into folds and roughened. The walls of the eustachian tube, though not entirely free from inflammatory thickening, are not affected quite so much as might have been expected.

The pus which was present has been removed in order to show the altered condition of the structures.

FIG. 55. *Stereoscopic.* ×3.

Viewed from the inner aspect.

OUTER wall of tympanic cavity of the right side, showing adhesions.

The clinical history of this case is not known, but numerous adhesions, obviously of comparatively recent formation, are seen especially around the long process of the incus and the manubrium and head of the malleus.

L. Superior ligament of malleus.
H. Head of malleus.
C.C. Chorda tympani.

FIG. 56. *Stereoscopic.* × $3\frac{1}{2}$.

Viewed from the outer aspect and in front.

PREPARATION showing the left middle ear from a case of chronic middle ear suppuration. The middle ear and antrum were filled with pus and epithelial debris of which some is seen in the photograph, especially about the upper portions of the incus and malleus. A small pedunculated granulation (G.) is seen springing from the region of the posterior margin of the tympanic ring. The stapes is absent, having probably been destroyed by caries.

G. Granulation.
R. Region of round window.
C. Carotid canal laid open by the saw in making the preparation.

FIG. 57. *Stereoscopic.* ×5.

Viewed from the outer aspect.

INNER wall of left tympanic cavity from a case of senile deafness. The right ear is shown in microscopic section in Fig. 92. This patient died at the age of a hundred and one years. She was completely deaf in both ears to all sounds that could be employed to test the hearing, *e.g.* loud bells, banging of tins, etc. The deafness had begun about the age of seventy-five and become gradually worse. On examining the left middle ear, it was found that there was no perforation or scar in the tympanic membrane. The hammer was present and the tip of the manubrium was adherent to the promontory. The long process of the incus had been eroded away in its lowest third. Both crura of the stapes had been eroded away and only a short stump of the anterior crus close to the footplate was left. Thus the incudo-stapedial articulation was destroyed. The footplate of the stapes (S.) was fixed to the walls of the oval window, but there was no evidence of bony ankylosis. The muco-periosteum of the middle ear was thickened and adhesions were present at various parts. Apparently therefore, suppurative disease had been present at some period in the patient's life, and brought about the changes described. If so, however, it was probably of short duration for there was found no perforation or scar in the tympanic membrane.

The profound deafness was not, of course, due to the changes in the middle ear, but to changes in the labyrinth and auditory nerves the result of age.

S. Footplate of stapes, with stump of anterior crus.
R. Round window.


G
R
C


S
R

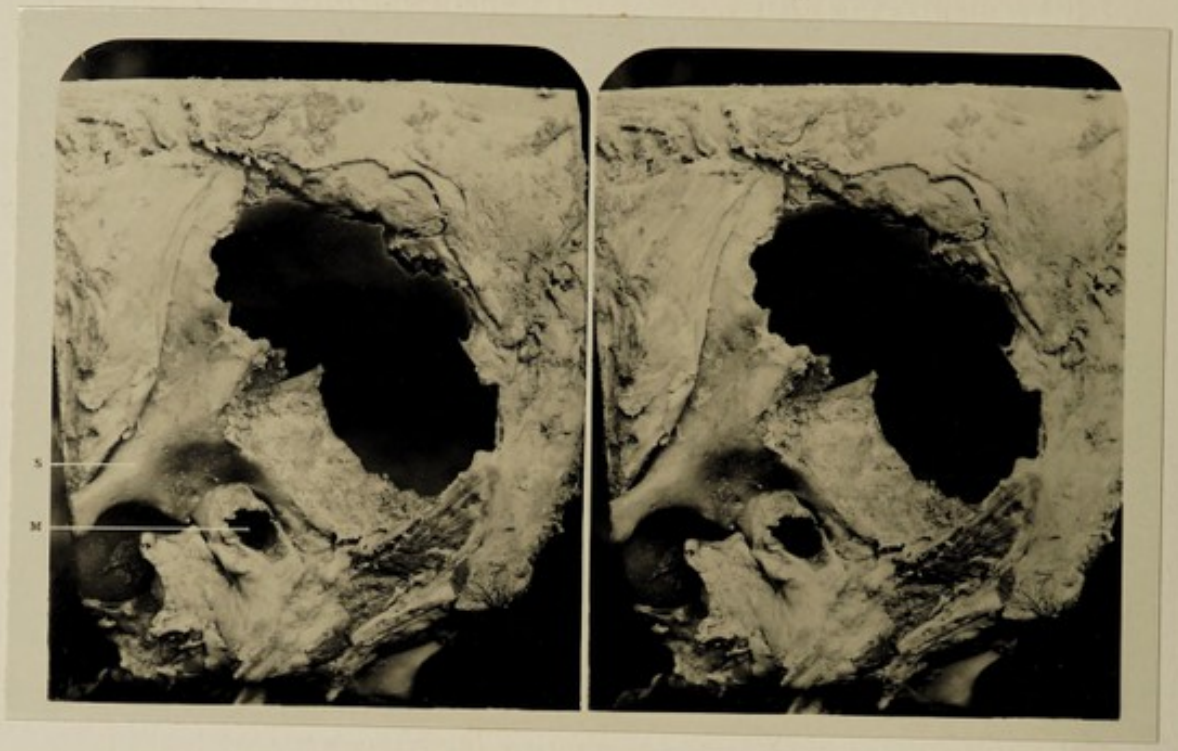

S
M

FIG. 58. *Stereoscopic.* ×2½.

Viewed from the outer aspect.

PREPARATION showing extensive destruction of the left temporal bone in an infant six months old. The patient had suffered from middle ear suppuration for several weeks before it died from septic meningitis. The squamous portion of the bone and the walls of the antrum have been destroyed by necrosis over a large region.

S. Root of zygoma.
M. External auditory meatus.

FIG. 59. *Stereoscopic.* Natural size.

Viewed from above.

PREPARATION showing a rather large, irregular opening in the roof of the attic and antrum, due to caries, the result of chronic middle ear suppuration. Through this opening infection passed into the temporo-sphenoidal lobe and caused the formation of an abscess which resulted in death. Left ear.

FIG. 60. *Stereoscopic.* $\times \frac{1}{3}$.

Viewed from above.

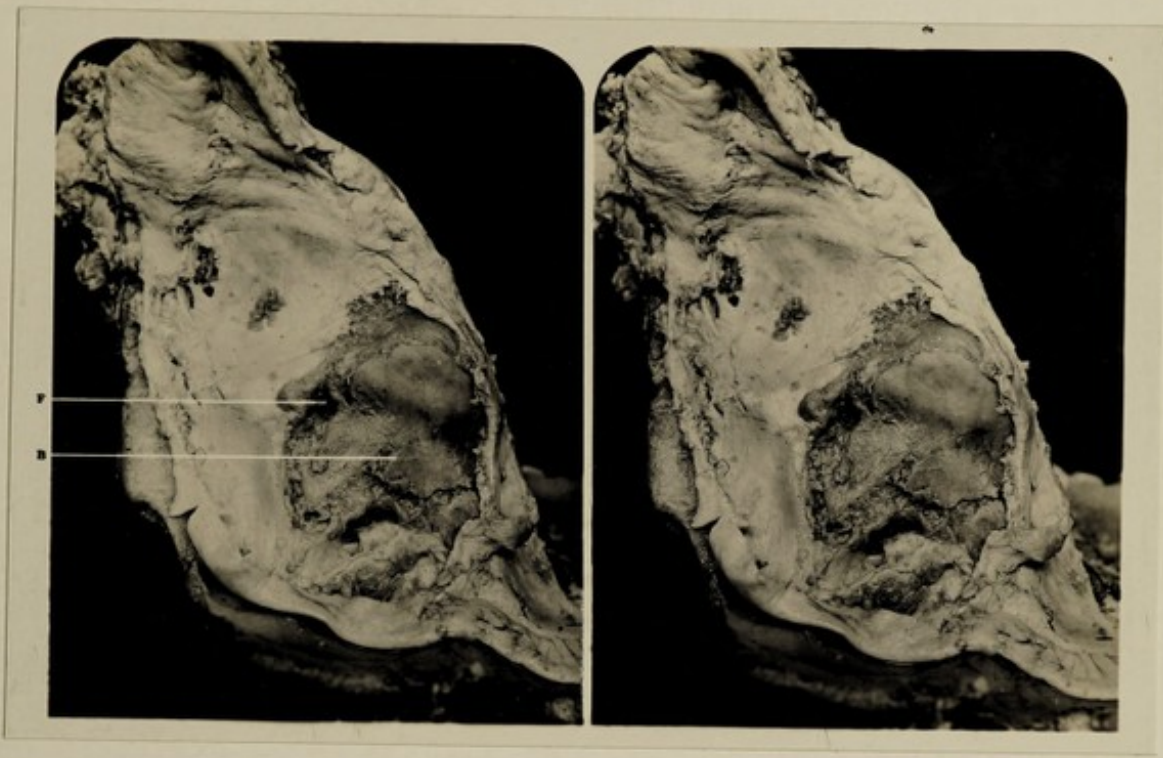
PREPARATION showing the upper surface of the petrous portion of the left temporal bone from a case which died of diffuse septic meningitis. The fistula through which infection occurred is shown (F.) and leads through the tegmen tympani into the middle fossa. The dura mater was necrotic over the area B., and the bone is seen to be bare in this region. A large polypus, shown in Fig. 51, was present in the external meatus. The meningitis was far advanced when the patient was admitted to the infirmary.

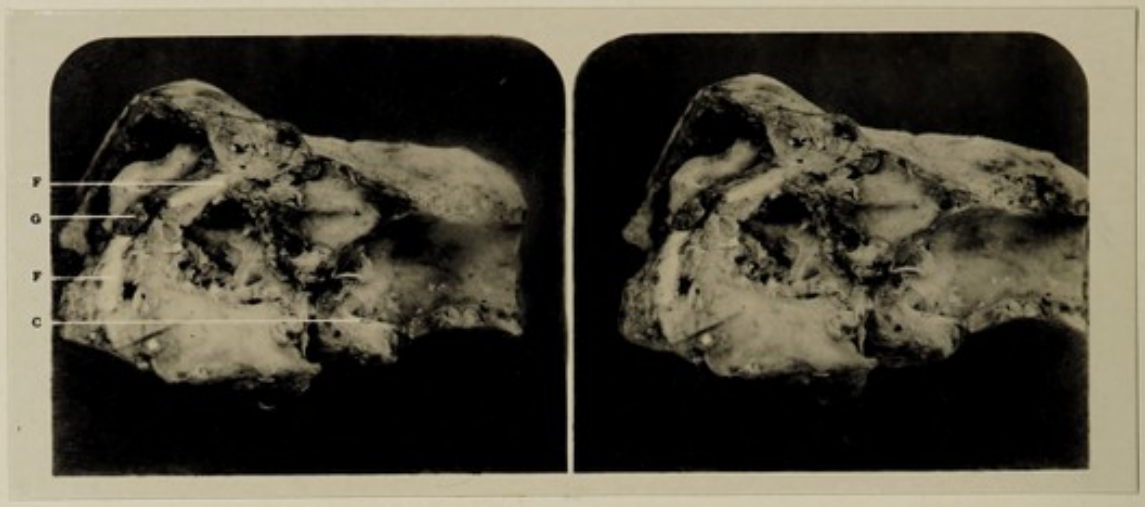
F. Fistula leading into middle ear.

B. Large area of bone laid bare by destruction of the dura mater.

FIG. 61. *Stereoscopic.* Natural size.

PETROUS portion of right temporal bone from a case of diffuse septic meningitis; *viewed from behind.* The intracranial infection was the result of chronic middle ear suppuration, and the pathway of infection was by way first of the labyrinth (see Fig. 84), and from there by way of the aqueduct of the vestibule. A stylet has been passed into the latter, which was much wider than normal, owing apparently to caries of its walls. See Figs. 62 and 84, which show preparations from the same case.


F
B


F
G
T
C

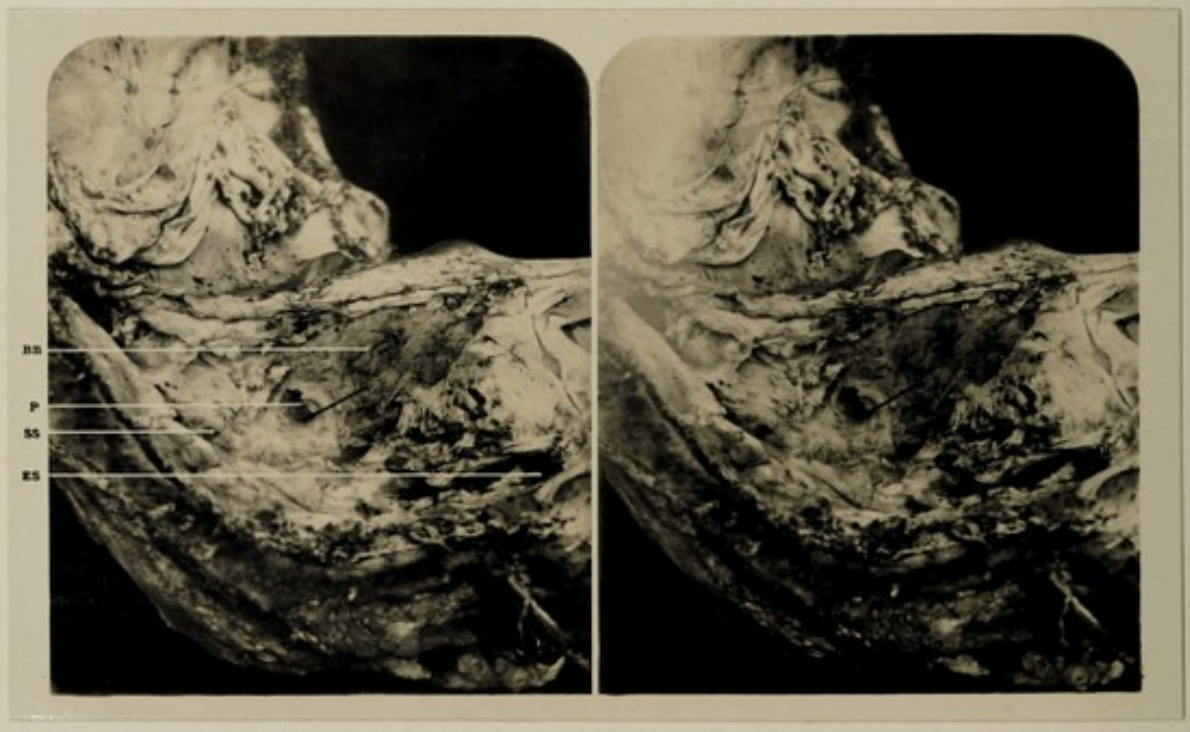

ES
P
SS
ES

FIG. 62. *Stereoscopic.* Natural size.

SAME preparation as that shown in Fig. 61, but *viewed from in front.* The bone covering the facial nerve was removed at the operation and revealed the existence of a granulation at the bend of the nerve (G.). This granulation was in the bony canal of the nerve and by its pressure caused facial paralysis. It is interesting to note that after operation, in the course of which the facial canal was laid open, without injuring the nerve, the paralysis rapidly disappeared. The meningitis continued, however, unaffected by the operation, and proved fatal within a week. At the operation the stapes was found to be absent. See Figs. 61 and 84.

F.F. Facial nerve.
G. Granulation on facial nerve.
C. Carotid canal.

FIG. 63. *Stereoscopic.* $\times\frac{3}{2}$.

Viewed from behind.

PREPARATION of the left temporal bone from a case of cerebellar abscess. The opening of the fistula (P.) into the cranial cavity is seen on the posterior wall of the bone. A stylet has been passed into the fistula. The sigmoid sinus, S.S., cut open in almost its whole length, is shown to its exit from the skull (E.S.). The fistula is seen to be above and internal to the sinus. This is the usual position in cases of cerebellar abscess, but occasionally the fistula is external to the sinus.

B.B. Posterior surface of temporal bone.
P. Opening of fistula.
S.S. Sigmoid sinus laid open.
E.S. Exit of sigmoid sinus from skull.

FIG. 64. *Stereoscopic.* $\times \frac{4}{3}$.

Viewed from behind.

PORTION of the right temporal bone (macerated) from a case of septic thrombosis of the sigmoid sinus. A large opening is seen leading from the mastoid process to the groove for the sigmoid sinus. The opening was produced by caries of the bone, the result of chronic middle ear suppuration.

S.S. Sigmoid sinus.

P. Opening from mastoid process into groove for sigmoid sinus.

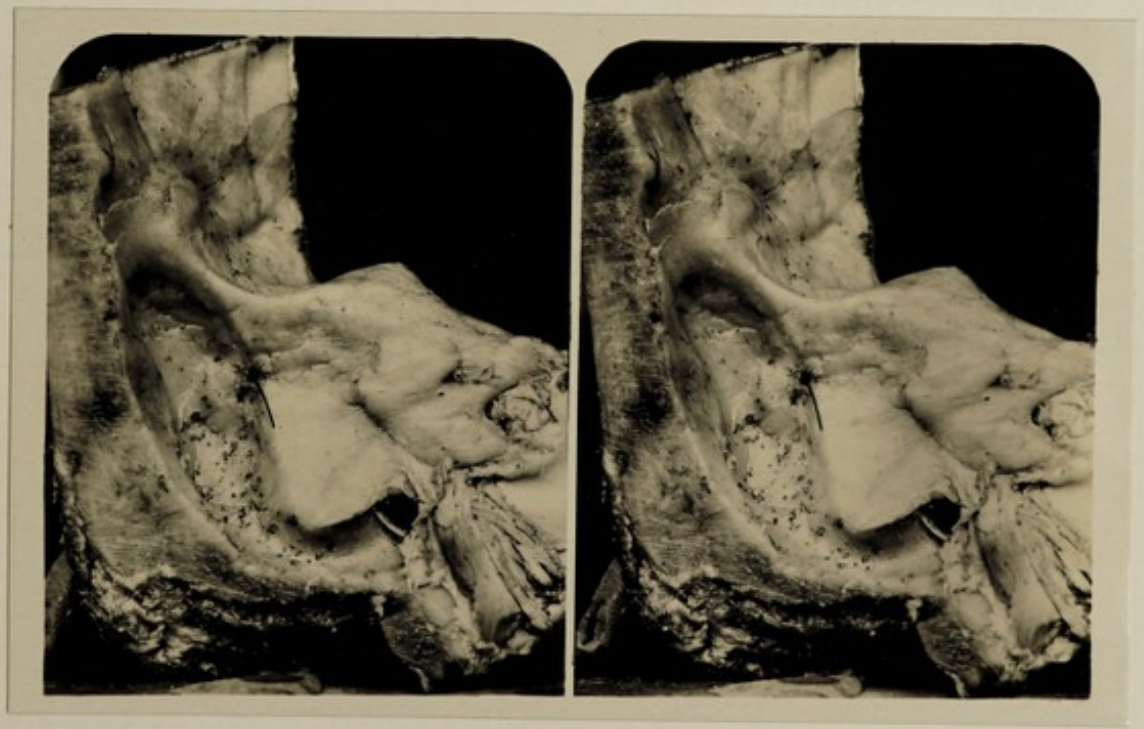
FIG. 65. *Stereoscopic.* $\times \frac{3}{2}$.

Viewed from behind.

PREPARATION of left temporal bone from a case of septic thrombosis of the sigmoid sinus. The opening of a fistula leading from the mastoid antrum to the posterior fossa of the skull, is seen in the groove for the sigmoid sinus, close to the internal lip of the groove. A stylet has been passed into the fistula. The little black specks seen in the groove indicate the presence of thrombosis in the numerous little veins passing from the bone into the sinus.

In this specimen the sinus is found further forward than is usual, consequently when the infection reached the inside of the skull the first structure to suffer was the sinus. Had the latter been placed further back, it would have escaped infection, and a septic meningitis or cerebellar abscess would have resulted instead. Cf. Fig. 63.


SS
P
SS



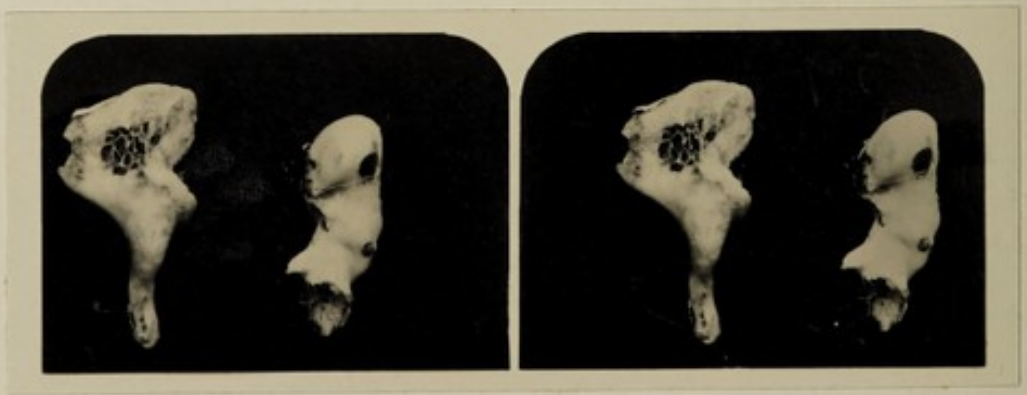


FIG. 66. *Stereoscopic.* $\times \frac{3}{2}$.

Viewed from above.

THE right temporal bone from a case of temporo-sphenoidal abscess.

The infection passed through the roof of the antrum and entered the middle fossa of the skull at the point M. where the bone is carious.

M. Small area of carious bone in the roof of the mastoid antrum, by which the infection found its way from the middle ear to the middle fossa of the skull.

FIG. 67. *Stereoscopic.* $\times 3\frac{1}{2}$.

CARIES of the malleus and incus of the left ear. The ossicles were removed during the radical mastoid operation for chronic middle ear suppuration. The short process of the incus has been completely eroded away; the body of the ossicle also shows the presence of caries, and the articular surface is roughened and eroded. The lower end of the long process of the incus also shows signs of caries.

The manubrium of the malleus has been completely destroyed and has disappeared; and the head and neck of the bone are reduced to the hollow shell which is seen in the photograph.

FIG. 68. *Stereoscopic.* ×4.

THE tympanic membrane of the right side, *viewed from the outer aspect.* There is a large atrophic patch (P.P.) in the posterior and inferior quadrants. The atrophy is most pronounced in the lower portion where even the radiating fibres of the membrane have almost entirely disappeared. The membrane is indrawn, and the short process rather more prominent than normal. Shrapnell's membrane has been destroyed by a suppurative process which had dried up probably many years ago.

P.P. Atrophic patch in tympanic membrane.

FIG. 69. *Stereoscopic.* ×6½.

INNER wall of tympanum of the left side; *viewed from the outer aspect.* From a case of otosclerosis.

The bone has been thoroughly macerated so that all the soft parts have been removed. In spite of this it will be noticed that the stapes remains in position in the oval window. This is, of course, due to the fact that bony ankylosis has occurred at the stapedio-vestibular articulation. A small spur-like exostosis is seen below the posterior crus of the stapes. These exostoses are frequently present in otosclerosis (see Fig. 71).

Though in no way associated with the otosclerosis, it is interesting to observe that the tympanic recess (A.) is well developed in this specimen. This small cavity represents in man the tympanic bulla which forms such a large portion of the middle ear cavities in many of the vertebrates, *e.g.* carnivora, rodents, etc.*

H. Hook-like process round which the tendon of the tensor tympani passes.

A. Tympanic recess.

* See "Notes on the Comparative Anatomy of the Middle Ear." Gray. *Journ. of Anat. and Physiology.* Vol. XLVII. p. 391.


P
P


H
A


APEX

FIG. 70. *Stereoscopic.* ×3.

(From the same case as Figs. 78, 79, and 80.)

Viewed from the outer aspect.

PREPARATION of the left ear from a case of otosclerosis of old standing. The deposit of bone round the margins of the oval window is so considerable that it has involved the crura of the stapes as well as the footplate. The bony lip of the round window is also noticeably thickened. A thin fibrous band is seen passing from the posterior crus of the stapes to the bone below. There is no reason to suppose that this is pathological, as such bands are frequently found in quite normal ears. The mucous membrane is normal and shows no sign of inflammatory activity past or present.

FIG. 71. *Stereoscopic.* ×2½

(From the same case as Figs. 76 and 77.)

Viewed from the outer aspect and below.

INNER wall of the tympanum and adjacent structures from a case of otosclerosis of twenty-five years' duration.

There is no thickening of the mucous membrane nor any sign of inflammatory process. The blood-vessels over the promontory are dilated. This condition is not uncommon in otosclerosis and gives rise to the familiar rosy-pink tint which the tympanic membrane sometimes presents when examined in the living subject, through the aural speculum. The deep crimson tint of the injected vessels on the promontory is diffused and rendered a rosy-pink colour by the pearl-coloured semi-translucent tympanic membrane.

There are several exostoses on the inner wall of the tympanic cavity as described below. The microscopic appearances in this case are shown in Figs. 76 and 77. A full description, clinical and pathological, of this case has been given by the writer.*

A. Anterior crus of stapes.
P. Promontory showing dilatation of the blood-vessels and two or three small bulging exostoses.
E. Spur-like exostosis below the oval window.
R. Round window.

* Gray. *Otosclerosis; Idiopathic Degenerative Deafness*, p. 104. H. K. Lewis. 1917.

FIG. 72. *Not Stereoscopic.* ×8.

(From the same case as Figs. 73, 74, 75, and 83.)

MICROSCOPIC section through the petrous portion of the temporal bone from a case in the early stage of otosclerosis, cut in the horizontal plane.

The diseased portion of the bone (N.) is seen, almost circular in outline, immediately in front of the oval window. It will be noticed that this is the only region of the bone which is diseased. The footplate of the stapes is not fixed.

N. Area of diseased bone.
F. Footplate of stapes.
V. Vestibule.
P. Posterior semicircular canal.

For a detailed description of the history and pathological changes in this case see the author's work : *Otosclerosis ; Idiopathic Degenerative Deafness.* Albert A. Gray. H. K. Lewis & Co. 1917.

FIG. 73. *Not Stereoscopic.* ×80.

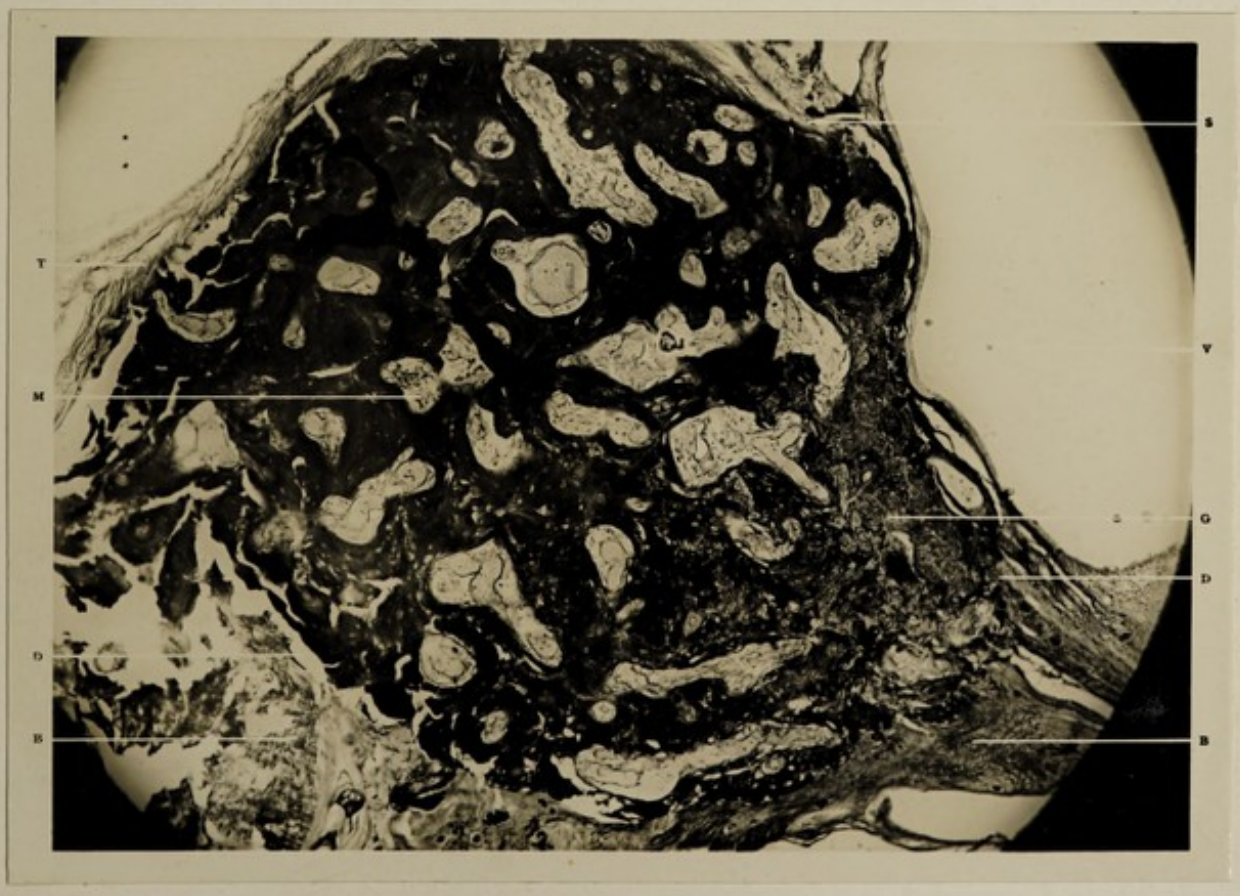
(From the same case as Figs. 72, 74, 75 and 83.)

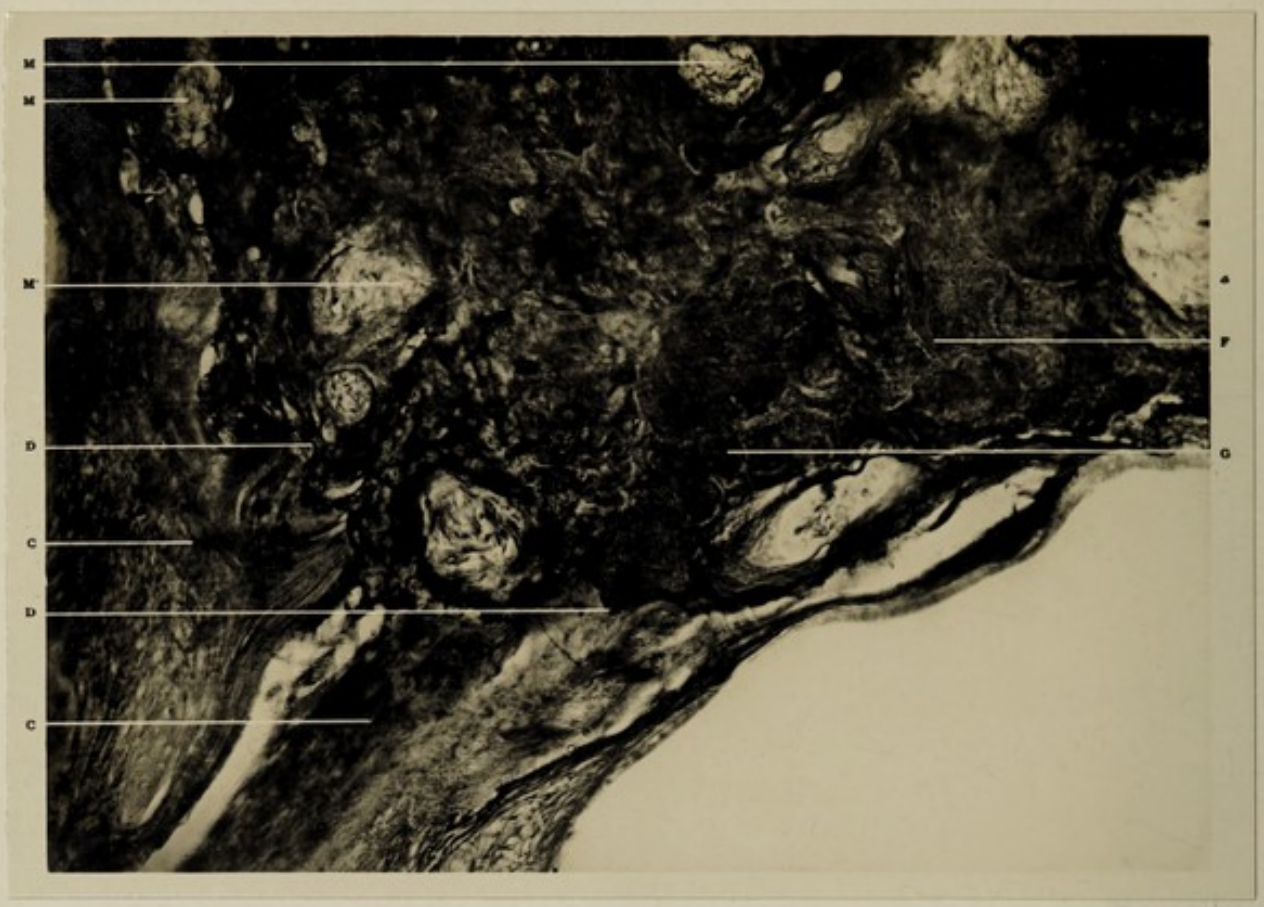
HORIZONTAL microscopic section from an early case of otosclerosis.

The diseased portion of the bone occupies most of the field and is almost spherical in outline. The greater portion of the diseased area shows large spaces containing marrow (M.) and deposits of new-formed bone with well-marked lamination. A smaller portion of the diseased area is stained paler (G.). This portion has no marrow spaces or new bone deposit ; it is an early stage of the process, the old bone of the capsule having been absorbed, but the new bone has not yet been formed. (See Fig. 74.)

T. Muco-periosteum of tympanic cavity.
M. Space containing marrow in the region where well-laminated dark-staining new bone has been deposited.
D.D. Line of demarcation between the diseased area and the normal bone of the capsule of the labyrinth.
B.B. Normal bone of the capsule of the labyrinth ; marrow is not found in this region.
G. Pale-stained portion of diseased area in which the bone of the capsule of the labyrinth has been absorbed, but no marrow spaces as yet formed nor any new bone deposited (see Fig. 74).
V. Vestibule.
S. Stapedio-vestibular articulation ; the disease has not yet caused ankylosis : cf. Figs. 77 and 78.


N
F
V
P


S
T
V
M
G
D
D
B
B


M
M
M
D
C
D
C
A
F
G

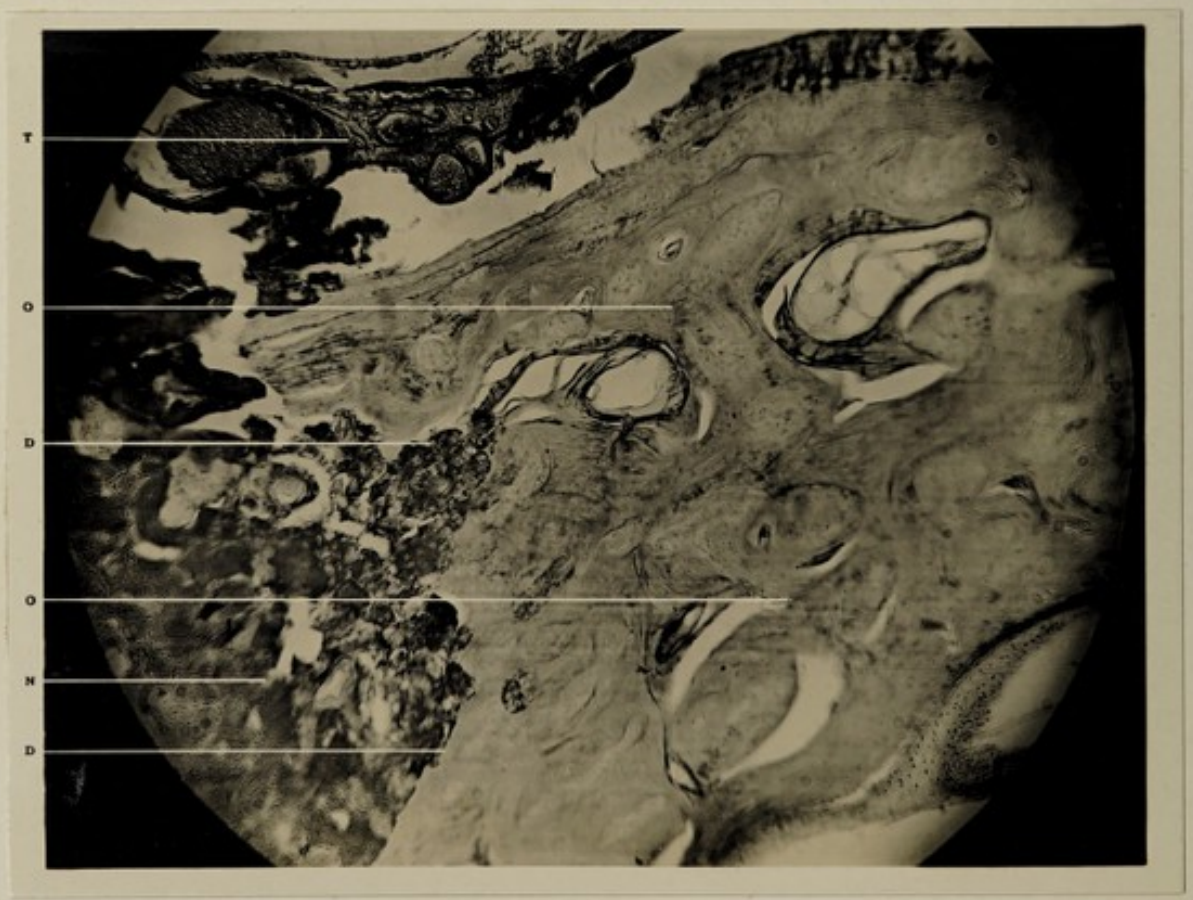

T
O
D
O
N
D

FIG. 74. *Not Stereoscopic.* ×170.

(From the same case as that shown in Figs. 72, 73, 75 and 83.)

MICROSCOPIC section showing the earlier changes in the bone in an early case of otosclerosis.

In the photograph three regions may be distinguished.

(1) Below and to the left a region stained pale and showing a striated appearance ; this is the normal capsule of the labyrinth (C.C.).

(2) Above and in the middle a dark-staining region with two or three spaces containing marrow (M.M.M.). This is the region in which the new bone is first beginning to be deposited.

(3) To the right a region staining rather pale (F.). In this region the normal bone of the labyrinth has been absorbed, but new bone has not as yet been deposited. Giant-cells (G.) or osteoclasts, irregular in shape and ill-defined in outline, are seen in this region. This region represents an earlier stage of the disease than region 2.

The sharp line of demarcation (D.) between the normal bone of the capsule and the diseased area should be noted.

For further information in regard to the clinical history, etc., of this case the reader is referred to the author's work :—*Otosclerosis*, etc. Albert A. Gray. (H. K. Lewis & Co., Ltd.) 1917.

FIG. 75. *Not Stereoscopic.* ×100.

(From the same case as that shown in Figs. 72, 73, 74 and 83.)

SECTION of the temporal bone from an early case of otosclerosis showing the line of demarcation and the adjacent portions of the normal and diseased bone.

The particular feature of interest in this photograph, is that it shows the actual process of the budding off of large cells from the wall of a blood-vessel. In the region of normal bone near the line of demarcation a blood-vessel is seen cut across. From the wall of this vessel large cells are seen which have just budded off. Similar cells may be seen forming a pathway towards the diseased area, and a number of them are seen in this area near the line of demarcation. These cells are clearly absorbing the bone, and may therefore be looked upon as osteoclasts.

There is, however, good reason to believe that in some types of bony change in otosclerosis, the osteoclasts are formed by the coalescence of osteoblasts in the way described by Kölliker ; and an example of this has been demonstrated by the present writer.*

T. Tympanic plexus.
O.O. Normal bone of the capsule of the labyrinth ; stained faintly.
D.D. Line of demarcation.
N. Focus of diseased area, stained deeply.

* Gray. *Otosclerosis ; Idiopathic Degenerative Deafness*, pp. 126 and 127. (H. K. Lewis & Co., Ltd.) 1917.

FIG. 76. *Not Stereoscopic.* ×8.

(From the same case as that shown in Figs. 71 and 77.)

HORIZONTAL section of the labyrinth from a case of otosclerosis in which the deafness had been in existence for twenty-five years.

The diseased area is seen in front of the oval window, and extends forward to the lowest whorl of the cochlea. This area shows the usual osteo-porotic changes of otosclerosis. No other diseased area was present in the labyrinthine capsule. The anterior margin of the footplate of the stapes is fixed by bone to the wall of the oval window.

A. Area of diseased bone.
V. Vestibule.

For a full description of the clinical history, pathological changes, etc., in this case see *Otosclerosis ; Idiopathic Degenerative Deafness*, p. 104. Albert A. Gray. (H. K. Lewis & Co., Ltd.) 1917.

In recent times Jenkins* has demonstrated the similarity between the common type of bony change in otosclerosis and that found in osteitis deformans. His description does not, of course, apply to the rarer forms of bony change in otosclerosis as shown in Figs. 78, 80, 81 and 82 in this atlas.

* *Journal of Laryngology and Otology*, July 1923.

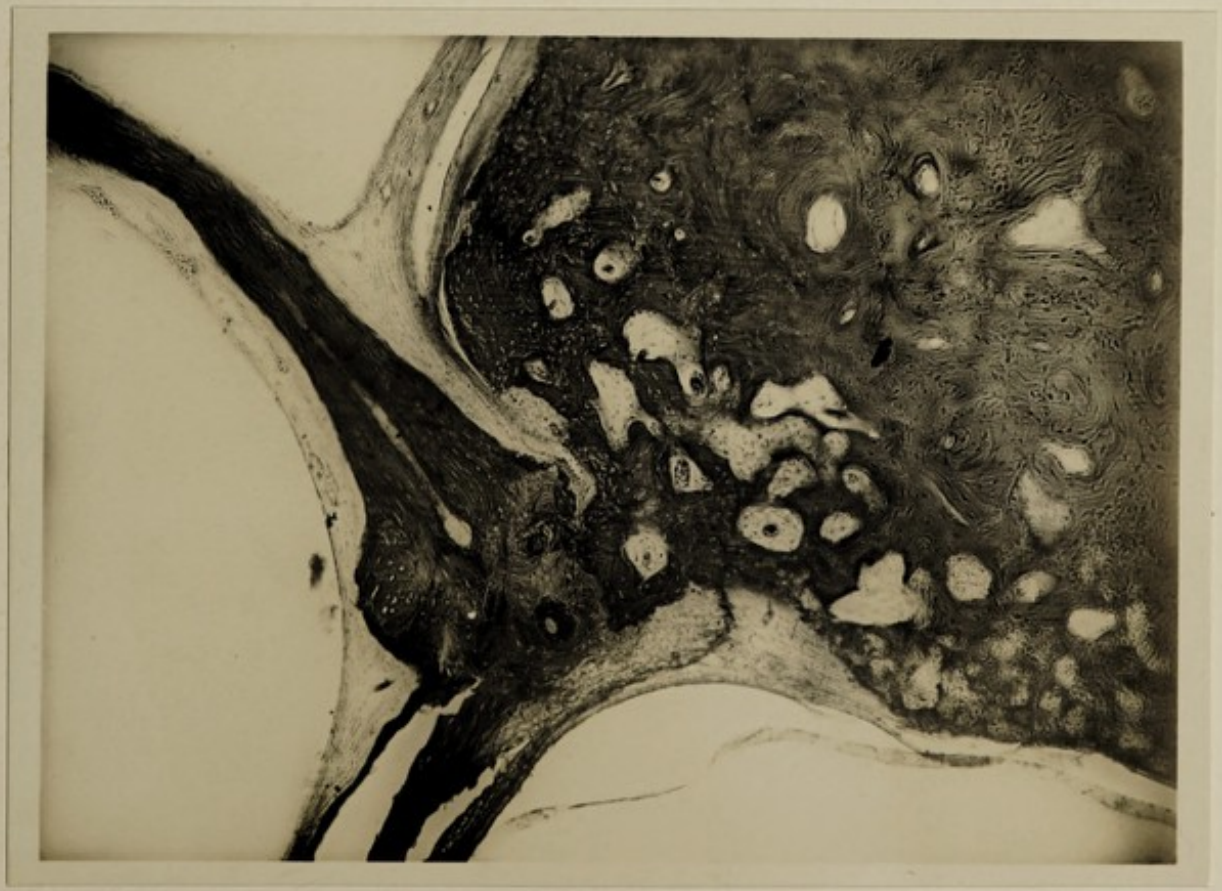
FIG. 77. *Not Stereoscopic.* ×120.

(From the same case as that shown in Figs. 71 and 76.)

SECTION from a case of otosclerosis of twenty-five years' duration. The anterior crus of the stapes is shown and the adjacent region of the anterior wall of the oval window. A portion of the diseased area in the latter region is shown. The bony change is that which is found usually in otosclerosis. The new-formed diseased bone has at one point destroyed the stapedio-vestibular articulation, and a bridge of the new-formed bone is seen beginning to extend into the footplate of the stapes and causing ankylosis.

For clinical and other details of this case see :—*Otosclerosis ; Idiopathic Degenerative Deafness*, p. 104. Albert A. Gray. (H. K. Lewis & Co., Ltd.) 1917.


A
V




M
N

FIG. 78. *Not Stereoscopic.* ×8.

(From the same case as that shown in Figs. 70, 79 and 80.)

HORIZONTAL microscopic section of the left temporal bone, from an advanced case of otosclerosis. The patient died at the age of eighty-five, the disease having been in existence for more than sixty years. In this case there was striking evidence of hereditary transmission of the disease.

The section shows two types of bony change. First that in front of the oval window (N.) and extending into the footplate of the stapes. This shows the change which is most typical and by far the most common in otosclerosis; the old normal bone of the capsule has been absorbed, and new porous bone has been laid down in excess. The second type (H.) is seen behind the oval window: more bone is absorbed than is deposited, hence there is a remarkable rarefaction of the bone, and large spaces containing marrow are formed. Bony ankylosis of the stapes is seen both at the anterior and posterior margins of the oval window.

For a full history of this case see *Otosclerosis; Idiopathic Degenerative Deafness*, p. 122, by Albert A. Gray. (H. K. Lewis & Co., Ltd.) 1917.

N. Diseased area in front of oval window.
H. Diseased area of rarefied bone behind oval window.
C. Lowest whorl of cochlea.
V. Vestibule.
M. Internal auditory meatus.
P. Posterior semicircular canal.

FIG. 79. *Not Stereoscopic.* ×80.

(From the same case as that shown in Figs. 70, 78 and 80.)

SECTION from a case of otosclerosis in which the disease had existed for more than sixty years. The mass of bone to the left is the portion in front of the oval window, while that to the right is the footplate of the stapes, very much thickened by the new-formed bone. It will be noted that the diseased area in front of the oval window is separated from the normal bone of the capsule of the labyrinth by a sharp line of demarcation, and it is stained more deeply than the normal bone. A fine bridge of bone unites the diseased bone in front of the oval window with the footplate of the stapes, causing ankylosis. For a full description of this case the reader is referred to the author's work.*

* Gray. *Otosclerosis; Idiopathic Degenerative Deafness*, p. 122. (H. K. Lewis & Co., Ltd.) 1917.

FIG. 80. *Not Stereoscopic.* ×120.

(From the same case as that shown in Figs. 70, 78 and 79.)

MICROSCOPIC section showing a rare type of pathological change in the bony capsule of the labyrinth in a case of otosclerosis. Most of the field is occupied by large spaces containing bone-marrow (M.M.). The rest of the field shows islands and trabeculae of bone. In these latter portions some of the bone is stained rather faintly (B.B.B.); this is the remains of the original bone of the capsule of the labyrinth. In most places this pale-staining bone is lined by a layer of new-formed dark-staining bone (N.N.). In certain places (A.) absorption of both old and new bone is taking place; and since the absorption occurs more quickly than the deposition the bone as a whole presents the appearance of great rarefaction.

B.B.B. Old normal bone, staining faintly.
M.M. Bone-marrow.
N.N. Newly deposited bone staining deeply.
A. Place at which absorption of both old and new bone is taking place.

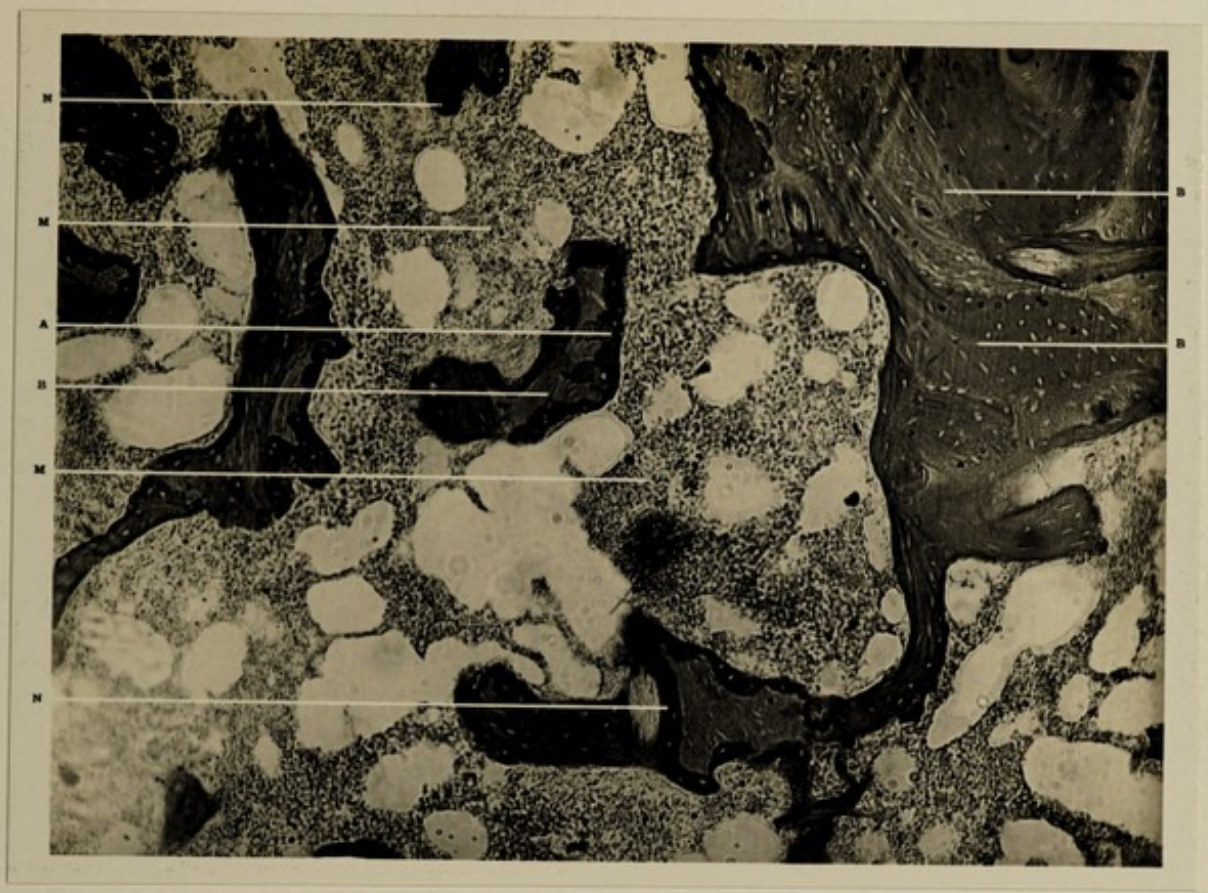
For a detailed description of the history and pathological changes in this case see the author's work :— *Otosclerosis; Idiopathic Degenerative Deafness*, p. 122. Albert A. Gray. (H. K. Lewis & Co., Ltd.) 1917.

FIG. 81. *Not Stereoscopic.* ×8.

(From the same case as is shown in Fig. 82.)

MICROSCOPIC section from a case of otosclerosis The section is cut in the horizontal plane. The diseased area in the bone (A.) is seen in the usual place in front of the oval window. This is the only focus of diseased bone that is present. It is shown more highly magnified in Fig. 82.

A. Area of diseased bone.


N
M
A
B
M
N
B
B


A

FIG. 82. *Not Stereoscopic.* ×80.

(From the same case as that shown in Fig. 81.)

SECTION from a case of otosclerosis in which the bone in the diseased area is being absorbed, while no new bone is being deposited. Consequently the diseased area stains *less* deeply than the normal bone of the capsule of the labyrinth. It will be noticed that the blood-vessels are widely dilated, and in one portion of the diseased area the absorption of bone has been so complete that nothing but a network of blood-vessels is left. The line of demarcation is as sharply defined as in the more typical cases of otosclerosis in which new bone is deposited in place of that which is absorbed.

For the clinical and other details of this interesting case see:—*Otosclerosis; Idiopathic Degenerative Deafness*, p. 92. Albert A. Gray. (H. K. Lewis & Co., Ltd.) 1917.

FIG. 83. *Not Stereoscopic.* ×250.

(From the same case as Figs. 72, 73, 74 and 75.)

MICROSCOPIC section of the organ of Corti from an early case of otosclerosis.

There is no discoverable departure from the normal in the organ of Corti. The disintegration in the hair-cells and other parts, which is seen in the photograph, is due to post-mortem changes and artefacts produced during decalcification and preparation. The rods of Corti and the hairs of the hair-cells are well preserved.

FIG. 84. *Stereoscopic.* ×4.

Viewed from in front.

RIGHT labyrinth from a case of septic meningitis. This preparation was made from the specimen shown in Figs. 61 and 62. The pathway of infection was from the middle ear to the labyrinth and then from the latter, by way of the aqueduct of the vestibule to the intracranial cavity. The disease was very acute and very quickly reached a fatal issue. As seen in the preparation the whole labyrinth is filled with an opaque substance which consists of pus mixed with a considerable amount of blood, thus indicating the acute nature of the inflammation.

The horizontal and posterior semicircular canals have been broken in the course of preparation.

The reader should compare this with a normal labyrinth, Fig. 38, which was prepared in the same way by the author's method.

S.C. Superior semicircular canal.
A.S. Ampulla of superior semicircular canal.
H.C. Horizontal semicircular canal (broken).
N.A. Facial nerve.
P.C. Posterior semicircular canal (broken).
C. Cochlea.

FIG. 85. *Stereoscopic.* ×4½.

(From the same case as Fig. 86.)

COCHLEAR portion of left labyrinth from a case of chronic suppuration of the middle ear and labyrinth. Prepared by the author's method.

The vestibule and canals from this case are shown in Fig. 86.

Although the cochlea has retained its shape, the structures within it, *e.g.* basilar membrane, etc., have disappeared as a result of the destruction by the chronic suppurative process. The cavity of the cochlea is filled with white cloudy masses; these are caused by the coagulation of the pus during the process of preparation. This figure should be compared with Fig. 84, which shows the appearances of the labyrinth in a case of acute suppurative disease.

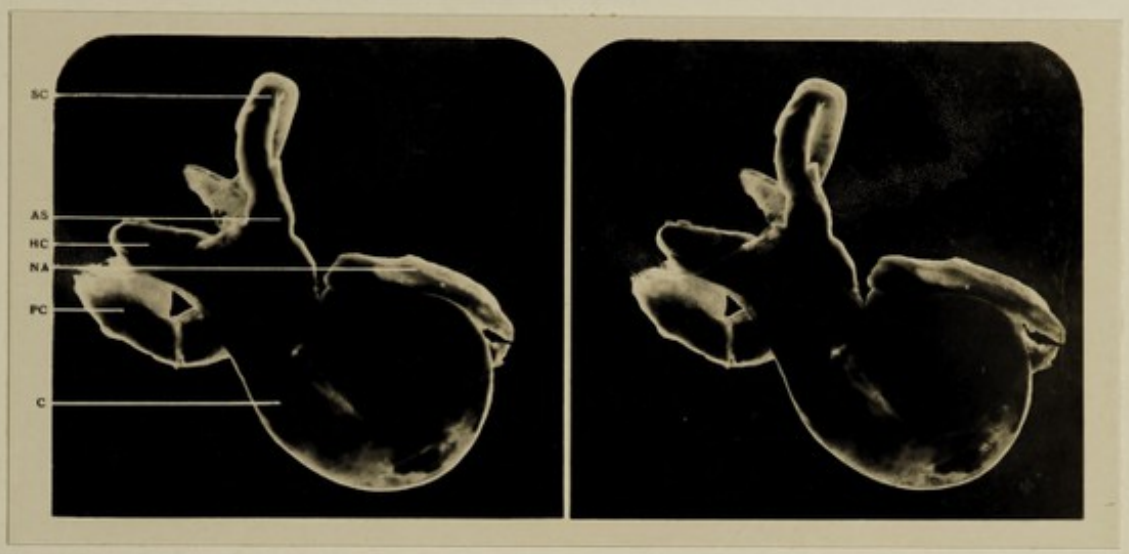

SC
AS
HC
NA
PC
C

FIG. 86. *Stereoscopic.* ×4½.

(From the same case as Fig. 85.)

PREPARATION showing extensive destruction in the region of the labyrinth by caries. All the membranous structures of the labyrinth were destroyed by the chronic suppurative process, but the cochlea and portions of the semicircular canals had retained the outline of the bony labyrinth. The bone surrounding the vestibule, however, was destroyed by caries, and the structures came away in two separate portions when removed post-mortem. The cochlear position is shown in Fig. 85. There was no history of vertigo in this case nor any symptoms of disease of the labyrinth beyond the profound deafness in the affected ear. It must be observed, however, that the patient died at a time previous to the introduction of the nystagmus tests for disease of the inner ear. It is also interesting to note that there was no intracranial infection at all. The patient died from malignant disease of the jaw.

FIG. 87. *Stereoscopic.* ×4.

THE soft structures of the left labyrinth. Prepared by the author's method. This preparation was made from a patient who died from malignant disease of the uterus, at the age of eighty-three. She complained of deafness, vertigo and slight tinnitus during life. It will be observed that there is a large crystalline deposit shaped like an arrow-head in the utricle. It is quite probable that this was the cause of the vertigo.*

* For a clinical description of this case see *The Ear and its Diseases*, p. 337. By Albert A. Gray. Baillière, Tindal & Cox. 1910.

FIG. 88. *Stereoscopic.* ×3.

Viewed from in front.

RIGHT labyrinth from a case of deaf-mutism.

On microscopic examination the labyrinth was found to be rather larger in dimensions than normal, but otherwise no pathological change could be detected, though probably some pathological differences would have been found on microscopic examination. See Figs. 90 and 91.

FIG. 89. *Stereoscopic.* ×10.

Viewed from behind.

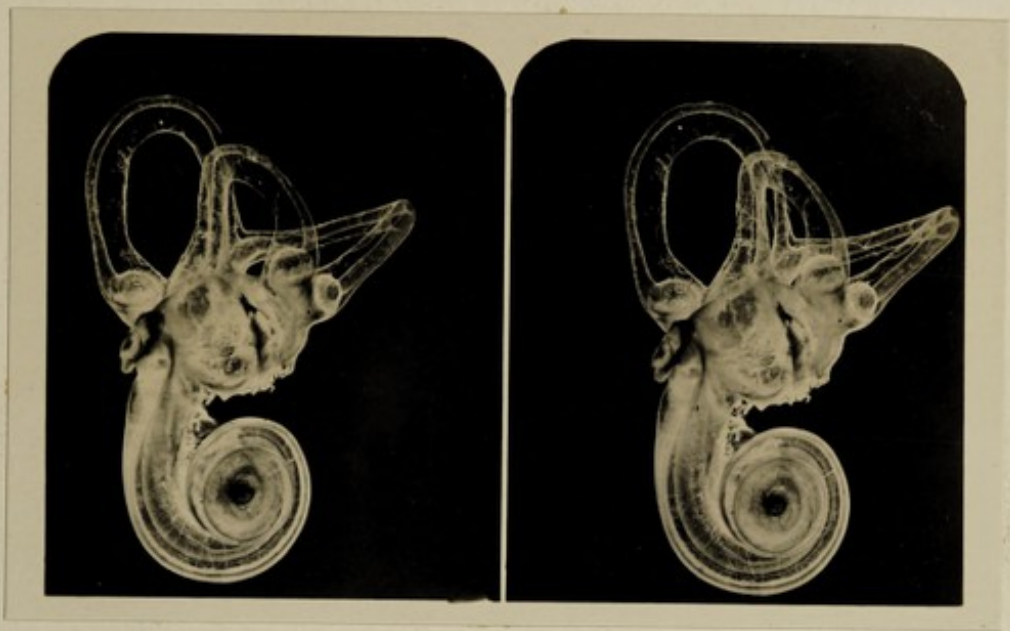
PREPARATION showing the membranous structures of the vestibule and portions of the cochlea and semi-circular canals of the right labyrinth from a case of deaf-mutism. Two calcareous masses may be seen in the vestibule; one (A.) in the utricle occupying the position of the crista acustica, and a smaller one (B.) in the saccule.

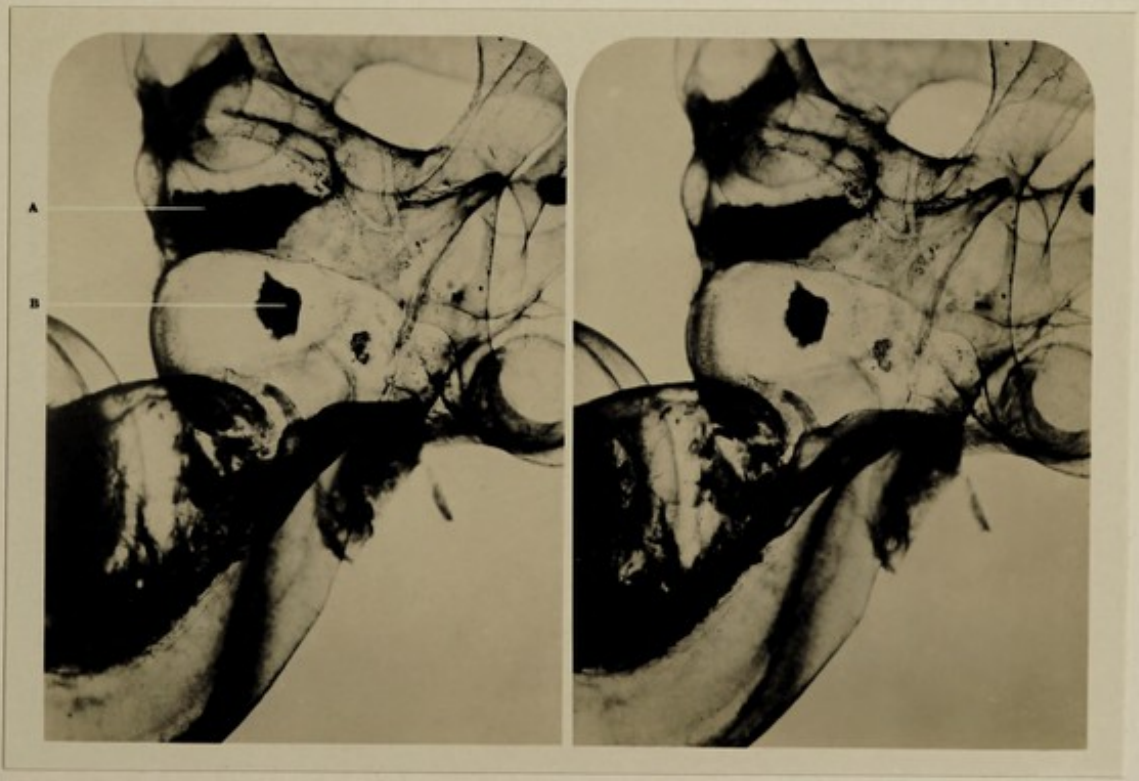
As regards the macroscopic appearances of the labyrinth of deaf-mutes, it is a remarkable fact that in all three cases examined by the author, the organ was distinctly larger in all its parts than that of the normal adult.*

A. Crystalline deposit in the utricle.

B. Crystalline deposit in the saccule.

* Gray, *Journal of Laryngology, Rhinology and Otology.* May, 1910.




A
B


R
S
M
C

FIG. 90. *Not Stereoscopic.* ×100.

HORIZONTAL microscopic section from the middle whorl of the cochlea from a case of deaf-mutism. The organ of Corti is disorganised and is the seat of inflammatory changes, round-cell infiltration. There is nothing to indicate the presence of a tectorial membrane. The membrane of Reissner is relaxed and is thickened in the region over the organ of Corti. There is round-cell infiltration in the endosteum over the outer wall of the ductus cochlearis especially in the region of the stria vascularis. The stria vascularis itself, however, does not show the hypertrophic appearance which is seen in Fig. 91.

FIG. 91. *Not Stereoscopic.* ×300 ca.

MICROSCOPIC section through the ductus cochlearis of the uppermost whorl of the cochlea of a deaf-mute. The most striking pathological feature is the remarkable development of the stria vascularis. As is shown in the photograph the stria vascularis projects far into the ductus cochlearis, reaching almost to the organ of Corti. It consists of a core of connective tissue covered by a layer of cubical epithelial cells, and presents an appearance somewhat similar to the tegmentum vasculosum of the cochlea of the bird and the reptile. This is interesting in view of the fact that the stria vascularis of man and mammals corresponds morphologically with the tegmentum vasculosum.

The cellular elements of the organ of Corti are not differentiated. Taken altogether, therefore, the appearances in this case of deaf-mutism suggest arrested development rather than destruction by inflammatory activity as shown in Fig. 90. Changes similar to those shown above have been described recently by Fraser.*

R. Membrane of Reissner.
S. Stria vascularis.
M. Scala media.
C. Organ of Corti.

* Fraser, *Journal of Laryngology and Otology*, 1922. Pp. 13, 57, 126.

FIG. 92. *Not Stereoscopic.* ×8.

(From the same case as Fig. 57.)

HORIZONTAL section of the right labyrinth of a woman who died at the age of a hundred and one years.

The patient was so deaf that even the loudest sounds that were made in close proximity to either ear were not heard, *e.g.* a loud-sounding dinner-bell produced no sensation of hearing.

It will be seen that there is no pathological change in the bony capsule of the labyrinth, and the stapes is not fixed in the oval window. The dislocation of the posterior margin of the footplate of the stapes is an artefact.

The sections were not sufficiently thin to permit of satisfactory photographs being obtained of the high magnifications, but it may be mentioned that pronounced retrograde changes were found in the organ of Corti, and the cells of the ganglion spirale were degenerated to an extreme degree. There was no sign of inflammatory activity. The deafness had begun at about the age of seventy years, and the case was one of apparently uncomplicated senile deafness.

M. Modiolus.
S. Saccule.
F. Facial nerve.
U. Utricle.
V.V. Aqueduct of vestibule.
P. Posterior semicircular canal.