# THE SURGICAL ANATOMY AND OPERATIVE
## SURGERY OF THE MIDDLE EAR

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# SURGICAL ANATOMY

## AND

# OPERATIVE SURGERY OF

# THE MIDDLE EAR

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# INTRODUCTION

THE subject of the following monograph is one of immense importance to the otologist, and any investigation by a surgeon of so wide a reputation and such varied experience as the author is of espécial value.

In translating the monograph I have endeavoured to render M. Broca's work into appropriate English idiom, but at the same time to follow his language and style as closely as possible.
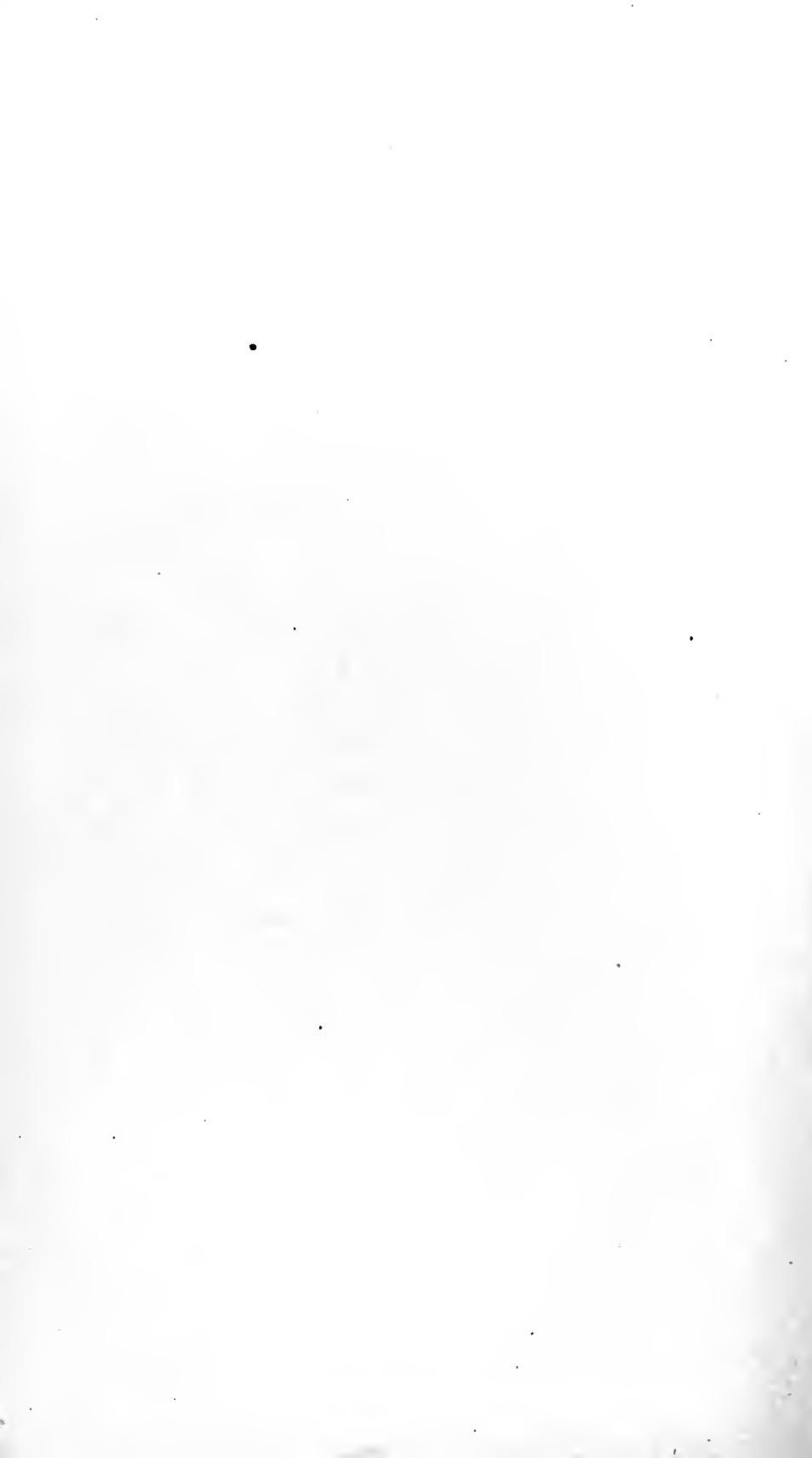
Where necessary, I have added footnotes, especially when the opinion expressed in the text has in any way differed from that current in this country.

<div align="right">MACLEOD YEARSLEY.</div>

10, UPPER WIMPOLE STREET, W.,
  *July* 18, 1901.

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# THE SURGICAL ANATOMY AND OPERATIVE SURGERY OF THE MIDDLE EAR

## I

### SURGICAL ANATOMY

It is not my purpose to give here a didactic and complete description of the middle ear and its adnexa, but to bring into prominence the various landmarks thanks to which the surgeon can attain certain success ; to lay stress upon the structure of the mastoid and the arrangement of its cells ; and to state with precision the situation of the organs, which to treat with caution is indispensable. Too often, indeed, good surgeons, whilst operating, wound the lateral sinus or the facial nerve. Hence it is necessary not only to know where to attack, but where to let alone : it is necessary to know exactly what to avoid.

What makes these studies so complex is that in this region anatomical relations vary with the age of the subject, and consequently important operative deductions vary also (see figures).

**External Form.**—The mastoid process is situated at the inferior part of the outer surface of the temporal bone, behind the auditory meatus. Slightly oblique forwards and downwards, it is usually conoidal in form. Its anterior border, thick and rounded, is distinctly vertical ; its posterior border is, in the adult, inclined about 45 degrees downward and forward. Behind its superior part is the mastoid foramen, through which passes an emissary vein of variable size, generally communicating with the lateral sinus.

The bulk of the mastoid depends partly on the strength of the muscles inserted in its tip, and thus it is natural that it should be in general proportion to the size of the bones of the individual, as Lenoir proved at the Anthropological Museum ;. but, on the

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other hand, it increases in pretty direct ratio with age up to the
period of complete development of the subject.     The figures show
this very well.    In the fœtus at term (Figs. 31, 41-44) it may be
said that there is no mastoid process ; in the child of three years
(Figs. 32, 45), of five years (Fig. 46), it is already perfectly sketched
out ; at thirteen years it is modelled in miniature on that of the
adult (Figs. 37, 38, 50, 53).    This is in opposition to the forma-
tion of certain other parts of the temporal bone—the ossicles, for
example, which are nearly full size in the fœtus at term.    It is
the exo-cranial part of the petrous bone whose development is
thus retarded.

Of the three portions of the temporal bone—squamous, petrous,
tympanic—two really take part in the formation of the mastoid
process : the squamous above and in front, the petrous behind
and below.    The junction of the two parts forms the squamo-
mastoid suture, represented by *sms* in the figures ; this short
suture on the external surface of the process, leaving the parietal
slope, joins the anterior border above the tip.

I do not believe, despite the assertion of Chipault, that this
notch of termination can be felt through the soft parts, but on a
dry mastoid the suture is visible at all ages in the form of a
groove more or less irregular and unequal.    In laying bare the
bone it can be easily recognised, because at its level, especially
in somewhat aged subjects, the instrument has some difficulty
in raising the periosteum, and the shreds of the latter leave a
white line.

The squamous portion of the mastoid forms a triangle, bounded
by this suture, the meatus, and a horizontal ridge—the *supra-
mastoid ridge* (*csm* in the figures)—which prolongs behind the
posterior root of the zygomatic process (*linea temporalis* of
German authors).    This ridge, more or less prominent in
different subjects, is always appreciable, even in the child.
It is an important landmark, for it is generally situated a little
below the floor of the middle fossa of the cranium, sometimes at
a level with, very rarely above, this floor ; so that if one attacks
the bone with the gouge resting below it, one is nearly certain
not to penetrate the cranial cavity unwittingly.

On the outer surface of the process another irregularity is seen,
which furnishes the surgeon with one of the best of landmarks,
the *spine of Henle*, represented by H in the figures (*spina supra-
meatum* of the Germans).    It is a more or less rugose and promi-
nent plate, situated behind and above the postero-superior

quadrant of the meatus, below the origin of the supra-mastoid ridge. This lamella is incurved nearly concentrically to the circumference of the meatus, but its upper extremity is a little more anterior than is the inferior.

Occasionally this spine scarcely projects at all; on the other hand, to find it in laying bare the process, it is often necessary to use the instrument as if one wished to penetrate the postero-superior segment of the bony meatus. It is bounded in front by a vascular zone, which varies greatly in different subjects. This is sometimes a simple chink, like a scratch, within the borders of which appear only microscopic foramina. Very often in front of the lamella a very deep cup-shaped depression is found, pierced by foramina (Figs. 24 and 37); sometimes it is even a large hole (Fig. 38).

Whatever may be said, this spine does not appear to spring from the tympanic bone. This is the distinct result of the researches of O. Lenoir as well as of those of Ch. Millet. In well-preserved skulls the posterior boundary of the tympanic ring is always seen to sink obliquely above and inside into the funnel of the auditory canal, and stop separated from the spine by a space that is always distinguishable, often considerable (Figs. 37 and 38). Further, comparative anatomy is conclusive. In old horses the tympanic ring is practically closed completely; the two extremities of the ring are, in regard to one another, not separated by a millimetre; but in this animal, exactly at the spot where the spine of Henle is found in man, a special osseous point can be seen, separated very distinctly from the tympanic ring, with which it is not united in the least. In the gorilla the spine of Henle, usually very distinct, clearly separated from the tympanic ring, is situated just above the circumference of the bony meatus.

I do not believe, therefore, that the spine is connected with the tympanic ring, but I would rather connect it, with O. Lenoir, with an osseous point known in embryology under the name of epitympanal (Geoffroy Saint-Hilaire), its special factor of importance being the above-mentioned vascular foramina, which seem of very distant morphological or even operative interest.*

* See Fig. 34 for details, and p. 53 for explanatory text. Figs. 25 and 26 (explanatory text, p. 45) are sections prepared to show the connections of these foramina and the limitrophic cells of the meatus. When the foramina are large and numerous, there are points there where the mucous membrane of the cells is nearly in contact with the external periosteum, making the passage of pus easy. In the young child this corresponds to the spongy spot

The spine of Henle, when it exists, is a valuable operative landmark; but is it constant, and can one count upon it? Certain authors contest its constancy, but all those who have really studied the subject give it a great value. Kiesselbach found it 82 times out of 100 and Schultze 109 times in 120. My pupil and friend Lenoir, in an abstract of 100 adult skulls in a perfect state of preservation, has only verified the absence of the spine in one single instance, and even then the anomaly was unilateral, thus making one absence in 200 mastoids. In twenty cases the spine was slightly marked, but yet recognisable by a practised eye and finger.*

The distinct conclusion is, then, that we are right in depending upon this bony landmark in the adult. Is it the same in the child? To determine this question M. Lenoir has examined fifteen crania (thirty mastoids) of children of different ages at the Anthropological Museum; he has at the same time studied the distinctness of the supra-mastoid ridge and of the squamoso-mastoid suture.

He concluded that this landmark cannot be much relied upon in a regular manner below four years of age, and it is only from ten years that it can be considered as certain to be always distinct; the same may be said of the supra-mastoid ridge.

But in *infants* a very characteristic appearance is to be seen on the surface of the bone over the cortex which hides the antrum. Behind the spine of Henle, as I have pointed out, several vascular foramina are to be found, more or less numerous and deep, and thence they are very often continued above the bony meatus and below the supra-mastoid ridge (Figs. 24, 37, 38). In the infant these vascular openings transform this region into a perfect sieve, which can be seen very well in operating upon the living subject, in the form of a depressible, friable lamina. In the recent cadaver a regular purple rounded spot is seen, like a sanguineous effusion in the bony substance. I have always seen

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which is discussed on p. 5 and Fig. 39, and the antrum is then covered simply by a thin perforated lamina. These foramina have several connections with the persistent petro-squamosal sinus. The displacement of the limitrophic cells, which become postero-external, is explained on p. 41.

\* There is certainly a difference of opinion regarding the constancy of the supra-mastoid spine or spine of Henle. Probably the author is in the main correct in giving it as nearly always present. I have, however, met with a good many cases, both in the dead and living subjects, in which it was but very feebly marked. The fossa which accompanies it is, on the contrary, always present, although it may at times be a mere dimple, and I have therefore always laid more stress upon the presence of this *supra-mastoid fossa* than upon the spine as a guide to the antrum.—*Translator.*

this spot in the fœtus of more than eight months and in children under two years. This *spongy spot* (Fig. 39) is situated exactly at the level of the antrum. It is at first above the meatus, then above and in front ; much later the vascular zone coincides with the posterior part of the spine of Henle, and from that time the spine becomes a landmark. These landmarks change, therefore, in proportion as the subject grows older, for they move below and behind in a circumference concentric to the auditory meatus.

Structure. — The temporal bone is hollowed out by cavities continuous with the pharynx by the medium of the Eustachian tube and lined with mucous membrane. From the functional point of view, the most important of these cavities is the *tympanum*, which contains the auditory ossicles. To this drum is attached a very variable arrangement of cells, which render the mastoid process and the neighbouring parts pneumatic.

Around these air cells is a *cortex*, of which the surgeon must recognise the density at the level of the outer surface of the process. In the young child this shell is thin and but little resistant, but in the adult this does not hold, and the variations of thickness and of hardness are very considerable. The sections (children, Figs. 20-23, 29 and 30; adults, Figs. 47, 48, 51) show that if, in places, the cortex is scarcely one millimetre thick, in other subjects one cannot break through less than 6 millimetres to reach the largest cells (Fig. 51). It is useful to remember that, in the course of an operation, a hard mastoid must not be mistaken for an eburnated process.

The system of cavities surrounded by this cortex is, as I have said, very variable ; or rather, it is composed of two parts : the *antrum*, constant in its presence and pretty nearly so in its position ; the *cells*, very different in various subjects, which radiate around it and can be divided, according to the part of the temporal bone in which they are situated, into *squamous*, *mastoid*, and *petrous*. It is on account of these variations that, according to their richness in cells, Zuckerkandl has divided mastoids into pneumatic (36·8 p. 100), mixed (43·2 p. 100) and diploïc or sclerosed, that is to say, unprovided with cells (20 p. 100). And what tends to complicate these individual differences is that in the first place similar mastoids, diploïc or sclerosed at one point, present at another a well-developed cell group, and in the second place, amongst these variations, some are congenital, others acquired, and that progressive eburnation, bordering upon

' sclerosis,' of the mastoid is often the result of chronic suppura-
tions in the tympanum.

These cells are inconstant; development demonstrates that
they are the annexes of the antrum.  It is, therefore, in the
study of the antrum that we ought properly to begin the pure
anatomical description of this region.  But the operator must
know the organs in the order of superposition in which he will
find them, that is to say, from the surface to the deeper parts ;
therefore I commence by speaking of the secondary cells.

The *mastoid cells*, properly speaking, that is to say the cells
which occupy the mastoid portion of the temporal bone, are
nothing as regards the group which bears this name in current
surgical language ; unless, indeed, the squamous and petrous
cells are added to them, at least for the most part.  The only
true mastoid cells are situated below a horizontal line passing
near the junction of the upper third with the lower two-thirds of
the meatus.  This is the group of special cells, and when these
cells are important, it is among them that the largest cavities
are found, as the cells in Figs. 53, 54, 55.  These figures show,
further, that among the mastoid and squamous cells is a perfect
buttress which appears to mark, deep down, the remains of the
mastoido-squamous suture.

These cells, the most easy to reach by operation when they
are well developed, are those by which one endeavours princi-
pally to distinguish mastoids into pneumatic, diploïc and mixed ;
no external indication allows us to recognise their importance
beforehand, and, for example, one can conclude nothing from
the bulk of the mastoid.  Figs. 53 and 54 show very large cells
in a small mastoid from an old man.  Which proves nothing,
moreover, for the squamous and petrous cells, which are of great
interest pathologically and anatomically.  The mastoid cells are,
to speak truly, only annexes of the others.

The *squamous cells* are situated in the part of the squamous
bone which contributes to the formation of the posterior wall of
the external auditory meatus.  Certain among them form, in
contact with the meatus, the group of cells bordering the meatus
(*limitrophic cells*).  These are prolonged sometimes above the
meatus, and even in front of it, into the root of the zygoma,
above the temporo-maxillary articulation.*  In Figs. 53, 54, 55,

* It is important to remember these cells in the zygoma in opening the
mastoid in children, as they may otherwise mislead one into believing that
the antrum has been reached when it is still intact.—*Translator.*

squamous cells of small size are seen ; those in Fig. 52 are, on the contrary, large and well formed. In general, they are small, but it is necessary to remember their existence, for their opening is indispensable for an operation to be complete.

The *petrous cells* occupy the base of the process, above a horizontal line passing through the junction of the upper third and the lower two-thirds of the meatus. Above they may extend fairly far (Figs. 53, 54) ; in front they are limited by the *arched premastoid lamina* (Fig. 51, p. 59), which will be further studied ; behind they extend towards the lateral sinus, in front of which they may extend (Figs. 52, 53, and 54), almost to touch the occipital.

It is by the study of horizontal sections (Figs. 20-23, 27-29, 47, 48, 51), that these petrous cells are accurately seen. These sections show, further, the various relations which they may have with the lateral sinus, from which they are separated by a compact plate, sometimes thick (Fig. 51), sometimes very thin (Figs. 47, 48). They also show that petrous cells can be present behind the antrum for the length of the posterior surface of the petrous bone (Fig. 51, C″).

When one studies the mastoid anatomically in the cadaver, and not by operation on the living subject, it is by excavating by degrees, after having opened all the preceding cells, that the *antrum* is at last reached. Often enough—in about the third case in the adult—one opens into these cells by a very distinct canal, with a superficial opening clearly defined, which might be called the external aditus. This orifice is occasionally very easy to see, and from that time the antrum can be found with ease ; on the contrary, it may be hidden by a convex septum, and if the cell which is bounded behind by this septum is spacious, one may fancy that the antrum has been opened. But a careful search in the superior anterior angle of this false antrum with the point of the probe fails to find the narrow opening of the *aditus ad antrum* leading to the tympanum ; and by excavating below and under this lamella the antrum is reached at the level of the spine of Henle.

In thus hollowing out the mastoid, the order of the formation of the cells is followed backwards. After the tympanum, which is the primordial cell, the antrum is the first of the accessory cells, and from it are derived by budding, so to speak, the others.

In the fœtus, the mastoid process does not exist ; in the new-born child it is scarcely present ; but yet the antrum is found

in them, prolonging the attic behind into the thickness of the petrous bone, and the dimensions of this antrum are already nearly as considerable as they will be later on in the adult.*

From this antrum, by a progressive aëreolation around it, the air cells, which gradually invade the other parts of the temporal bone, proceed. At birth, contrary to what has been said, there are nearly always some present, which is easy to demonstrate by a procedure which Faraboeuf has taught us : a little mercury is poured into the tympanum of a new-born child, then the bone is turned over and lightly shaken ; the metal collects in the antrum and, if the bone be scraped with a bistoury behind the tympanic ring, very distinct vacuoles filled with the liquid are generally to be found.

The squamoso-mastoid suture opposes, for a certain time, a barrier to the advance of the cells, which do not pass it until the first year has elapsed ; and, much later, the trace of this suture is generally found in the interior of the process in the form of a wall bounding one or several cells, exactly beneath the furrow which marks it on the surface (Figs. 53, 54).

The antrum being the most constant cell in the whole system, it is particularly important to study its surgical anatomy, in order to determine :

1. Its depth.

2. Its relations with appreciable external landmarks.

3. Its exact relations with neighbouring organs of which it is necessary to be careful.

1. **The Depth of the Antrum.**—This question, a cardinal one from the operative point of view, has received various solutions. The answer depends greatly on the age of the subject, and at an equal age, varies in different individuals.

In the foetus at term and in infants under one year, the depth of the antrum is very slight ; it is only from 2 to 4 millimetres, and there is nothing easier than to penetrate this cavity by scratching with a bistoury at the spongy spot previously described.

In the years which follow birth, the antrum becomes gradually deeper, but with individual differences for which it is impossible to establish any law. Thus, in a subject of three years (Fig. 45)

* Cheatle has pointed out that the antrum was thus developed with the tympanum, and suggested in consequence that it should in future be called ' the tympanic receptacle,' the name ' mastoid antrum ' being misleading.— *Translator.*

the antrum was already 10 millimetres deep, and only 4·5 milli-metres in a child of five (Fig. 46). On another occasion I have found an antrum situated 11 millimetres from the surface in a subject aged three and a half years. In the adult one meets with similar variations, and it is necessary to know the maximum depth at which the antrum may be searched for without danger ; in our series, in two subjects (Figs. 46 and 48) of twenty-five and forty-five years, the antrum was 16 and 15 millimetres deep ; but in two very old subjects, sixty and seventy-five years, it was 25 and 29 millimetres (Figs. 50 and 52).

I am therefore obliged to conclude that, if a rule is laid down to stop if any cavity is not found at 5 or 6 millimetres (Politzer), at 20 millimetres (Noltenius), at 25 millimetres (Schwartze, Chipault), one risks missing an antrum which possibly is present. The more one fails to find it, the more one should act with caution, but one ought not to give up too soon. The practical interest of this discussion is not very great, for in chronic otitis, when opening is decidedly indicated, one has only to broach the cavities another way, by attacking the tympanum first by Stäcke's method ; and in acute mastoiditis the rarefying osteitis contributes to make the work easier. But that is not constant, and then it is sometimes necessary to have a perfect faith in clinical diagnosis and anatomy in order to reach the antrum.

2. **Position of the Antrum in Relation to External Landmarks.**—The antrum really possesses in the previously-mentioned land-marks—spongy spot in young children, supra-mastoid ridge, squamoso-mastoid suture, spine of Henle—relations capable of giving the surgeon almost perfect safety.

I need not revert at length to the *spongy spot* in young children. By working at this level with a curette or with the point of a bistoury the antrum is very quickly reached. This spot is situated *above and behind the meatus*.

When this ceases to be appreciable, the anatomical deter-mination becomes less easy ; but even then it is not very difficult.

To begin with, we know that, whatever be the age of the sub-ject, the antrum is situated *below the supra-mastoid ridge, above and in front of the squamoso-mastoid suture*. These two lines, I know, are not always distinct, especially in the child ; but when they are present—it is the rule in the adult—they are valuable for the precise delimitation of the field of operation.

. The constant landmarks are (1) the *spine of Henle ;* (2) when this spine is not present, the *superior pole of the ellipse formed by the meatus.**

If we suppose (which we are practically permitted to do) that the antrum is displaced, we can conclude that, situated just above the arch of the bony meatus before term, the centre of the antrum in the fœtus at term is above and a little behind this point ; then it is displaced gradually downward and from before backward. Near the age of ten years it is on the horizontal track by the spine of Henle, and from this moment it no longer becomes lower, but keeps directly behind at a distance, nearly fixed, of 7 millimetres, which it reaches at adolescence.

Before passing to the study of the relations of the antrum with certain organs which it is important to treat with respect, I will say a few words regarding the *aditus ad antrum,* the canal which joins the antrum and the tympanum. This description will be abridged ; it will be completed when I come to speak of the topographical anatomy of the drum, and of the attic in particular.

The aditus is a canal which, in the adult, is 3 to 5 millimetres long, 3 millimetres high, and 3 to 4 millimetres deep. In the figures it will presently be seen in section (AD) occupied by a probe, and thus it will be shown that its direction and form depend upon the age of the subject, and vary with the position of the antrum.

The aditus always opens from the deep part to the anterior wall ; but in the new-born infant it is seen in the middle part of this wall, and opens there as a rectilinear canal obliquely below, forwards and inwards; the straight probe enters without difficulty, and goes right across to the other end of the drum, the orifice of the Eustachian tube (Fig. 42). The deeper the antrum descends behind the meatus, the higher in the anterior wall is it necessary to search for the aditus, and thence the canal, which continues to tend towards the attic—that is to say, above the tympanic ring—descends no more ; at first it even ascends a little, to lightly curve with an inferior internal concavity, as in the adult it cannot be directly catheterized by a straight instrument of any size.

On the arch of the outer wall of the aditus more or less numerous small cells open. Its threshold rests on the horizontal

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* As I have pointed out in a previous footnote, the supra-meatal fossa is always present when the spine of Henle is absent, although it may be but a mere dimple.—*Translator.*

portion of the aqueduct of Fallopius; on its inner wall projects the horizontal semicircular canal. Its upper wall is formed by the *tegmen tympani*, a plate always very thin, often deficient, pierced by the branches of the meningeal vessels; vestiges of the internal petro-squamosal suture can be seen here (Figs. 16 to 19).

3. **Deep Relations of the Antrum and Aditum.**—Across the roof of the tympanum the aditus is in very close relation with the temporal fossa of the cranium and the temporal lobe of the brain.

The three organs which must always be remembered in operating are (1) the horizontal semicircular canal; (2) the facial nerve ; (3) the lateral sinus.

(*a*) The *horizontal semicircular canal* is situated just behind the inner wall of the aditus. It is against this wall that the protector must be placed to prevent any injury ; otherwise the canal is surrounded by a solid eburnated shell, which of itself offers a strong resistance to instruments. Besides, whether it is that I have never touched it, or that its injury is no inconvenience, I have never had to record any troubles due to an impairment of the internal ear in my operations.

(*b*) The *facial nerve*, leaving by the hiatus Fallopii, is directed outwards, parallel to the axis of the petrous bone, on a course of about 10 millimetres ; then it is bent to pass vertically down, to leave the cranium at the level of the stylo-mastoid foramen. It is the horizontal part of the facial canal, with the elbow, that passes under the threshold of the aditus, protected only by a lamella, sometimes extremely thin. Often enough, as represented in Fig. 49, the horizontal portion of the canal is better protected, and much more internal.

The vertical part of the canal descends in the anterior region of the mastoid, behind the posterior limb of the tympanic ring. There it passes through a compact lamina known to modern authors under the name of the *arched premastoid lamina* (marked by *p* in Fig. 51). In this vertical part the facial is only separated from the foramen for the jugular vein by a band of tissue ordinarily fragile, and hollowed by large pneumatic cells (Fig. 49).

The result of this anatomical study is that if, *in the child*, we seek the antrum where it is, so to speak, too high, the opening is absolutely without danger to the facial nerve ; and if, when the antrum is exposed, we demolish the outer wall of the aditus the nerve is equally secure from risk, provided that, in making

the inferior cut with the chisel, we incline the instrument a little
upwards (Figs. 40, 42, 43).

*In the adult* the antrum is lower, behind the meatus, the
inferior extremity of which is there separated by the elbow of
the facial.   But one can carefully cut over the nerve by using
the chisel in the anterior part of the breach, especially below,
resting it at a sufficient distance from the meatus, and keeping
the instrument parallel to the canal.   One therefore acts with
great caution when a certain depth is reached.   On an average,
Noltenius estimates the distance separating the spine of Henle
and the facial to be 13 millimetres in depth.   But the knowledge
of an average has not any interest for us ; the dangerous zone
will without doubt occasionally be much more extensive, but it is
sufficient to be able to have cases in which it is reduced to
10 millimetres in order that we may be on our guard at this
depth at once and quickly.   The best precaution to take is not
to open too low.   In operating at the height of the spine of
Henle, and in working towards the aditus, one passes above the
elbow of the facial, and once the aditus comes into view one is
master of the situation, as then the whereabouts of the facial is
known.

(*c*) The *lateral sinus* is, of the three organs, the one which most
engrosses us, especially because it is menaced in the most common
operation—the simple opening of the mastoid—so that it is very
often wounded by the surgeon.   This accident is explained in
part, and in part only, by the anatomical variations so important
to be recognised ; and this restriction once admitted, it is ex-
pedient to acknowledge without further delay that it is nearly
always due to the clumsiness of the operator.   This assertion
doubtless appears somewhat sweeping to surgeons who have
involuntarily opened the sinus, but I can only express it after
having opened more than 300 mastoids without ever having met
with such an accident, save in one instance where, the bony
excavation having ended, I perforated the venous canal with a
probe in exploring a purulent pocket which surrounded it.   If,
then, there exists an anatomical arrangement such that the
surgeon, in finding the antrum, is fated to come upon the sinus,
my operative statistics prove that it must be very rare.   But it
suffices that it may be possible to make it necessary to study it
in detail.*

* This opinion is contrary to that expressed by Lake in the *Journal of
Laryngology*, May, 1898, p. 230.   That observer made sections of a number

Certain authors make a great to-do about the fact that the groove for the lateral sinus, situated at a very variable distance behind the external auditory meatus, may be found very close to this canal in horizontal projection; it may even be reported in front—to be 'procident' to such a degree as to be in front of the antrum. Thus, Hessler has reported four cases of caries of the middle ear with the sinus situated in front of the antrum; after he had passed through 2 to 4 millimetres of spongy bone, he reached the dura mater and wounded the sinus, which forced him to interrupt the operation without having reached the focus of the caries; and Hessler notes twelve analogous cases in the literature.

To suppose that in these observations no error of interpretation or of operative technique has entered—an objection which is liable to occur in observations made on the living subject— one can only conclude that the anatomical arrangement which they have demonstrated is possible, but by no means frequent. Frequency can only be established by the *anatomical* study of a numerous series. Now, Hartmann, in 100 preparations, only found two in which trephining would touch the sinus; in his memoir, so exact from an anatomical point of view, Ricard says that he has only met, in horizontal section of the petrous, with one single case where such danger existed, and yet he adds, ' in this extreme case, a distance of 12 millimetres still separated the sinus from the posterior wall of the external auditory meatus.'

Now, what do these anatomical facts, *from the operative point of view*, signify? Nothing much, and the following is the reason.

When the mastoid region is examined, behind the process properly speaking, between it and the occipital, is a sort of mastoid scale, bounded by a vertical line going from the parietal slope of the superior border of the temporal to the digastric fossa. It is on this line or behind it that the mastoid foramen is found. It is on the inner surface of this scale, behind the pyramid, that the lateral sinus descends, below its elbow, the bend corresponding to the asterion, that is to say at the junction of the occipital, the parietal and the mastoid, and encroaching more or less on the postero-inferior angle of the parietal. There

of mastoids, and found that they could be classified into three groups : (1) those in which the lateral sinus will not be encountered in an operation on the antrum; (2) those in which it may or may not be met with ; (3) those in which it is unavoidable.—*Translator.*

it is the rule not to find any cells, but a diploïc plate between two compact laminæ, as in the rest of the cranial vault. If the sinus was invariably to be found in this region, it would always be very far from the process properly speaking, but it is enough to look at the inner surfaces of several crania to know that the groove for the lateral sinus is more or less large, that its bend is more or less high and more or less forward, not only in one subject and another, but on one or other side; and the rule is that the lateral groove is larger and deeper on the right side than the left.

Suppose now a very large and very deep groove, and we understand perfectly how in horizontal and transverse projection it can be very little behind the meatus, or may even be in front of it at this level. But would that be to say that the antrum was not in its place? Absolutely not, for it can well be lodged in the thickness at the base of the pyramid. In these conditions it is very evident that if a probe were driven in at the spot where we should describe the antrum, it would directly puncture the sinus instead of entering the cranium in front and within it. But, before reaching there, the probe would pass through the antrum; that is to say, the surgeon, operating at the seat of election and with care, would meet with a cavity, and from that time would be prepared, if he remembered it, for the possible presence of the sinus; the deep wall of this cavity ought not to be attacked save with great caution and under special indications (*vide* p. 47).

This anatomical arrangement, then, is far from being responsible for all the dangers which have been attributed to it, and to declare that a mastoid is impossible of opening, it is not sufficient to have proved, in an intact cranium, the falling forward of the sinus; it is still necessary, by a horizontal section at the level of the spine of Henle, to have demonstrated that there is no cavity between the cortex and the sinus at the field of operation. It is this proof which is too often made an excuse, for anatomically it demands the sacrifice of the skull examined, and in the live subject the surgeon who involuntarily opens the sinus has a tendency, too natural for blame, to remember an anatomical arrangement which he will repeat sooner than accuse himself of clumsiness (*vide* Fig. 30).

Now, this absence of the antrum at the seat of election, the cells being reduced to deep petrous cells, separated from the cortical by the too forward sinus until perpendicular to the

meatus, I have only proved anatomically in two instances of Millet (*vide* Fig. 30) ; and I have operated, without, moreover, wounding the sinus, upon two children—brother and sister—in whom it appeared to exist, so far as one can judge in the living subject.

This discussion has a real importance from a practical point of view. It is very certain indeed—and I cannot do better than quote the phrase so clearly expressed by Ricard—that ' the posterior half of the mastoid is dangerous on account of its vicinity to the lateral sinus, but the danger diminishes in proportion as one leaves the base to approach the summit of the process.' But several operators have concluded that, because the anterior part of the base can be also dangerous, the summit ought to be opened ; this is to attack the bone in a region where the cells are often wanting ; it is to risk not finding pus and to pass several millimetres near it.

In reality it is necessary to look for the cells where they are constant, that is to say in the petrous bone, properly speaking ; and by searching among the petrous cells, in the base of the mastoid and in front, we can nearly always find the antrum by means of very distinct external landmarks.

The preceding method becomes wrong if, on account of chronic inflammatory processes, the cellular system of the eburnated mastoid becomes obliterated, or nearly so. But then, if operated upon, the opening is indicated, with the antrum, of the aditus and the tympanum, and from that time it is always easy to find a natural cavity by beginning with the tympanum and following Stäcke's method.

An examination of the figures shows well that in the young child the sinus, however forward (Fig. 45), is always a good way from the antrum (Fig. 46). In the adult we have never found more difficulty than in the case of Fig. 54 ; and nevertheless in that case also the operation was well effected. In the cadaver the sinus has always been found very hollowed (Fig. 51) or nearly level. For the child the sections 20-23 and 27-30 should be consulted.

### The Attic and Aditus.

I have not the least intention of describing in detail the anatomy of the tympanic cavity : topographical anatomy interests me solely as indivisible from surgical procedures. With the foregoing knowledge, the surgeon is, in measure, to study

the operative procedure, which allows him to open the cells of the mastoid and to reach as far as the drum by passing through the aditus.

But I say—and this indication is not the only one—that very often, in chronic suppurative otitis cases, it will be more convenient to reach the aditus by its tympanic entrance and not by its mastoid exit. This is Stäcke's operation, and to understand it, it is necessary to know the exact arrangement of the upper part of the drum, called the ' attic ' in modern otological language.

The *tympanic cavity* is hollowed out in the base of the petrous bone, between the external meatus and the internal ear. It is customary to compare it to a slightly raised drum, whose two bases are depressed in the centre, and which is described as having two surfaces and a circumference, arbitrarily divided into four walls.

The inner or labyrinthine surface has not any interest from an exclusively operative point of view. It is altogether otherwise with the outer or tympanic surface.

The important fact to retain is the following: If, as I am going to do, the tympanic cavity be compared to a cylinder, and if the outer wall be considered as pierced by a large opening which is closed by the tympanic membrane, it must be acknowledged that this opening does not occupy the whole surface of the wall, but that, above and below, above especially, it is surrounded by a bony frame of considerable size. It is like a door in which the threshold is raised by a step above the floor, and whose lintel is placed at a considerable distance from the ceiling. In other terms, when the membrane is seen at the bottom of the external auditory canal, one ought to be warned of what is below this membrane ; the bony circle into which it is set limits a little gutter, which is, above, a relatively large vault ; it is this vault, this epitympanic cavity, this cupola, which modern aurists are accustomed to call the ' attic.'

The attic is, then, the part of the tympanum situated above an imaginary plane passing through the short process of the malleus. The outer wall, that which separates it from the meatus, is closed below for a slight height above the head of the malleus enclosed in the tympanum, by the membrane of Schrapnell ; above this membrane by a bony wall which Walb calls the *pars ossea*, but which is better named, with Gellé, the *wall of the cabin of the ossicles (le mur de la logette des osselets, outer attic wall).*

The attic, in fact, lodges the greater part of the chief ossicles,

that is to say, the head and neck of the malleus, the short process and the body of the incus.

The internal wall of the attic (part of the labyrinthine wall situated above the fenestra ovale) only possesses surgical interest by its relations with the transverse semicircular canal and the facial, which is there projecting; the posterior wall is occupied almost entirely by the tympanic orifice of the *aditus ad antrum*, 5 to 6 millimetres high, usually larger above than below. It is just near this aditus, of which I have already pointed out the relations with the facial and the semicircular canal, that the short process of the incus is seen resting almost on its floor.

Above the aditus and the attic is the roof of the tympanum. This *tegmen tympani* separates the middle ear from the middle cerebral fossa. More or less marked according to the subject, the petro-squamous suture can be seen there, sometimes large enough to constitute a perfect 'dehiscence' of the roof. Then the dura mater and the tympanic mucosa are in contact.

It will be easy, in Figs. 16-20, to study the mode of junction between the squamous part of the temporal and the petrous, the former serving, in short, as a cover, above and outside, to the cavities of the middle ear. Fig. 18, particularly, shows that in a young enough subject these two bones can be isolated from one another without fracture.

The mode of union between these two bones at the cerebral fossa is especially interesting. The plate of the petrous hides that of the squamous, and the connection is much more extensive as the subject is older. The result is that the internal petro-squamous suture passes farther outward, and ends by corresponding with the upper surface of the auditory meatus. The definite gaps are, in short, arrests of development; they favour the development of meningitis and brain abscess.

I shall not further lay stress on the topographical anatomy of the attic in this place; I prefer to consider the technical details when I shall discuss them in speaking of Stäcke's operation.

## II

### OPERATIVE PROCEDURES

I SHALL study successively :

1. Simple opening of the mastoid.
2. Opening the mastoid and the tympanum.
3. Stäcke's operation, pure or completed by opening the mastoid.
4. Opening the cerebral or cerebellar fossæ of the cranium.

### I. Opening the Mastoid.

**Choice of Operation.**—Very various methods have been described for opening the mastoid. From the preceding anatomical facts it follows that our choice should be guided by the following considerations : (1) the first task should be to look for the antrum ; (2) this search should be made by the post-auricular route ; (3) the post-auricular incision should be made as close as possible to the pinna ; (4) all the bony cavities, in which pus may be lodged, should be widely opened.

1. The antrum should be our first object: of all the cells which we have studied anatomically, it alone is constantly present and nearly constant in its relations. I consider it is necessary to abandon Delaissement's method, which consists in opening the cells at the tip. Delaissement gives as the first reason that those cells are the largest ; that is possible when they are present, but often they do not exist. He says, further, that it is necessary to open the abscess at the lowest point ; as a matter of fact, it is necessary to at once bring to light the antrum and all the other cells, as I shall presently explain. He insists upon the distance of the sinus at this level, and that is, without doubt, his true reason ; the truth is, that it is necessary to learn to avoid the sinus at the base of the mastoid, and my statistics prove that it is possible to do so.

2. It is again fear of the sinus that has influenced the surgeons who have proposed and practised opening the antrum by the external auditory meatus. The operation, doubtless, presents no difficulties ; but if, by this route, the sinus and the middle fossa are far away, the facial nerve is very liable to be wounded. On the other hand, all the cavities of the mastoid cannot be well exposed ; the antrum is reached nearly at its centre, but on

account of the facial, the opening cannot be extended beyond this point; the bone cannot be excavated behind when it is diseased in that region. It is enough to look at a specimen to thoroughly convince one's self that the dressings are difficult, and made by a narrow orifice, which is scarcely accessible even to a probe.

3. None of these objections hold in the case of the post-auricular route, in which the sole danger is the wounding of the sinus. But this injury must be exceptional in the hands of a skilled operator, and the first condition for its avoidance is to reject absolutely the cutaneous incision adopted by Poinsot. This author advises an incision parallel to the concha, from which it is separated by an interval of 10 to 15 millimetres. Trace this incision, and between the lips thrust a pointer perpendicularly into the bone, you will stand a great chance of going straight into the sinus. And, let it be thoroughly understood, there will be no question of seeing the bony landmarks upon which I have insisted above. To see them it is necessary to incise in the post-auricular groove, and then to push forward the pinna with a rougine until the commencement of the funnel of the meatus is seen, for the auricle stretches behind over the anterior part of the mastoid.

4. The cellular system is very complex and very variable; often certain groups only communicate with the antrum by a very narrow opening. The only method capable of insuring an effective drainage consists in successively breaking down all the bony laminæ which separate the cells from the antrum and from the exterior: to create, consequently, a single cavity, widely open behind the meatus.

Such are the general principles; let us see their application.

**Operative Technique.**—I shall first describe the *typical operation* which is practised on the cadaver, or on the living subject when the skin, subcutaneous tissues, and bony cortex are healthy.

The *skin incision* should be traced in the post-auricular groove, the pinna being turned forward by an assistant, or by the left hand of the operator. It should measure the length of the mastoid and be recurved above the meatus. To get plenty of light, a posterior transverse incision can be made at the base of the mastoid, crossing the first; a practised operator can easily do without this incision, which leaves a visible scar, whereas the pinna entirely hides the scar in the post-auricular groove.

The incision is at once continued boldly down to the bone, at

2—2

the same time dividing the periosteum.   It necessarily divides
the posterior auricular artery and its branches, causing smart
hæmorrhage; but no time need be wasted trying to stop the
bleeding, which can be done conveniently after the soft parts
have been freed.

The next thing to be done is to lay bare the whole region of
the mastoid and meatus by means of the rougine.   Without
detaching the membranous meatus, the rougine is pushed
towards the bony funnel, so as to see the contour thereof with
its upper boundary and the spine of Henle.   The base of the
mastoid and this point should be laid bare.   For several
seconds, when the whole field of operation is thus brought to
view, there is every facility for using the pressure forceps on the
lips of the incision.

Beyond their hæmostatic function, these forceps, to the number
of two or three to each lip, act also as automatic retractors;
they should be allowed to fall externally, and over their rings on
either side an aseptic compress should be placed of sufficient
weight, so that it may at once keep the forceps down and protect
the field of operation.

This done, the bone is distinct at the bottom of the sponged
and gaping wound, and the bony landmarks can be clearly seen
and verified with the nail, the temporal ridge, the spine of
Henle, if the subject is not very old the line of the mastoido-
squamous suture, and the posterior and superior boundary of the
bony meatus.   To make out the latter well, one need only
protrude a channelled sound introduced into the membranous
meatus.*

With these landmarks the antrum may be found with
certainty.

The only suitable instrument is the cold chisel, driven by a
small leaden mallet.   I believe it is unnecessary to insist upon
this point, judging by to-day; day by day the partisans of
gimlets, trephines, drills, etc., grow fewer.

In the adult, one should work in an area about 1 centimetre
square, situated behind the upper part of the meatus, level above
with the supra-mastoid ridge or the temporal line (Figs. 1 and 2).

A sharp chisel is taken, about 1 centimetre broad, and applied
very perpendicularly to the bone, 5 millimetres behind the

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* When this is done, it will be found very useful to pass a strip of gauze
through the membranous meatus and out by the wound, to act as a retractor.—
*Translator.*

meatus marked by the spine of Henle, parallel to the circumference of the meatus, with its superior angle as high as the upper pole of the meatus. With the left hand the chisel is steadied solidly to prevent it from moving or slipping, and, by two or three very sharp strokes with the mallet it is made to penetrate 2 or 3 millimetres deep. One works similarly on the upper border of the square, viz., under the supra-mastoid ridge, then on the inferior border, i.e., 1 centimetre below the ridge and parallel to it. For these two strokes, equally, the chisel is held perpendicular to the bone.

There now remains the posterior side of the square: it is the side made dangerous by the lateral sinus, although the danger is rare at 15 millimetres behind the meatus. To finish the area, the chisel must no longer be held perpendicular to the bone, but sufficiently oblique — at about 45 degrees — and in several strokes, always very sharp, the square of cortex is raised (Fig. 3).*
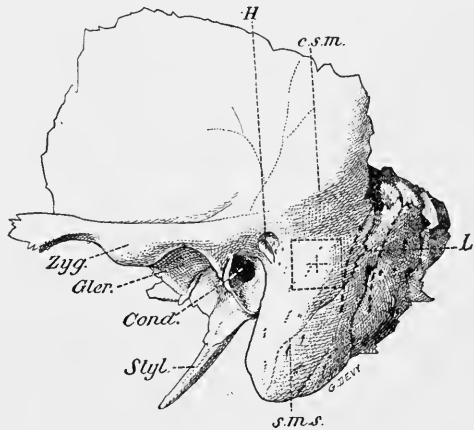


Fig. 1.

The area of operation and its relations to the spine of Henle (*H*), the two ridges, supramastoid (*c.s.m.*) and mastoido-squamous (*s.m.s.*), the lateral sinus (*L*) and the bony meatus (*Cond.*).

Often, especially if the cavities are full of pus and enlarged by rarefying osteitis, the antrum will be quickly found under the square. But often, also, it is necessary to go deeper. This is done with care, always with the chisel and mallet, millimetre by millimetre, pushing the work equally on all sides of the square in depth, but not making it wider. From the depth of about 1 centimetre one becomes more and

* The raising of this square of cortex in this position would, I think, be taken exception to by most otologists in this country as being too far back. Most English surgeons prefer to commence their excavation nearer to the spine of Henle (or supra-meatal fossa). Personally, the square area of operation in which I commence my opening of the mastoid is one which, similar to that of Broca in its dimensions, is placed higher and more anterior, including the spine of Henle within it, its anterior face being formed by the posterior-superior boundary of the meatus.—*Translator.*

more cautious, because of the facial below and in front, and
the sinus behind, and the square should be transformed into a
funnel; chiselling above, in front, and within, working in con-
sequence towards the region of the aditus.  For this, a chisel
1 centimetre broad is too large, and it is necessary to use a
small one of a breadth of about 4 to 5 millimetres.

These small chisels are used exclusively in the child under
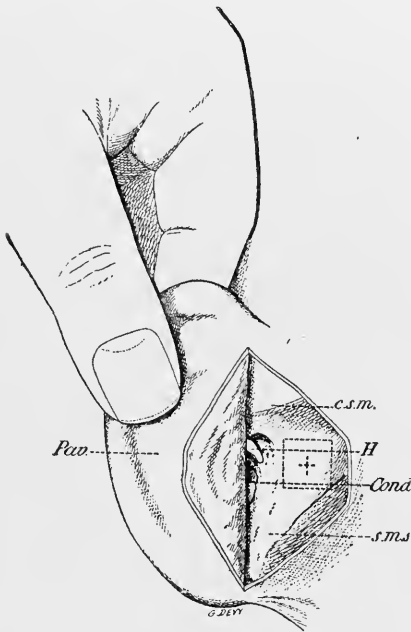fifteen years, especially under ten, and the same operative
method is employed as in
the adult, with this differ-
ence: that the area of
attack should be only 5
millimetres square and
should be situated 3 milli-
metres behind the meatus.
If neither the spine of
Henle nor the supra-mas-
toid ridge is seen at this
age, the horizontal tangent
from the superior pole of
the meatus can be taken
as the upper line.

It is in an access of pru-
dence that I have insisted
on the other landmarks
which distinguish certain
points of the bone.  As
a matter of fact, the supe-
rior pole of the meatus is
sufficient, and it is lucky
that this is so, for in the
young child it may be the
only one appreciable; it is always so during the first year.



Fig. 2.

The same figure with such landmarks as
are visible after the post-auricular skin
incision, the pinna (*Pav.*) being turned
forward.

If no mastoid lesion exists, then one must act as I shall
describe for an older child: the square may be made 5 millimetres
in size, but hammering must be done with caution, by very
sharp, small taps, on a well-steadied chisel, for the bone is easy
to penetrate.

This contingency is, it is true, altogether exceptional.  It is
very rare in the young child (the cortex being very thin and
porous at the level of the antrum, as I have already said) that
an operation is done before the formation of a *subperiosteal abscess*

at the bottom of which is found a *bare point of bone*. It is very rare, also, that the bare portion does not exist as regards the antrum at the place of election, *above* and behind the meatus. If by chance these two rarities are combined, one is still easily guided by the spongy spot described above (see p. 54, Fig. 39). In the child under one year, in excavating the friable point, normal or diseased, of the cortex covering the antrum, the operation can always be done simply with the curette.

It is the only case in which I do not advise the use of the mallet and chisel, provided that : (1) the curette is perfectly appropriate, small, hollow, strong, and sharp ; (2) the bony point for attack is rigorously kept to; (3) one acts with prudence and directs the cutting part above and in front towards the aditus.

The precise spot has always shown me, in the young child, the pathological baring at the seat of election of the antrum. At a later date it is not the same, and it is important to know this in cases where
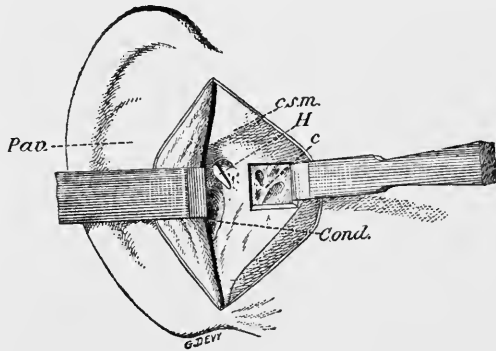


Fig. 3.

The oblique position of the chisel which, for the posterior track, removes the cortex previously marked out over the three sides of the area of operation. *Pav.*, the pinna turned forward, allowing the entrance to the bony meatus to be seen. Other lettering as in previous figures.

an operation is done after the formation of an abscess or a fistula.

It would seem at first sight that one ought always to enter at the point, friable or perforated, of diseased bone, and, as one progresses, to allow one's self to be conducted to the antrum by the lesions seen. It is thus that one is exposed to operative complications, to perforation of the sinus especially. Often enough, as a matter of fact, the pathological opening is very much back as regards the sinus; and, on the other hand, one does not know whether the deep bony wall of the lateral groove is still present ; as it is not rare that, if one seeks to enlarge the pathological opening with an instrument, the first cut breaks into the sinus, and an exploration with a probe ought to be sufficient for that.

The absolute rule in operative surgery ought, then, to be not to primarily occupy one's self with lesions of the cortex, bare bone, or fistula—at least, those that do not correspond to the well-marked seat of the antrum—*every well-conducted operation should begin with the discovery of the antrum at the seat of election.* The rest of the time is occupied in *laying bare all the secondary cells*, without leaving any cul-de-sac where pus can collect.

Now is the time when the surgeon should remember the anatomical facts upon which I have already insisted: for to leave a cell ignored is to allow the symptoms to persist, and to have to do a secondary operation. The practice is ordinarily very simple, for the cells communicate freely among themselves, and the curette by itself breaks away, so to speak, several thin septa. But when the mastoid can be said properly to be sclerosed, it must not be concluded that the antrum alone exists, and also, when no appreciable cell can be found in the base, a suppurating cavity may be present at the tip, as I have twice seen. These anatomical variations merit attention, and to give an account of the way in which a surgeon should act, it seems best to refer him to p. 55, and those that follow, where are figured (Figs. 40-56) the cells of various types of mastoids at various ages. Old otorrhœas, which are often accompanied by consecutive eburnation of the mastoid, are always to be mistrusted. But it must not be forgotten—the figures bear testimony—that, without any previous otorrhœa, these embarrassing dispositions may well be congenital.



Fig. 4.

The antrum being opened, it is enlarged with the chisel held obliquely; the beak of the protector (*Prot.*), introduced beneath the cortex, guards the deep parts from accident. Other lettering as in previous figures.

An expert operator can work without trouble with a small spoon-shaped curette, but Stäcke's protector gives absolute security. The beak of the instrument is inserted under the cortex, at first below, towards the tip, then behind, towards the

sinus; and on this beak, which prevents all violent penetration into the deep parts, towards the sinus or towards the facial, the bony septa thus marked are destroyed by short blows on the chisel. When the curette touches everywhere on smooth bone, limiting a single cavity, on the wall of which the beak of the protector or the probe no longer finds any diverticulum in which it becomes engaged, the surgeon stops—safe above, in front, and within—where the mastoid exit of the aditus, easy to catheterize, is found.
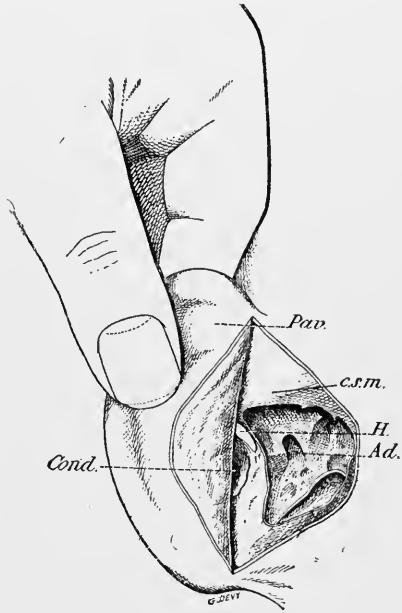
The bony cavity can only be examined when it is perfectly free from blood. This is easy to attain if at first complete stoppage of the bleeding of the soft parts is assured, and if, on the other hand, with tampons of dry sterilized gauze, temporary pressure on the oozing bony surfaces is used.

I never wash the wound. I have given up immediate



Fig. 5.

Antrum and secondary cells are widely opened. *Ad.*, aditus ad antrum, the relations of which to the supra-mastoid ridge are seen (*c.s.m.*); spine of Henle (*H*), and entrance to bony meatus (*Cond.*), visible together by the turning forward of the pinna (*Pav.*).

union, and I confine myself to packing the cavity with iodoform gauze. With a well-arranged tampon and a compressive dressing, it is needless to tie the vessels of the soft parts.

In making the dressing, a packing of iodoform gauze should be placed in the meatus.

### II. Opening the Mastoid and Tympanum.

This operation comprises the following steps: (1) Skin incision; (2) exposure of the bone; (3) finding the antrum and excavation of the mastoid: (4) opening of the aditus and attic.

1. The *skin incision* is the same as in the preceding case, with the difference that it is longer and recurved above the pinna over the temporal fossa. If a fistula is present or an abscess behind

the post-auricular groove, after having traced in the groove the typical incision, a transverse cut is added, passing through the fistula or bisecting the purulent pocket at its broadest part.

2. The *exposure of the bone* comprises here, beyond that of the whole mastoid, that of the lower part of the temporal fossa and the meatus. To effect the latter a straight thin rougine is inserted, with which the posterior wall is separated, inferior and superior to the membranous meatus, up to the tympanic ring ; then, at this level, right to the bottom of the osseous canal, the cutaneous tube is cut, and, in going back along the surface against the anterior bony wall, the membranous meatus is brought down entire. Auricle and meatus are then turned forward, held in place by forceps covered by an aseptic compress, and from that time the whole bony part of the region is seen ; mastoid, bony meatus, and tympanic frame, with what remains of the membrane.

Such operation is only done, as a matter of fact, in chronic middle-ear suppurations, in which the membrane is perforated or largely destroyed.

To obtain a clear view it is first necessary, as I have already said, to obtain a perfect cessation of bleeding from the soft parts, without which the blood accumulates in the dependent parts, and fills the meatus. To stop the oozing in the bony meatus a dry packing is made with a plug of dry aseptic gauze, which is kept in place during the search for the antrum.

3. *Finding the antrum and excavating the mastoid* is carried out exactly as has been said above, at the seat of election, which will be the seat of appreciable external lesions. It is in the actual case especially that I would insist upon this precept, for it is in chronic mastoidites and otites, to which alone the complete operation is applicable, that these lesions are usual.

These lesions are not the only ones. The mastoid undergoes, under these conditions, more or less profound alterations ; but in spite of this, without entering into a description of the various cases which may be met with, it is possible to give several general precepts of operative surgery.

It is in cases where the work is all done that a large cavity, going nearly into the tympanum, widely gaping under the fistula, is found. The caries has eroded the wall of the attic, the posterior wall of the meatus, and the curette soon finds proof of several small friable bony spots.

Sometimes the cavity contains sequestra of more or less size.

These are removed with the curette almost without having to enlarge the spontaneous opening in the cortex, and the operation is in no way modified.

Usually, after having opened the antrum, the meatus is separated from it by a marked thickness of bone; it is this wall that it is necessary to remove to throw into one cavity the whole of the cells of the middle ear, including the tympanum. It is necessary, in other words, by cutting the aditus and breaking away the wall of the attic, to enter the latter. The following is the way in which this should be done:

Stäcke's protector is introduced into the aditus, of which the exit is seen in the antrum, above, in front, and within, as has been said above, and the pro-tector is pushed in this direc-tion. When the subject is a young child, or when the caries has enlarged the aditus and the antrum, and has re-duced to a thin plate the wall of the meatus, the handle of the protector can be lifted at the first attempt, so as to de-press the beak nearly hori-zontal, or even a little lower, making it enter at once into the antrum. Ordinarily, the narrowness of the aditus is such that this movement is impossible, and it is only after having enlarged it by several strokes of the chisel
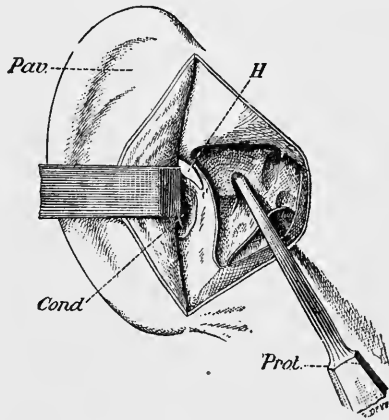


FIG. 6.

The same figure as the preceding one. The protector (*Prot.*), directed at about 45 degrees above and forward, is introduced into the aditus.

that the first part of its passage will become possible. In these positions the plate of the protector is applied against the inner wall of the aditus—that is to say that it protects the semicircular canal, and, below, its lower border guarantees the facial against accident. One must guard against using the instrument with roughness, and keeping any weight on the handle, or injury to the nerve may result; it should be kept in place by its own weight.*

* One cannot always depend upon one's assistant to thus keep the protector from exercising undue pressure upon the facial nerve. It is my custom, therefore, to insert a small piece of aseptic sponge into the aditus. Then, by

The protector being in place, obliquely above, forwards and inwards (Fig. 6), the freeing of its beak is begun by several blows on the chisel, which do not concern the meatus, but finally enlarge the antrum above. Soon the handle can be given its definite position, the beak entering the tympanum (Fig. 7). From this time the aditus and attic can be attacked. At first the chisel is applied, perfectly perpendicular to the bone, at a tangent to the superior pole of the meatus, and with several taps of the mallet it is driven almost in contact with the protector. If the blade is not thin enough the bone will not be broken; on the other hand, there is little danger to fear. The middle cerebral fossa is far enough away, and one only risks, if it breaks quickly, baring the dura mater to a slight extent, from which I have never seen any inconvenience. If so bold a penetration is dreaded, the wall of the attic can be worked upon with a gouge, as I shall describe for Stäcke's operation, and gradually broken away over the upper wall of the aditus, after the beak of the protector has been exposed.



FIG. 7.

By several cuts with the chisel the opening of the aditus has been enlarged, especially above and in front, and the protector (*Prot.*) has been placed in its definite position, obliquely from below forwards, and at a right angle to its former position. The membranous meatus, hidden under the retractor of the pinna (*Pav.*), is completely separated and displaced downwards from the bony meatus (*Cond.*), which appears in its entirety. The chisels are placed at their point of attack to remove the outer attic wall, the upper one (I) perpendicular to the bone, the lower one (II) obliquely above and inwards.

The upper track finished, the lower one is completed, and it is here the facial is found. The chisel must be applied at the junction of the upper one-third with the lower two-thirds of the meatus, mostly at mid-height of the meatus, and it must be directed above and within, so as to make a trapezoid breach,

using the chisel with care, and keeping it well under control, the bridge of bone which forms the outer wall of the aditus can be removed over the plug of sponge without risk of injuring the nerve.—*Translator*.

so that the piece removed from the wall of the meatus has a base as high as the half of the meatus at most, and in the depth a base as large as the meatus.

Usually the bony fragment cannot be brought away in one piece, but in several fragments, advancing by small taps towards the deep parts. The work must be proceeded with equally above and below, the chisel-cuts at the upper part being always perfectly perpendicular to the bone, the lower ones being, on the contrary, more and more obliquely ascending. The enlargement of the breach is finished by the rounding off of the angles, especially the upper ones, which still overhang the protector a little, and when they are planed the work ceases.

At this stage of the operation it is necessary to have a clear view, for which a chisel of about 1 millimetre must be used. Here, temporary pressure with pledgets of dry antiseptic, or better, aseptic gauze, gives much help. These pledgets, prepared beforehand, follow the size of the cavity, are packed tightly in with the point of the chisel;
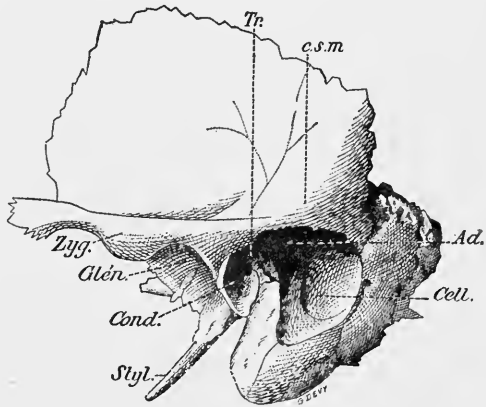


FIG. 8.

Final result of a complete opening of the mastoid cells (*Cell.*) of the aditus (*Ad.*) and of the tympanum (*Tr.*); *c.s.m.*, Supra-mastoid ridge, *i.e.*, the longitudinally prolonged root of the zygomatic arch (*Zyg.*); *Cond.*, bony meatus; *Glen.*, glenoid cavity; *Styl.*, styloid process.

with an ordinary tampon, fluid is sponged from the surface. The tampon is lifted out by a sharp blow with the left hand, which should never leave the mallet, or it may be lifted out by using the chisel as a curette, and then for a short time the cavity can be seen distinctly, so that the chisel can be applied with every necessary precision.

Such is the typical operation when the cells of the mastoid are sufficiently large. But, after chronic middle-ear otitis, it is not rare to find that the bone has undergone a condensing osteitis which chokes up the cell system, making it nearly *nil*, when a narrow aditus is found with a microscopic antrum.

In  these conditions the  operation  can  nearly always be  con-
ducted  by  the  method  which  I  shall  describe,  if  one  keeps
above  and within,  distinctly  towards the  aditus,  breaking  away
as is required,  with  caution,  it  is  true,  under  the  supra-mastoid
ridge.     One must  go  steadily  on  sometimes  to a  great  depth  to
reach  a  rudimentary  antrum  surrounded  by  particularly  hard
bone.     With  skill  and  practice  this  can  be  done,  but  it  is  not
necessary  to  be  excessively  persevering,  and  when  the  work  be-
comes  too  assiduous  the  cells  can  only  be  entered  by  the
tympanum  (always  easily  accessible),  that  is  to  say,  by  Stäcke's
operation.

When  the  antrum,  aditus,  and  attic  are  opened,  the  toilette  of
this  large  cavity  is  proceeded  with ;  all  the  osseous  projections
that  can  be  found  are  rounded  off  with  the  chisel  over  the  pro-
tector,   which   guards   against   accidents ;   cholesteatomatous
masses   are   cleared   away,   friable   carious   portions   of   bone
removed,  granulations  of  the  soft  parts  are  curetted,  and
fistulous  tracts  excised.

To  finish,  some  surgeons  circularly  incise  the  meatus  towards
the  concha  to  obtain  a  large  orifice,  the  posterior  border  of
which  they  suture  to  the  post-auricular  incision ;  so  that  the
bony  cavity  is  only  accessible  by  this  entrance.     This  method
gives  incontestable  success,  but  I  think  that  the  later  dressings
are  much  easier  if  the  post-auricular  cavity  is  left  widely  gaping.
But,  on  the  other  hand,  it  is  necessary  that  the  meatus  should
also  remain  widely  open.     To  obtain  this  result,  it  should  be
split  above  and  behind  up  to  the  concha,  in  the  axis  of  the  open-
ing  of  the  aditus,  and  by  packing  kept  stretched  in  front  and
within ;  I  have  given  up  suturing  each  angle  to  the  posterior
extremity  of  the  post-auricular  incision  in  order  to  make  sure  of
this  stretching.     In  making  the  cleavage  the  posterior-auricular
is  cut  in  the  concha ;  its  ligature  is  not  needed,  and  the  packing,
followed  by  a  compressing  dressing,  suffices  to  stop  the  hæmor-
rhage.*

The  cavity  being  well  dried  by  several  aseptic  gauze  pledgets,
the  dressing  is  proceeded  with ;  a  pledget  of  iodoform  gauze,
introduced  by  the  meatus  and  pressed  into  the  post-auricular
wound,  is  pushed  with  Lister's  forceps  to  the  bottom  of  the

* Save in exceptional circumstances, I think it better to attain this end by
careful packing, *viâ* the meatus only, the post-auricular wound being sutured
throughout.     This ensures union by first intention and a consequently
unnoticeable scar.   Subsequent packing is carried out through the meatus,
and, if carefully done, there need be no anxiety as to the result.—*Translator.*

tympanum and well pressed in. A second layer covers the post-auricular wound.

I shall not here describe the after-treatment of these patients. I would only insist upon the fact that, to obtain a good result, it is indispensable to keep the meatus and tympanum widely open, or it will tend continually to contract. It must always be packed by the meatus and behind the ear, as has been said.

### III. Stäcke's Operation.

Stäcke's operation consists in opening the attic by way of the meatus, by breaking down the 'outer attic wall.'

The *skin incision* is the same as that for the previous operation. In the same manner the *exposure of the bone* is always extended farther above and behind—over the mastoid, properly speaking, leaving it so that a complete post-aural opening can be done if it is thought necessary. The pinna is turned forward, so as to separate completely the membranous meatus from the bony canal. After swabbing with aseptic gauze, the meatus is seen with the rest of the tympanum with great distinctness, after removing the malleus, if it still remains, with forceps, and then the bony operation is commenced.
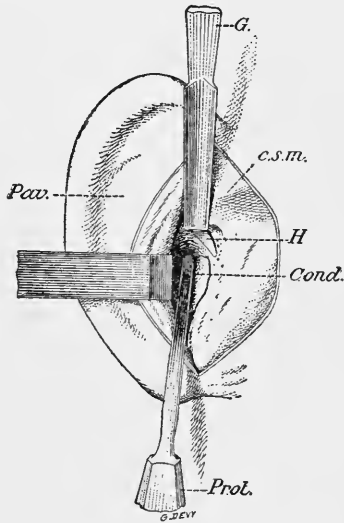


FIG. 9.

The *opening of the attic*, done without completely opening the mastoid, is the essence of the operation.

The protector—it is for this operation that Stäcke designed his model—is introduced into the tympanic opening, and the beak is made to enter the attic, obliquely above and inwards, behind the

*Pav.*, pinna turned forward with the membranous meatus displaced down from the bony meatus (*Cond.*). The protector (*Prot.*) is introduced, directed down and up, into the attic, where its beak has disappeared. The gouge (*G*) is placed, slightly oblique, against the meatus, above the spine of Henle (*H*) and below the supra-mastoid ridge, just against the upper border of the meatus.

attic wall, where its position is verified. The wall of the attic can then be worked upon, for which purpose a gouge is better

than the straight chisel employed in the preceding operations. Stäcke has had a special gouge made, with a light cutting blade turned towards the dorsal surface of the groove; made thus, the instrument bites better, with less tendency to slip against the bone without cutting it. The bone, as a matter of fact, is hard. But, with a little practice, one can manage better with the gouge contained in the usual surgical armamentarium; it is enough to direct it well against the bony surface and not parallel thereto.

It is in the postero-superior angle of the meatus, below the supra-mastoid ridge, within and above the spine of Henle, that the gouge is applied, the groove of which, more or less wide, can be adapted nearly to the con cavity of the meatus; the cutting blade should be placed boldly in the meatus from the first, sufficiently deeply, and breaks away the bony wall from the deep part towards the surface by successive chips. It is wisest to work thus, and it is only by having much practice in the method that the operator can do this quickly, applying the gouge against the spine of Henle, i.e., at the border of the meatus, and, by several strokes of the mallet, removing the postero-superior wall of the meatus in one piece.



FIG. 10.

The wall of the attic having been removed, the attic (Att.) is opened and, on the protector, obliquely below and inwards in the aditus, the retrograde opening of the aditus and mastoid can be proceeded with.

The attic is thus opened, and at this stage of the operation no organ is in any danger; provided the aditus is not approached, the facial is far away. But it is always necessary to approach the aditus, in order to explore and open it, as well as the antrum; therefore it is necessary to work with caution.

After the ablation of the outer attic wall, the tympanum and attic are widely opened at the bottom of the meatus. The malleus, if it still exists, has been removed before opening the tympanum. With a long, straight curette the incus is extracted, then the granulations which fill the tympanum, and the aditus is seen where the short process of the incus was found.

Then retrograde opening of the aditus and antrum is carried

out, the facial and semicircular canal being guarded from injury by the protector. The beak of the protector is engaged, nearly transversely, but a little obliquely from above inwards, in the entrance of the aditus, and above it, towards the roof, the breach is slightly enlarged ; the beak can then be directed below and outwards (Fig. 10), to make it enter the antrum ; and the aditus, then the antrum, then the various cells, are opened, exactly as has been described in the preceding operation, but in the inverse order.

After the *pure Stäcke operation*, the *membranous meatus* is split behind to the concha, then rearranged in the osseous meatus and kept against it by a tampon of iodoform gauze, packed tightly, and pushed to the bottom of the tympanum. The post-auricular wound is sutured, and the later dressings applied through the meatus.

After *Stäcke's operation, completed by retrograde opening*, one acts exactly as in the complete opening previously described.

## IV. Opening the Mastoid, the Tympanum and the Cranium.

**Choice of Methods.**—Before entering into the detail of operative technique several pathological facts are indispensable, for upon their recognition depends the choice of method.

Everyone knows that intracranial complications are frequent in the course of chronic otitis. These complications, so fatal if left to themselves, often justify surgical interference. They number four :

1. *Meningites*, which are general and suppurative, incurable ; others, diffuse, but not suppurative (auricular meningitis) or localized by adhesions about the diseased bone, curable if opened and well drained.

2. *Extra-dural abscesses*, situated between the bone and dura mater, on the cerebral or cerebellar surfaces of the petrous, or on both at once.

3. *Thromboses of the sinuses*, and particularly of the lateral sinus, with infection spreading more or less far, either towards the torcular Herophili or towards the neck.

4. *Encephalic abscesses*, cerebral or cerebellar.

*Cerebral abscesses* nearly always occupy the inferior surface of the temporal lobe, near to the occipital lobe, just above the petrous, from which they are often separated by a bed of nervous tissue, apparently healthy. *Cerebellar abscesses* are behind the

cerebellar surface of the petrous, near the corresponding anterior surface of the cerebellar hemisphere.

A general fact results, well established since modern surgical endeavours have given a practical interest to these anatomical researches : the various intercranial lesions nearly always have their origin and their maximum in proximity to the causal auricular focus.

Another anatomico-pathological fact to be well remembered is that several lesions are often associated, extra-dural abscesses most frequently with all of them ; the co-existence of cerebellar abscess with thrombosis of the sinus is equally frequent.



Fig. 11.

Case XXIII. from my 'Treatise on Cerebral Surgery.' Complete opening of the mastoid and tympanum.

Consequently, it should always be remembered that, if sometimes the symptomatology is sufficiently clear to allow of a precise diagnosis, it is by no means usually so. An intracranial complication is recognised, some one in particular being suspected; yet to consider it to be an abscess is to willingly be deceived, and, as a rule, it is not possible to specify if the purulent pocket is extra-dural, cerebral, or cerebellar.

The general conclusion is that the various methods should thus be expressed by the surgeon : (1) Entering the cranium as near as possible to the diseased petrous bone ; (2) searching, with the maximum of rapidity and the minimum of damage, for the several lesions together ; (3) making easily and quickly all the

necessary explorations in cases (always very numerous) where diagnosis is uncertain.

For abscess in the temporal lobe, it is certain that the trephining of the squamous just above the auditory meatus answers very well to the first of these conditions, and is connected besides with the mastoid method which I shall describe. But what is to be done with extra-dural abscesses, with sinus thromboses? And if the diagnosis is erroneous it is very dangerous to enter upon two successive and difficult operations—to search for the sinus, and for a cerebellar abscess.

For cerebellar abscess, to trephine the occipital is to be obliged to pass through the whole cerebellum to find a pocket situated close to the petrous.

*Suppose, on the contrary, that the patient has already undergone complete opening of the mastoid and tympanum*—and I have endeavoured in several papers already to show that, in these cases, this operation is always indicated by the condition of the ear—we shall see that, after that operation, it is most easy to enter the cranium very rapidly in all the necessary parts.

### V. Opening the Cranium by the Mastoid Route.

Two varieties are distinguished according as bony lesions guide the surgeon from place to place, or where he must go, as in the cadaver, by a regular process, to seek this or that lesion through seemingly intact bone.

**1. There are Perforating Bony Lesions.**—These cases scarcely merit mention if they do not have the effect of teaching us, by the natural work of necrosing and rarefying osteitis, that we are right in insisting, in orthodox operative surgery, upon the mastoid route. It is sufficient to look at the appended figures, all drawn from specimens obtained after operation upon the living subject.

When an *extra-dural abscess* of any importance is present it is the rule that, after excavating the mastoid and the tympanum, the intracranial pocket can be very simply reached with a curette by scraping the carious bone. It is then found that, in perforating the roof of the aditus and tympanum, one enters just under the temporal lobe, above the petrous; it is also seen that in front of the sinus, of which the osseous wall is ordinarily eroded under these circumstances, a pocket collected between the dura mater and the cerebellar surface of the petrous can be emptied without trouble.

Often enough one is also led close to the sinus when it is not

thrombosed ; a similar continuity is less frequent with encephalic abscesses.

2. **There are no Perforating Bony Lesions.**—A few words will suffice to describe the various operations.

(a) *Opening the Temporal Fossa.*—Just at the summit of the roof of the aditus apply the chisel perpendicularly to the bone, penetrate to 2 or 3 millimetres, and limit the osseous cut at the two extremities of this horizontal track by two short vertical and descending cuts, containing between them a breadth nearly equal to that of the meatus. Then, by an oblique chisel-cut in the first tract, remove the piece of bone. The dura mater is thus bared (1) at the part exactly below the temporal fossa, just above the
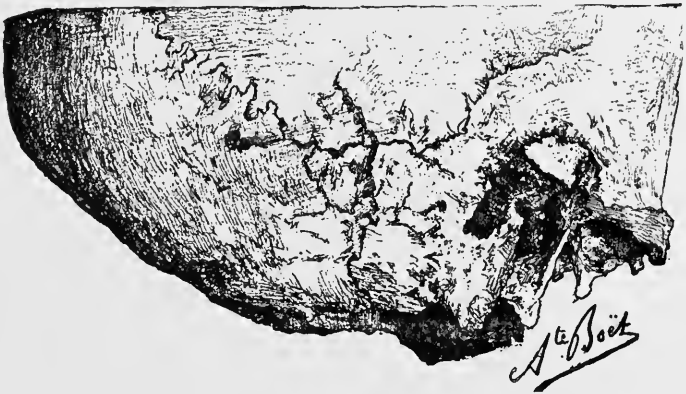


FIG. 12.

Case XIV. from my ' Treatise on Cerebral Surgery.' The temporal fossa has been opened by removing the floor of the aditus. The breach is seen to be wide, it is exactly sub-auricular, and it can be very easily enlarged in every direction. See Fig. 13, its entrance into the middle fossa.

longitudinal root of the zygomatic process; (2) at the anterior and external part of the cerebral surface of the petrous. The chisel is abandoned from this time, and if it is wished to enlarge the opening, a curette is used for the roof of the aditus and tympanum, gouge-forceps for the temporal fossa.

Fig. 13 shows with great distinctness what point of the base of the cranium is reached, just below the temporal lobe—that is to say, at the seat of election of circumscribed meningitis, of abscesses and their lowest point.

(b) *Opening the Cerebellar Fossa.*—We have here to reach (a) the lateral sinus ; (b) the cerebellum.

(i.) *Opening the Lateral Groove.*—The antrum forms the best

landmark for finding the sinus. After having opened it, cleaned and thoroughly put it in order (Fig. 11), the mastoid wall behind it is widely bared, which at once allows of an inspection of the condition of the mastoid vein. Then, behind it, on the line passing from the auditory meatus to the external occipital protuberance, successive bony chips are raised by a well-sharpened chisel, held obliquely above and within, for a space of 1 or 2 millimetres, so that the dura mater can be seen. Then the opening can be made larger with the chisel, or better with gouge-forceps.

Fig. 14 (taken from a subject in which caries had entirely eroded the temporal fossa) shows distinctly where the sinus is
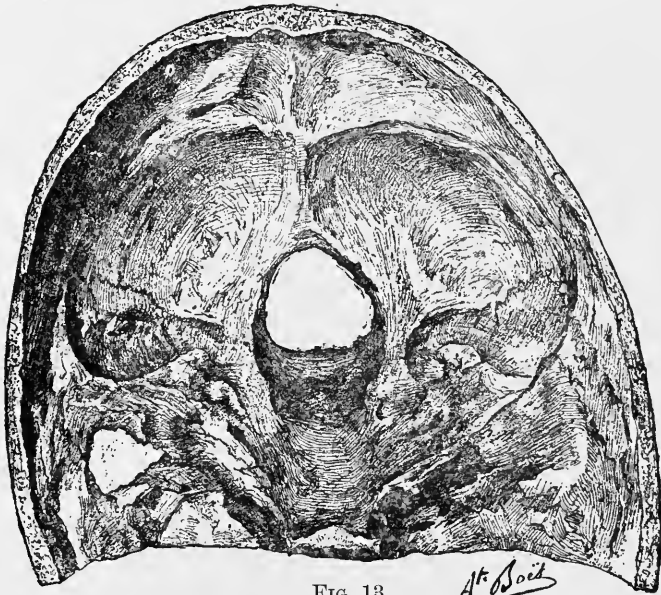


FIG. 13.

Entrance into the cranium through the roof of the aditus.

situated in relation to the antrum (see Fig. 11, showing the petro-mastoid excavation).

It is in Fig. 15, behind the superior border of the petrous, that the entrance of this opening into the cerebellar fossa is seen ; and it demonstrates perfectly what is otherwise evident, that from the point of view of the complications of otitis, the groove of the lateral sinus is the centre of the cerebellar fossa, by which we can understand how extra-dural or intra-cerebral abscesses are brought about.

(ii.) *Opening the Cerebellar Fossa.*—To reach the cerebellum it

is necessary to go in front and within to get behind the lateral
sinus.



FIG. 14.

Case XVI. from my ' Treatise on Cerebral Surgery.'   Through the
preceding sub-auricular breach another can be seen which passes
into the cerebellar fossa.   In this particular case it approaches
very closely to the whole lateral sinus.   See Fig. 15, the entrance
of the two openings into the middle cerebral and cerebellar fossa ;
and it may be noted that the two openings can be joined without
fear of injury to the sinus.
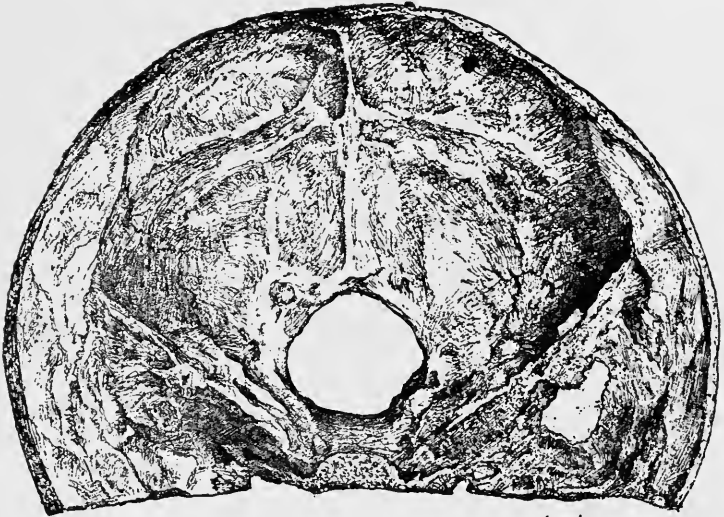


FIG. 15.

Entrance into the cranium both towards the cerebrum and cerebellum.

The simplest and most prudent procedure to avoid opening
the sinus, the wounding of which necessitates the abandonment

of the operation, consists in proceeding at once to the baring and recognition of the sinus. Then in front and within it, to break in the posterior wall of the petrous with curette and gouge, and to enlarge the opening as much as is wished with gouge-forceps towards the mastoid wall, and necessarily towards the occipital. It is useless to describe the opening with gouge-forceps of the cerebellar fossa behind the sinus. The only delicate point is to reach those abscesses which are situated in front of the sinus, when the sinus is not thrombosed, and cannot be opened without danger.

It is at the level of the posterior surface of the aditus and the tympanum that the work ought then to be finished, being careful to direct the instruments rather above than below : for below one is not far from the jugular foramen at its junction with the sinus. A practised operator can directly attack this region.

## THE ATLAS.

This atlas is composed of two parts, arranged under my direction by my pupils and friends, O. Lenoir and Ch. Millet.

Both have taken upon themselves the task of collecting variations of the relations of the cavities of the middle ear from birth to adult age; to show, also, the individual variations in structure.

The first part comprises photographs of sections made by Millet on dry specimens, and displays certain developmental details. I have accompanied them by an explanatory text, which sums up the anatomical portion of Millet's thesis (Paris, 1897-1898).

The second part is formed by drawings taken by O. Lenoir from preparations which reproduce most of the operative stages; they thus follow the introduction to the semi-schematic figures which illustrate the description of the operative technique.

All the drawings are natural size.

The sections of Millet have been made on three different planes.

1. *In the horizontal plane.*—To have a fixed point, allowing a section to be always made at the same level, we have chosen the spine of Henle. One section passing through it, immediately above the meatus, allows at once of the examination of the antrum, the aditus and the highest part of the tympanum or attic (Figs. 27-30).

A new section was made afterwards 5 millimetres lower. This

directly divides the meatus about its upper part and shows the direction of its posterior wall. The tympanum alone is visible, the track of the section passing at the level of the mastoid below the floor of the antrum (Figs. 20-23).

2. *In a vertical transverse plane, perpendicular to the outer surface of the temporal.*—Thus the meatus and the tympanum are cut in half. On the anterior surface of the section is then seen the plane of section of the outer wall of the middle cerebral fossa, its floor corresponding to the upper part of the tympanum and meatus—in short, the anterior half of the tympanum and the anterior wall of the meatus (Figs. 16, 17, 19).

On examination of the posterior surface of the section, the posterior wall of the meatus, the posterior half of the tympanum,



FIG. 16.—One month.          FIG. 17.—Sixteen months.

and the opening of the aditus are seen. Thus the relations of the facial with the aditus and the posterior wall of the meatus (Figs. 34 and 35) can be made plain. In these two figures the direction of the descending portion of the facial is indicated by a black line.

A second section, parallel to the preceding one, but made more posterior, passing through the spine of Henle, allows of a view of the relations of the retro-spinal fossette with the limitrophic cells (Fig. 25).

One after another, millimetre by millimetre, successive sections can be made, cutting the mastoid from below up, showing continuously its relations and development (Figs. 31, 32).

3. *In an oblique plane,* passing in front at the level of the

opening of the Eustachian tube and behind, 1 centimetre from the posterior wall of the meatus.

In such sections the middle ear is shown entire, and, in making a succession of parallel sections, the relations of the facial can easily be made apparent (Figs. 33-36).

In the vertical sections of Figs. 16-19, passing through the middle of the meatus and the tympanum, the anterior half of the tympanum and the anterior wall of the meatus are seen. They show the progressive growth of the mastoid. The petro-squamous suture is seen very plainly to be formed by the super-position of a paper-like plate coming from the petrous portion, like the internal table of the temporal wall. The outer table of the temporal descends and insinuates itself between the mastoid and the posterior limb of the tympanal. Between the two plates is a spongy tissue which gradually becomes hollowed out by cells.



FIG. 18.—Fifteen days.

Fig. 18 represents a specimen obtained from a child in whom the squamous and petrous could be separated after birth. That done, the middle ear appeared entire. The squamous forms a cover to the tympanum, aditus, and antrum.
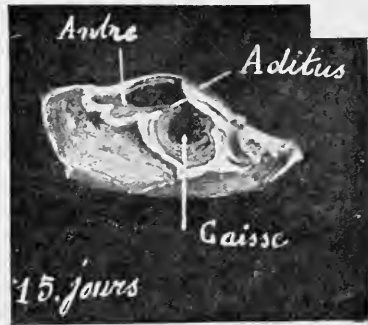
The modifications which the relations of the middle ear undergo with age are not limited to the development of the mastoid alone, but also extend to that of the auditory meatus, subordinate itself to that of the cranial cavity; in short, to the size to which the brain develops. Certain bony parts, which originally take no part in the formation of the lateral portions of the cranium, become horizontal and participate in the formation of the base. This is seen in Figs. 16, 17, 19. According as the child gets older, the inner plate of the squamous becomes incurved, so that its lower part, becoming horizontal, takes part in the formation of the middle cerebral fossa.

It is the upper border of the longitudinal root of the zygomatic process (*linea temporalis*) which corresponds externally to the junction of the vault with the base of the cranium.

From this enlargement of the cerebral fossa it results that the cells, which primarily corresponded to the upper part of the

antrum, the aditus, and the tympanum, become carried to the external part, and constitute the limitrophic cells of the meatus.

The relation of the middle ear with the temporo-sphenoidal lobe becomes altered at the same time; whereas at birth, and during the first months, the roof of the antrum, of the aditus,
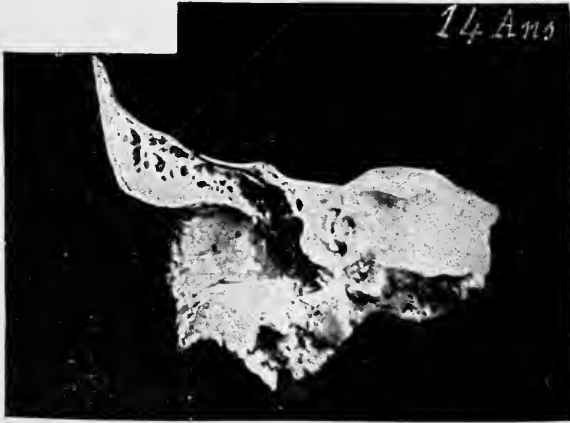


Fig. 19.—Fourteen years.

and of the tympanum corresponds to the point of union of the lower and lateral surfaces of this lobe, it ends, especially at the level of the tympanum, by only coming in relation with its inferior surface.

At birth, the petro-squamous suture, *at the level of the cerebral*



Fig. 20.—One month.



Fig 21.—One year.

*fossa*, passes exactly above the antrum, the aditus, and the tympanum. Gradually it is carried much more external, and finally corresponds to the inner third, sometimes even to the middle of the bony meatus. Then the connection between the

middle ear and the cerebral fossa becomes less intimate ; on the contrary, the relations with the sinus and the cerebellar fossa become closer.

The adjoining figures (20-23) represent horizontal sections at 5 millimetres below the spine of Henle, showing how that is produced.

In a subject of one month (Fig. 20) this section shows the antrum badly ; this cavity is, as a matter of fact, at this age on a higher plane than the tympanum, and, to see it well, a horizontal section must be made passing above the meatus (*cf.* Fig. 20 and Fig. 27). In Fig. 29 the floor of the antrum, slightly hollowed, is shown resting upon a mass of spongy tissue comprised between the two tables of the petrous, which primarily abut at the level of the occipito - mastoid suture, turning aside to approach one another ; the first, without and in front, joins the wall at the level of the petro-squamous suture ; the second, in front and within, forms the posterior surface of the petrous. This spongy mass separates the antrum from the lateral sinus.



Fig. 22.—Seven years.

Primarily superficial, the antrum, following the consecutive development of the mastoid and the meatus, becomes deep in the adult. Further, when in the latter the mastoid portion, besides the relations which it has deeply with the petrous portion, enters, for an appreciable extent, into the formation of the lateral wall of the cerebellar fossa, this latter part is reduced to its minimum at birth. The posterior surface of the petrous appears to be prolonged right up to the occipito-mastoid suture. At its external extremity still, this posterior surface of the petrous, formed by the inner table of the temporal and the direction of which is oblique from before backwards and from within outwards, is slightly inflected to unite with the outer table, the direction of which is such that it appears to prolong that of the occipital (Fig. 20). This form is modified according to the development of the cerebellar fossa.

At the level of this fossa, the enlargement is produced at the expense of the mastoid region, which, primarily reduced to its
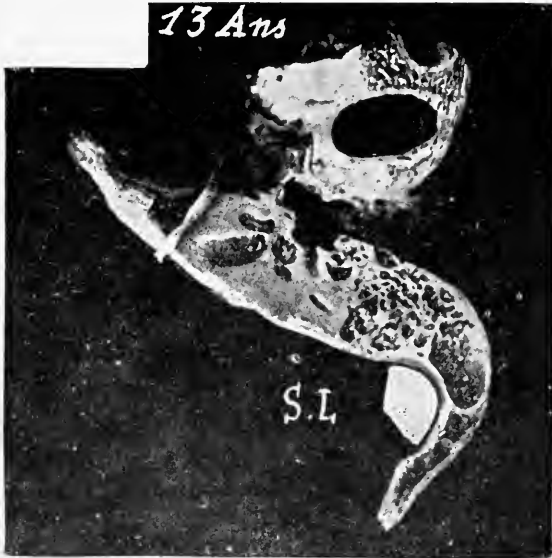


Fig. 23.—Thirteen years.

minimum, undergoes in consequence a preponderant increase. To the cartilaginous tissue interposed between it and the occipital



Fig. 24.—Three years.

osseous tissue succeeds. Whilst, primarily, the two tables of the temporal are separated almost immediately at the level of

the occipito-mastoid suture—that is to say, at the limit of the posterior surface of the petrous—and when the temporal also takes no part in the formation of the lateral wall of the cerebellar fossa, a bony surface making part of this wall is formed progressively, a true mastoid wall. But, in enlarging, the mastoid region undergoes a movement of inflection analogous to that of the cranial wall; the two tables of bone, between which the antrum is situated, are progres-



Fig. 25.—Eight years.

sively carried outwards and forwards, and the posterior part of the mastoid region, mobile at the level of its junction with the occipital, undergoes a movement of rotation inwards about its antero-internal part, fixed by its continuity with the petrous portion. It results from this movement of rotation that the portion of the internal table situated behind the tympanic opening, and which primarily was antero-posterior, is inflected, carried forward, and forms the posterior wall of the osseous auditory meatus; at the level of the inner table, this inflection of the mastoid portion, which at birth did not exist, has for its result the lengthening of the posterior surface of the petrous, and, conse-



Fig. 26.—Fourteen years.

quently, of the transverse diameter of the cerebellar fossa.
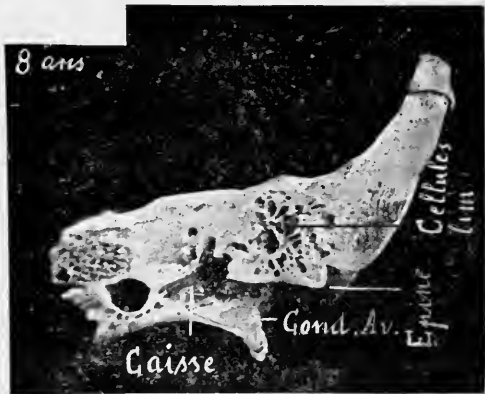
As one sees it, the tympanic bone, which has often been made to play the principal part in the development of the meatus, does not possess, from the point of view of the modifications
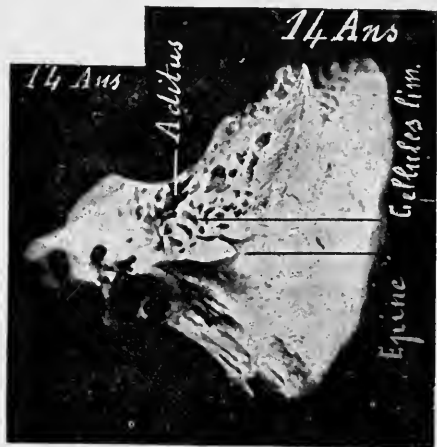
which this development impresses upon the relations of the middle ear, any but a secondary importance. In reality the temporal, or more correctly the squamous, forms the superior



and posterior walls of the meatus, the tympanic bone the anterior and inferior; the latter contributes, further, to its regularity and rounded form, disappearing on the superior and posterior walls, which are sensibly rectilinear and which it partly covers.

It is to be noted that the direction of the meatus in the child differs essentially from that of the adult; it is oblique from above downwards and from behind forwards.

FIG. 27.—One month and a half.

This arrangement is only transitory; it changes gradually, as it is easy to understand by looking over the foregoing figures. According as the inflection of the cranial wall, at the level of the middle cerebral fossa,



becomes more marked, the external table becomes lower, and soon the superior wall of the meatus tends to approach the horizontal. Similarly behind, according as the cerebellar fossa is developed, the posterior wall is carried forward. So that, oblique in the child in its first years, the meatus loses progressively this obliquity and tends to become perpendicular to the external surface of the cranium.

Whilst the preceding sections contain the relations between the formation of the groove of the lateral

FIG. 28.—Two years.

sinus and the posterior wall of the meatus, in Fig. 24 the relations of the sinus marked on the external table, with the spine of Henle, the meatus and the cribriform zone, are seen. Further

on (see Fig. 39) the operative importance of this zone in the young child is seen, as well as the importance of these foramina in the post-auricular extension of the mastoid abscess.

Sections 27 and 28 show the relations of these foramina and the limitrophic cells. These two sections are perpendicular to the outer surface of the temporal. The first is oblique from above downwards and behind forwards, the second approaches the horizontal.

These limitrophic cells merit the attention of the surgeon. Sometimes, as a matter of fact (always when the tip is sclerosed), they are the exclusive seat of mastoid suppuration and can



Fig. 29.—Thirteen years.

burrow from the meatus without any post-auricular abscess. Or better, a retro-auricular abscess is connected with a baring of this region, towards the meatus consequently, and may be mistaken for a periostitis, but a cure cannot be effected without opening the limitrophic cells.

### The Relations of the Sinus and the Antrum.

To complete the study of the relations of the sinus, it is necessary to prepare sections passing through the spine of Henle, *i.e.*, clearly opening the antrum. At birth (Figs. 20-27) the descending portion of the lateral sinus, about $1\frac{1}{2}$ centimetres

long, is found situated at the level of the rounded angle formed
by the posterior surface of the petrous and the lateral surface
of the cerebellar fossa, to the end of the occipito-mastoid suture,
in front and within it.

By a horizontal section, passing through the floor of the
antrum, it is easy to verify the relations which affect it. This
section covers a triangular form, the inner angle corresponding
to the upper border of the petrous, the outer base represented
by the outer table of the temporal, and the two sides, anterior
and posterior, formed by the line of section of the corresponding
surfaces of the petrous. In a similar section, the middle ear,
by series and by arrangement, never appears wholly, its
direction being oblique from behind forwards, from without in-
wards, and from above downwards. The antrum presents its



highest part, the
orifice of the Eus-
tachian tube the
lowest part; but,
by successive sec-
tions made above
and below, nothing
can be easier than
to make these re-
lations plain. If in
a section passing
through the floor
of the antrum the

FIG. 30.—Fourteen years.

posterior extremity of the antrum be limited by a line drawn
perpendicular to the outer table of the temporal, it will be
seen that this line, of which the point of origin corresponds to
the petro-squamous suture, cuts the posterior surface of the
petrous at the limit of the anterior border of the sinus, or
slightly in front of it. The antrum is, further, separated from
the posterior surface of the petrous by a bed of spongy tissue
whose thickness varies between 4 and 5 millimetres (Fig. 27).

Properly speaking, the antrum at this period does not show
any relation to the lateral sinus, in front and outside of which it
is situated.

Successive horizontal sections show that the anterior border
of the sinus corresponds externally to an oblique line
from above downwards and from behind forwards, beginning
above a little behind the petro-squamous suture, and passing

at about 5 millimetres behind the upper part of the tympanic opening.

According as the modifications of the cerebellar fossa above described have place, the lateral sinus, situated in the rounded angle formed by the posterior wall of the petrous and the lateral wall of the cerebellar fossa, keeps this invariable position, in relation to which the situation of the antrum varies progressively. Primarily external and anterior in relation to the sinus, it becomes quite internal to it, remaining anterior. As a matter of fact, the primary situation of the antrum becomes modified after this movement of rotation; its posterior extremity is carried outwards and becomes external; the spongy tissue, or the cells which have succeeded it, and which are in relation with this posterior extremity, are carried equally outside; the antrum ceases to be superficial by becoming deep. The successive disposition of the planes then becomes reversed : whereas at birth the antrum occupies the superficial plane and the sinus the deep plane, it is the reverse which becomes the rule (Figs. 27-29).

But if the question be thoroughly regarded from the surgical point of view, it will not only make one ask what is, in horizontal projection, the distance between the sinus and the meatus, but it will require also a description of the structure of the mastoid.

When the cell system is well developed, when the sinus is more or less ' procident,' that is to say, that its bend is placed more or less in front, it is of little import; the surgeon will always be separated by the cavity of the antrum, which he must open ; and, without knowing it, it will be very difficult to break in the wall, thin or thick, which separates it from the groove of the lateral sinus. The preceding sections show that nearly always this wall is sufficiently resistant not to be mistaken ; and, on the other hand, if it is eroded by pathological processes, it is enough to explore the wound with every gentleness to avoid baring the sinus.

When the cavities of the mastoid disappear from a hyperostosing chronic osteitis, its form, bulk, and external relations do not change. It is otherwise when any swelling behind widens the two tables of the temporal.

The lateral sinus is situated in the rounded angle formed by the union of the posterior surface of the petrous and the inner surface of the mastoid region. To this inner angle another corresponds externally, very distinct, situated at the point of union of the posterior wall of the meatus and the outer surface

of the mastoid. The space which separates these two angles is measured by the width of the two tables of the bone, and is limited on the outer surface of the mastoid, a region situated entirely in front of the sinus and where there is sufficient room to enter the deeper parts without fear of wounding it.

In pneumatic mastoids, where this region reaches its maximum size, and even among the diploïc, the lateral sinus is located far from the posterior wall of the auditory meatus; it approaches it, on the contrary, in sclerosed mastoids. When the internal angle approaches the outer angle and the sinus comes to lie directly against the posterior wall of the auditory meatus, from which it is only separated by a bed of bony tissue, about 2 or 3 millimetres thick; the external region, consequently—that is to say the
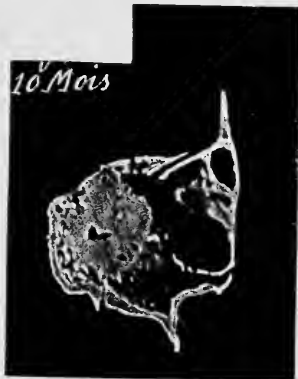


FIG. 31.—Ten months.          FIG. 32.—Three years.

operation region—becomes *nil;* the perpendicular to the inner surface of the mastoid, passing immediately in front of the sinus, adjoins the limit of the posterior wall of the meatus (Fig. 30). The surgeon should then go towards the postero-superior wall of the meatus.

**Formation of the Mastoid.**—The mastoid process is not built up at the expense of any special osseous point, but at the expense of the squamous and petrous, and not, as has been often said, at the expense of the petrous alone.

At about six months there exists a bony prominence in which the form begins to show itself. It is pretty clearly visible in the course of the first year; generally it is well formed towards the age of two or three years. According as the subject grows the

mastoid lengthens, as if the outer table of the temporal obeyed the dragging exercised by the sterno-mastoid and digastric muscles.

In the transverse and vertical sections, made millimetre by millimetre, and from before backwards (Figs. 31-33, see also Figs. 16-19), especially at the age when the petro-squamous suture is still very apparent, the mastoid is seen to be formed of two distinct parts, the first belonging to the squamous, the second to the petrous, and that in relation to the antrum the one is anterior, superior and external, whilst the other is inferior, posterior and external. Later on, their union becomes complete, and if on the outer surface the petro-squamous suture persists with distinctness, often about the adult age, the other points of fusion between the squamous and the petrous become sufficiently strong to make it possible to mark out on the sections what belongs to the one and the other.

## THE FACIAL NERVE.

When the surgeon destroys the postero-superior part of the meatus to join the tympanum and antrum, he risks cutting the facial, of which I have above described the course, well shown in Figs. 34 and 35.

The outer wall of the middle ear can be removed entirely without the operator coming in immediate contact with the nerve, on condition that the bony gap, whatever its size at the surface, does not measure at its deeper part more than the height of the internal wall of the aditus. Any attempt having for its object enlargement towards the floor would be fatal in consequence of the section of the nerve, which at this level begins its oblique course. It is enough to remember that, in its lower half, the descending portion of the nerve crosses, at the level of its descending part, the plane passing by the membrane to become external.

But it is not, generally, in the descending portion that the nerve is wounded ; at this point it is deeply situated and protected by a thick bed of compact tissue. Further, it results from the arrangement of the middle ear and from the high position of the aditus, that the surgeon must attack not the posterior wall of the meatus alone, but the postero-superior, leaving untouched the lower half, which, in the vicinity of the tympanic opening, corresponds to this compact tissue in which the facial is lodged, and which, owing to its sclerosed structure, rarely presents any

lesion. Be that as it may, this point must be remembered, that
the surgeon, if he has full liberty to destroy, if he thinks neces-
sary, the whole posterior wall of the meatus in its outer part,
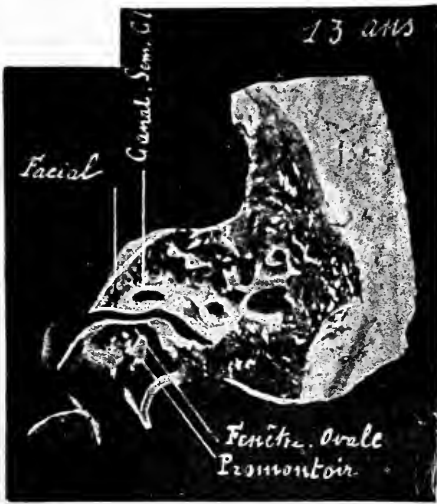


FIG. 33—Thirteen years.            FIG. 34.—Two years.

must not interfere with the upper half in the immediate
neighbourhood of the tympanic opening, and must leave inter-



FIG. 36.—Twelve years.

FIG. 35.—Six years and a half.
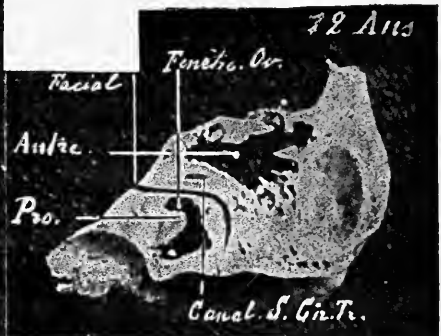
posed between the tympanum and the mastoid cells a block of
bony tissue about 4 or 5 millimetres thick, prolonging the
posterior wall of the tympanum, and which, in the oblique

plane downwards and outwards, apparently continues the inner wall of the aditus.

It is, we believe, during the curetting of the tympanum that the nerve is most often wounded. It is equally for this reason that it is the rule to see, after more or less interval, the paralysis get better, for under these conditions the section of the nerve is never complete. On the contrary, when the nerve is cut in its descending portion it is rare to see any amelioration. There exists, in fact, a dangerous spot, situated behind the oval window (Figs. 34, 35), near the junction of the inner wall and the posterior wall of the tympanum, in front and below the opening of the aditus, just where the nerve bends to go below and outside. At this level the facial canal makes a slight projection, the more appreciable as in front of it is found the infundibulum of the oval window. The curette, after having encountered the promontory, falls into this infundibulum and catches the projection of the canal. And this projection corresponds to the point where the wall of the nerve is very thin and at times even incomplete.

The object of the succeeding figures is to show well what is, according to the age, the operative topography of the parts studied in the preceding sections.

Fig. 37 shows the dry bone in the adult: at H is the spine of Henle, which is seen to be independent of the tympanic ring (see photograph 24, taken in the child).
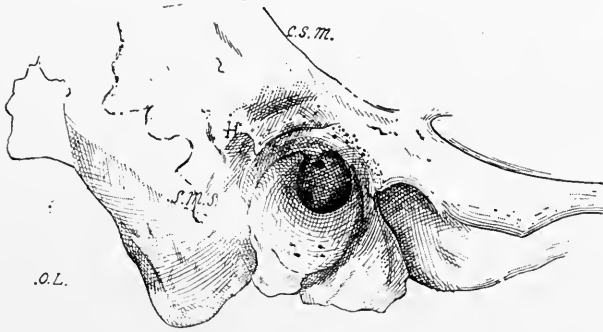
Fig. 37.

Lettering as in the preceding figures.
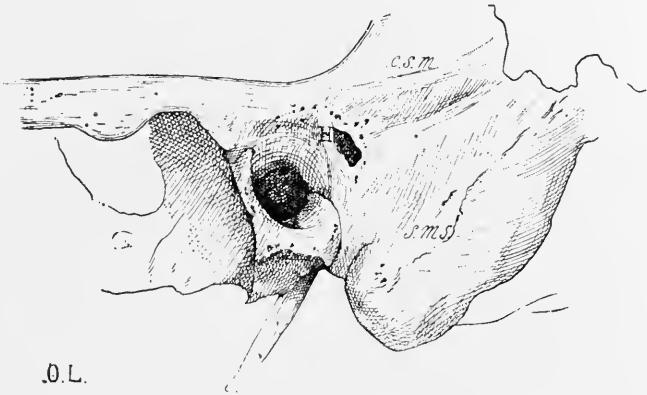


Fig. 38.

Behind the spine of Henle (*H*) a large foramen is seen leading into the petro-squamous sinus. Other lettering as in the preceding figures.
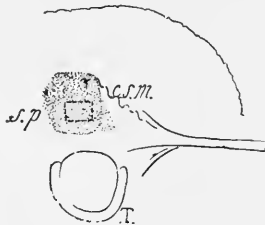


Fig. 39.

The cribriform spot above the meatus in the fœtus at seven and a half months.
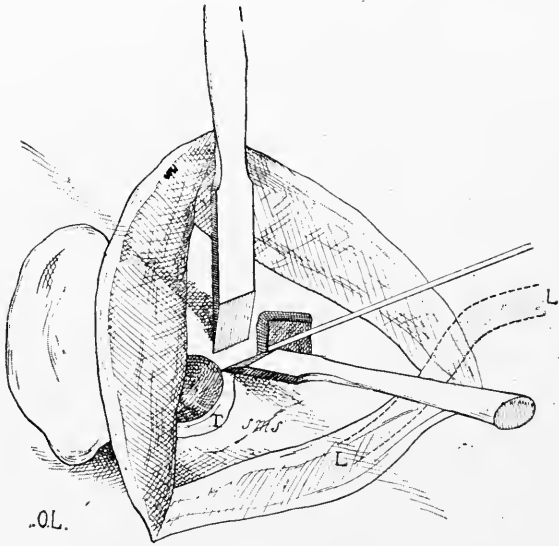
FIG. 40.

Fœtus of eight and a half months (left side). The an-
trum is opened, a probe is in the aditus, which the
chisels are ready to open. Note their inclination,
which avoids cutting both the middle portion and
elbow of the facial. *T.*, tympanic ring. Other letter-
ing as in the preceding figures.
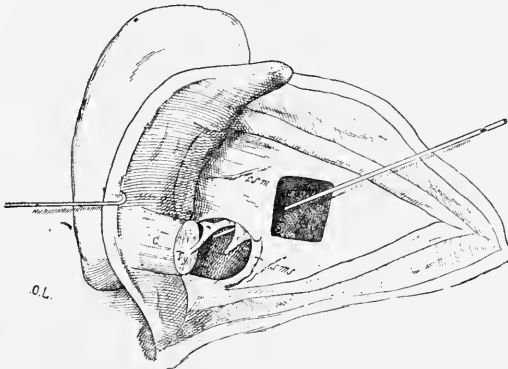


FIG. 41.

Fœtus at term. The auditory meatus (soft parts)
is turned forwards with the pinna and has by
chance carried with it the tympanic membrane,
to which the malleus still adheres. The end of
the probe is seen between the malleus and incus.
Lettering as in the preceding figures.
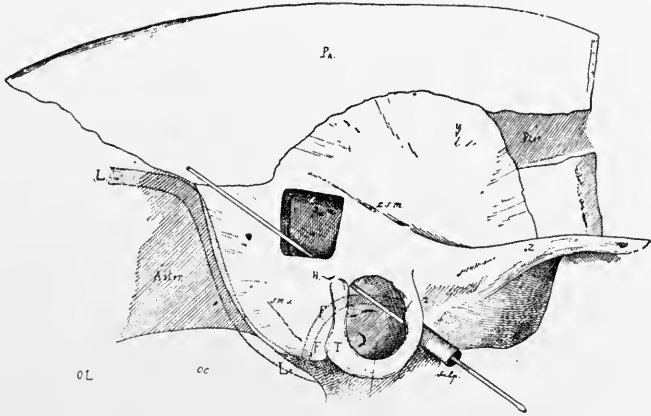
FIG. 42.

Fœtus at term. Note the position of the antrum, the course of the facial and of the sinus. The probe is seen passed through the aditus and engaging in the Eustachian tube. Position of the sinus in relation to the asterion fontanelle. *P*, promontory; *F*, facial; *Z*, zygoma; *Pter.*, pterion; *Aster.*, asterion fontanelle; *Oc.*, occipital. Other lettering as in the preceding figures.
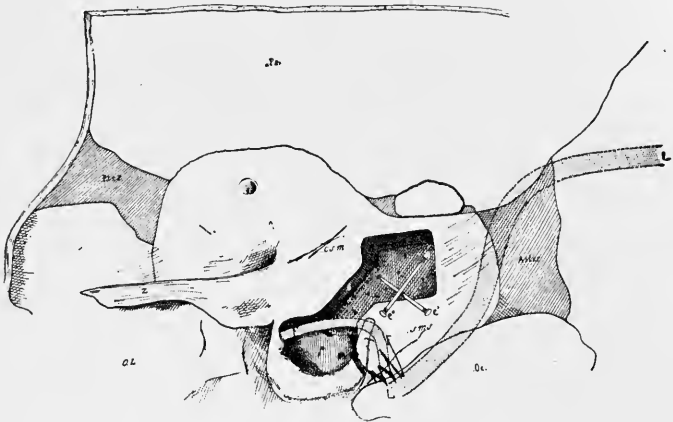


FIG. 43.

The facial and the sinus are seen to be out of danger. Two pins, *e'* and *e''*, pierce the middle and inferior fossa of the base of the skull respectively.
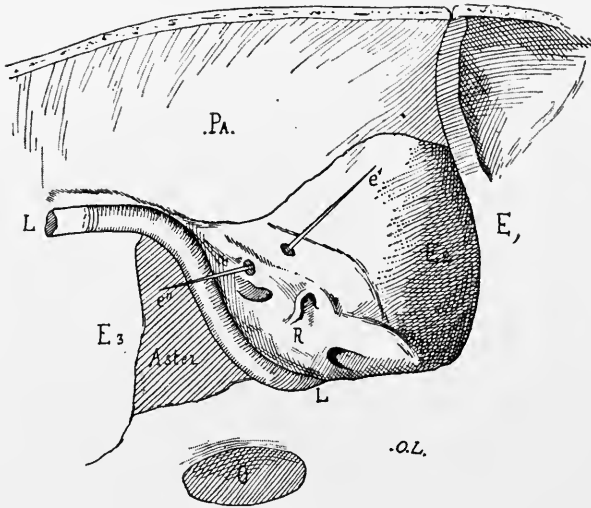
FIG. 44.

Made to show, from the interior of the cranium, the two
pins, *e'* and *e''*, of Fig. 43, piercing the antrum; *c*, auditory
meatus; *m*, malleus; *e*, incus. Other lettering of Figs. 43
and 44 as in the preceding figures.
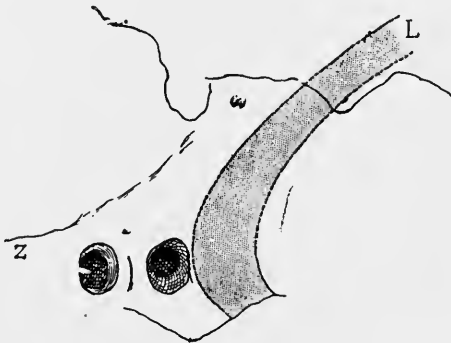


FIG. 45.

Boy of three years (left side). Simple uncover-
ing of the antrum, which is at a depth of
10 millimetres. No mastoid cells, correctly
speaking. Outer table 1·5 millimetres thick.
Very compact diploïc tissue. Of all the
subjects dissected this is the one in which
the sinus is nearest to the antrum.
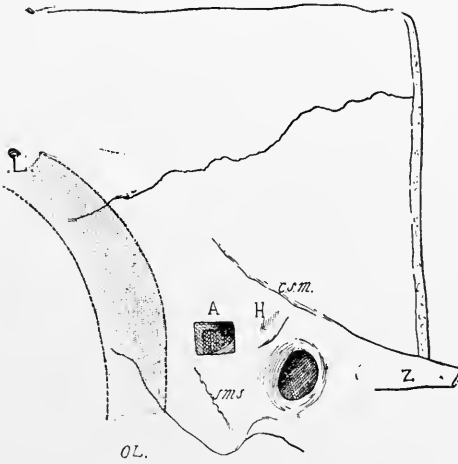
Fig. 46.

Boy of five years (right side). Simple opening
of the antrum, which is 4·5 millimetres
deep. External table 1 millimetre thick.
Spine of Henle rudimentary. Lettering as
in the preceding figures.
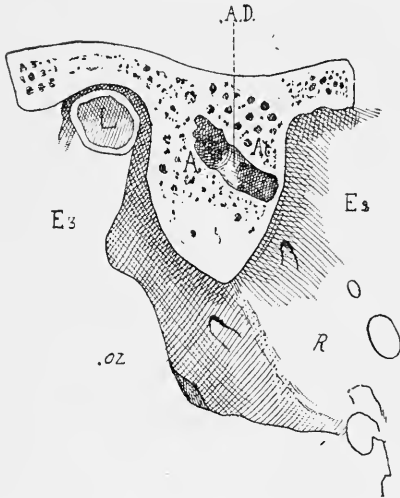


Fig. 47.

Man of twenty-five years. Horizontal
section passing through the antrum, of
which the inferior wall is seen, and
through the attic, where the incus can
be seen with its short process lying in
the aditus. Bony canal of the sinus
very marked; one can always, from the
surface of the mastoid, attack well
behind and reach the antrum without
wounding the sinus.
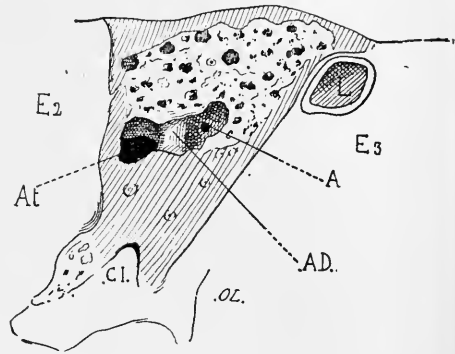
Fig. 48.

Horizontal section, subject aged forty-seven
years (right side). External table 1 to 5
millimetres; antrum 16 millimetres deep.
Pneumatic mastoid. In the attic the part
seen is the inclined plane formed by the
outer attic wall, partly arched by the external
auditory meatus.
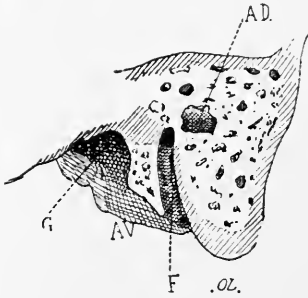
FIG. 49.

Subject of forty-seven years (right side). Frontal section, posterior view of anterior segment. The form and height of the antrum are seen. Note that the trans-tympanic portion of the aqueduct is not in the threshold, but limited at 1 millimetre below and 3 millimetres behind (most frequent arrangement). The canal F is only separated from the fossa G by several pneumatic cells in a very thin plate. The lettering in this figure and Figs. 47 and 48 is : $A$, antrum ; $AD$, aditus ; $At.$, attic ; $L$, lateral sinus ; $E^2$, middle fossa ; $E^3$, inferior fossa ; $R$, Petrous ; $C1$, internal auditory meatus ; $F$, aqueduct of Fallopius ; $G$, jugular fossa.
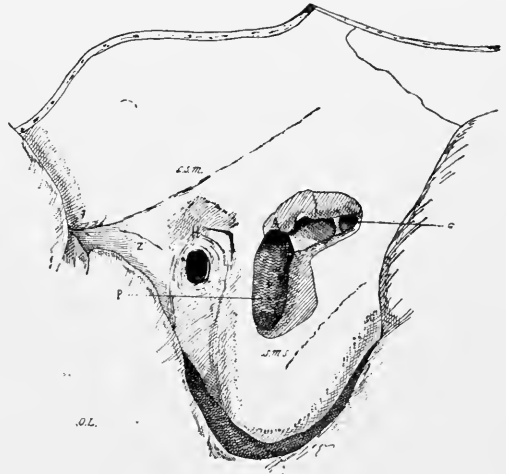


FIG. 50.

Man of seventy-five years (left side). Sclerosed mastoid. Antrum 27 millimetres deep. In consequence of the thickness of the outer table, the mastoid cells, properly speaking, can only be reached by the hole $P$. hollowed out towards the antrum. $P$, cells in the tip ; $C$, petrous cells. Other lettering as in the preceding figures.
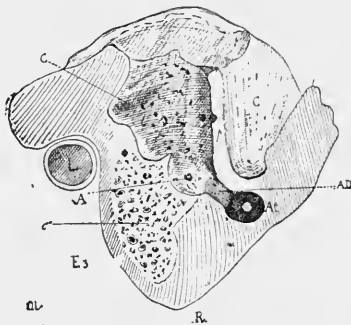


FIG. 51.

Man of seventy-five years (left side), horizontal section. This section passes through the antrum, aditus, and attic, where the head of the malleus can be made out. Behind the premastoid plate ($p$) the route hollowed out to reach the antrum can be seen. On account of the presence of the cells $C'$ behind and inside the antrum, it can be easily seen, in this subject, how inflammation could reach the cerebellar fossa. Other lettering as in the preceding figures.
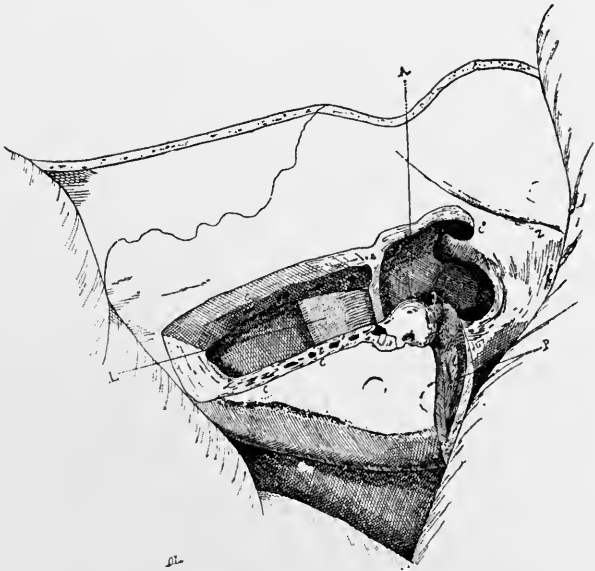
FIG. 52.

Man of seventy-five years (right side). Sclerosed mastoid
in the mastoid part, properly speaking. External table
4 to 5 millimetres thick; antrum 27 millimetres deep;
numerous petrous and squamous cells. It is seen how
easily the dura mater and the sinus can be laid bare.
Atticotomy has been combined with antrectomy.
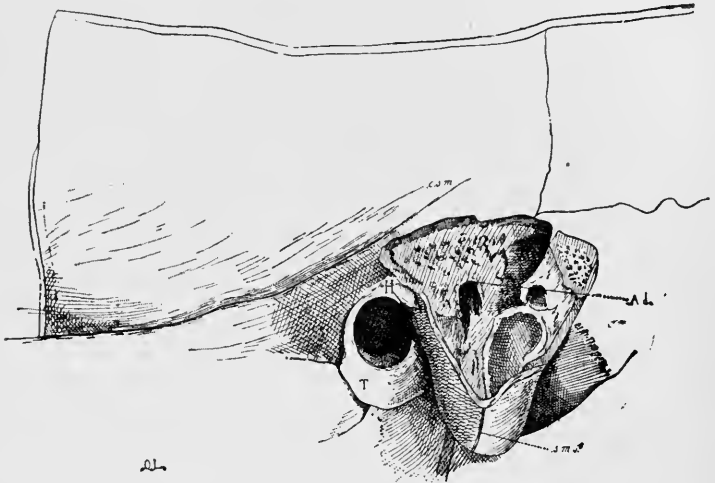Lettering as in the preceding figures.



FIG. 53.

Woman of sixty years (left side). Pneumatic mastoid with large
cells, divided into two groups by a buttress following the direction of
the mastoido-squamous suture. Lettering as in the preceding figures.
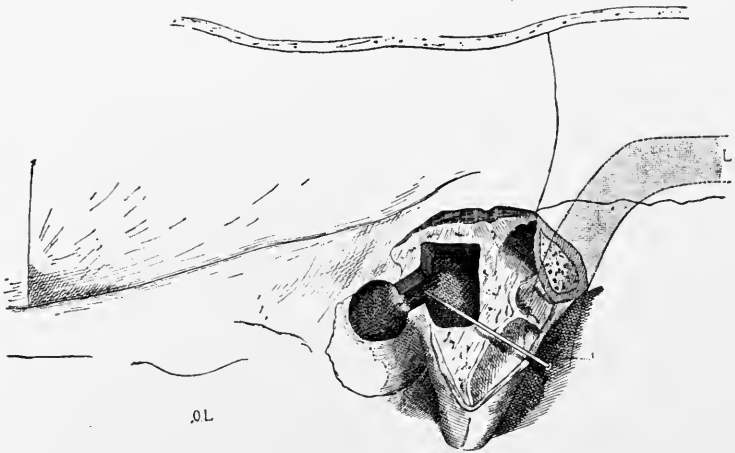
FIG. 54.

Woman of sixty years (left side). The antrum has been opened at a depth of 25 millimetres following the direction of the pin. The lateral sinus L is 8 millimetres distant from our track. The wall of the aditus is destroyed.
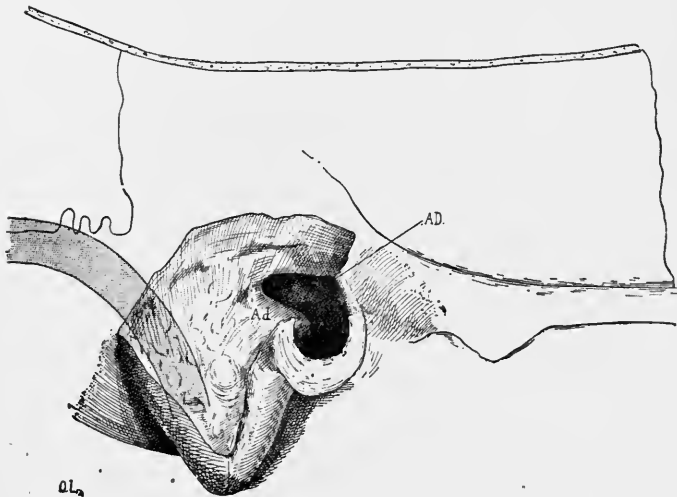


FIG. 55.

Woman of sixty years (right side). On this side atticotomy completes antrectomy. As on the other side, the mastoid is pneumatic, the antrum 25 millimetres deep. AD., aditus ad antrum; Ad., external aditus; L., lateral sinus.
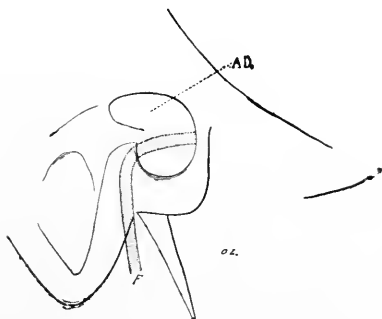
Fig. 56.

Woman of sixty years (right side). On
the same side $F$, shaded ; exact size.
The facial is seen to be in no danger.
$AD$, aditus ad antrum ; $F$, facial.

THE END