THE UNIVERSITY OF MINNESOTA

GRADUATE SCHOOL

Report

of

Committee on Examination

This is to certify that we the undersigned, as a committee of the Graduate School, have given Dr. James Lee Rogers final oral examination for the degree of Master of Science in Ophthalmology & Oto-Laryngology. We recommend that the degree of Master of Science in Ophthalmology & Oto-Laryngology be conferred upon the candidate.

Minneapolis, Minnesota

December 15 1920

Wm R Murray
Chairman

Horace Newhart.

R. E. Scammon

H. E. Robertson

C. M. Jackson

THE UNIVERSITY OF MINNESOTA

GRADUATE SCHOOL

Report

of

Committee on Thesis

The undersigned, acting as a Committee of the Graduate School, have read the accompanying thesis submitted by James Lee Rogers for the degree of Master of Science in Ophthalmology and Oto-Laryngology They approve it as a thesis meeting the requirements of the Graduate School of the University of Minnesota, and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science in Ophthalmology and Oto-Laryngology.

Wm R Murray
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1918

OBSERVATIONS ON THE DEVELOPMENTAL ANATOMY

OF THE TEMPORAL BONE

A THESIS

Submitted to the Faculty

of the Graduate Schoolof

the University of Minnesota

by

James Lee Rogers

In partial fulfillment of the

Requirements for the degree of

Master of Science in

Ophthalmology and Oto-Laryngology

June

1921

OBSERVATIONS ON THE DEVELOPMENTAL ANATOMY

OF THE TEMPORAL BONE

Graduate thesis for Master's Degree in Opthalmology and Oto-laryngology - Graduate School, University of Minnesota.

From the Institute of Anatomy, and the
Department of Opthalmology and Oto-laryngology.

The purpose of this paper is to record a series of observations on the development of the temporal bone in later fetal life and childhood, and to consider the varying relations of its several parts at different ages, with particular reference to their surgical significance.

The study has been limited, in the main, to those phases of the subject concerning which our information is obviously incomplete or upon which there exists a decided difference of opinion.

Material and Methods

A considerable amount of material was available for this study, including 294 temporal bones, some dried and some fresh and in situ, as well as a series of 32 skulls in various stages of development. Of the temporal bones, 14 were of fetal stages, 32 of newborn children, 18 of children of different ages (2 to 15 years inclusive) and 230 of adults.

Of the skulls 14 were fetal, 14 were newborn, and 4 were of children. There was also available a large series of adult skulls for comparison with those of earlier stages.

To insure exactitude of measurements, and to determine accurately the relations of the various parts of the organ of hearing, the subject has been attacked with a variety of methods.

First, a series of casts in Wood's metal were prepared, reproducing the cavities of the external, middle and internal ear, together with the nerves, air cells, osseus auditory tube, tensor tympani muscle, carotid artery, aqueducts, etc. In all 40 such casts were prepared. Fifteen of these were of adult ears, 5 of children, 10 of newborn infants, and 10 of fetuses. Drawings of some of these preparations are shown in figures 1 to 14 inclusive.

Second, the antra of a series of temporal bones were filled with bismuth paste and radiographed to show their position at different ages. As a check on this procedure, the antra were later trans-illuminated by introducing the small electric light of a bronchoscopy tube in the cavity of each bone and tracing the outline on the surface. In older children and adults an opening was drilled through the tegmen tympani into the antrum to admit the light. In the fetus and infant the antrum could be reached through the external meatus.

The size and position of the antra were determined by radiography and trans-illumination in 40 bones (10 adults, 7 children, 8 newborn infants and 15 fetuses). Drawings of these specimens are shown in figures 15 to 24 inclusive.

Third, to determine the relations of the inner structures of the ear to surface landmarks, a series of casts in Wood's metal was prepared and the bone in these specimens was later rendered transparent by the Spalteholz clearing method so that the cochlea, antrum, nerves, air-cells, etc. could be observed in situ. Three of these preparations were made. Of these, one was of an adult, one of a child, three years old, and one of a newborn infant (Figures 25 and 26).

Fourth, to further determine the relations of the antrum, facial nerve and other structures to the surface landmarks, regional dissections were made on the cadaver. Of these 8 were of the adult, 2 of children, and

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8 of newborn infants. The angle of inclination of the tympanic membrane was also determined in 55 ear drums. Of these 6 were adult, 4 children, 24 newborn and 24 fetuses. As a check on measurements and relations, 32 temporal bones were sectioned in various planes. Of these 20 were adult, 2 children and 10 newborn infants.

The value of the study of the middle and inner ear by means of casts has long been recognized. As the pneumatic cavities of the ear are rather complicated in shape, it is only by representing these spaces as solids that one can obtain a clear concept of their precise form and extent, and of their relations to one another and to the neighboring nerves, vessels and other structures. Only by a clear knowledge of the intimate topographical relations of the middle ear to the surrounding cavities is the significance of the frequent inflamations of the former fully understood.

A variety of materials have been used to replace the air spaces in making casts. Benxold used a mixture of wax and resin. Von Stein employed a rubber and chloroform solution, and then vulcanized the mass. Bruhl cleared the bone and injected mercury. James Brown injected dental rubber and vulcanized. Wood's metal seems to give the most satisfactory results for this type of preparation, and certain refinements of the method introduced here have been found of considerable value in securing more perfect and complete specimens.

Technique of Making Casts of the Temporal Bone with Wood's Metal.

To make casts of the middle and inner ear, it is best to secure well dried temporal bones in which the nerves, and mucous membrane of the cavities have disintigrated and disappeared, so that the canals will be clear. If any of these dessicated tissues remain, they should be removed with the air blast. The canals and nerve openings are then covered with adhesive tape, with the exception of the external auditory meatus which is left open. It is well to make pin holes in some of the canal openings, and to place small pieces of cotton over them to receive the displaced air. The bone is now encased in a thick layer of plaster of Paris except for the area immediately around the external auditory meatus. After heating the encased bone at about 100 degrees centigrade for 24 hours in a sand bath, it is ready to receive the molten Wood's metal* which is poured into it to the level of the suprameatal (Henle's) spine. As the bone is heated above the melting point of the metal, the latter will not solidify, and the specimen can be agitated to remove air bubbles. It is a good plan to drop a little water on the metal at the meatus to solidify it and then the bone can be picked up, and rotated to remove the air and get the metal into all parts. After cooling, the plaster of Paris casing is removed and the specimen is placed in 30 per cent hydrochloric acid to dissolve the bone.

Technique of Preparing Transparent Bone Specimens.

The method used to render the injected specimens of bone transparent, as shown in figures 25 and 26, is that developed by Spalteholz of Leipzig in 1906.[(23)]

After the temporal bone is filled with Wood's metal, it is decalcified, by placing it in a two per cent solution of hydrochloric acid which is changed daily for one month. It is then transferred to a one per cent

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*Wood's metal is composed of tin 4 parts, lead 8 parts, bismuth 16 parts and cadmium 3 parts. It has a very low melting point, about 62 degrees centigrade.

solution of hydrochloric acid which is also changed daily for two weeks. The purpose of this procedure is to secure complete decalcification of the bone, without destroying the specimen with the acid. The bone is then washed in running water for two weeks, or until it gives a neutral reaction to blue litmus, after which it is bleached for two hours in hydrogen peroxide and again washed. After bleaching, the specimen is again washed, and is then dehydrated by passing it through a series of graded alcohols of 60, 75, 95 and 98 per cent. It should be left in each mixture about 24 hours. After dehydration, the specimen is cleared by placing it in benzol for four days, changing the solution at the end of 48 hours. The final preserving fluid in which the specimen is to remain, consists of methyl salicylate 5 parts, and isosafrol 3 parts. As these fluids have the same refractive index as the prepared bone the latter becomes translucent. Sometimes it may be made more transparent by adding little more isosafrol. Air bubbles may be removed by placing the specimen under a bell jar and exhausting the air with a suction pump.

Observations.

The Membrana tympani.

Upon examination of the literature on the tympanic membrane, one is confronted with a great variance of opinion regarding the inclination of this structure. Observers seem to be about equally divided as to whether the inclination in the newborn is equal to, or less than that of the adult, and several maintain that the ear drum is almost horizontal at birth.

The angle given by Lucian for the adult is 55 degrees, Howell 130, Flint 45, Kirk 45, Piersol 60, Gray 55, Morris 50, Freiligh (11) 50, Symington (20) 45, and Pollak 45. Shaw, Gray, Henle, , von Troltsch, Gruber and Cheatle(7) state that the tympanic membrane is nearly horizontal at birth, while Symington, Pollak, Cavanaugh (6) and Freiligh(11) maintain that the angle in the adult and newborn is about the same. The data obtained by the measurement of individual ear drums in this study is shown in the following table (Table No.1). The figures indicate the degree of inclination from the perpendicular. The measurements as given in Table Number 1 show that a large individual variation is frequent in both new born and adult drums. The averages show the membrane approaches a little more closely the horizontal in the fetus and that it gradually becomes more erect in later fetal life. There seems to be no constant change in the angle after birth.

The angles as given in the following table were determined with the "Stangen-Goniometer" of Martin and Ranke.

Table 1.

Inclination of the Tympanic Membrane

Age	Individual Cases	Average Degree of Inclination
Four months fetus	61,63	62
Five " "	55,57,60,62,72,80	64.4
Six " "	58,59,60,64,64,65	61.5
Seven " "	55,60,61,62,63	60.2
Eight " "	58,59,60,65,65	61.4
Nine " "	55,57,57,61,62,63,63,68	60.8
Newborn	54,55,56,57,58,60,60,65	57.
Child of three years	55,60	57.5
Adult	45,55,57,60,60,69	57.5

Table 2.

Dimensions of the Tympanic Membrane

Age		Diameters (mm)	Average diameter (mm)
Fourth fetal month	Max.	6.8, 6.8	6.8
	Min.	5.5, 5.5	5.5
Fifth fetal month	Max.	7.1, 7.5, 7.5	7.4
	Min.	6. , 6. , 6.5	6.2
Sixth fetal month	Max.	7.2, 7.3, 7.2, 8	7.6
	Min.	6.3, 6.6, 6.6, 7.5	6.7
Seventh fetal month	Max.	7.8, 8. , 9.	8.3
	Min.	7.6, 7.7, 7.8	7.7
Eighth fetal month	Max.	8. , 9. , 9.6	8.9
	Min.	8. , 8. , 8.3	7.8
Ninth fetal month	Max.	9. , 9. , 9.2, 9.7, 10	9.3
	Min.	7.5, 8. , 8. , 8.5, 8.5, 9	8.2
Newborn	Max.	9. , 9. , 9.3, 9.5, 9.5, 9.8, 10. , 10. , 10. , 10. , 10. , 10.2, 10.3	9.8
	Min.	7.8, 8. , 8. , 8. , 8. , 8. , 8. , 8.2, 8.3, 8.4, 8.4, 8.6, 8.8	8.2
Seven month child	Max.		11.
	Min.		8.5
One year child	Max.		11.
	Min.		9.
Two year child	Max.		11.
	Min.		9.
Adult	Max.		11.
	Min.		9.

As these measurements were taken to the extreme edge of the sulcus tympanicus they will be found to be slightly larger than the drum membrane proper.

It is generally stated that the dimensions of the tympanic membranes at birth are almost identical with those of the adult, there being little or no increase in the post-natal period of development. The figures quoted in Table Number 2 show that the tympanic membrane increases steadily in size in the last half of fetal life and that also there is a distinct increase in its diameter in the first year after birth, at the end of which period the adult dimensions are attained.

The Antrum.

The "Mastoid" Antrum should be called the tympanic antrum because, considered from any point of view, it is a part of the tympanic cavity. The antrum appears in the fetus at the same time as the tympanic cavity, and at the time of birth is developed to about adult dimensions, but the mastoid cells do not appear until the second year, and they are generally diploetic untill the fifth. Definite air cells first appear at the seventh or eighth year, and are first seen as well developed spaces after the ninth year. The antrum must also be considered at all stages as continuous with the tympanic cavity and as lying entirely within the petrous bone. It is covered by the tegmen tympani which also is the roof of the tympanic cavity and the auditory tube.

The relations of the antrum to its adjacent structures vary considerably at different ages. Up to the time of birth it is directly over the meatus, its upper part lying above the zygomatic process and its anterior margin extending forward beyond that of the meatus.

In the fetus and newborn the incus lies in the aditus and its long process projects into the antrum. As shown in figures 15 to 24 inclusive, as the child grows older the antrum gradually shifts from its location above the meatus to a more posterior and inferior position, and in the adult it is directly posterior to it. Its position in the child materially aids drainage in acute infections.

The lateral (external) canal of the bony labyrinth forms the inner boundary between the antrum and epitympanic recess. Its bony covering is easily recognized as a thin white ridge of dense bone. In the young child its wall is only about one-fifth of a millimeter in thickness, and a probe or curette introduced into the middle ear, could easily rupture into the canal.

The thickness of the bone separating the antrum and lateral canal at different ages, is approximately as follows:

Newborn	Three Years Old	Five Years Old	Adult
0.2mm	0.3 to 0.5 mm	0.5 mm	1 mm

As the mastoid develops, the antrum becomes farther and farther removed from the external surface of the temporal bone. The thickness of the bony wall, bounding the lateral surface of the antrum at different ages, is approximately as follows:

Newborn	Five Years Old	Ten Years Old	Adult
1 to 2 mm	6 mm	10 mm	15 mm

The above figures are about the same as those given by Symington (20). The dimensions of the antrum in the newborn are about 10 by 11 mm, which is approximately the same as in the adult .

The Facial Nerve.

The general course and relations of the facial nerve in the temporal bone are much the same in the infant and adult, and there seems to be a consistent and uniform growth of its parts. The distance from the nerve's entrance into the internal auditory meatus to the central point of the geniculate ganglion is shown in the following table:

Five month fetus	Seven month fetus	Newborn (average) of 10 cases	Three year child	Adult (average) of 10 cases
8 mm	9 mm	10 mm	12 mm	13 mm

The distance from the center of the ganglion to the point where the nerve turns sharply downward is 10 mm in the newborn, 11 mm at three years, and an average of 13 mm in the adult. This portion of the nerve lies within the tympanic cavity and in its course over the promontory around the fenestra rotundum it is protected only by a thin shell of bone in the adult; and in the child up to the fourth year, it is often covered only by a thin membrane of connective tissue. This exposed condition accounts for the liability to facial paralysis in the child following acute otitis media. As the nerve runs directly beneath the anterior part of the external (horizontal) canal, a roughly used probe or Staeke's director for locating the epitympanic recess may easily injure it. As Cheatle (7) aptly says, "Such an instrument is safe only in experienced hands, and then it is not needed."

The course and relations of the facial nerve can be best seen in the superior views of the various casts. The distance from the posterior rim of the tympanic membrane to the nearest point of the facial nerve, is from 3 to 5 mm both in the fetus and the adult.

The exposed condition of the nerve, in early life, after its exit from the stylo mastoid foramen, is of importance both to the obstetrician and the surgeon. In the fetus and young infant, it emerges about 3 mm behind and a little below the most posterior part of the margin of the tympanic membrane. As there is no mastoid process at this time, the nerve runs downward over the petrous portion of the bone. This condition accounts for some of the facial paralyses produced by pressure from instruments at this point during delivery.

It is also to be noted that this external portion of the nerve lies in the path of an incision such as is made in operation for mastoiditis in the adult. If such an incision were made in the infant, the nerve would be cut and a facial paralysis would result; but as the antrum in the young child is much higher, and as there is no mastoid containing air cells, there is little need for such an incision. The relations of the exit of the facial nerve, the antrum, the tympanic membrane, and the developing mastoid process, are shown in figures 15 to 24 inclusive.

After the first year, the vertical portion of the facial nerve is gradually covered by the deposit of the layers of bone forming the mastoid process, and by the outward growth of the posterior portion of the tympanic ring, which forms the external osseus meatus. The thickness of the bone over this portion of the nerve is shown by the following measurements: One year, 0 mm; three years, 6 to 10 mm; Five years, 11 mm; adult 13 to 15 mm.

In all fetal and infant specimens examined, the nerve came straight to the surface, but as Freiligh (11) states, in some cases the nerve bends downward before emerging, and in these cases the exit would be two or three millimeters lower.

<u>The Inner Ear.</u>

If lines were projected through each posterior canal, they would meet a little posterior to the hypohysis, and form approximately a right angle. Likewise, lines through the superior semicircular canals would meet above the posterior rim of the foramen magnum and be about at right angles to each other. It can be seen that the canals of one side are at right angles, and that either canal of one side is at right angles to its mate on the other side. This makes the posterior canal of one side parallel to the superior canal of the other and vice versa. This is shown in figures 29 to 30.

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Upon measurement, it will be found that in only about a third of the cases will these angles be exactly 90 degrees. Other cases will vary 10 degrees above or below.

The lines projected through the superior canal of the newborn meet within the foramen magmum while in the adult they meet well back of it. This is partly due to the fact that the foramen magmum is farther posterior in the infant skull and partly because the superior canal lies more nearly in the transverse plane. The lines running forward through the posterior canals of the newborn meet in the region of the clivus while in the adult they meet farther forward in the region of the sella-turcica. This is also due to the fact that the posterior canal of the newborn lies more nearly in the transverse plane than that of the adult.

Alexander (1) and Shaw (18) found the adult inner ear larger than that of the newborn. Booth (3) found the postembryonic growth to be about 18%. Hyrtle found the inner ear of the adult and child about the same size but that there is an increase in size in old age. The diameters at different ages is shown in tables Number 3 and 4.

The inner ear changes but little in size after the fifth fetal month, as is shown in the following tables (Numbers 3 & 4).

Table No.3

Maximum length of inner ear, including cochlea, vestibule and posterior canal.

	Present series	Alexander (1)	Seibermann (17)	Shaw (18)
Five months fetus	18 mm			
Seven months fetus	18 mm			
Newborn	17 mm	15 mm	19 mm	18 mm
Three years old	18 mm			
Five years old	16 mm			
Adult	18 mm	18 mm	18.5 mm	20 mm

Table No.4

Diameters of the Inner Ear Parts at Different Ages

	Vertical diameter of cochlea	Horizontal diameter of sup. canal	Ant. post. diameter of external canal	Vertical diam. of post. canal
Five months fetus	7.5 mm	8. mm	7. mm	8. mm
Seven months fetus	7. mm	7.5 mm	7. mm	
Newborn	7. mm	8.5 mm	7. mm	7.25 mm
Three years old	7.5 mm	8.25 mm	7. mm	
Five years old	7.5 mm	8.5 mm	7. mm	8. mm
Adult	7.5 mm	8.5 mm	7. mm	8. mm
Seibenmann (17) Newborn	7.7 mm	8.8 mm	8.1 mm	7.2 mm
Adult	7.5 mm	8.6 mm	7.2 mm	7.2 mm
Shaw (18) Newborn		5. mm		
Adult		6. mm		

The distance of the horizontal canal from the lateral surface in the infant is from 4 to 6 mm while in the adult it is from 12 to 20 mm. The horizontal canals and the oval window are the most frequent points of entrance for infection. The angles of the semicircular canals to each other and their positions in relation to the rest of the skull are shown in figures 29 and 30.

The relation of the semicircular canals to each other is shown in the following table. The figures indicate the degree of the angle. (From Siebenmann (17)).

	Superior to external	Superior to posterior	Posterior to external
Adult	82.	79.	99. *
Newborn	85.	88.	92.

* One of the angles taken in this series of four cases was of 105 degrees, which accounts for this large angle.

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Most grateful thanks are due Professor Scammon for many helps in securing data and criticizing the text of this paper.

Plates Nos. 1, 2 & 3

Casts of interior and middle ear.

Plate No.1

Wood's metal casts of internal and middle ear of fetus and newborn.

X1- (Natural size)

Plate No.2

Wood's metal casts of internal and middle ear of newborn and child.

X1- (Natural size)

Plate No.3

Wood's metal casts of internal and middle ear of child and adult.

X1- (Natural size)

Plate No.4

A series of temporal bones showing the position of the antrum as determined by X-ray and transillumination.

Figure 15, Newborn
Figure 16, Seven months child
Figure 17, One year old
Figure 18, Two years old
Figure 19, Three years old
Figure 20, Four years old
Figure 21, Five years old
Figure 22, Ten years old

Plate No.5

Figure 23, Lateral view of skull of newborn child showing position of tympanic antrum as determined by X-ray and transillumination.

Figure 24, Lateral view of adult skull showing position of tympanic antrum as determined by X-ray and transillumination.

Plate No.6

Figure 25, Lateral view of temporal bone of newborn child which has been injected with Wood's metal and cleared with Spalteholz's method. X 1½

Figure 26, Medial view of same specimen as Figure 25. X 1½

Plate No.7

Figure 27, Dissection showing position of antrum in relation to external osseus meatus in newborn child.

Figure 28, Dissection showing position of antrum in relation to external osseus meatus in the adult.

Plate No.8

Figure 29, Drawing of the base of the skull showing the positions and angles of the superior and posterior semicircular canals in newborn child. X ½

Figure 30, Same as Figure 29 of adult skull. X ½

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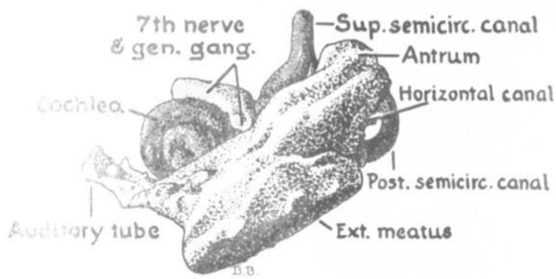
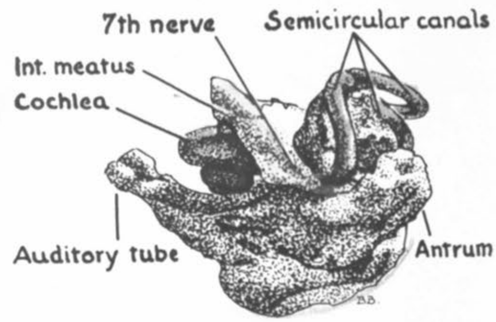


5 Mo. Fetus ~ Lateral View ~ (Left)

Fig. 1



5 Mo. Fetus ~ Superior View ~ (Left)

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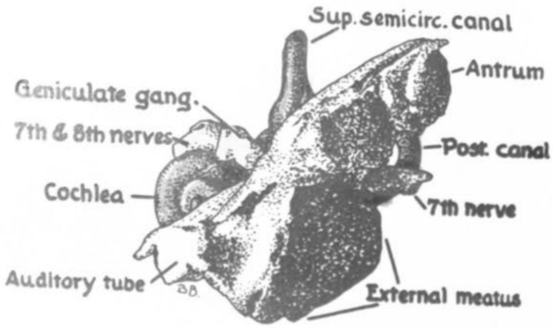
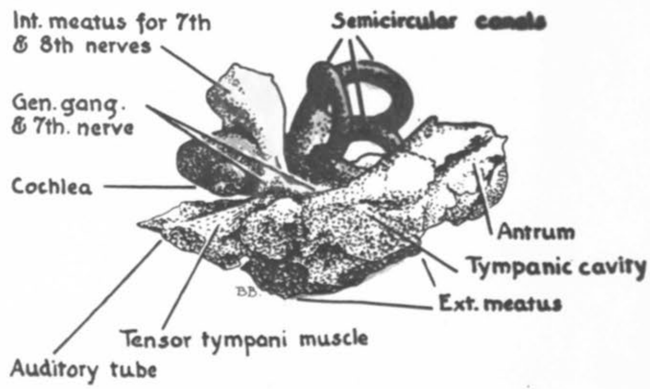


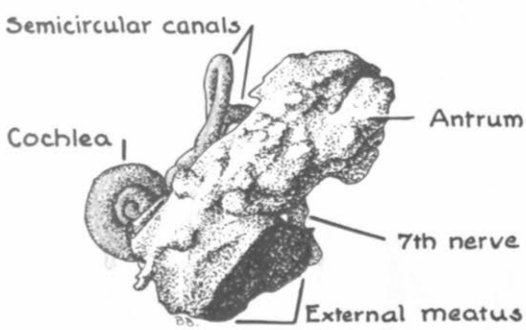
7 Mo. Fetus ~ Lateral View ~ (Left)

3



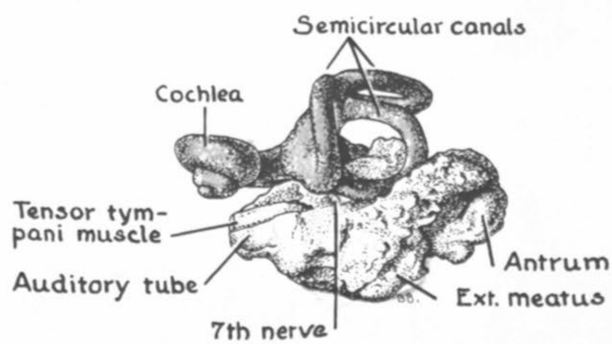
7 Mo. Fetus ~ Superior View ~ (Left)

4



Newborn ~ Lateral View ~ (Left)

5

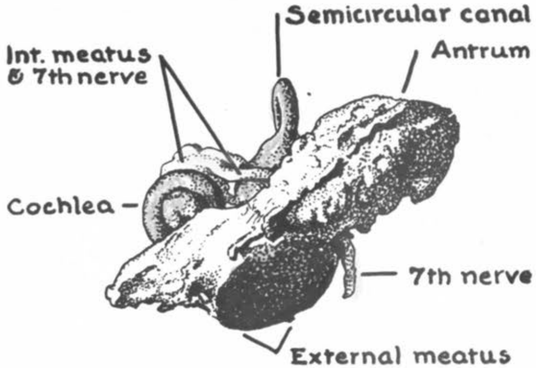


Newborn ~ Superior View ~ (Left)

6

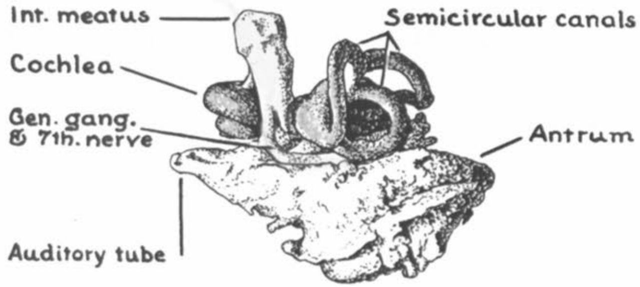
Plate no I

7-20 2M



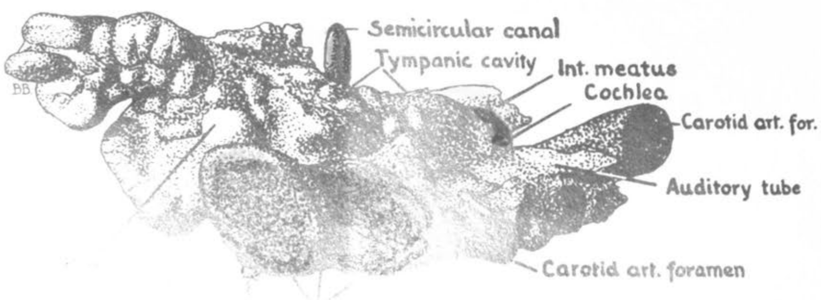
NEWBORN ~ LATERAL VIEW ~ (LEFT)

Fig 7

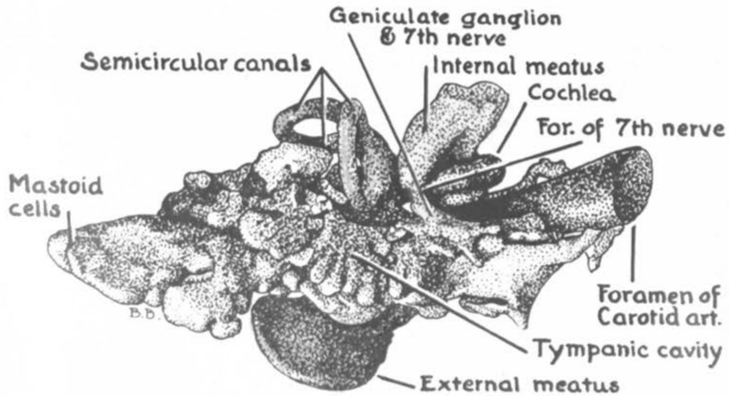


NEWBORN ~ SUPERIOR VIEW ~ (LEFT)

Fig 8



~ LATERAL VIEW ~ (RIGHT)

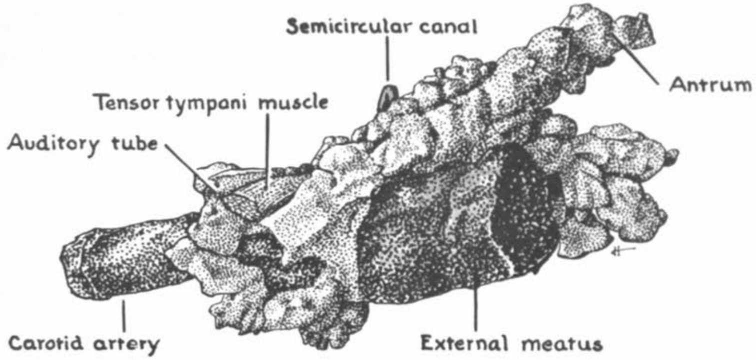


3 YR. CHILD ~ SUPERIOR VIEW ~ (RIGHT)

Fig 9

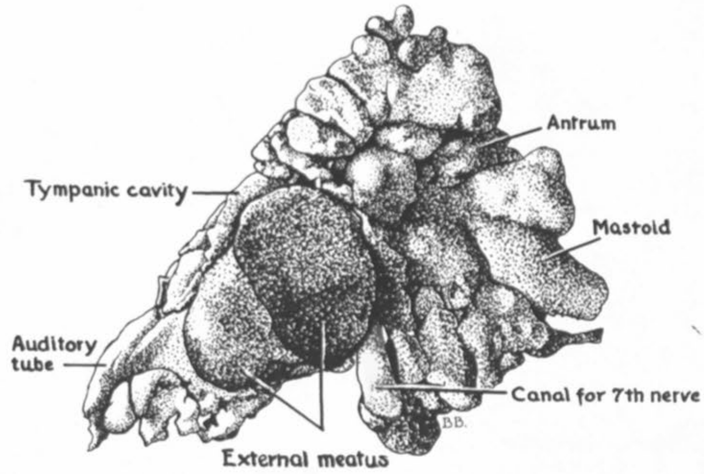
Plate No. 2

Fig 10



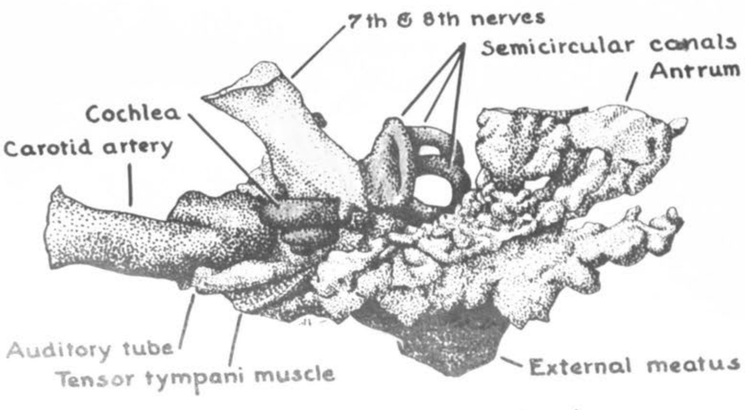
5 YR. CHILD ~ LATERAL VIEW ~ (LEFT)

Fig. 7



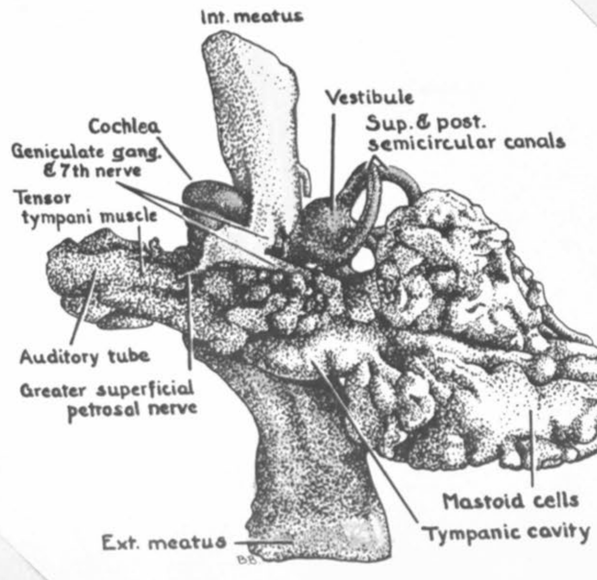
ADULT ~ LATERAL VIEW ~ (LEFT)

8



5 YR. CHILD ~ SUPERIOR VIEW ~ (LEFT)

9



ADULT ~ SUPERIOR VIEW ~ (LEFT)

Plate No. 3

7-20 2M

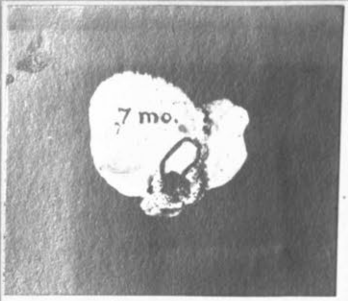
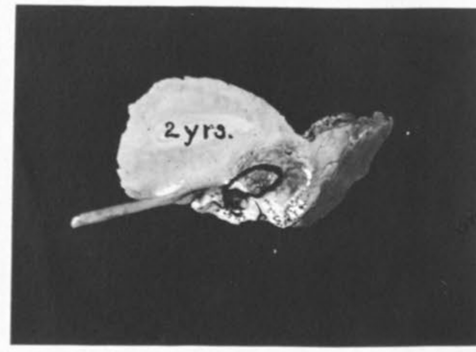


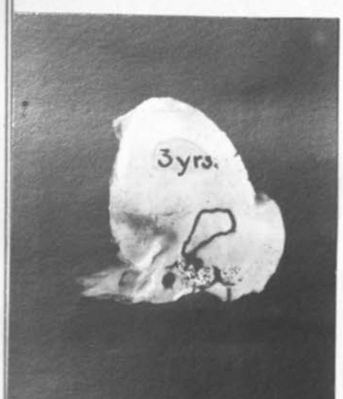
Fig. 15

16

17



18



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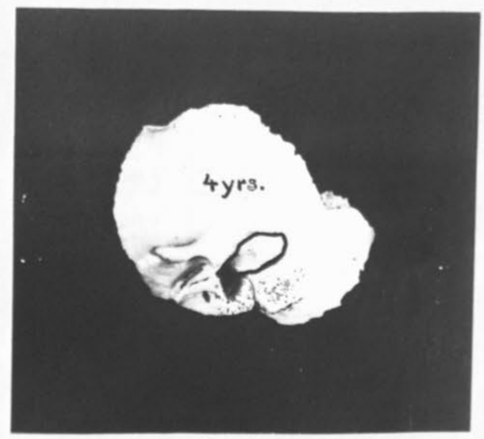
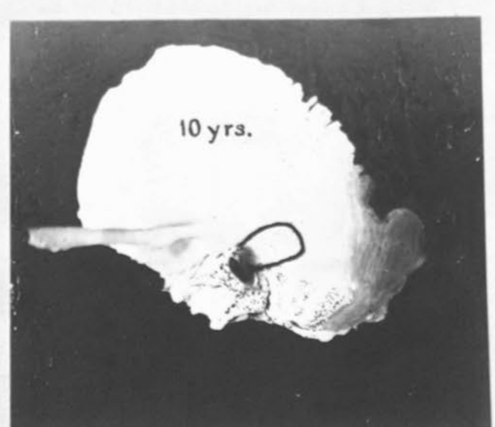


20

21



22.

Plate No 4

7-20 2M

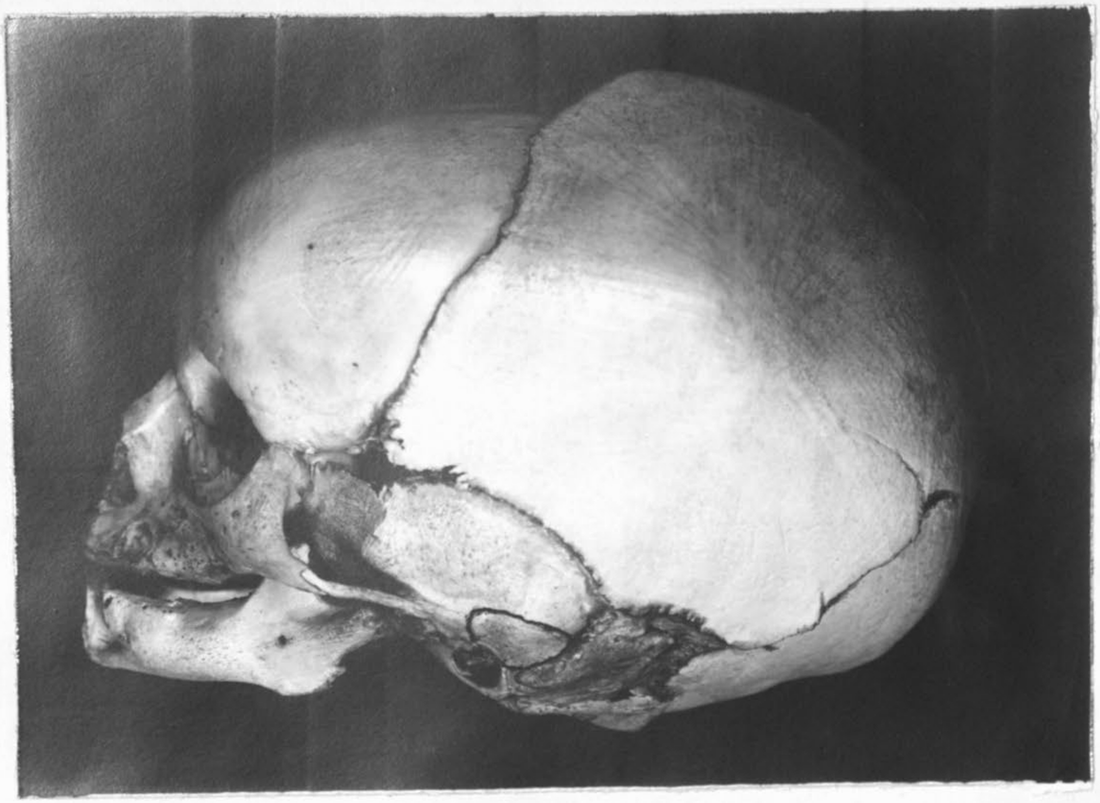


Fig. 23

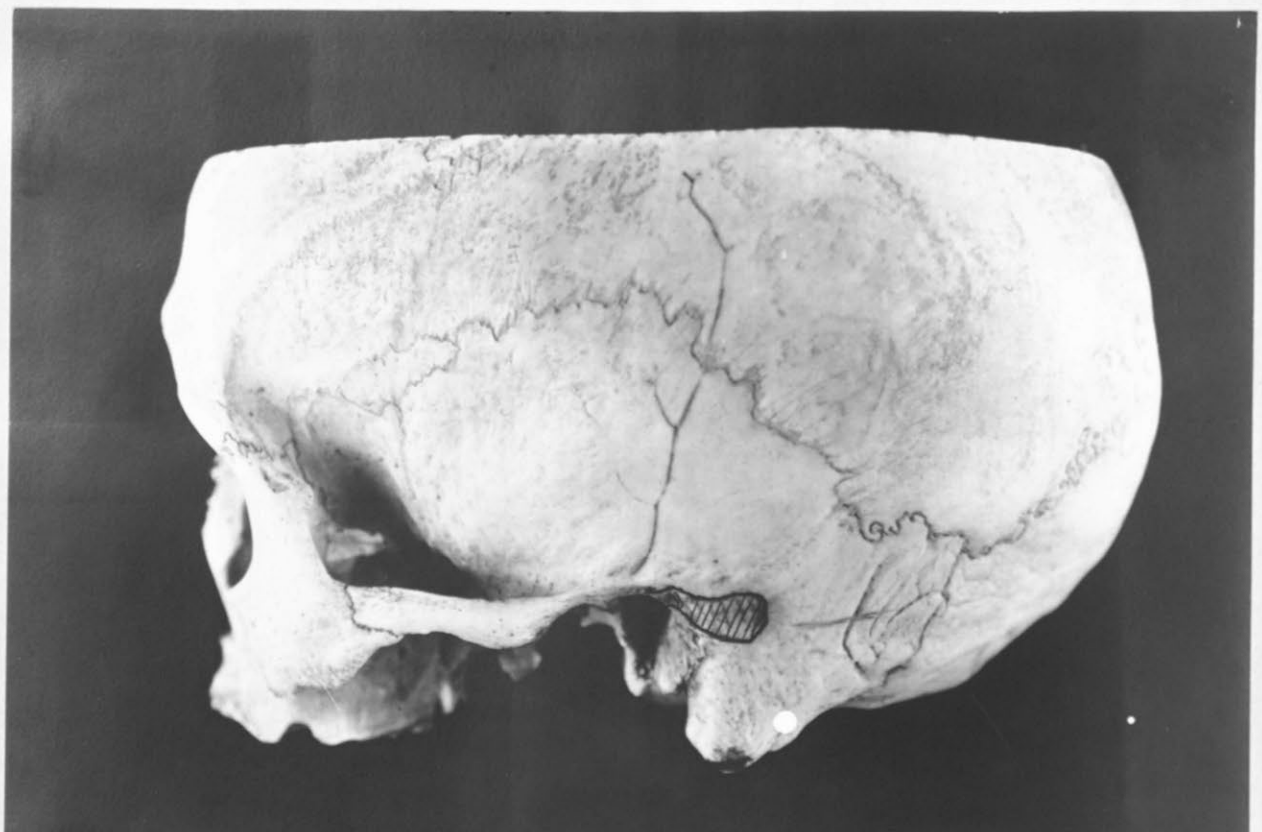


Fig. 24

7-20 2M

Plate No 5

Fig 25

Fig 26

Plate no 6

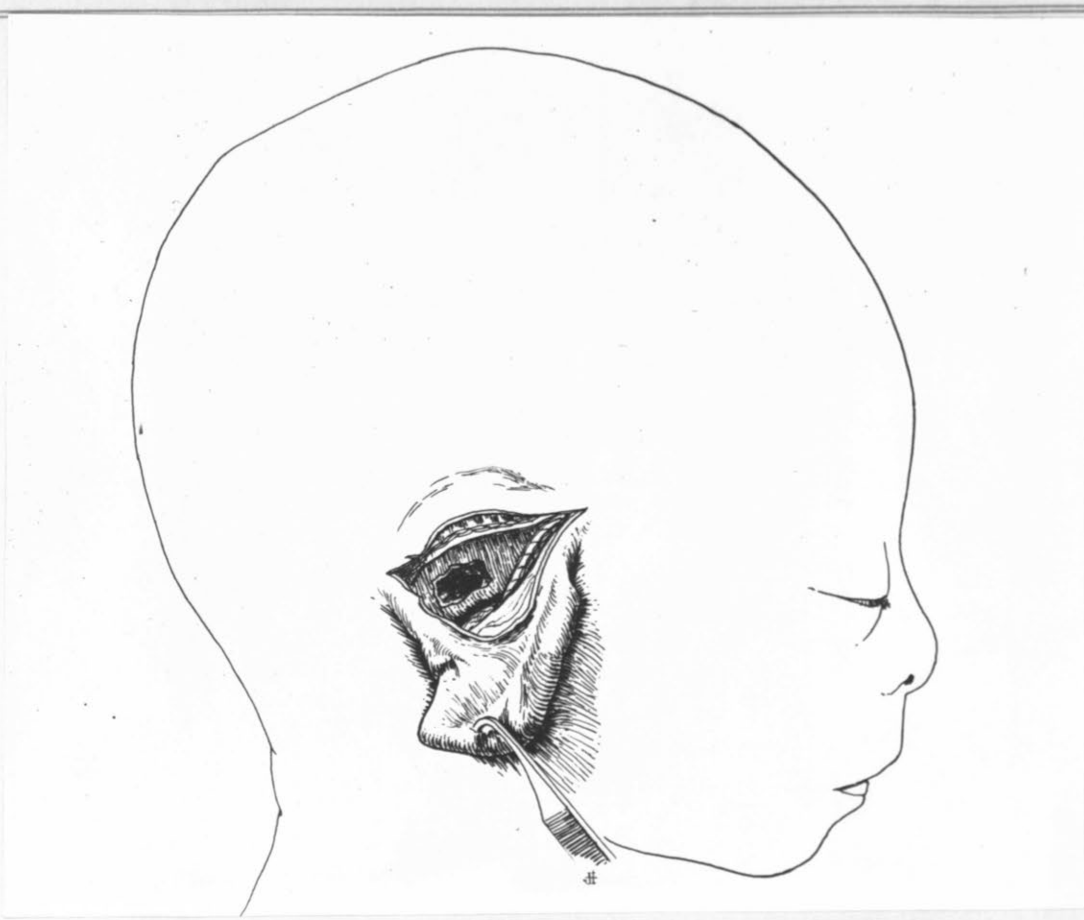


Fig. 27

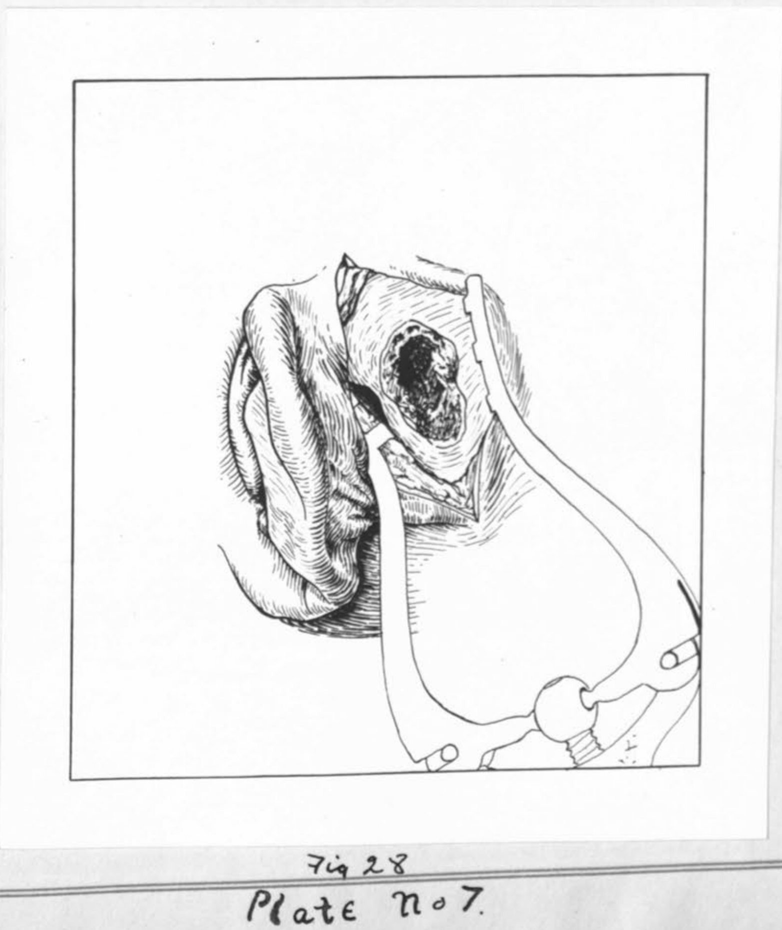
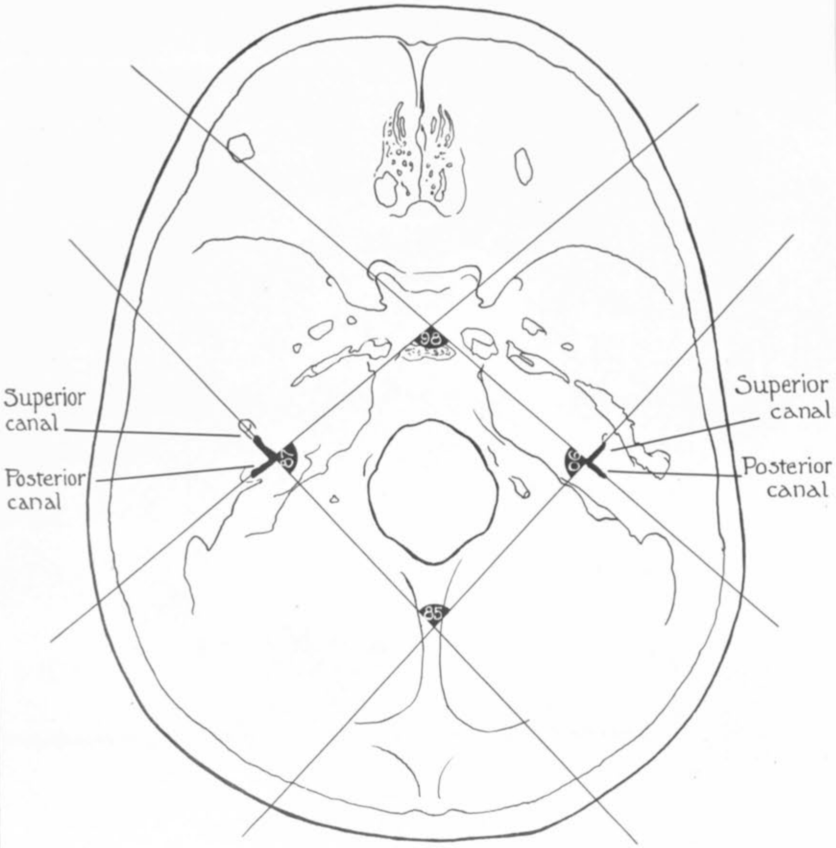


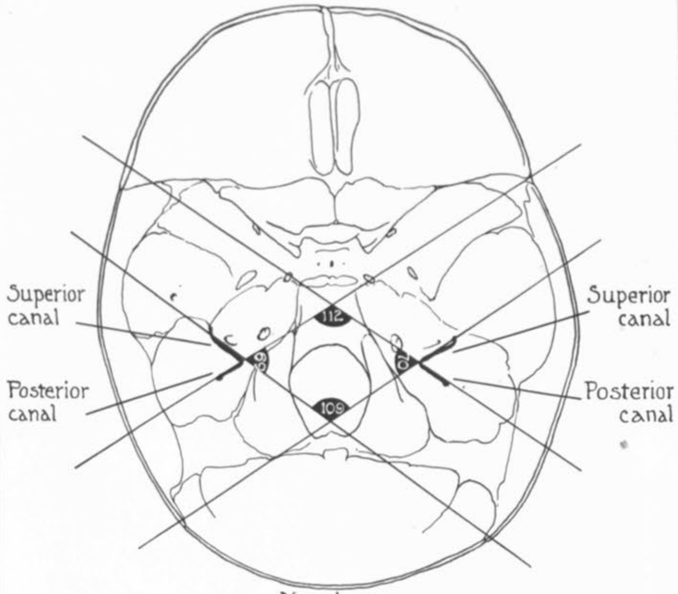
Fig 28

Plate No 7.



-Adult-
Showing position of canals in relation to each other and to planes of skull.
(From dissection)

Fig 29



-Newborn-
Showing position of canals in relation to each other and to planes of skull.
(From dissection)

Fig. 30

7-20 2M

Plate No 8