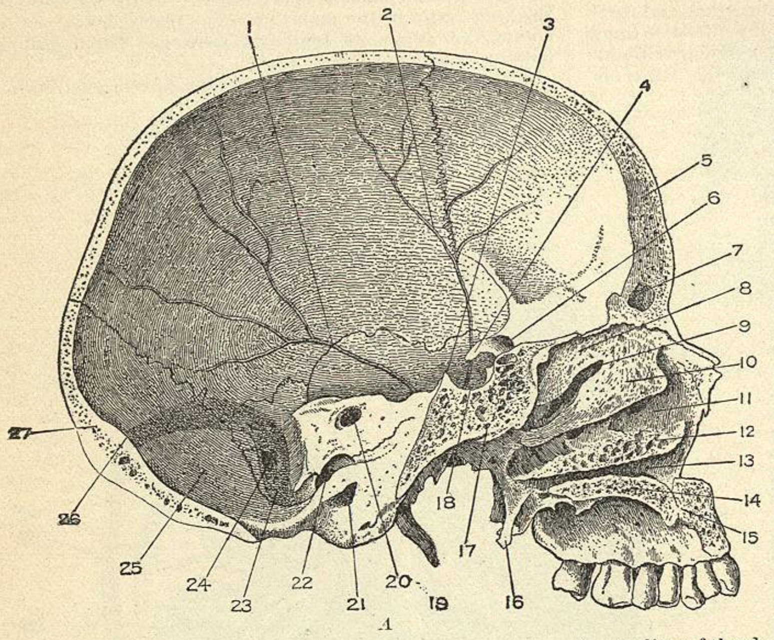
The adult chimpanzee and gorilla possess those enormous crests which give so horrible an aspect to their skulls. These bony ridges are adaptations and are due to the extreme development of the muscles of mastication and of those cervical muscles which insure the equilibrium of the head on the spinal column. The cranium, being too small to afford sufficient room for the insertion of these muscles, has been forced, in the course of development, to deposit these crests for the purpose of affording an enlarged bony area for muscular attachments. In this connection it is interesting to note that the young of these anthropoids have no crests, and that the distance on their skulls between the temporal lines marking the insertion of the temporal muscles is almost as great as in man.

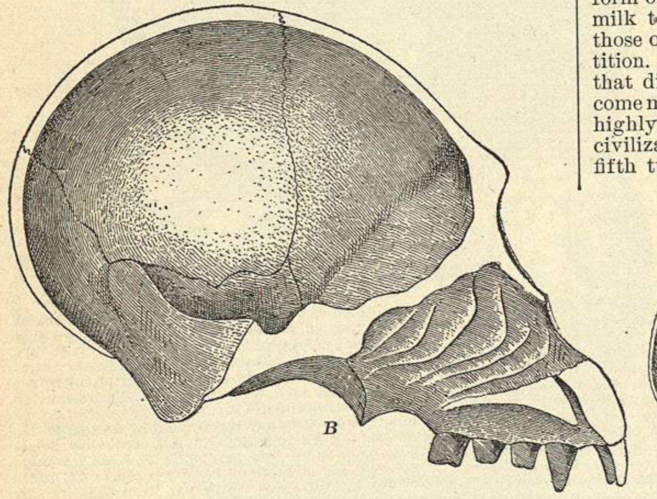
The size of the teeth in proportion to that of the body is much greater in the anthropoids than in man.

Ignoring the canines and incisors, we may state that the size of the premolars and molars, in apes, is larger in relation to the length of the face. In man the arrangement of the teeth on the alveolar border is in a compact line forming a continuous series; there is no conspicuous projection of any one tooth above the common level. On the contrary, in all apes there is observed an interval (*diastema*) between the lateral incisors and the canines of the upper jaw, and between the canines and the first premolars of the lower jaw. These diastemæ receive, in each jaw, the projecting part of the opposite canine.

Man and the anthropoid apes have alike five tubercles in the lower molars. Very often the fifth posterior tubercle is missing in the last two molars of man. In the anthropoids the wisdom tooth is of the same size as, or a little smaller than, the other molars, and this is usually the case in man, though in the latter it is often entirely wanting. The dental arch in the anthropoids usually has the form of **U**, while in man it tends to the elliptical or parabolic form.

It is in consequence of the inequality of the development of the face that the size and form of the teeth are different in man and the apes. The milk teeth of man present a much greater similarity to those of the anthropoids than the teeth of the second dentition. It is an instructive fact that all the characters that distinguish man from the anthropoids tend to become more marked with the change from a natural to a highly artificial environment, as in the development of civilization. Thus in European races the absence of the fifth tubercle in the molars of the lower jaw is more frequent than in Melanesians and Negroes. The wisdom tooth is apparently in a state of retrogressive evolution among several populations. In the white races especially it is almost always smaller than the other molars and the number of its tubercles is reduced to three instead of four or five; very often it does not erupt, remaining permanently in its alveolus. It is interesting to know that the differences between man and the anthropoids that have been noted above are very pronounced only when adult individuals are compared. The fœtus of the gorilla at five months bears a very close resemblance to a human fœtus of the same age. Young chimpanzees or gorillas, by their not very prominent muzzle, by their globular skull and relatively large cranium, and other traits, remind one of young Negroes. In comparing the skulls of chimpanzees, from the fœtal state through all the subsequent changes to the adult, we can follow step by step the transformation of a face that is almost human into a muzzle of the most repellent and bestial aspect. As has been indicated above, all of these changes have been brought about by the development of the cranium upward and behind in man, and the growth of the face below and in front in the anthropoids, "as if these parts moved in different directions in relation to a central point in the interior of the skull near to the *sella turcica*."





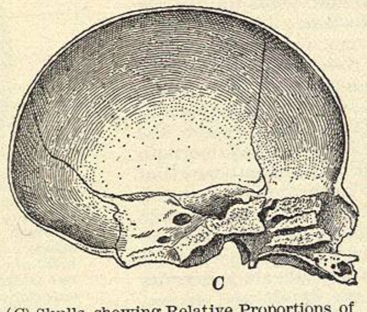


FIG. 4308.—Sagittal Sections of Human (*A*), Chimpanzee (*B*), and Infantile (*C*) Skulls, showing Relative Proportions of Cranium and Face and Relative Sizes of the Three Skulls. *A*: 1, Posterior division of middle meningeal artery; 2, anterior division of the artery; 3, dorsum sellæ; 4, anterior clinoid process; 5, diploë of frontal bone; 6, optic foramen; 7, frontal sinus; 8, superior turbinated bone of the ethmoid; 9, superior meatus; 10, middle turbinated bone of the ethmoid; 11, middle meatus, showing antral openings; 12, inferior turbinated bone; 13, inferior meatus; 14, hard palate; 15, anterior palatine canal; 16 hamular process of the internal pterygoid plate; 17, body of sphenoid (diploetic instead of pneumatic); 18, pituitary fossa; 19, styloid process; 20, internal auditory canal; 21, anterior condyloid foramen; 22, jugular foramen; 23, groove for lateral sinus; 24, mastoid foramen; 25, cerebellar fossa; 26, internal occipital protuberance (site of torcular Herophili); 27, diploë of occipital bone.

CRANIOLOGY.—The races of mankind display great variations in their physical attributes, and these differences are more or less characteristic of the stock to which they belong. For instance, the various races manifest great differences in the size and form of the cranial cavity and of the face. Variations are observed in the prominence of the chin, and in the form of the dental arch, the palate, the nasal aperture, the orbit, etc. Craniology deals with these variations to the extent that they affect the skull. In order that the differences between skulls may be recorded, it is necessary that accurate measurements, in many details, should be made. Some craniologists have multiplied the measurements to more than a hundred, but those worth mentioning are comparatively few. These measurements constitute Craniometry. In order to make the various measurements required, many complicated instruments have been invented, but for all practical purposes the calipers designed by Fowler are sufficient.

While there is a great difference of opinion as to the value of the various measurements, all anatomists endeavor to select such fixed *anatomical points* on the skull as may be easily located. Some of these "anatomical points" are as follows (Figs. 4304, 4305, 4306, 4307, 4308, *A*):

Nasion.—The middle of the naso-frontal suture.

Glabella.—The mid-point between the two superciliary ridges.

Ophryon.—The mid-point of the narrowest transverse diameter of the forehead.

Bregma.—The point of junction of the sagittal and coronal sutures.

Vertex.—Highest point of the cranial vault.

Obelion.—A point in the sagittal suture on a line extending between the parietal foramina.

Lambda.—The point of junction of the sagittal and lambdoid sutures.

Maximum Occipital Point.—That point on the squamous portion of the occipital bone and in the sagittal plane that is most removed from the glabella.

Inion.—The external occipital protuberance.

Opisthion.—The mid-point of the posterior margin of the foramen magnum.

Basion.—The mid-point of the anterior margin of the foramen magnum.

Mental Tubercle.—The tubercle of the chin.

Alveolar Point.—The mid-point of the anterior margin of the alveolar border of the upper jaw.

Subnasal Point.—The mid-point of the inferior margin of the anterior nasal aperture at the base of the nasal spine.

Stephanion.—The point where the temporal crest crosses the coronal suture.

Pterion.—The region of the antero-inferior angle of the parietal bone. As a rule there is a *sphenoparietal suture* so that the squamous portion of the temporal bone is separated from the frontal.

Asterion.—The region of the postero-inferior angle of the parietal bone.

Jugal Point.—Located at the angle between the upper border of the zygomatic process and the posterior border of the frontal process of the malar bone.

Gonion.—The outer surface of the angle of the mandible.

Auricular Point.—The centre of the aperture of the external auditory canal.

Preauricular Point.—That point which lies immediately in front of the upper end of the tragus on the posterior root of the zygoma.

Postauricular Point.—That point on the supramastoid crest which lies immediately behind and 18 mm. (a finger's breadth) below the upper attachment of the auricle.

Dacryon.—That point at the supero-internal angle of the orbit where the fronto-nasal suture meets the lachrymomaxillary suture.

Another anatomical point used in craniometry is the *mid-point* of the *spheno-ethmoidal suture* (called by some anatomists the gonion).

The Temporal Crest (*linea temporalis*).—Curving in a longitudinal direction over the lateral region of the calvarium is the temporal crest. It is often double. The upper ridge marks the limit of attachment of the temporal fascia, whilst the lower line defines the attachment of the temporal muscle. It commences in front on the external angular process of the frontal bone at the fronto-malar suture and sweeps backward and upward across the lower part of the frontal bone, and then crossing the coronal suture at the stephanion, passes to the parietal bone. Curving over this toward the postero-inferior angle of the parietal, it is continued on to the temporal bone to form the supramastoid crest.

The Supramastoid Crest.—The upper edge of the zygomatic process of the temporal bone passes back over the external auditory canal and becomes confluent with a ridge (posterior part of the temporal ridge or crest) that separates the mastoid from the squamous portion of the temporal bone; this ridge is the supramastoid crest or posterior root of the zygoma.

The *basicranial axis* is represented by a line drawn from the basion to the mid-point of the spheno-ethmoidal suture, and is formed by the basi-occipital, the basisphenoid, and the presphenoid bones.

The *basifacial axis* is indicated by a line drawn from the mid-point of the spheno-ethmoidal suture to the subnasal point.

The *craniofacial axis* comprises the basi-occipital, basisphenoid, presphenoid, and mesethmoid bones.

The *basibregmatic axis* extends from the basion to the bregma.

The *craniofacial angle* is the one formed by the basicranial and basifacial axes. It is useful in making comparative measurements of crania.

The *longitudinal arc* of the cranium is measured from the nasion along the vertex to the opisthion, and may be subdivided by measuring the lengths of its frontal, parietal, and occipital portions so that the relative proportions of these bones may be noted.

The *basinasal length* is the distance from the basion to the nasion.

The *basi-alveolar length* is the distance from the basion to the alveolar point.

The *dental length* is the distance, in the upper jaw, from the anterior surface of the first premolar to the posterior surface of the third molar.

The *total circumference of the cranium*, in the sagittal plane, may be obtained by adding together the longitudinal arc, the distance between the opisthion and the basion, and the basinasal length.

Reid's Base Line.—This is a line drawn from the auricular point to the lower margin of the orbit.

The *horizontal circumference* of the cranium is measured around a plane cutting the glabella anteriorly, and the maximum occipital point posteriorly.

In ascertaining the *maximum breadth of the cranium*, which is very variable in its position, it should be noted whether it is above or below the squamo-parietal suture.

The *length of the cranium* may be measured between a number of different points, as between the nasion, glabella, or ophryon anteriorly, and the maximum occipital point, or the inion posteriorly.

The *bistephanic width* of the cranium is the distance from one stephanion to the other in the horizontal plane.

The *biasterionic diameter* of the cranium is the distance, in the horizontal plane, from one asterion to the other.

The opisthion and the floor of the posterior cranial fossa occupy the same horizontal plane as the hard palate. The basion is a little higher than the opisthion. By consequence the plane of the foramen magnum in the higher races is oblique, being directed downward and slightly forward.

In order to describe the cranial peculiarities correctly and to have fixed coördinates to which the measurements can be referred, the skull should be placed, when studied, in the horizontal plane. Anthropologists are not agreed as to this initial plane. In Germany the plane in favor is one passing through the centre or top of the contour of the osseous external auditory canal and the inferior border of the orbit. In France and England Broca's alveolo-condylean plane is adopted; this plane passes through the alveolar border of the superior maxilla and the condyles of the occipital bone.

Cranial Capacity.—The size of the brain cavity or the cranial capacity is estimated in various ways. Were it not for the fact that the brain cavity of the skull contains so many foramina which it is difficult to close, fluids would be the most accurate agents to use in ascertaining cranial capacity. But practically leaden shot, or seeds, or glass beads are the most serviceable. Cranial capacity is intimately correlated with the development of the brain, and, apart from individual variations and the proportion of head size to stature, it may be stated that the size of the cranium in highly civilized races is greatly in excess of that observed in the lower races.

For the purposes of comparison skulls are grouped according to their cranial capacity as follows: *megacephalic*, with a brain capacity over 1,450 c.c. (mixed Europeans, Japanese, Eskimaux); *mesocephalic*, with a capacity varying from 1,350 c.c. to 1,450 c.c. (some African Negroes, American Indians, Chinese); *microcephalic*, with a capacity below 1,350 c.c. (Veddahs, Australians, Andamanese, Bushmen).

The Cephalic Index.—Comparisons between crania may be made by *indexes*. An index is the ratio between two dimensions that have a natural relation; the normally greater dimension is employed as a base and is assumed to be 100. The ratio is expressed as follows:

Greater dimension : lesser dimension :: 100 : index. Or,

$$\frac{\text{Lesser dimension} \times 100}{\text{Greater dimension}} = \text{Index.}$$

The cephalic index expresses the relation of the breadth to the length of the cranium and records the proportion of its maximum breadth to its maximum length (the latter being assumed to be equal to 100) in the following formula:

$$\frac{\text{Maximum breadth} \times 100}{\text{Maximum length}} = \text{Cephalic index.}$$

According to the amount of the cephalic index skulls are classified as follows: *Brachycephalic*, index over 80 (American Indians, Malays, Andamanese); *mesaticephalic*, index varying from 75 to 80 (mixed Europeans, mixed Polynesians, Chinese); *dolichocephalic*, with an index below 75 (Australians, Zulus, Fijians, Kaffirs, Eskimaux).

The dolichocephalic skull is more primitive than the brachycephalic one. Generally tall men have long heads, while short men have short or rounded ones. The Norwegians are the tallest men as well as the largest-skulled nation in Europe; the Auvergnats are the shortest of European whites and possess the roundest heads.

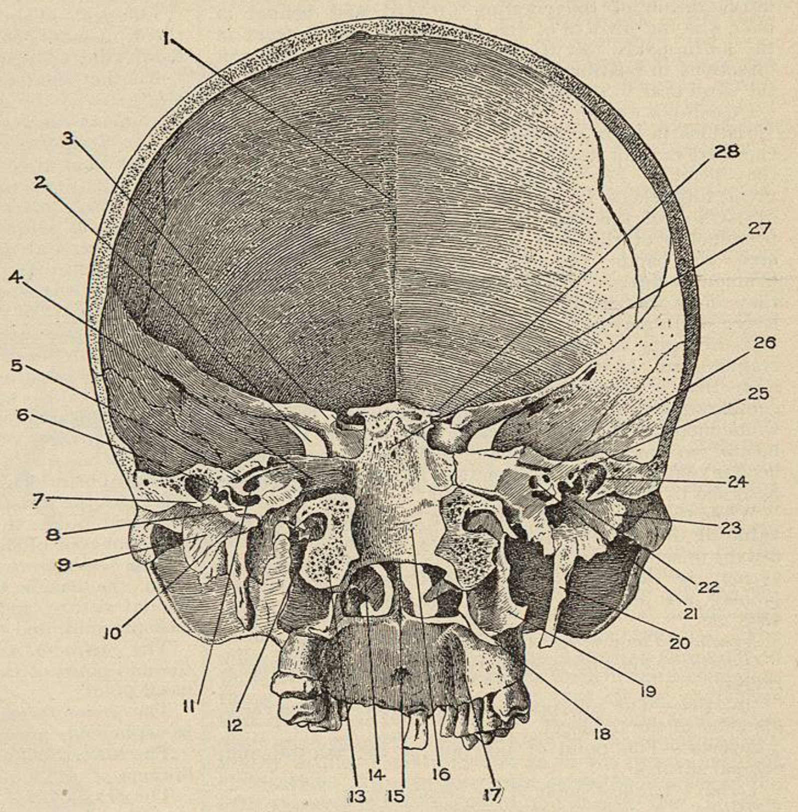


FIG. 4309.—Coronal Section of the Skull through Middle of Occipital Condyle, the Posterior Part of the External Auditory Canal, the Tympanum, Vestibule, Internal Auditory Canal, on each Side, and the Bregma. Front portion tilted forward and viewed from behind. 1, Groove for superior longitudinal sinus; 2, sphenoid fissure; 3, anterior clinoid process; 4, commencement of internal auditory canal; 5, commencement of aqueductus Fallopii at bottom of internal auditory canal; 6, aqueductus Fallopii; 7, floor of attic and roof of external auditory canal; 8, promontory bounding canal of cochlea; 9, auditory process separating external auditory canal from the glenoid fossa in front of it; 10, groove for the membrana tympani; 11, spiral cribriform tract at bottom of internal auditory canal; between 11 and 5 is seen the falciform crest; 12, anterior condyloid foramen; 13, condyle of occipital bone; 14, inferior turbinated bone; 15, vomer; 16, basilar portion of occipital bone; 17, hard palate; 18, hamular process of the internal pterygoid plate; 19, external pterygoid plate; 20, styloid process; 21, spiral cribriform tract; 22, atrium; 23, external auditory canal; 24, attic; 25, aqueductus Fallopii; 26, commencement of aqueductus Fallopii; 27, dorsum sellæ; 28, posterior clinoid process.

The Height Index.—This index expresses the proportion of the height to the length of the cranium and is obtained by the following formula:

$$\frac{\text{Basiobregmatic height} \times 100}{\text{Maximum length}} = \text{Height or vertical index.}$$

According to the index skulls are divided into *hypsicephalic*, index 75.1 and upward; *orthocephalic*, index from 70.1 to 75; and *chamæcephalic*, index below 70.1.

The Nasal Index.—This index expresses the proportion of the maximum nasal width to the nasal height (measured from the subnasal point to the nasion) and is obtained by the following formula:

$$\frac{\text{Maximum nasal width} \times 100}{\text{Nasal height}} = \text{Nasal index.}$$

The form of the nasal aperture is of great value from an ethnic point of view, since it is so intimately associated with the shape of the nose in the living. According to the nasal index skulls are classified as follows: *Platyrhine*, with index above 53 (Australians, Negroes, etc.); *mesorhine*, index varying from 48 to 53 (Japanese, Chinese); and *leptorhine*, index below 48 (mixed Europeans, American Indians, ancient Egyptians).

The Orbital Index.—This index, though varying considerably in different races, is of much less value for purposes of classification than the nasal index. It expresses the proportion of the height to the width of the orbit. The orbital height is the distance, at its middle, between the lower and upper margins, while the width is measured from the dacryon to the most distant point on the anterior edge of the outer border of the orbit. The orbital index is obtained by the following formula:

$$\frac{\text{Orbital height} \times 100}{\text{Orbital width}} = \text{Orbital index.}$$

Skulls are divided, according to the index, into *megaseme*, index above 89; *mesoseme*, index between 89 and 84; and *microseme*, index below 84.

The Palatomaxillary Index.—This index is used to record the variations occurring in the form of the palate and dental arch. The width is measured between the outer surfaces of the alveolar borders immediately above the second molar tooth of each side, while the length is taken from the alveolar point to the mid-point of a line drawn from the posterior border of one superior maxilla to that of the other. The index is obtained by the following formula:

$$\frac{\text{Palatomaxillary width} \times 100}{\text{Palatomaxillary length}} = \text{Palatomaxillary index.}$$

According to the index skulls are classified as follows: *Brachyuranic*, index above 115; *mesuranic*, index between 110 and 115; and *dolichuranic*, index below 110.

The Dental Index.—From an ethnic point of view the proportion of the space occupied by the premolar and molar teeth (dental length), on one side, to the length of the basinasal line has been found to be a character of much value. The dental index is obtained by the following formula:

$$\frac{\text{Dental length} \times 100}{\text{Basinasal length}} = \text{Dental index.}$$

According to the index skulls are divided into *megadont*, index above 44 (Australians, Negroes); *mesodont*, index between 42 and 44 (Mongolians); *microdont*, index below 42 (Caucasians).

The Facial Index.—The characteristic features of the race are most readily noted in the face, and measurements of the skeleton of the face are of more value than those of the cranium, though more complex. As a general rule, to which there are many exceptions, it may be stated that a long or dolichocephalic cranium is associated with a long face, and a brachycephalic one with a shorter and rounder face.

There are two varieties of facial index, according to whether the mandible is included in the measurements or not. With the mandible present the measurement is taken from the nasion above to the mental tubercle below, and compared with the greatest bizygomatic diameter. This constitutes the *total facial index*, and is obtained by the following formula:

$$\frac{\text{Naso-mental length} \times 100}{\text{Bizygomatic diameter}} = \text{Total facial index.}$$

Since the mandible is frequently missing in skulls it is important to express the relation of length to the breadth of the face by the *superior facial index*, which can be obtained by the following formula:

$$\frac{\text{Naso-alveolar length} \times 100}{\text{Bizygomatic diameter}} = \text{Superior facial index.}$$

According to the facial index the following types of face are noted: *chamæprosopic* (broad or low face), *mesoprosopic* (medium-size face), and *leptoprosopic* (high or narrow face). The terms *brachyfacial* and *dolichofacial* have also been employed to record the different faces observed. The proportion of the width of the face to that of the cranium is expressed by terms which indicate that the zygomatic arches are either concealed or observed when the skull is inspected from its norma verticalis. In the former case skulls are roughly described as *cryptozygous*; in the latter as *phænozygous*.

The Alveolar Index.—The degree of projection of the superior maxillæ, so characteristic of certain races, is most readily ascertained by the *alveolar index*. This expresses the proportion of the basi-alveolar to the basinasal length, the latter being equal to 100. The index is secured by the following formula:

$$\frac{\text{Basi-alveolar length} \times 100}{\text{Basinasal length}} = \text{Alveolar index.}$$

According to the index races are classified into three groups: *prognathous*, index above 103 (Australians, various African Negroes, Melanesians, Tasmanians); *mesognathous*, index from 98 to 103 (Chinese, Eskimaux, Japanese, mixed Polynesians;) *orthognathous*, index below 98 (ancient Egyptians, mixed Europeans).

In calculating indices the *index calculator*, invented by Dr. Waterston, will be found of great service in saving time.

The amount of projection of the face may be measured by certain angles, the two most important of which are the following, viz., the facial and the maxillary.

The *facial angle* is that subtended by a line drawn from the most prominent part of the forehead above to the most projecting portion of the upper jaw below, and a second line drawn horizontally from the first through the centre of the aperture of the external auditory canal. The more acute this angle is, the smaller is the cranial capacity. The angle is 40° in the orang-outang, 70° to 75° in the African Negro, and 80° in the European whites.

The *maxillary angle* is subtended by lines drawn from the most projecting portion of the upper jaw to the most prominent points of the chin below and the forehead above. The more acute this angle, the more prognathic is the face and the less the chin. The angle is 110° in the orang-outang, 140° in the African Negro, and 160° in the European whites.

Sutures.—The lines of union or sutures between the several bones of the skull also give indications of great value in differentiating races. They are much simpler in the lower races than in the higher, and become obliterated earlier in life. Through this means the bones of the cranium unite into a compact mass and prevent the continued expansion of the brain cavity. Occasionally, in some races more frequently than in others, small distinct bones (Wormian bones) are observed in these sutures. One of these occurs so frequently in certain tribes of American Indians that it has been named the *Inca* bone. It is situated toward the back of the head.

The presence of inferior physical traits in certain races of men is either the perpetuation of the ape-like (pithecoid) characters of the lower animal, which was man's immediate ancestor, or they are atavistic.

As a very brief summary we may say that some of these inferior traits are a wide nasal aperture with synostosis of the nasal bones; simplicity and early union of the cranial sutures, with retarded union of the facial sutures; recession of the chin; prominence of the jaws; articulation of the temporal with the frontal bone; early appearance, large size, and permanence of the wisdom teeth.

In nearly all the black people (Soudanese, Australians, Melanesians, etc.) the wisdom teeth are ordinarily furnished with three separate fangs, while among the whites they decay early and have only two fangs.

It has been justly objected that ethnologists who are mere anatomists have claimed too much for craniology, and that they have given it a prominence which it does not deserve, too often applying it to the exclusion of other elements. The shape of the skull is no indication of race in the individual; only in the average of large numbers has it importance. Within the limits of the same race, as the Slavonians, the greatest variations in skulls are observed. Again the cranial indices were found to vary from 70 to 83 among the pure-blooded natives of one of the small islands of the Pacific Ocean.

Nevertheless, employed with a due regard for all the ethnic elements, and in large averages, craniometry is extremely useful as furnishing additional data for comparison.

The cranial characters not only vary according to *race*, but also in each race there are other variations due to *age* and *sex*.

AGE DIFFERENCES IN THE SKULL.—The skull of a new-born infant presents two striking peculiarities, viz., the great predominance of the cranial over the facial portion (8 to 1) (Fig. 4308, *C*) and its relatively large size in comparison with the body. The diminutive facial portion is due to the small size of the maxillary antrum, the undeveloped condition of the mandible and maxillæ, and the small size of the nasal fossæ which are as broad as they are high and almost filled with the turbinals. The parietal and frontal eminences are large and conspicuous, but the frontal sinuses and superciliary ridges are wanting. The bones of the vault are without any diploë, and therefore consist of a single layer. The sutures are absent in the cranium. Each angle of the parietal bone is undeveloped and in relation with a fontanel. The anterior fontanel is large and lozenge-shaped, the posterior small and triangular, and the lateral ones irregular in shape (Figs. 4310 and 4311).

The most striking facts about the base of the skull are the absence of the mastoid processes, the large angle formed by the pterygoid processes with the base, and the existence of the occipital condyles on the same level with the lower border of the symphysis menti. The frontal bones consist of two elements separated by a *metopic* suture.

The temporal bone consists of three parts, viz., the *squamosal*, *tympanic*, and *petrosal* (Fig. 4312). The squamosal has its postero-inferior angle prolonged downward into a *postauditory process*, which forms the outer wall

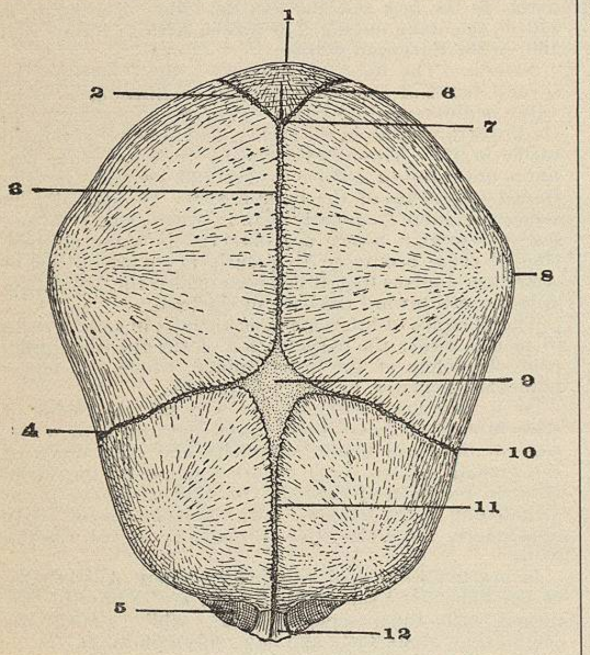


FIG. 4310.—Norma Verticalis of Infant. 1, Interparietal; 2 and 6, lambdoid suture; 7, posterior fontanel; 3, sagittal suture; 8, parietal eminence; 9, anterior fontanel; 4 and 10, coronal suture; 11, interfrontal metopic suture; 5, upper jaw; 12, nasal bone.

of the mastoid antrum. Its glenoid fossa is very shallow and has a relatively large postglenoid tubercle.

The horseshoe-shaped tympanic bone is attached to the inferior border of the squamosal by its anterior and posterior extremities. A striking feature of the norma lateralis is the absence of the bony external auditory canal. The petrosal presents a cartilaginous styloid process except for a minute nodule of bone (*tympano-hyal*) in its base. There are no mastoid sinuses, but a relatively large mastoid antrum; there is a large and conspicuous

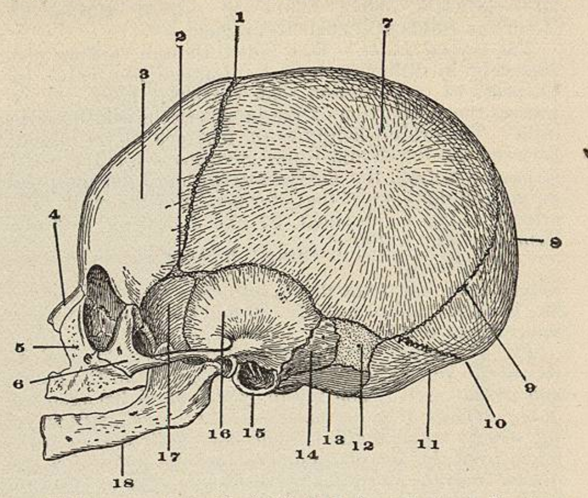


FIG. 4311.—Norma Lateralis of Infant. 1, Coronal suture; 2, antero-lateral fontanel; 3, frontal bone; 4, nasal bone; 5, superior maxilla; 6, malar; 7, parietal eminence; 8, interparietal portion of occipital bone; 9, lambdoid suture; 10, fissure between inter- and supra-occipital portions of occipital bone; 11, supra-occipital portion of occipital bone; 12, postero-lateral fontanel; 13, exoccipital; 14, petrosal; 15, tympanic plate; 16, squamosal; 17, alisphenoid; 18, mandible.

floccular fossa. The ossicles of the middle ear are about as large as in the adult. The processus gracilis may reach 2 cm. in length.

The occipital bone consists of four elements at birth, viz., *basi-occipital*, *exoccipitals*, and *squamo-occipital* (Fig. 4313). There are two deep fissures in the latter, separating it partially into a *supra-occipital* portion and an *interparietal* portion (the latter being a membrane bone). There is no jugular process or pharyngeal tubercle. The grooves for the lateral sinuses are lacking.

The maxilla presents on the oral surface of its palatine process the maxillo-premaxillary suture (Fig. 4306). The mandible at birth consists of two parts united by fibrous tissue in the line of the future symphysis menti.

The ethmoid presents three elements, viz., two lateral portions (*ectethmoids*) and a median portion (*ethmovomerine* plate). The uncinate process is undeveloped and the ethmoidal sinuses are represented by shallow depressions.

The sphenoid at birth consists of two lateral segments (*alisphenoids* with their pterygoid processes) and a composite median portion. This median portion is composed of the body of the sphenoid (ankylosed *presphenoid* and *postsphenoid*), the lesser wings of the sphenoid (*orbitosphenoids*), and the *lingulæ*. There is no foramen spinosum, and the future foramen ovale is merely a deep notch in the posterior border of the alisphenoid. The presphenoid is solid and gives no evidence of the sphenoidal sinuses which occupy this region in the adult. The Vidian canal of the adult occurs in the skull at birth as a *groove* between the lingula, the alisphenoid, and the internal plate of its pterygoid process. The sphenoidal turbinals lie in the perichondrium on either side of the ethmo-vomerine cartilage near its union with the presphenoid. They are two small triangular pieces of bone. The palate bones have their horizontal and vertical portions of the same length.

The vomer presents quite a different appearance from that in the adult.

The lachrymals are thin, delicate lamellæ. The inferior turbinal and the malar are relatively large. The nasals are broad and short.

From the above hasty survey of the skull of the new-

born child it will be observed that there are many more bones than are present in the adult. At various periods in intra-uterine life the bones are still more numerous. With increasing age the bones are reduced in number through the ankylosis of two or more adjacent bony segments into composite bones. The child has fewer separate bones in his skull than the infant, the adult fewer than the child, and so on, more or less, until old age. These facts are the explanation of the occurrence of blood-vascular and nerve foramina in various parts of the adult skull.

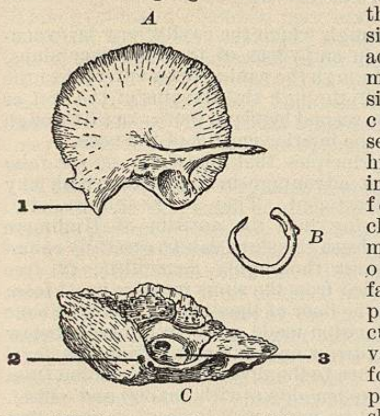


FIG. 4312.—Temporal Bone at Birth—the separate pieces. *A*, Squamosal; *B*, tympanic or annulus; *C*, petrosal. 1, Outer wall of antrum (postauditory process); 2, stylo-mastoid foramen; 3, promontory on inner wall of tympanum proper or atrium.

The foramina and canals which transmit nerves have been subdivided into primary and secondary groups. *Primary foramina* occur at the points where the nerves leave the general cavity of the dura mater. In a morphological sense a nerve becomes extracranial where it perforates the dura mater, since this membrane largely represents the primitive connective-tissue cranium. Two illustrations of primary foramina are the *foramen magnum* and the *optic foramen*. The former is formed by four bones (the exoccipitals, the basi-occipital, and the supra-occipital) ankylosing around the medulla oblongata. The optic foramen is formed by the presphenoid and the orbitosphenoid ankylosing around the optic nerve.

Owing to the fact that human and other high vertebrate adult skulls have undergone, during the evolutionary process, complicated modifications, resulting in highly composite bones, it is observed that elaborate bony canals occur in these adult skulls that are not represented in the adult skulls of more primitive vertebrates, as the Elasmobranchs. In similar manner the adult skulls of high vertebrates contain foramina and elaborate tunnels that are not found in their embryonic condition. Such channels come under the category of *secondary foramina*. A few illustrations are as follows, viz.: the Vidian canal, to which reference has already been made; the anterior ethmoidal canal formed by bony ankylosis of the ecto-ethmoidal and the frontal bones around the nasal branch of the ophthalmic nerve; the *iter chordæ posterius* is a passageway for the chorda tympani nerve to enter the tympanum, and is formed by the ankylosis of the squamosal and tympanic bones around the nerve. The inferior dental canal of the mandible is formed by the ankylosis of several bony embryonic elements around a portion of the inferior dental nerve.

In the adult the face is at least one-half the size of the cranium. About the age of puberty the air sinuses, especially the frontal sinus, expand and develop, leading to characteristic alterations in face and head form. The age of the skull may be approximately estimated by several factors; for instance the eruption of the teeth in infancy and adolescence. When permanent dentition is completed the wear of the teeth may assist in hazarding an approximation. Complete bony union between the sphenoid and occipital bones is an indication of maturity. In old age the cranial bones become thinner and the whole skull lighter; also the condition of the sutures may guide us, since the sagittal and coronal sutures do not undergo synostosis until late in life; also at this period the obtuseness of the mandibular angle increases on account of the flattening of the vault of the hard palate, which is induced by changes in the alveolar borders of the mandible and maxillæ; for owing to the loss of the teeth in the aged, these borders become absorbed. Through this means is induced also a change in the relative position of the mental foramina.

SEXUAL DIFFERENCES IN THE SKULL.—It is always a matter of difficulty to determine with certainty the sex of a skull. The cranial capacity of the female skull is about a tenth less than the male of the same race; her skull is smaller and lighter; it has less prominent mastoid processes; it is smoother in consequence of the inferior development of the muscular ridges. The supra-orbital margin of the frontal bone is sharper and thinner in consequence of the less pronounced character of the superciliary ridges. For the same reason the frontal eminences are more conspicuous and the forehead more vertical. The parietal eminences are more prominent and the glabella less so in the female than in the male.

The edge of the tympanic plate of bone is more rounded and tubercular, whereas in the male it is sharp and divides to ensheath the styloid process. In the female the height of the skull is reduced in consequence of a more flattened vertex. No one of these sexual differences is characteristic, but taken together they enable us to arrive at a fairly accurate conclusion. It may be interesting to recall in this connection that Broca taught that if a skull rests on its mastoid processes it is almost certainly a man's.

PNEUMATIC SPACES IN CONNECTION WITH THE NASAL FOSSÆ AND THE NASOPHARYNX.—Connected either with the nasal fossæ or with the nasopharynx are the following air sinuses or pneumatic spaces, viz., the maxillary, frontal, ethmoidal, orbital, sphenoidal, and tubotympanic (Figs. 4314, 4315, 4316, and 4317).

The *maxillary sinus* or *antrum of Highmore* (Fig. 4314) occupies the body of the superior maxilla, and therefore is situated to the outer side of the nasal fossa on either side. It is a pyramidal cavity with its apex directed toward the malar bone and its base formed by the outer wall of the nose. Its walls are relatively thin and are directed forward to the face, inward to the nose, upward to the orbit, backward to the sphenomaxillary and zygo-

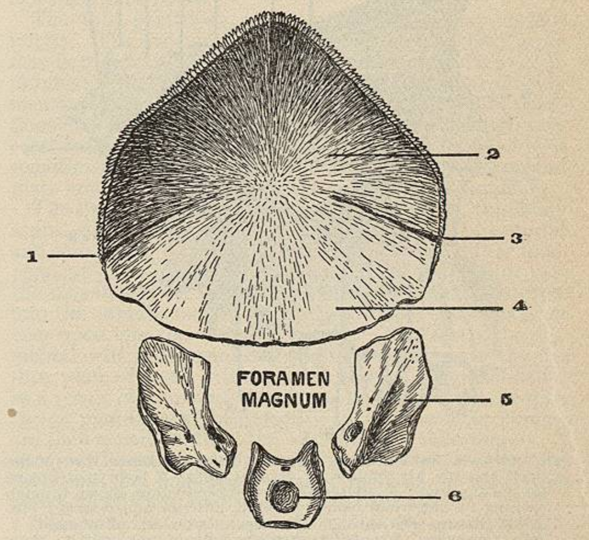


FIG. 4313.—Occipital Bone at Birth—Cerebral Surface. 2, Interparietal portion (develops in membrane); 4, supra-occipital portion (develops in cartilage); 1 and 3, infantile fissure that occasionally persists in adult; 2 and 4, form the squamo-occipital of the adult; 5, exoccipital; 6, basi-occipital.

matic fossæ, and downward to the alveolar border. Portions of several bones assist in the formation of the thin osseous partition, which nearly, save for the small antral orifices, separates it from the nasal fossa. These bones are the uncinate process of the ethmoid bone, the ethmoidal process of the inferior turbinated bone, a portion of the lachrymal, and the vertical plate of the palate bone. The floor of the antrum is separated from the roots of the molar and bicuspid teeth by bone of varying thickness. Ordinarily the floor of the antrum is on a level with the floor of the nasal fossa. But sometimes the floor of the antrum, when it is thin and devoid of spongiosa, sinks below the level of the fossa; under these circumstances suppuration at the roots of one or more of the teeth in this locality is very prone to extend to the antrum. Wide variations are noted in the size of the maxillary sinus. The cavity may be represented by a narrow cleft; more rarely it is entirely absent.

A large adult antrum will hold 32 c.c. The average capacity is 14.5 c.c. In a sinus of average dimensions the line of junction of its facial and nasal walls is indicated externally by the outer edge of the canine ridge.

Small recesses and pockets are frequently found on the inner surface of the walls of the sinus, thus favoring the collection of abnormal secretions. The sinus may rarely be completely subdivided into two compartments by a horizontal or vertical partition. In these circumstances both cavities may communicate with the middle meatus; or the superior or posterior compartment may communicate with the superior meatus, while the inferior or anterior one opens into the infundibulum. In the event of this anomaly, the surgeon might fail to find the source of suppuration in the superior or posterior compartment.

The antral orifice is unfavorably situated for natural drainage, since it is at the highest part of the antrum. It opens into the middle meatus of the nose through the posterior extremity of the hiatus semilunaris.

Ordinarily the antrum of Highmore is separated from the neighboring pneumatic spaces by thin bony partitions, and it communicates only with the nasal fossa.

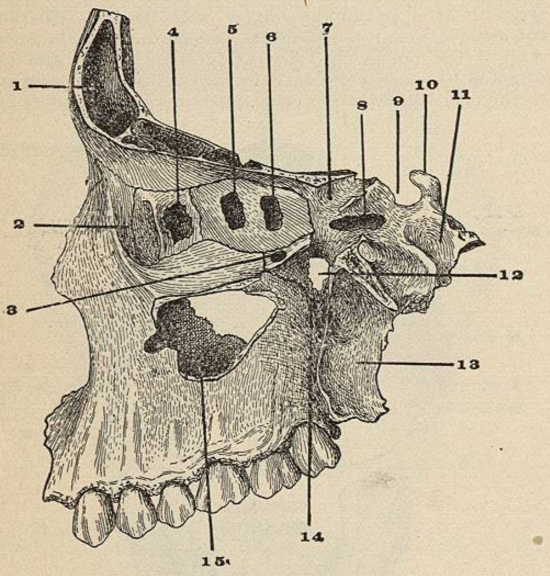


FIG. 4314.—A Section of the Skull showing the Inner Wall of the Orbit and the Air Sinuses. 1, Frontal sinus; 2, lachrymal groove for the nasal sac; 3, orbital sinus; 4, infundibulum shown through opening in lachrymal bone; 5 and 6, anterior and posterior ethmoidal sinuses seen through openings in os planum of ethmoid; 7, optic foramen; 8, opening through body of sphenoid to show sphenoidal sinus; 9, pituitary fossa; 10, dorsum sellæ; 11, cavernous groove; 12, sphenopalatine foramen; 13, external pterygoid plate; 14, sphenomaxillary fossa; 15, maxillary sinus or antrum of Highmore revealed by removal of malar process.

Occasionally I have seen a direct, non-pathological channel of communication between the antrum and the anterior ethmoidal cells. In other specimens I have seen, as I explain below, a direct channel of communication between the antrum, the orbital, the posterior ethmoidal, and the sphenoidal sinuses.

At birth the maxillary sinus exists in a very rudimentary form, but reaches its full development about twelve years of age.

The opening through which the cavity may be evacuated and drained, in empyema of the maxillary sinus, may be made (1) through the canine fossa external to the canine eminence; (2) through the alveolus of the first or second molar or the second bicuspid tooth; or (3) through the lateral wall of the inferior meatus of the nose.

There are two principles that place the *canine fossa operation* at a great advantage in comparison with any other method of treatment. They are as follows, viz.: (1) by a free opening into the antrum of Highmore through the canine fossa the sinus can be carefully examined and its contents thoroughly controlled; (2) free drainage is established from the sinus into the nasal fossa and on a level with the floor of the sinus. When the bone is exposed by an incision made a few millimetres below the gingivo-labial furrow and extending from the level of the canine eminence to the first molar, the canine fossa (Fig. 4303, *32*) is broken down with mallet and chisel. The opening should be made well forward in order that it shall approach closely to the nasal wall of the sinus, and downward so as to be on a level with the alveolar floor of the cavity. An opening of this character is preferable because (1) it is most suitable for the further procedure of making the opening into the nasal fossa from the sinus; (2) it gives the best view of the sinus; (3) it is the most favorable situation for drainage. Care should be taken to avoid injury to the infra-orbital nerve. The margins of the opening should be made as smooth as possible. The mucoperiosteum should be injured as little as possible.

In creating a nasal opening from the antrum, blood should be prevented from escaping into the nasopharynx by inserting therein a small sponge attached to a tape. Prior to making the opening the anterior third of the inferior turbinal should be amputated. This gives free access to the naso-antral partition, which is to be broken through. This is done by mallet and chisel through the opening in the canine fossa. The operator should work as far forward as possible, keeping close to the antral floor. As soon as the chisel has penetrated the partition, a Krause cannula with probe-pointed trocar should be used to define and enlarge the opening. This opening should then be enlarged with mallet and chisel until the front third of the lateral wall of the inferior meatus has been removed. The opening should be large on account of the great tendency to after-contraction. During the operation care should be taken not to injure the nasal septum.

The *frontal sinus*, one on either side, lies between the outer and inner tables of the frontal bone over the root of the nose and extends outward under the superciliary ridges (Fig. 4314, *1*). The septum of bone which separates them is very seldom in the mesial plane. It may be so far removed from this plane that an opening made on one side of it may expose the sinus on the opposite side of the body. The sinus, on either side, communicates, through the infundibulum and front part of the hiatus semilunaris, with the fore part of the middle meatus of the nasal fossa. The sinus is smaller in young people and in women than in men. While there is no necessary correlation between a capacious frontal sinus and a prominent superciliary ridge, it may be stated as a general rule that there is a greater probability of the presence of a well-developed sinus where there is a prominent supra-orbital area (including a prominent superciliary ridge and nasal eminence). The outer table of the sinus is the thickest, but varies considerably in different skulls. Its average thickness is about 5 mm. It has a large amount of diploic tissue, which accounts for the possibility of septic infection when it is opened, and also for the hemorrhage that occurs from it. The inner table is thin and brittle. The floor of the cavity overlies the orbit, as well as the upper border of the lachrymal and the anterior part of the superior border of the lateral

mass of the ethmoid. The floor is the thinnest wall, especially at the supero-internal angle of the orbit. Accordingly when there is empyema of the sinus the pus tends to point at the upper and inner angle of the orbit. This pneumatic chamber may extend upward on the forehead for 40 mm.; laterally as far as the external angle of the orbit; backward as far as the lesser wing of the sphenoid, on either side, thus separating the horizontal portion of the frontal bone (the roof of either orbit) into two tables, viz., orbital table and cerebral table. It may communicate by a large opening with a well-marked sinus in the crista galli.

The cavities are very unsymmetrical and irregular. They may be very small or altogether absent. The sinus may be present on one side and absent on the other. The sinus becomes funnel-shaped as it passes downward to the ethmoidal infundibulum. The ostium of the frontal sinus is found at a short distance from the septum and at the most dependent part of the cavity. It may be situated 28 mm. behind the outer table of the frontal bone. Incomplete trabeculæ of bone often divide the sinus into recesses of various sizes and shapes.

The frontal sinus is absent at birth. It appears about the seventh year and develops only slightly up to puberty, when it increases rapidly in size, reaching its maximum growth about the twentieth year.

When through empyema or other diseases of the frontal sinus it becomes necesary to open the cavity, there are several methods of procedure. 1. The infero-external wall (orbital surface) of the sinus may be opened at the upper and inner angle of the orbital fossa. The orbital surface of the sinus must be so freely removed that the little finger can be passed into the cavity after its contents have been thoroughly evacuated by syringing with an antiseptic solution. The little finger of the other hand should be placed in the corresponding nostril and pushed up to a point where the finger in the sinus can be felt. With a sharp gouge an aperture of considerable size should be made along the space between the two fingers. A serious objection to this operation is the almost certain injury of the pulley attachment of the superior oblique muscle and the production thereby of distressing diplopia. 2. A more satisfactory procedure, after exposing the bone by making an incision through the shaven eyebrow, is to open the cavity through the external table of the vertical portion of the frontal bone—that is, through the forehead. After the tissues have been raised and turned back sufficiently to expose the bone, the cavity is best entered just above the mesial or inner extremity of the supra-orbital margin, and slightly lateral from the median line of the forehead. On account of the very great variations of the shape and size of the sinus the safest procedure is to open its outer wall by a small drill run by an electric motor and controlled by a foot-switch, though the mallet and chisel are much used. The sinus can be explored with a probe through this opening and the relations of its walls and its size determined. Then a button of bone may be removed by a trephine, or a larger drill may be used, or the mallet and chisel. Care should then be exercised in securing a large opening into the nasal fossa in the same manner as indicated in the operation through the orbital surface. This operation not only avoids the possibility of injuring the superior oblique muscle, but facilitates direct inspection and treatment of the sinus.

Lothrop's observations on the cadaver have demonstrated—and the demonstration can be verified by any experienced anatomist in the dissecting-room—that it is impossible to pass a probe from the nose through the infundibulum into the frontal sinus in the majority of subjects. Much more difficult is the procedure in the living subject. In many cases the frontal sinus can be catheterized when free access to the infundibulum is secured by amputating the anterior end of the middle turbinal. The care with which catheterization of the frontal sinus should be carried out is best emphasized by citing the case recorded by Mermod, an experienced rhinologist. He observed a case in which a watery fluid was escaping from one nostril, and judged that it came from the corresponding frontal sinus. The attempt at catheterization induced so much pain that he was compelled to desist. The patient died some days later, and an autopsy showed the entire absence of any frontal sinus. The watery fluid which escaped through a small opening in the floor of the anterior cranial fossa was probably

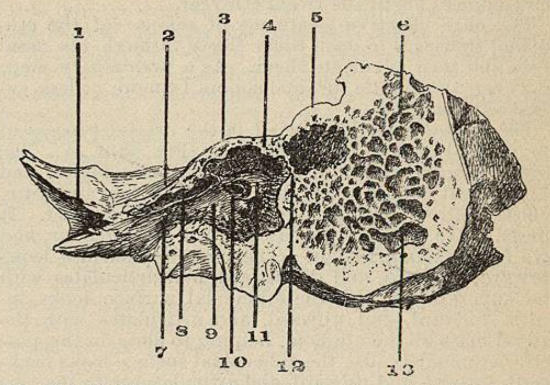


FIG. 4315.—Tubotympanic Pneumatic Cavity and Mastoid Sinuses, shown by removal of outer boundaries of the petromastoid portion of the temporal bone. 1, Carotid canal; 2, tegmen tympani over tube for tensor tympani muscle; 3, tegmen tympani over attic; 4, part of external wall of antrum; 5, tegmen tympani over antrum; 6, mastoid cells; 7, Eustachian tube; 8, processus cochleariformis; 9, promontory in atrium; 10, foramen ovale; 11, external horizontal semicircular canal; 12, part of external wall of antrum; 13, mastoid cells.

cerebrospinal fluid. Pyogenic infection was doubtless carried within the cranial cavity, although every antiseptic precaution had been observed in attempting to catheterize the supposed frontal sinus.

The *ethmoidal sinuses* (Fig. 4314, *5* and *6*) are placed between the cavities of the orbit and the supero-lateral part of the nasal fossæ, being separated from them by thin and papery walls. These pneumatic spaces are completed by the ethmoids articulating with the sphenoidal turbinate, palate, frontal, lachrymal, and superior maxillary bones.

The thin partitions are frequently absent at various points. For instance, some of the ethmo-maxillary septa may be absent, thus permitting the ethmoid cells to communicate directly with the maxillary sinus, as already mentioned; again the ethmo-frontal (orbital plate) partitions may be deficient so that a direct communication may exist between ethmoid cells; and, finally, a large sinus is sometimes present between the two walls of the orbital plate and extends well back toward the optic foramen.

The sinuses are separated into two groups by thin bony septa—an anterior and a posterior group. The anterior and sometimes a middle group of cells open either independently or through the ethmoidal infundibulum into the upper part of the hiatus semilunaris, and therefore into the middle meatus of the nasal fossa; the posterior ones open into the superior meatus. Ordinarily the ethmoidal cells are separated from the orbital cavity by the thin plate of bone called the *os planum*. Occasionally, as a result of arrest of development and in old people, the os planum may be defective in parts and the sinuses are then separated from the orbit only by membrane. A study of horizontal and coronal sections will disclose the fact that the pneumatic spaces increase in size from above downward, and from before backward.

The anterior ethmoidal cells ordinarily communicate, through the infundibulum, with the frontal sinus; occasionally they communicate directly with the maxillary sinus. The posterior ethmoidal cells occasionally communicate with the orbital sinus, and may through the latter communicate with the sphenoidal sinus or the antrum of Highmore, or with both the latter.

The ethmoidal cells, on account of their irregular and complicated anatomical features and the importance of their topographical relations, deserve very careful study,