external auditory meatus is formed by the outgrowth of the tym­panic ring (fig. 9, *a*) which is probably part of the first visceral arch (see Skeleton, *Visceral)* ; the squamozygomatic part is a dermal bone, while the styloid process is a part of the second visceral arch.

The mastoid process is not present at birth, but appears about the second year and becomes pneumatic about puberty. From what has been seen of the skull bones in the above necessarily concen­trated and abridged account, it is obvious that they do not corre­spond to the traces of segmentation as indicated by the cranial nerves, and for this and other reasons the “ vertebrate theory of the skull ” is no longer believed in.

For further details and references see Quain’s *Anatomy* (London, 1908); Cunningham’s *Anatomy* (Edinburgh, 1906); *The Develop­ment of the Human Body,* J. P. McMurrich (London, 1906).

*Comparative Anatomy.*

In this section only those parts of the skull which form the covering for the brain and the capsules for the olfactory and auditory apparatus are considered. Those parts of the face and jaws which are developed in connexion with the visceral arches are dealt with in the article Skeleton *(Visceral).* In the Acrania (Amphioxus) the enlarged anterior end of the nerve cord is merely surrounded by fibrous tissue continuous with the sheath of the rest of the nerve cord; there is therefore, in a sense, no true cranium.

In the Cyclostomata (hags and lampreys) a cartilaginous cranium is developed, the anterior part of which forms an unpaired olfactory capsule connected with the rest of the cranium by fibrous tissue only. In the floor, just in front of the anterior end of the notochord, an aperture, the *basi-cranial fontanelle,* remains unchondrified for the passage of the pituitary diverticulum into the skull.

In the Elasmobranchii (sharks and rays) and Holocephali (Chimaera) among the fishes the skull is still a complete cartilaginous ’box, though calcification of the cartilage often takes place. Taking the skull of the dogfish as a type, two large olfactory capsules are seen in front, and behind these the cranial brain-box is narrowed, being excavated at its sides for the great orbits. More posteriorly the auditory capsules widen the skull, and on the posterior (caudal) aspect the foramen magnum is seen with an occipital condyle on each side of it for the first vertebra to articulate with. On the upper (dorsal) surface of the skull are two apertures in the middle line; the more anterior of these is sometimes called the *anterior fontanelle,* though it has nothing to do with the bregma, described in man’s skull, but forms a rudimentary median orbit for the pineal eye (see Brain). The posterior fontanelle is a depression which leads into two lateral tubes, each of which passes into the auditory capsule and is known as an *aqueductus vestibuli* (see Ear).

In the cartilaginous ganoid fishes (sturgeon), which, like the elasmobranchs, are of great antiquity, the chondro-cranium is partly ossified so that ali- and orbito-sphenoids are found; in addition to this a large number of dermal bones have made their appearance, such as *nasals, frontals, parietals, supra* and *post tem­porals,* while in the roof of the mouth and pharynx a long membrane bone, the *parasphenoid,* is formed, and lies ventral to and strengthens the cartilaginous base of the skull. It will be noticed that these fish are important morphological landmarks, because in them the almost unchanged chondro-cranium coexists with a dermal ecto­cranium.

In the bony ganoids such as the “ bow fin ” (Amia) the dermal bones are still more numerous and, among others, squamosals, pro- otics and exoccipitals appear. These fish are also remarkable for a fusion of the anterior part of the vertebral column with the occipital region of the skull, an arrangement recalling Froriep’s observations on the skull of the calf embryo mentioned in the section on em­bryology.

In the bony fishes (Teleostei) the membrane or dermal bones are still more numerous, and many of them are unrepresented in the mammalian skull, while others, which are there quite rudimentary, are very large. The chondro-cranium tends to disappear in the vault, but the base is fully ossified. Among other cartilage bones the five ossifications of the auditory capsule are seen, the pro-, epi-, opisth-, pter- and sphen-otics, all of which are found as centres of ossification in man. In the cod, for example, the sphenotic, which is represented in man by the little lingula sphenoidahs, is larger than the alisphenoid.

In the Dipnoi (mud-fish) the chondro-cranium is very slightly ossified, only exoccipitals being found, but there is the same coales­cence with anterior vertebrae which was noticed in the ganoids. Dermal bones are plentiful.

In the Amphibia the chondro-cranium persists and is only ossified in front by the girdle bone or sphenethmoid, and behind by the pro- otics and exoccipitals, the latter of which bear the two condyles. The anterior fontanelle is well marked in the chondro-cranium, but is completely overlaid and concealed by the dermal fronto-parietals. The membrane bones though large are much less numerous than in the bony fishes.

In the Reptilia the skull varies immensely in the different orders, but speaking broadly, the chondro-cranium is less distinct than in the Amphibia, except in the ethmoidal region. In the base of the skull the basioccipital and basisphenoid are tending to replace the membranous parasphenoid, and instead of two exoccipital condyles only one in the mid line is present, though this in many forms *(e.g.* Chelonia) consists of three parts, a median borne on the basioccipital and two lateral on the exoccipitals. The parietal foramen is usually definitely marked in the dermal part of the skull and forms a median orbit for the pineal eye; this is especially the case in the Lacertilia (lizards). Except in the Ophidia (snakes) and Amphisbaenidae (worm-like lizards) there is a fibro-cartilaginous septum between the orbits so that the cranial cavity does not reach forward to the ethmoidal region. The pro-, epi- and opisth-otic bones are all developed, but the epiotic usually fuses with the supra-occipital and the opisthotic with the exoccipital.

In the Crocodilia the first attempt at pneumaticity is seen in the basisphenoid, which is traversed by a complicated system of Eus­tachian passages leading eventually to the tympanum. In the class Aves the general scheme of the reptilian skull is maintained, though the bones fuse together very early, thus obliterating the sutures between them. Almost all of them have air in their interior, and so are said to be pneumatic.

The single occipital condyle, if looked at in a young specimen, is seen to consist of a basioccipital and two exoccipital elements, though these are indistinguishable in the adult. The parasphenoid is represented by a broad plate which is called the basitemporal. The pro-, epi- and opisth-otic bones fuse together to form the auditory capsule.

In the Mammalia the calvaria varies considerably in the different orders, the characteristic features being best marked in adult males. Usually the different bones are interlocked by sutures, as in man, until adult life, but in some orders *(e.g.* Monotremata, Edentata and Carnivora) they fuse together quite early.

In the basicranium the cartilage bones presphenoid, basisphenoid, and basioccipital, are so well developed that the parasphenoid has disappeared. In the basisphenoid of the rabbit the cranio-pharyn- geal canal (see section on embryology) persists as a foramen at the bottom of the pituitary fossa. In the lower orders the face lies well in front of the brain case, as it does in reptiles and amphibians, but as the Primates are reached the increasing size of the calvaria causes it to overlie the face. Many of the bones are pneumatic, the process reaching its maximum in the elephant and the adult male gorilla. The periotic capsule blends with the squamosal and tympanic to form the petrous bone, though it is practically only in man that the second visceral arch ossifies on to this as a styloid process. There are usually two occipital condyles which have basi- and exoccipital elements, though there are many mammals in which there is one large crescentic condyle surrounding the anterior half of the foramen magnum.

Ossification of the processes of the dura mater occurs in the tentorium cerebelli of the carnivora and in the falx cerebri of the ornithorhynchus and porpoise. The orbits are in most mammals continuous with the temporal fossae. Sometimes, as in many of the ungulates and in the lemurs, they are outlined by a bony ring, but it is not until the higher Primates are reached that the two cavities are shut off and even then a vestige of their original con­tinuity remains in the spheno-maxillary fissure.

For further details see W. H. Flower, *Osteology of the Mammalia* (London, 1885) ; S. H. Reynolds, *The Vertebrate Skeleton* (Cambridge, 1897); R. Wiedersheim; C. Gegenbaur, *Vergleich. Anat. der Wirbelthiere* (Leipzig, 1901). . (F. G. P.)

Cranial Surgery

*Surgery of the Skull.—*Fractures of the vault of the skull may occur without the bone being driven in to compress the brain, and in such cases their existence may be revealed only after death. But if there is also a severe scalp wound the line of fracture may be traced in the bare bone as a thin red crack. “ Think lightly,” said the old physician, "of no injury to the head.” The patient with a suspected fracture of the skull is put to bed in a dark, quiet room, and he is watched. It may be that the crack has extended across a bony groove in which an artery is running, and, the artery being torn, haemorrhage may take place within the skull and the symptoms of compression of the brain may supervene. Experiments upon the lower animals have taught the surgeon how to recognize the exact spot at which the compression is situated. One set of muscles after another being thrown out of work in regular order, he knows exactly where the bleeding is going on, so, having made a hole in the skull by trephining, he turns out the clot and secures the leaking vessel.

Compression of the brain may be the direct and immediate result of a head-injury, a piece of the vault of the skull being driven in, and a local or a general paralysis of muscles being at