III - Historical Resume.

The history of the development of chondrocranium is not very old. It was E. Arendt in 1822 who for the first time recognised the cartilaginous skull in the pike. It was left for Huxley (1853) to name this cartilaginous skull as "Chondrocranium". He demonstrated that the bony skull in all animals is preceded by a solid and unsegmented cartilaginous chondrocranium.

**Trabeculae cranii**: Rathke (1839) was the first to recognise the trabeculae cranii in the grass snake. Trabeculae cranii have been regarded by Huxley (1874-75), Parker (1879), Platt (1897), Swinnerton (1901) and Allis (1931), as belonging to the visceral arch skeleton pressed into the service of the brain case. Allis (1923-25-31) further supported Huxley and indentified the trabeculae as the pharyngeal emements of the premandibular arch. De-Beer (1937) considers it 'an excess of refinement' to distinguish pharyngeal elements in trabeculae. According to him the participation of premandibular arch in the formation of the floor of the skull preceded the segmentation of the visceral arches into their elements.

Three vertebrate groups call for special mention in connection with their trabeculae: the Ophidia, the Chelonia and the Mammalia. In the Ophidia the trabeculae are very long and close together, and the curious feature is that
they do not fuse to form a trabecula communis, but remain separate except at their extreme front end. Among the Chelonia, Chelone and Dermochelys possess a taenia intertrabecularis which divides the hypophysial fenestra sagittally into two, between the trabeculae. The placental mammals are characterised by the possession of a median central stem, laterally to the hinder part of which the internal carotid arteries enter the cranial cavity; in all other forms these arteries run medially to the trabeculae. The mammalian condition is explained by the Monotremes and a series can be traced passing through non-mammals, monotremes, marsupials and placental mammals. The hypophysial plate develops first, medially to the internal carotid arteries as the central stem, much resembling the chelonian taenia intertabecularis, and it may arise from paired centres of chondrification (improperly called polar cartilages) to which the term hypophysial cartilages should be applied. The true polar cartilages and hind ends of the trabeculae are delayed in their appearance and are represented by the alicochlear commissure which are situated laterally to the internal carotid arteries and medially to the palatine nerves. The objection raised by Voit (1909) to the homology of the alicochlear commissure with the trabecula, on the grounds that in Lepus the internal 'carotid artery enters the cavum epiptericum and lies (topographically) laterally to the abducens nerve and that therefore the mammalian
carotid and its foramen are not homologous with their namesakes in lower vertebrates, is not valid. Gaupp (1910) has drawn attention to the fact that in other mammals the carotid does not traverse the cavum epiptericum, and yet the artery and its foramen are clearly the same. In Lepus the cavum epiptericum bulges medially, which accounts for the course of the artery through it. The same is presumably the case in Perameles. The difference between the placental mammal and other vertebrates in respect of the trabeculae is therefore not fundamental but the result of heterochrony in development as regards the lateral trabecular and polar cartilages and the median hypophysial plate and of a migration towards the side on the part of the internal carotid artery. The anterior parts of the trabeculae in placental (and other) mammals are of course fused and merged in the inter-orbitonasal part of the central stem.

Parachordals: Huxley (1874) was the first man to call the basal plate of the chondrocranium as the parachordal cartilages. Parachordals have been demonstrated throughout the vertebrate series from Cyclostomes to man and there is no question about their homology. In nearly all cases the parachordals are of paired origin, the subsequent fusion to form a median basal plate being secondary.

Group variations have been noted as follows:
(a). The condition of parachordals at their earliest chondrification has been:
(8)

(1) Parachordals lie closely apposed to notochord their lengthwise (Urodela, Anura and Mammalia).

(ii) The anterior ends of the parachordals diverge away from the notochord leaving a basicranial fenestra at early stages (Selachii, Teleostomi, Reptilia and Aves).

(iii) Parachordals fail altogether to touch the notochord at their first appearance (Protopterus).

A possibility of chondrification of the parachordals from more than one centre on each side has also been mentioned. Moreover in those cases where polar cartilages do not appear as separate chondrifications, it has been suggested that they arise as already fused with the anterior ends of the parachordals. It is true in Scyllium, Acipenser and possibly in Teleostei.

(b). It has been noted that the parachordals extend backwards and get fused with vertebral elements, thus lengthening their size. This has led to the question as to how much of the parachordals may be regarded as representing segmental vertebral elements free in previous phylogeny. In Scyllium the three pairs of hypoglossal nerve foramina indicate the presence of occipital and preoccipital arches in segments 5 to 7 inclusive (G Goodrich, DeBeer). In Urodeles the pre-occipital and occipital arches correspond respectively to segments 5 and 6 (Goodrich). The occipital arch of Anura
seems to correspond to segment 5 (van Geetars 1922). So it is evident that, that portion of the parachordals which lies in or behind segment 5 may be regarded as representing originally (phylogenetically) free vertebrae; there is no evidence of the existence (in ontogeny or phylogeny) of free vertebrae in front of segment 5. This conclusion is further supported by the facts that in Cyclostomes the parachordals occupy only the first 4 or 5 segments of the head and that the anterior ends of the parachordals in all cases are separated from the notochord indicating absence of vertebral nature.

(c). There is great variation in the position of notochord, when the basal plate has been completely formed. In Cyclostomes, Selachii, Holoccephali, Acipenseroidae and Dipnoi the notochord persists in the adult but in the remainder cases the notochord is either reduced and restricted to the hinder region of the basal plate (Polypterus) or partly chondrified by notochordal cartilage (Anura, Urodela) or completely destroyed (Mammals). A

The following variations have been noted:

(i) In Amia and Teleostei the notochord persistently separates the parachordals from one another at least in the hind region.

(ii) In Selachii, Polypterus and Dipnoi, the parachordals fuse with one another both above and below the
notochord.

(iii) In Holoccephali, Lepidosteus, Urodela, Gymnophiona and Lacertilia, the notochord or what remains of it lies dorsally to the basal plate, the parachordals having fused beneath it.

(iv) In Anura the notochord lies beneath the basal plate having been extended from it by the fusion of the parachordals above the notochord.

(v) In Mammals alone there is great variation as shown by Tourneux and Tourneux (1907, 1912) and by Bolk (1922). The notochord may run dorsally, ventrally or embedded in the basal plate. Levi (1909) has attempted to use the position of the notochord as a criterion for determining whether the parachordals represent vertebral pleurocentral or hypocentral elements, or both. DeBeer (1937) points out here that these variations reflect nothing but the different time relations of the process whereby the notochord at very early stages becomes separated off from the notochord plate of the foregut, and are of little value for the estimation of phylogeny and affinity.

(d). Allis (1928) denies the homology of the acrochordal (prootic bridge), in the different vertebrate groups and claims that there are two distinct transverse cartilaginous
bars at the front of the basal plate; the commissura acrochordalis in the premandibular segment (preparachordial) and commissura transversa in the mandibular segment (parachordal). Consequently he distinguishes two different morphological vacuities instead of a single basicranial fenestra. These Allis calls the (i) fenestra prootica medialis (Squalus, Acipenser, Polypterus, Amia and Lepidosteus) behind his commissura acrochordalis and transversa and (ii) the fenestra mesotica medialis (Salmo, Amiurus, Syngnathus and Lacerta) behind his commissura transversa. DeBeer (1931) does not agree with Allis on the ground that unless both the bars or fenestrae are shown in the same animal, the conclusions of Allis cannot be taken as final.

The Occipital Arches: The parachordals in all vertebrates except the Cyclostomes, project behind the auditory capsules and bear a number of neural arches. The hindmost of the neural arches is known as the occipital arch while the preceding ones are known as the preoccipital arches. In some cases (Acipenser, Amia, Lepidosteus, Ceratodus and Birds), a few vertebrae get fused with the occipital arches later and these have been called occipitospinal arches by van Wijhe (1922). The single product of fusion of the preoccipital, occipital and occipitospinal arches has been called by deBeer (1937) as the definitive occipital arch as there is no morphological difference between them.
Excepting Birds and Placental mammals where the occipital arches lean backwards, in the rest of vertebrates they are upright. The occipital arches may be free dorsally (Chelonia or Anas) or interconnected by a tectum posterius which may be merged with a tectum synoticum. The occipital arches may bear transverse processes or ribs which have assumed different names in different animals:

- Cranial ribs
- Metotic Cartilage
- Subcapsular process
- Paracondylar process

\[ \text{Acipenser and Ceratodus, } \text{Birds, } \text{Crocodilus, } \text{Mammals.} \]

**Cranio-Vertebral Joints:** In those cases where the notochord persists wholly or partially, there is no question of such a joint (Cyclostomes, Selachii, Acipenseridei and Dipnoi). The first example of a definite cranio vertebral joint is found in Batoid Selachii and in Holocephali where the centrum and base of the Ist. vertebra articulates with the basal plate and base of the occipital arch. This joint is intervertebral and hence intrasegmental. In Amphibia the interdorsal cartilages split, the cranial portion forms the occipital condyle of the skull and the caudal portion forms the socket on the anterior face of the atlas vertebra. Thus the joint is intravertebral. The cranio-vertebral joint in Sphenodon, Lacertilia, Ophidia and Mammals is intravertebral and intersegmental while in Chelonia, Crocodilia and Birds, it is intervertebral and intrasegmental.
Side wall of the Neurocranium: Two modifications are met with, one is regarding the formation of an interorbital septum and the other is regarding the loss of pila antotica. There has been a great controversy over the origin of the interorbital septum. Gaupp (1898) regards their formation from the preoptic roots of the orbital cartilages (Holoccephali and Teleostei). In Salmo the septum is formed anterior to the brain (olfactory nerve traverses the orbit) and in Gadus, ventral to the brain (olfactory nerve does not cross the orbit). In Gynnarchus, Cypraniformis and living Amphibia, there is no interorbital septum, but this is a secondary condition due to its loss. In Reptiles (except Ophidia) and Birds (except Apteryx) the interorbital septum is greatly enlarged. Others who regard interorbital septum a new structure, quote the example of Mammals where the internasal septum appears to be merely a posterior extension of the internasal septum.

Formation of a posterior myodome involves the disappearance of pila antotica and pila metoptica (Teleostomes), but if the myodome is lost they are reformed (Polypterus, Acipenser and Lepidosteus). In Amia the orbital cartilage is supported posteriorly by pila lateralis. In Ophidia the orbital cartilage and pillars are lost. In Mammals the orbital cartilage, preoptic root and pila metoptica are well developed but the pila antotica (taenia clinoorbitalis) is preserved only in Monotremes. There is no need of pila
antotica in Marsupials and Placentals as there is developed the ala temporalis (processus ascendens of the pterygoquadrate cartilage). Prefacial commissure is a constant structure from Selachii to man (in Mammals known as Suprafacial commissure). In Teleostomes lateral commissure duplicates the side wall formed by prefacial commissure while in Teleostei the prefacial commissure is lost. In mammals the side wall of the neurocranium is duplicated by the tegmen tympani, processus opercularis and parietal plate.

The basitrabecular (basipterygoid) process is a lateral projection of that hindmost portion of the trabecular bar which is formed of the polar cartilage when that element chondrifies independently. It always lies ventrally to the head vein and anterodoroally to the palatine nerve and typically makes contact with the basal process of the pterygoquadrate, with which it may articulate movably or undergo cartilaginous fusion. In Selachii it is represented by a portion of the subocular shelf; in Teleostomes it contributes to the formation of the lateral commissure; in Dipnoi and Urodele it is difficult to identify its existence; in Anura it is lost; in Reptiles and Birds it is well developed and forms the basipterygoid process; in Mammals it is recognised as the processus alaris (Hannover 1880).

Roof of the Chondrocranium: The roof is complete and massive in Selachii, Holocephali, Acipenser, Amia, Lepidosteus,
Ceratodus, Chelonea (Dermochelys) and Ornithorhynchus.

Cyclostomes have no roof; Polypterus possesses a roof only of epiphysial cartilage and tectum synoticum; Teleostei (Norman 1926) range from complete roofing (Cyclopterus) to one with only tectum synoticum (Syngnathus). Among Amphibians, Urodeles possess only tectum synoticum, Gymnophiona possess no roof, while Anura possess tectum transversum, tectum synoticum and taenia tecti medialis. In Reptiles and Birds, the roof is reduced to tectum synoticum (Lacerta possess tectum posterius also). In Mammals because of the presence of parietal plate and supraoccipital cartilages, the tectum posterius and synoticum cannot be distinguished (Levi 1909).

Nasal Capsules: The condition of nasal capsules in Petromyzon and Myxine (Cole 1905) shows that originally they were separate from the brain case. In Gnathostomes, the nasal capsules are fused with the brain case.

Primitively the nasal capsule has no floor but a rudiment of it is seen in the trabecular horns which are free in Selachii but in Tetrapoda become joined to the side wall of the capsule to form lamina transversalis anterior separating the fenestra naria in front from fenestra basalis behind. The fenestra basalis is narrowed in Urodela, Lacerta, Sphenodon and Chelonia by the development of ectochoanalis from the lamina transversalis anterior. In Ophidia the ectochoanalis
is independent and is known as hypochoanal cartilage. In Mammals a false palate develops which carries the secondary choana far back and the position of primary choana is marked by the Stenson's duct of the Jacobson's organ (Gaupp 1908). In some Mammals the floor is further developed by a median unpaired cartilago papillae palatinae which develops beneath the nasal septum (Wilson 1901, Broman 1920). In some case the ventral edge of the hind wall is bent forwards forming the lamina transversalis posterior.

Lamina transversalis anterior lies anterior to external nostral in Dipnoi while it is not formed at all in some Aves and higher Primates (Fret 1914, Virchow 1914). In Polypterus and Acipenser, the nostril apertures are in the side wall of the capsules which possess well developed walls, floor and roof. In Holosteii and Teleostei on the other hand, the nostril apertures are on the dorsal side of the snout and the nasal capsule has neither floor nor side walls and is nothing more than a fossa with a hind wall (lamina orbitonasalis), medial wall (nasal septum) and floor (trabecular or ethmoid plate).

The foramen through which the olfactory nerve enters the nasal capsule (foramen olfactorium advehens) is not the same as that through which the olfactory nerve leaves the cranial cavity (foramen olfactorium evehens).

Auditory Capsules: Van Wijhe (1906) has put forth a hypo-
thesis that the auditory capsules have arisen because of providing a rigid anchorage to the ear. The auditory capsule always arises by an independent centre of chondrification and it is later that it becomes attached to the parachordal plates. The commissures by means of which the auditory capsule is attached to the parachordal of its side were termed basicapsular by Gaupp (1900). There are two basicapsular commissures; the anterior basicapsular commissure situated behind the facial nerve and the posterior basicapsular commissure situated between the glossopharyngeal and vagus nerves (Polypterus, Acipenser, Amia, Lepidosteus, Gymnarchus, Ammurus, Anguilla, Solea, Cadus, Ceratodus and Salmo). In other Teleosts, however (Gasterosteus, Syngnathus, Clupea) and in Amphibia the posterior basicapsular commissure lies in front of the glossopharyngeal nerve and thus has the relations of the basivestibular commissure of Amniota. The basicapsular fenestra (or basicochlear fissure) is a space bounded anteriorly by the anterior basicapsular commissure and from the sides by the auditory capsule and the parachordals. The posterior boundary is formed either by the basivestibular commissure or by the posterior basicapsular commissure (in the later case a part of the fenestra metotica which transmits the glossopharyngeal nerve is confluent with the basicapsular fenestra). W. K. Parker (1871), Stohr (1881), and Gaupp (1906) regarded the basicapsular fenestra as the equivalent of the fenestra ovalis (or vestibuli) becoming obliterated in fish but
persisting in Tetrapoda. DeBeer (1937) does not agree with this view.

The facial nerve never traverses any part of the cavity of the auditory capsule and passes out in front of it. Similarly the glossopharyngeal nerve never traverses any part of its cavity and passes out behind the capsule.

The relations of the auditory capsule to the basal plate present no difficulty in the lower vertebrates where the two structures are visibly distinct in origin. In Amniota, the cochlear capsule which projects into the territory of the basal plate was thought by Gaupp (1900) to be formed from the basal plate but Noordenbos (1905) has clearly shown that it is an extension from the auditory capsule.

The term foramen perilymphaticum is applied to the posterior opening in the wall of the auditory capsule of Tetrapoda, through which the ductus perilymphaticus leaves the cavity of the capsule and enters the recessus scalae tympani. Gaupp (1900) regarded the fenestra rotunda and aquaeductus perilymphaticus as the product of subdivision of the foramen perilymphaticus, but it is shown by deBeer that they are not its equivalent. DeBeer (1929) substituted the term processus recessus for foramen perilymphaticum.

Sclerotic Cartilage: The sclerotic cartilage develops in the connective tissue surrounding the eyeball and Gaupp (1906) regards it as a part of the chondrocranium. The
sclerotic cartilage is free and movable. It is interesting to note that the primitive vein of the head passes between the sense capsule and the primitive side wall of the skull, represented by the dura mater. Thus, the vena capitis medialis runs medially to the auditory capsule for as long as it exists; the orbital sinus is medial to the sclerotic, and the orbitonasal vein passes medially to the lamina orbitonasalis. The distribution of the sclerotic cartilage has been studied by Stadtmüller (1914). A sclerotic cartilage is present in all groups of vertebrates except: Cyclostomes, Siluroid, Teleosts, Anguilla, Gymnophiona, Marsupial and Placental Mammals.

**Visceral Arch Skeleton:**

(a) **Skeleton of the Branchial Arches:** Gaupp (1905) has reviewed the development and morphology of the branchial arches so thoroughly that very little has been added after him. The question which is unsettled is regarding the median copulae or basibranchials. Gegenbaur (1872) first regarded them as elements between the bases of the branchial arches but later on he came to regard them as derived from the bases of the branchial arches in front of them. This is more probable and as is shown by Gibian (1913) and Stone (1926).

During the course of evolution the function of the hyobranchial apparatus changes from supporting gill arches between open gill-slits to surrounding the larynx and the front of the trachea and supporting the tongue. This is
correlated with the tendency towards reduction in the number of arches as is evident from the following:

- Cyclostomes ... large number of branchial arches.
- Heteranchiids ... 9 pairs of branchial arches.
- Chlamydoselache ... 7 "
- Ophidia & Birds ... 1 "
- Mammals ... 3 "

Similarly there is a tendency towards reduction in the number of pieces into which each arch is segmented.

- Fishes of all groups ... 4 elements in each branchial arch (pharyngo -, epi-, cerato-, and hypobranchial).
- Higher Vertebrates ... 2 elements in each branchial arch (epi-, and ceratobranchial)

Two problems have cropped up:

(i) Should the segments of the arches of higher vertebrates be regarded as homologous with those of fish?

(ii) Whether the primitive condition of the branchial (or visceral) arches was segmented as in fish or unsegmented as in Cyclostomes.

Regarding the first problem Gaupp (1905) and Buni (1909) are very doubtful and regard that segmentation has evolved in the two cases quite independently. Braus (1905) and van Wijhe (1904) have considered the second problem and they have
found that in all fishes branchial arches chondrify independently in a continuous mesenchymatous rudiment but Gaupp (1905) maintains that evidence of embryology cannot be applied to phylogeny.

Branchial arches in a fish are independent of the neurocranium and this is a primitive feature. The splanchnocranium is phylogenetically older than the neurocranium as is evident from the fact that splanchnocranium is present in Balanoglossus, Urochordata and Amphioxus where skull is absent.

(b). Labial Cartilages: The history of these cartilages in various vertebrate groups is given below:

Selachii - Two dorsal pairs in the upper jaw and one ventral pair in the lower jaw.

Holocephali - Some of the cartilages which surround the nasal apertures and mouth, may represent labial cartilages (W.K. Parke).

Teleostomi - Three pairs of cartilages:

(i) Premaxillary cartilages (Norman 1926)
(ii) Maxillary cartilage (Sagemehl 1891)
(iii) Labial cartilages (Lower labials).

Siluroidea - One or more of these cartilages may be elongated and support barbel.

Dipnoi - A subnasal cartilage and 2 pairs of lower labials one of which fuses with Meckel's cartilage.
Labial cartilages have been homologised with anterolateral and posterolateral cartilage of Cyclostomes by Sewertzoff (1916) while Pollard (1895) maintains that they are equivalent to the oral cirri of *Amphioxus* and *Palaeospondylum* (Bulman 1931).

(c) Hyoid Arch Skeleton: In Selachii the hyoid arch is composed of two elements, the hyomandibula and ceratohyal. Each branchial arch consists of our elements. This raises an important question as to whether the hyoid arch was even divided into four elements. In some animals it has been found that more than two elements are present in the hyoid arch. Thus a hypohyal is present in *Heptanchus*, Teleostomi, Urodela, Lacertilia and Iepus (deBeer 1930, Woodger 1930) and a pharyngo-choyal is present in Holocephali, *Stegostoma*, *Mistelus* and *Galeus* (deBeer 1935). Gegenbaur (1870) regards the hyomandibula of Selachii to correspond with the ephihyal element. The autostylic condition of Holocephali is primitive and the hyostylic conditions of Selachii and Teleostomi have evolved independently of each other. This fact is supported by the peculiarities in the hyoid arch skeleton of Teleostomes given below:

1. The dorsal element sometimes chondrifies in two portions a dorsal hyomandibula and a ventral symplectic, which may remain separate (*Acipenser*) or fuse to form a single hyosymplectic (*Salmo*) or it may chondrify as a single hyosymplectic (*Polypterus*, *Amia*, *Gasterosteus*, *Anguilla*).
(11) The dorsal end of the hyomandibula articulates with the wall of the auditory capsule laterally and dorsally to the head vein.

(iii) The contact between the ventral end of the hyosymplectic or symplectic and the mandibular arch takes place ventrally to the ramus mandibularis internus facialis i.e. this nerve runs dorsally to the quadratosymplectic ligament to the medial side of the pterygoquadrate cartilage, and thence to the medial side of Meckel's cartilage.

(iv) The hyomandibular branch of the facial nerve passes out either behind the hyomandibula (Acipenser) or through it (Amia, Lepidosteus, Salmo, and most Teleosteoi) or in front of it (Gadus) or forks round it, the ramus mandibularis in front and the ramus hyoideus behind (Polypterus).

(v) The ceratohyal is attached to the hyomandibula or hyosymplectic not directly but by the intermediary of an independent cartilage the interhyal (Stylohyal).

In Dipnoi and Tetrapoda, the dorsal end of the hyoid arch is forked. The medial prong forms the columellaauris or stapes (Schmahlhausen 1923) and lies ventrally to the head vein. The lateral prong forms the processus dorsalis or interhyal laterohyal or intercalary and lies lateral to the head vein and to the orbital artery when the latter runs over the columella auris. Schmahlhausen (1923) regards
Selachian hyomandibula as homologous with the medial (columellar) prong and Teleostome hyomandibula as homologous with the lateral (laterochyal) prong of Dipnoi and Tetrapoda. DeBeer (1937) in view of the above consideration, considers that the columella auris is the pharyngohyal and the laterohyal is the epihyal of the hyoid arch.

The basihyal or anterior copula raises some difficulty when it is found that in Scyllium and Mammals it betrays a paired origin while in Salmo, Amblystoma, Rana, Lacerta and Anas it reveals a median chondrification.

The so-called 'Urohyal' of Teleostei does not appear to form part of the hyoid arch skeleton at all, but to be a tendon ossification developed between the sternohyoid muscles. It appears to correspond to the Y-shaped 'parahyoid' of evidently paired origin formed in Polypterus.

(d) **Mandibular Arch**: The mandibular arch arises in the same manner as the other visceral arches. The same question arises here, whether this arch was originally segmented into four pieces like the branchial arch of fish (pharyngomandibular, epimandibular, ceratomandibular and hypomandibular). The pterygoquadrate and Meckel's cartilages are generally regarded as the epimandibular and ceratomandibular elements respectively. The pharyngomandibular element has been claimed by Sewertzoff (1923) to be present as a separate element in Scaphirhynchus and in Acipenser, while it gets fused later with the medial surface of the basal process of the pterygo-
quadrate in *Mustelus*, *Squalus*, and *Scyllium*. Allis (1923) considers polar cartilages to be the pharyngomandibulars which appears to be far fetched (deBeer 1937). As regards the hypomandibular element, it has been described by Sewertzoff (1927) in *Hexanchus* and by Jaekel (1927) in the fossil Acanthodes. In *Squalus*, Birds and in *Halicore* there are two centres of chondrification in Meckel's cartilage and this led van Wijhe to regard the distal end of the Meckel's cartilage as the hypomandibular element. In Holocephali, *Hexanchus* and others there is found a median basimandibular between the distal ends of the Meckel's cartilages. From the above account it is evident that mandibular arch also had four elements originally.

The coronoid process of Meckel's cartilage (*Amia* and *Lepidosteus*) is considered homologous with the posterior ventral labial cartilage of *Polypterus* by van Wijhe (1882). In Mammals the posterior portion of Meckel's cartilage becomes detached as the malleus and its retroarticular process in many forms, seems to have become the manubrium inserted in the tympanic membrane.

The pterygoquadrate cartilage has not four processes as described below:

1. **Basal Process**: Huxley (1876) regarded this process as the top end of the mandibular arch, and is directed towards the neurocranium.

2. **Otic Process**: It is directed towards the auditory
capsule.

(3) Ascending Process: It rises upwards from the pterygoquadrate cartilage anteriorly to the otic process.

(4) Pterygoid Process: It is a forward extension of the anterior end of the pterygoquadrate and the pterygoid processes of the two sides may fuse.

Relations of the Jaws to the Brain Case.

Huxley (1876) subdivided the types of suspension of the jaws into three categories: viz. amphistylic, hyostylic and autostylic. With the extension of knowledge, these three categories have further been subdivided and Gregory (1904) has made an attempt to classify them according to phylogenetic order. Gregory's scheme has been slightly modified by deBeer (1937) and below is given the final analysis of the relations of the jaws to the brain case in the chondrocranium.

Palaeostylic - Primitive ancestral condition; no relation between brain case (if present) and visceral arch skeleton e.g. Amphioxus.

Paraautostylic - foremost visceral arches fused to brain case: e.g. Cyclostomes.

Autostylic - the pterygoquadrate is articulated or fused with the brain case by its own processes without participation of the hyoid arch: e.g. Ancestral Elasmobranchs, Holocephali, Ancestral Osteichthys, Dipnoi, Amphibia,
-{27}-

Tetrapoda.

Autodiastlyc - autostylic forms in which the pterygoquadrate is apposed but not fused to the brain case; e.g. Ancestral Elasmobranchs and Osteichthyces, Tetrapoda.

Autosystylic - autostylic forms in which the pterygoquadrate is fused to the brain case by its own processes; e.g. Holocephali, Dipnoi, Amphibia.

Holostylic - peculiar autosystylic type found in Holocephali.

Amphistylic - condition combining autodiastlyc relations of the pterygoquadrate with suspensory function of the hyomandibula e.g. Henpranchias.

Hyostylic - pterygoquadrate suspended not by its own processes but by a hyomandibula articulated with the auditory capsule medioventrally to the head vein; e.g. most Selachii.

Methystylic - pterygoquadrate suspended not by its own processes (except ethmoid) but by a hyosymplectic or hyomandibula articulated with the auditory capsule dorsolaterally to the head vein; e.g. Teleostomi.