DISCUSSION
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For the sake of convenience, the discussion portion of the thesis has been divided into the following three parts:

1. Weberian apparatus 
2. Trunk vertebrae 
3. Caudal vertebrae.

1. WEBERIAN APPARATUS

(A) PARS SUSTENTACULUM

The Dorsal intercalaries

Matveiev (1929) describes the dorsal arch in *Scardinius erythrophthalmus* (Cyprinidae) to be double because he found separate basidorsals and dorsal intercalaries in the first three anterior vertebrae. In the posterior vertebrae, he regards the dorsal intercalaries to have fused with the basidorsals, thereby forming only one dorsal arch. According to him, the double condition of the dorsal arch in fishes is a primitive feature and has been lost in majority of Teleostei. He states further that in Cyprinidae there is a secondary recapitulation of the double condition of the arches in the anterior vertebrae due to the presence of a Weberian apparatus which delays the fusion of the dorsal intercalaries and the basidorsals. Ramanujam (1929) also reports the occurrence of the dorsal intercalaries in the first two vertebrae of *Clupea harengus*. However, Faruqi (1935) has
shown that Ramanujam's claim regarding the presence of dorsal intercalaries in anterior part of the vertebral column is based on his misinterpretation of facts. Watson (1939) has totally denied the existence of separate dorsal intercalaries at any stage of the development in *Carassius auratus*.

According to the present investigation also, the dorsal intercalaries are absent. These have not been found at any stage during the development of the vertebral column in the fishes studied inspite of the presence of Weberian apparatus in them. Even in *Rasbora daniconius* (Ham. Buch.), a fish belonging to the family Cyprinidae and in which a Weberian apparatus too is present, the dorsal arch is single throughout the length of the vertebral column.

**The Neural spine complex.**

Nusbaum (1881) has reported the presence of a dorsal cartilaginous mass at the anterior end of the vertebral column in *Cyprinus* and considers it to be a part of the skull. Matveiev (1929) describes in *Scardinius erythrophthalmus* the presence of a dorsal cartilaginous mass which is formed by the interspinous bones of the neural arches of the first three vertebrae. Watson (1939) also reports a dorsal cartilaginous mass in *Carassius auratus*. He disagrees with Nusbaum's view as he does not find any connection between the dorsal cartilaginous mass and the
skull. Supporting Matveiev's view (1929), Watson (1939) states further, that the interspinous bones along with the second, third and fourth basidorsals take part in the formation of the dorsal cartilaginous mass. The basidorsal of the first vertebra, however, forms a part of the scaphium.

According to Nookerjee, Ganguly and Nookherji (1952), the dorsal cartilaginous mass in *Esemus daniricus* is formed by dorsal portion of the neural arches of the first four vertebrae. Ramaswami (1955), while describing the skull and weberian apparatus in the subfamily Sobioninae, states that the large neural spine of the third vertebra is united with the second neural spine and the fused structure thus formed extends later on over the first vertebra.

A dorsal cartilaginous mass has also been found at the anterior end of the vertebral column in *Gasbora daniconius* (Ham,Buch.) investigated by the author. It is seen to be formed as an independent procartilaginous triangular arch on the dorsal side of the spinal cord and connected with the distal end of the third basidorsal in the 6 mm. long embryo of the fish. Later on, it becomes cartilaginous in 8 mm. long embryo and extends from the first vertebra up to the fourth vertebra. It lies attached with the distal end of the third and fourth basidorsals. The second basidorsals also join this structure at a later stage. The development of the
dorsal cartilaginous mass is, thus, similar to that described by Ramaswami (1955) who regards it as the fused neural spines of the region. Therefore, this dorsal cartilaginous structure has been termed Neural spine complex by the author. The location of the structure in the position of neural spines of the first four vertebrae and its attachment with their neural arches also lends support to the new term, the neural spine complex.

Tilak (1964) describes that the position and structure of the first six vertebrae varies in different siluroid fishes. In *Pseudotropius atherinoides*, *Nectropius navalchor*, *Silomia silondia* and *Clupisoma garve*, the fourth neural spine is strong and bifid. In *Ailia coila*, it is single. The fifth and sixth neural spines in *Pangasius pangasius*, *Nectropius navalchor* and *Pseudotropius atherinoides* are reduced in size. In *Clupisoma garve* and *Silomia silondia* these are, however, stout. In *Clarias magur* (Cuv. & Val.) also, the neural spines of the fourth, fifth and sixth vertebrae are separate and bifid.

Tilak (1964) also reports the absence of a neural spine complex in most of the siluroids studied by him. The neural spine complex has also been found to be absent in the development of the vertebral column in *Clarias magur* (Cuv. & Val.), a representative of the group Siluri studied
by the author. The neural arches of the first, second and third vertebrae of *Glaucias magur* (Cuv. & Val.) are, however, fused with the tectum posterius which is distinctly a part of the supra-occipital bone of the skull.

It is, thus, evident that the position and structure of the neural spines of the first six vertebrae is variable and a neural spine complex is absent in most of the families of the group Siluri. The absence of a neural spine complex in many Siluri appears to be a secondary feature, necessitated by the development of an osseous recesses in these fishes.

**The Sinus Imparis.**

Watson (1939) in *Carassius auratus* states that the spinal cord in the 11 mm. long embryo lies surrounded by a peculiar ring of cartilage which is continuous anteriorly with the cranial cartilage. The thickened base of this ring of cartilage is present between the notochord and the spinal cord and extends on either side of the latter so that in cross-section, the cavity appears to be semi-circular. This peculiar ring of cartilage develops independently of the rest of the first vertebra. In the skull it flattens out and forms the roof of the cavum sinus imparis. He has termed this cartilaginous ring as sinus imparis and regards it as a non-bony extension of the exoccipitals.
In the present study also, a somewhat similar tissue is present on the lateral and ventral sides of the hindbrain and the beginning of the spinal cord in the 6 mm. long and 7 mm. long embryos of *Raabura daniconius* (Hem.Buch.) and *Clarias magur* (Cuv. & Val.) respectively. This tissue is in the form of a thick fibrous band and is continuous with the sclerotomic cells surrounding the notochord. Developmentally, the fibrous tissue arises from an aggregation of mesenchymatous cells in the early stages of development. It has also been termed sinus imparis by the author in the present study on account of its resemblance with the similar structure mentioned by Watson (1939).

There are different views regarding the homology of the sinus imparis. It is considered to be a part of the skull (Musbaum, 1906), a perineural cartilage (Faruqi, 1935), a non-bony extension of the exoccipital (Watson, 1939), or a dorsal arch of the occipital vertebra (Hookerjee, Aitra and Kazumdar 1949). Hookerjee, Ganguly and Hookherji (1952) have discussed this structure in detail revealing that it is not an extension of the exoccipital bone in *Esomus daniricus*. They consider it to be a modified dorsal arch of the occipital vertebra which gets produced posteriorly to provide proper articulation between the skull and vertebral column. Hence, they called it a 'perineural tube.'
The sinus imparis, as observed by the author in Rasbora daniconius (Ham., Buch., and Clarias macropterus (Cuv. & Val.) develops only from a group of mesenchymatous cells. This grows gradually to form a thick fibrous tissue which lies on the ventral side of the hind-brain or the beginning of the spinal cord. In the skull, it flattens out to form the roof of the cavum sinus imparis which lies in close contact with the exoccipitals in later stages. The exoccipitals are seen to develop as membrane bones, independently of the sinus imparis which now becomes restricted between the exoccipital bone and the first vertebra.

It is, thus, quite evident that the sinus imparis arises as an independent structure much before the formation of the exoccipital bones. It is only the roof of the cavum sinus imparis which is connected with the exoccipital bones. The sinus imparis, therefore, is not an extension of the exoccipitals as stated by Watson (1939). As it is present inbetween the skull and the first vertebra, the sinus imparis represents a part of the cranio-vertebral joint. This is in accord with the view of Mookerjee, Ganguly and Mookherji (1952).

The Parapophyses of the first and second vertebrae.

The term transverse process has been widely used by many workers who called any lateral process of vertebra as transverse process.
The homologies of the transverse processes of the first and second vertebrae in fishes have aroused a great deal of controversy. Huber (1881), Grassi (1882), Hora (1922), Ohmanlov (1927), Sarbahri (1932) and Nelson (1949) regard the lateral processes of the first and second vertebrae arising from the centrum as transverse processes.

Watson (1939) mentions that the transverse processes of the first and second vertebrae in Carassius auratus are not homologous with the true transverse processes or the diapophyses as these proceed direct from the centrum and not from the neural arch. He homologizes them with the dorsal or upper ribs of the pike and other teleosts (Budgett, 1902; Goodrich, 1930) on the basis of similarity in origin and structure. Ramaswami (1955) describes the transverse processes of the first vertebra originating from the centrum and calls them the dorsal ribs.

Nockerjee, Bajulv and Rockherji (1952) consider the transverse processes of the first and second vertebrae in Asopus dainsicus as lateral processes.

It is, thus, quite clear from the above account that the transverse processes of the first and second vertebrae have been named differently by various workers and the variations centre round the term 'apophysis.' Owen (1866) defines apophysis as 'an outgrowth from some basal unit.' Gadow (1933) using the term apophysis in combination with
the prepositions like dia-, para-, hypa- outgrowths, described the diapophyses, parapophyses, hypapophyses on the basis of muscular attachments and skeletal articulations as follows:

The parapophyses are "short processes arising from the latero-ventral side of the centrum."

The diapophyses are "processes arising below the level of the zygapophyses from the neural arch or basiodorsals."

The ribs are lateral extension of some of the ventral arcualia which become further developed as short or long, horizontal or ventral outgrowths in the trunk and the tail regions respectively.

In the present study in Jasbora daniconius (Eam. Buch.), the so-called transverse processes of the first vertebra are present in the form of a pair of massive bony processes on the latero-ventral sides of the centrum. Developmentally, these structures are seen to arise independently as small bony processes in the 8 mm. long embryo on the latero-ventral side of the notochord to which these become fused soon. The basiventrals (ventral arcualia, are absent in the first vertebral region. The origin of these processes is, thus, different from that of the transverse processes or ruts of all other vertebrae of the body. It, however, resembles with that of the parapophyses of Gadaw (1933). Hence, the author
has termed these structures of the first vertebra as parapophyses. These are homologous to the transverse processes.

The transverse processes of the second vertebra in *Astrocion* *daniconius* (Tamb.] are absent altogether, an observation not reported by any worker so far in any cyprinoid fish. However, in *Clarias magur* (Cuv. & Val.), a silurid fish, the transverse processes of the first vertebra are absent and those of the second vertebra are present as bony wing-like structures on the latero-ventral sides of the centrum. The origin and homology of these processes is also similar to that of the parapophyses of *Astrocion* *daniconius* (Tamb.], described above and hence have also been termed accordingly.
The Transverse process of the fourth vertebra

There are several views regarding the homology of the transverse processes of the fourth vertebra in teleost fishes. Bridge and Haddon (1889) regard them as transverse process in silurid fishes. Chranilov (1927) also considers them as transverse processes on the basis of their attachment with the centrum.

Goodrich (1930) describes the transverse processes of the fourth vertebra developing between the transverse septa and the coelomic wall in Esox and Cyprinus and regards these as pleural ribs.

Watson (1939) also homologises the transverse processes of the fourth vertebra with the pleural ribs of the posterior vertebrae in Carassius auratus.

Sarba hi (1932) termed these processes as lateral processes in Labeo rohita.

Nookerjee, Ganguly and Nookherji (1952) described them as massive lateral processes arising from the basiventrals and forming the ossa suspensorium.

Tilak (1964, while describing the osteocranium and the Weberian apparatus in the fishes of the family Schilbeidae, considers these as parapophyses.
In the present investigation, small bony processes are present at the distal end of the fourth basiventrals, both in *Asbora daniconius* (Ham., Buch.) and *Clarisc magur* (Cuv. & Val.). These processes extend outwards and backwards. Developmentally these arise independently at the distal end of the basiventral as membrane bones and resemble the ribs. These structures are small in size and form characteristically an *ossa suspensorium* in *Asbora daniconius* (Ham., Buch.) and a portion of the osseous recesses in *Clarisc magur* (Cuv. & Val.). In order to differentiate the transverse processes forming an *ossa suspensorium* or an osseous recesses from those of the other vertebrae in which they are simple (called ribs), the processes on the lateral sides of the fourth vertebra have been termed transverse processes in the present study. The transverse processes of the fourth vertebra are, thus, distinctly homologous to the pleural ribs.
The Ossa suspensorium

According to Alexander (1962), "The ossa suspensoria are processes descending from the fourth ribs to meet below the aorta as a roughly vertical transverse shield shaped plate."

Wright (1884, '85), Sorensen (1890,'95) and Bloch regard the ossa suspensoria as modified transverse processes or the parapophyses. Weber (1820), Muller (1843), Nusbaun (1881), Sagemehl (1891) and Chranilov (1929), however, consider them as pleural ribs. Watson (1939) has described the ossa suspensorium as a modification of the true ventral ribs which are distinctly found in the vertebrae. He claims that the parapophyses do not take part in the formation of the ossa suspensoria which are homologous with the haemapophyses present in the other vertebrae of the Gold fish, Carassius auratus. Katsvelev (1929) also holds a similar view about the ossa suspensorium.

The present investigations in Rasbora daniconius (Ham. Buch.) reveal clearly that the ossa suspensoria are formed from the fourth ribs, thereby supporting the views of Chranilov (1929) and others. An ossa suspensorium is not found in Clarias megur (Guv. & Val.), in which the transverse processes of the fourth vertebra are fused with the osseous recesses.
According to Alexander (1962), the ossa suspensoria are nearly vertical in *Hoplias, Leperimus* (Cyprinidae) and horizontal in *Astyanax, Borycon, Cetatocharpes* and *Serrasalmo*. He regards the horizontal position of the ossa suspensoria as primitive.

The ossa suspensoria, as observed by the author, are nearly horizontal in position in *Asabores daniconius* (Ham. & Sch.) and hence are indicative of the primitiveness of the fish.
The Centrum of the second and third vertebrae

Bloch (1900), Chranilov (1927) and Sarbahi (1932) report that the centra of the second and third vertebrae are inseparably fused together. This has been challenged by Latvelv (1929) who claims that the centra of the second and third vertebrae in Scardinius erythrophthalmus remain separate. Ramaswami (1952) also describes the fusion of the centra of second and third vertebrae in several fishes studied by him. He, however, maintains that the articulation between them can be marked out clearly.

It has been found out in the present study that the centra of the second and third vertebrae in Asbora daniconius (Ham. Buch.) and the centra of the second, third and fourth vertebrae in Claras magur (Cuv. & Val.) are also completely fused together forming a rigid axial structure in the region. A loose vertebral column in the region of the weberian ossicles is likely to dampen the impetus which is transmitted by the ossicles from the air-bladder to the internal ear. The fusion of the second and third centra in the vertebral column, therefore, seems to help the weberian ossicles to be held firmly in their respective positions so that these are able to function more efficiently. In Claras magur (Cuv. & Val.) an osseous recesses is also present in the region which may provide additional rigidity to the vertebral column.
Mockerjee, Ganguly and Mookherji (1952) state that the centra of the first four vertebrae are fused in *Echidna danricus*. The author's finding is inconsistent with their views only in respect of the number of vertebrae involved in the fusion.

(B) PARS AUDITUM

The Claustrum

There are many views regarding the origin of the claustrum. Beauchelot (1868) and Sorensen (1895) derive the claustrum from the inter-spinous bones of the first vertebra whereas Wright (1884) and Bloch (1900) mention its origin from the supradorsal portion of the first vertebra. Grassi (1892) and Sagemehl (1884), however, hold a view that it is derived from the skull. Musbaum (1908) states that the claustrum arises as a spinal process of the third vertebra instead of the first vertebra. According to Goodrich (1909), Matveiev (1929), Sarbahi (1932) and Mookerjee, Ganguly and Mookherji (1952), the claustrum develops as a modification of the neural arch of the first vertebra only.

In the present work, it has been observed that the rudiments of the claustrum in *Mesobatrachus daniconius* (Ham. Bush.), and *Clariscus magur* (Cuv. & Val.) are present as separate mesenchymatous or procartilaginous structures on the latero-ventral side of the spinal cord near the first basidorsals in the 6 mm. long and 8 mm. long embryos.
respectively. These rudiments become cartilaginous later on and ultimately show superficial ossification also.

It is, thus, evident that the claustrum arises separately from the skull. It, therefore, can not be derived from the skull as stated by Grassi (1862, and Sagemehl (1864), although it may become connected with the tectum posterior at a later stage. Moreover, the neural arch and neural spine are absent in the first vertebra from which the claustrum has been derived by many previous workers.

Chranilov (1927) and Anaswami (1953) homologise claustrum with the neural spine of the first vertebra. Kindred (1919) and Watson (1939) consider it to be an intercalated structure. Dora (1922) also regards the claustrum as an additional piece of the neural arch of first vertebra. The claustrum is present very close to the dorsal side of the first basidorsal in the fishes studied. The first basidorsal and the claustrum together form a more or less arch-like structure on the side of the spinal cord. In other vertebrae, the basidorsals form a neural arch. The claustrum is, therefore, a separate and intercalated structure resembling the dorsal portion of the neural arch of other vertebrae.
The Scaphium

A large number of workers is of the opinion that the scaphium arises from the neural arch of the first vertebra. Notable among them are Beaudelot (1868), Nusbaum (1881), Grassi (1882), Wright (1884), Sorensen (1890), Segemehl (1884), Kindred (1919), Mora (1922), Chramilov (1927), Matveiev (1929), Sarbahi (1932), and Hockerjee, Sanyali and Nookhanji (1952). However, Watson (1939) has stated a double origin of the scaphium in Carassius auratus, deriving it partly from the basidorsal of the first vertebra and partly from an independent mesenchymatous rudiment. Goodrich (1909), on the other hand, regards the scaphium as rib of the first vertebra.

In the present investigation, the rudiment of the scaphium is seen to develop as a mesenchymatous cell aggregation on the dorso-lateral sides of the notochord in the region of the first vertebra in 5 mm. long and 7 mm. long embryos of Nitabura daniconius (=am.Puch.) and Clarias magur (Guv. & Val.). This represents the first basidorsal also which gets completely modified as scaphium. Contrary to Watson's view (1939), no other mesenchymatous rudiment is associated with the first basidorsal in the formation of the scaphium. The scaphium is cartilaginous in earlier stages and ossified in the later stages of development. Since in other vertebrae, the basidorsals form neural arches, the scaphium is regarded homologous to the neural arch of the first vertebra by the author.
The Intercalarium

Matveiev (1929) believes that the intercalarium is formed by the fusion of an independent mesenchymatous rudiment with the neural arch of the second vertebra. According to Watson (1939), however, the intercalarium originates from an independent ossification in the inter-ossicular ligament which fuses with a part of the basidorsal of the second vertebra. He states further that in the family Siluridae, the intercalarium does not articulate with the vertebral column but retains its independent bony nodular structure, a view also supported by Tilak (1964).

In the present work also, the intercalarium arises as an independent structure directly by ossification of the middle portion of the inter-ossicular ligament in Asembra danicenius (Lamach.) and the ligamentum triquetres in Clarias mugur (Cuv. & Val.) in the 8 mm. long and 10 mm. long embryos respectively. There is no indication of a separate rudiment of intercalarium in the earlier stages of the embryos in which the inter-ossicular ligament and the ligamentum triquetres both are present. As these ligaments themselves develop from a mass of mesenchymatous cells, the formation of the intercalarium can also be taken from the mesenchymatous rudiment. However, the author has observed the intercalarium to originate
directly as an ossified structure near the middle of the ligaments. Moreover, the intercalarium which lies on the outer lateral side of the posterior end of scaphium, is attached with the second basidorsal and the tripus by the unossified portion of the same ligament which forms it. It is possibly for this reason that the second basidorsals are said to be associated in the origin of the intercalarium.

The homology of the intercalarium has been discussed by many investigators like Muller (1843), Beaudelot (1868), Grassi (1882), Wright (1884), Goodrich (1909), Kindred (1919) and Noda (1922) who consider it to be the neural arch of the second vertebra. On the other hand, Bridge and Haddon (1893) regard intercalarium as a compound bone consisting of neural arch of the second vertebra and its transverse process. However, Sagemohl (1891) and Sorensen (1895) derive the intercalarium only from the rib of the second vertebra. Musbaum (1908) homologises intercalarium with the neural arch of the fourth vertebra. It has been shown developmentally that the intercalarium is present as an independent bony structure in the region of the second vertebra where separate basidorsals and neural arch are also seen. The intercalarium, therefore, appears to be a separate intercalated structure.

**The Tripus**

There is a considerable diversity of opinion among workers about the origin of tripus, Grassi (1882)
describes its origin from the transverse processes of the third vertebra. Wright (1864) mentions its development from the rib of the third vertebra together with an ossification of the outer wall of anterior chamber of air-bladder. However, a majority of workers have derived the tripus from the rib of the third vertebra (Müller, 1843; Beaudelot, 1868; Sagemehl, 1891; Bridge and Haddon, 1893; Bloch, 1900; Reis, 1905; Goodrich, 1909 and Kindred, 1919). Nusbaum (1906), on the other hand, considers the tripus to develop from the rib of the fifth vertebra. According to Bora (1922), the tripus is a compound bone formed by the 'coalescence of three distinct elements, the transverse process and rib of third vertebra, and the rib of the fourth vertebra.'

Natveiy (1929) attributes its origin to the fusion of an ossified ligament lying between the lower anterior arches together with the ribs of the second and third vertebrae and the transverse processes.

According to Watson (1939), the tripus is developed by the fusion of the basiventral of the third vertebra with a distal rod-like mesenchymatous extension of the pleurial rib. In the present study, however, the tripus is seen to develop only from paired pro-cartilaginous basiventrals in the region of the third vertebra in 6 mm. long and 7 mm. long embryos of Rasbora daniconius (Heem. Buch.) and Clarias magur (Guv. & Val.) respectively.
The third basiventrals are completely modified as tripus which is cartilaginous and partly bony in late stages of the development. The tripus is, therefore, regarded homologous with the rib of the third vertebra as both of these structures arise from the basiventrals. The tripus is a large elongated triangular plate bearing three processes, an anterior process, an articular process and a transformer process.

**The Osseous recesses**

The occurrence of a characteristic structure, an osseous recesses has been described by Bridge & Haddon (1889) in some silurid fishes. It has also been stated by him that this structure encloses the anterior part of the air-bladder and develops by the union of the transverse processes of the fourth and fifth vertebrae. While describing the osteocranium and Weberian apparatus in two species of the silurid genus *Eutropiichthys*, Tilak (1961 b) does not mention about this structure.

The author has also not found a bony recesses in *Rasbora daniconius* (Ham. &cuch.). However, a well developed bony recesses is present in *Clarias megur* (Cuv. & Val.). It arises first as a membranous structure in the embryo measuring 10 mm. in length. Later on, it becomes bony and extends from the beginning of the first vertebra upto the sixth vertebra. The bony recesses is in the
form of a large transverse plate near the anterior end 
of the vertebral column forming a capsule like structure. 
The capsular space is bounded dorsally by the transverse 
bony plate of the osseous recesses, by the notochord and 
the ventral portion of the recesses on the inserside and 
by the wall of the airbladder on the outer side.

The osseous recesses seems to provide protection 
to the scaphium, intercalarium and tripus which are lodged 
in it. Its presence at the anterior end of the vertebral 
column provides an additional rigidity also to the axial 
skeletal organ. This rigidity is very essential for an 
efficient working of the weberian ossicles.

So far as the author is aware, a bony recesses has 
not been reported by any worker in Cyprini. On the other 
hand, an osseous recesses is invariably found in Siluri.

The views of the different workers regarding the 
origin and homology of the weberian ossicles can be 
condensed into three theories as follows :-

(i) The weberian ossicles are homologous with the 
ear ossicles of mammals (Weber, 1820 etc.).

(ii) The weberian ossicles are homologous to 
vertebral parts of some anterior vertebrae 
from which they are entirely derived (St. 
Hilaire, 1824; Muller, 1843; Beaudelot, 1868; 
Grassi, 1882; Sagemehl, 1884, 1891; Bridge 
and Haddon, 1895; Sidorjak, 1898; Busbaum, 1908; 
Sachs, 1912; Chranilov, 1929 a,b; etc.)
(iii) The Weberian ossicles are derived in part from the ossification of ligaments and in part from the anterior vertebrae (Wright, 1884; Sorensen, 1890; Bloch, 1900; Reis, 1905; Matveiev, 1929 and Watson, 1939 etc.)

The development of the Weberian ossicles, as studied by the author in *Asa bore daniconius* (Ham. Buch.) and *Glariae magur* (Cuv. et Val.) and incorporated in the thesis, supports the third theory. The claustrum arises as an intercalated structure and resembles in position only with the dorsal portion of the neural arch (if it happened to be present) of first vertebra. The scaphium develops completely from the basidorsal of the first vertebra and is homologous with the neural arch. The inter-calarium originates by ossification of the middle portion of inter-ossicular ligament. The tripus arises from the third basiventral and is homologous with the rib of the third vertebra.

2. TRUNK VERTEBRAE

The Notochord

Goette (1879), Grassi (1882), Scheel (1893), and Thamarajan (1936) state that the notochord is present as a continuous constricted thread like structure in the vertebral portions of adult fish. However, Little (1902) and Sarbahi (1932) are of the opinion that the notochord
is restricted to the inter-vertebral regions only in the adult stage. It has been explained by Gegenbaur (1898) that the notochord strands are present in the vertebral regions to maintain continuity of the notochord. According to Hockerjee and Ganguly (1951), there is a persistent notochord which is well developed in the inter-vertebral regions and restricted in the vertebral regions of the vertebral column in clupeoid fishes. Hockerjee, Ganguly and Hookherji (1952) also report the occurrence of a persistent notochord in *Esomus danricus*.

In the present study also, the notochord has been found to be persistent throughout the length of the vertebral column. However, it is more developed in the inter-vertebral regions than the vertebral regions. Barbahi (1932) holds that the notochord is absent in the urostyle of *Labeo Rohita*. Hockerjee, Ganguly and Hookherji (1952) have, however, reported the presence of notochord in the urostyle of *Esomus danricus*. The developmental stages of *Easbora danicopius* (Ham. Buch.) and *Glarias magur* (Cuv. & Val.) show that the urostyle is developed by the upwardly deflected terminal portion of the notochord which remains persistent throughout life. However, thick ossification takes place round the notochord in the urostyle in these fishes.
The Centrum

The centrum has been studied by a large number of workers, notable among whom are Kolliker (1879), Klaatsch (1893), Gadow and Abbott (1895), Gegenbaur (1898), Ridewood (1921), Ramanujam (1929), Faruqi (1935), Hookerjee, Mita and Rasumdar (1940), Hookerjee and Ganguly (1951), Kamel (1956) and many others. Their work has created much controversy regarding the structures taking part and the mode of formation of the centrum. The views of previous workers can be condensed as follows:

(i) The centrum arises by ossification of the fibrous sheath within the notochord (Gadow & Abbott, 1895; Ramanujam, 1929 etc.).

(ii) The centrum formation occurs outside the elastica either by ossification of the bases of dorsal and ventral arches or by ossification of separate sclerotomic cells (Klaatsch, 1893; Gegenbaur, 1898 etc.).

(iii) The centrum formation takes place by both the methods together (Hookerjee and Ganguly, 1951; Kamel, 1956 etc.).

Parker and Haswell (1940) state that the centra as well as the arches of the vertebrae are formed entirely from the skeletogenous layer and not from the sheaths of the notochord.
Mockerjee, Mitra and Nasumdar (1940) have shown that not only in fishes but in all chordates, the centrum is formed from the perichordal tube. However, Mockerjee and Ganguly (1951) report the origin of centrum by ossification of the perichordal tube and the notochordal sheaths. This has been supported by Kamel (1956) who mentions the centrum formation in Gambusia affinis from two concentric cylinders of bone, an inner older one (termed chordal centrum) and an outer newly deposited one (termed perichordal centrum). These two cylinders of bone are separated by the elastica externa.

In the present study, it has been noticed that the notochordal cells are distinctly vacuolated in the central region. This central core of notochordal cells is then surrounded by a layer of distinctly nucleated small cells forming a notochordal epithelium. The elastica externa lies external to the notochordal epithelium. The notochordal epithelium is not uniform in thickness. There occurs a regular sequence of alternating regions of thin and thick notochordal epithelium throughout the length of the notochord. At a still later stage, a calcified ring develops in the space between the elastica externa and the notochordal epithelium in the vertebral region only. This is called the chordal tube which represents the chordal centrum of earlier workers. Later on, the sclerotoxic cells present outside the
elastica externa also become ossified. A thick coat of perichordal ossification is, thus, seen outside the elastica externa. The centrum is, therefore, formed by two concentric ossified rings, a chordal ring and a perichordal ring. This finding of the author agrees with the third mode of centrum formation given above.

**The inter-vertebral ligament**

Kolliker (1879) states that the inter-vertebral ligament is formed by an inner layer of notochord. Ramamujam (1929) describes that the fibrous sheath between the two consecutive centra in Clupea harengus becomes modified into an inter-vertebral ligament. Faruqi (1935) mentions the presence of a binding material between the two successive centra and homologises it with the inter-vertebral part of the perichordal tube in Amphibia, Aves and Mammals. Hookerjee and Ganguly (1951) report in Milus ilisha that the inter-vertebral ligament is formed by the secretion of the notochordal epithelium. Aanil (1956) states that the inter-vertebral ligament is the modified intervertebral portion of the fibrous sheath which lies between the notochordal epithelium and the elastica externa. In Rasbora daniconius (Ham. Buch.) and Clarias magur (Cuv. & Val.) also, there is a prominent fibrous sheath between the elastica externa and the notochordal epithelium in the inter-vertebral regions. This sheath has been observed by the author to form an
inter-vertebral ligament in later stages of the development, a finding similar to that of Kamel (1956).

The Ribs

The ribs, as described by Gadow (1933), are lateral extensions of some ventral arcualia.

Hesse & Schwark (1873) and Kolliker (1879) report an independent origin of the ribs. Karuqi (1935) states that the ribs in Plasmodobranch, Urodela, Reptilia, Aves and Mammals represent the distal portion of the ventral arches or parapophyses. Hookerjee, Mitra and Rasumdar (1940) mention two kinds of ribs occurring in vertebrae, (a) a dorsal rib situated between the epaxial and hypaxial muscles and (b) a ventral or pleural rib lying internal to the hypaxial muscles and external to the peritoneal lining of coelome.

In the development of the vertebral column of *Lambora daniconius* (Ham. Buch.) and *Clarias magur* (Cuv. & Val.) studied by the author, the ribs are seen to arise directly as independent membrane bones near the distal end of the basiventrals of the trunk vertebrae. These become stout and thick by further ossification and get attached with the basiventrals. Later on, the basiventrals disappear altogether in *Clarias magur* (Cuv. & Val.) and the bony ribs then become attached directly to the centrum. In *Lambora daniconius* (Ham. Buch.), however, the basiventrals persist as separate structures
showing superficial ossification. According to Goodrich (1930) also, the basiventrals remain distinct and separately ossified in some Cypriniformes, a condition which is regarded primitive by him. The structure of the basiventrals of the trunk region in *Asbora daniconius* (Ham.Buch.) is thus, similar to that described by Goodrich (1930) and hence, is indicative of primitiveness.

The origin of the ribs is, therefore, similar to that described by Hasse Schwark (1873). Moreover, the ribs belong to the ventral or pleural type of Ackermee, Mitra and Rasumudar (1946) as they extend in between the hypaxial muscles and the peritoneal lining of the coelome.

The neural arch

Kamamujam (1929) and Faruqi (1935) state that the arches in teleosts do not rest directly on the notochordal sheath. On the other hand, Kamel (1956) mentions that the basidorsals rest directly on the elastica externa. It has been observed in the present investigation on the development of the vertebral column in *Asbora daniconius* (Ham.Buch.) and *Clarias macurr* (Cuv. & Val.) that the basidorsals are supported distinctly on the elastica externa, a view similar to that of Kamel (1956).

Ackermee, Mitra and Rasumudar (1946) state that the arch consists of three elements, i.e., an anterior incomplete membrane bone element forming prezygapophyses,
(b) A membrane bone element with cartilage cells at the base and (c) another incomplete membrane bone element whose extreme end carries the backwardly projected posterior zygapophyses. This view has been supported by Cockerjee, Ganguly and Sookherji (1952) and discarded by Kamel (1956).

In the present study, it has been found in *Asabore daniconius* (Ham. & Buch.) that each half of the neural arch in the first and second typical trunk vertebrae (described in observation chapter as fifth and sixth vertebral elements) develops from two elements, a cartilaginous basidorsal and a separate membrane bone. In the remaining trunk vertebrae, however, the lateral halves of the neural arches develop independently and directly as membrane bones. On the other hand, in *Clariscus magur* (Guv. & Val.) the development of the neural arches of all the trunk vertebrae is alike and resembles with that of the first two typical trunk vertebrae of *Asabore daniconius* (Ham. & Buch.).

The neural arches, therefore, arise in two ways:-(a) From two elements, a cartilaginous basidorsal and a separate membrane bone element. (b) Only from one bony element. This is partly in agreement with the view of Cockerjee, Mitra and Kasumdar (1940). The difference in the mode of development of the neural arches in the two fishes seems to be correlated with habitat and habitat of the fish.
The Zygopophyses

The Preszygapophyses

The origin of the anterior zygopophyses has been described in Gadus aeglifimus by Faruqi (1935) as a knob situated at the base of the neural arch. He further states that the "zygapophyses in the Teleostei have been independently evolved and are not homologous with those of the tetrapoda." Hookerjee, Ganguly and Hookerji (1952) derive the preszygapophyses from the anterior elements of the arch.

In Asbora daniconius (Ham.Buch) and Clarias megurus (Cuv. & Val.) investigated by the author, the preszygapophyses develop clearly as upwardly directed outgrowth of the anterior side of the neural arch near its middle. Further, these are formed only when the neural arch has fully developed. Therefore, the question of separate origin of the preszygapophyses, independent of the neural arch, does not arise.

The Postzygapophyses

Ramanujam (1929) and Faruqi (1935) believe that the posterior zygapophyses develop as outgrowths from the centrum. Hookerjee, Mitra and Nasumdar (1940) state that the postzygapophyses in Lebistes reticulatus are formed from the posterior membrane bone elements of the neural arch and not from the centrum. This has been
supported by Mookerjee, Ganguly and Hookerji (1952). According to Kamel (1956), the postzygapophyses originate as small projections of bone from the perichondral centra.

In the developmental studies of the vertebral column of *Neobora daniconius* (Ham. Buch.) and *Clarisa megur* (Guv. & Val.) carried out by the author, the postzygapophyses develop as small bony processes from the dorso-lateral sides of the centrum in hinder most part of the vertebral region. It is, thus, clearly evident that the postzygapophyses do not arise from the neural arch as stated by Mookerjee, Mitra and Hazumdar (1940). On the other hand, the postzygapophyses arise directly from the centrum, a finding which is in conformity with the view of Kamalujam (1929), Faruqi (1935) and Kamel (1956).

3. CAUDAL VERTEBRAE

The Haemal arches

According to Gadow (1933), the haemal arches are characteristically present in fishes on the ventral side of the centrum in the caudal vertebrae only and correspond to the neural arches of the dorsal side. As regards the origin of the haemal arches, Faruqi (1935) states that the haemal arch develops first as an arch of connective tissue which eventually becomes ossified. Mookerjee, Mitra and Hazumdar (1940) describe the pro-cartilaginous origin of the basiventrals which
passing through the mesenchymatous condition, give rise to the haemal arch by ossification together with two other bony elements. This view has been supported by Mookerjee, Ganguly and Mookherji (1952).

In the present study, it has been found out that the haemal arches develop directly as separate bony structures on the ventro-lateral side of the notochord in the 10 mm. long embryo of *nasebora daniconius* (Ham. Buch, where the basiventrals are also absent. However, in *Clarice magur* (Guv. & Val.) the haemal arches arise in the embryo of 10 mm. length from the cartilaginous basiventrals which become greatly extended and arch-like ventrally. Later on, this cartilaginous arch is ossified to give rise to the bony haemal arch. There are, thus, two modes of formation of the haemal arches which develop either directly from an independent membrane bone element or by ossification of the cartilaginous arch formed previously by the basiventrals.

**The Caudal fin skeleton**

The earliest reference of the work on the topic dates as far as back as 1882, the year in which Newton described the caudal skeleton in *Clupea*. Later on, Ussow (1900) reported the existence of an unpaired 'hypochordal' cartilage in the caudal vertebrae of teleosts, mentioning also that it is probably formed by the fusion of the bases of the lower arches.
Whitehouse (1910) also states the existence of a 'promural urostyle' in Clupea pilchard. Ragan (1910) of the opinion that the urostyle represents the aborted neural arches of the posterior centra. According to Goodrich (1930), the caudal fin skeleton consists of urostyle, hypurals and epurals. He believes that the hypurals in higher teleosts develop from the haemal spines and their number exceeds that of the epurals. However, Whitehouse (1910) holds a view that both the hypurals and the epurals are formed by the fusion of the arch elements with their respective spines and radials. MacKerjee, Mitra and Mssumdar (1940) have shown that the hypurals and epurals are formed by the fusion of the arch elements and spines together. The view of these workers has been supported by MacKerjee, Ganguly and Mookherji (1952).

In the present work, the author has observed that the origin of the neural arches of the caudal vertebrae is similar to that of the haemal arches. Both these structures arise first as cartilaginous arches which become ossified in later stages of development. The neural arch, continues apically as a small cartilaginous rod-like structure termed epural. It has been seen that only neural arch is ossified and the apical rod remains cartilaginous. The origin of the hypurals is also similar to that of epurals described above. It is, thus, evident that the epurals and hypurals develop from
the dorsal arch element and the ventral arch element along with their respective spines as suggested by Mookerjee, Mitra and Masumdar (1940). The development of the fourth hypural in Rasbora daniconius (Ham. Buch.) and fourth and fifth hypurals in Clarias magur (Cuv. & Val.) is different from other hypurals. These arise from a median basal plate-like structure formed by the fusion of the posterior prolongation of the third basiventrals and fifth basiventrals respectively. This also clearly shows that the hypurals arise from the ventral arch.

The Dorsal Radial

There is a cartilaginous rod-like structure which lies posterior to the epurals on the dorso-mesal side of the notochord but not attached to it. This is termed the dorsal radial. In Rasbora daniconius (Ham. Buch.) and Clarias magur (Cuv. & Val.) the dorsal radial is seen to arise separately and independently of an arch element. It remains free from the notochord but is attached with the fin rays distally. The dorsal radial is a constituent of the caudal fin skeleton.

The Ventral Radial

Apart from the hypurals, five serially arranged cartilaginous rod-like structures are present in Rasbora daniconius (Ham. Buch.) and three in Clarias magur (Cuv. & Val.) posterior to the upturned potion of the notochord. These cartilaginous rods arise independently and
separately from the meso-ventral cartilaginous elements of the urostyle. These are, therefore, not similar in origin to that of the hypurals which arise from paired basiventrals. Hence, the author has termed them as ventral radials. Earlier workers have, however, not clearly mentioned their origin and ranked them with the hypurals.

The caudal fin in *Mesbora daniconius* (Ham. Buch.) is a symmetrical forked structure which is divided into two equal lobes, a dorsal lobe and a ventral lobe. The skeleton of the dorsal lobe consists of three epurals, single dorsal radial, five ventral radials and a urostyle. The skeleton of the ventral lobe comprises all the four hypurals only. The caudal fin in *Clarias magur* (Guv. & Val) is a large single lobed structure. The skeleton comprises a single dorsal radial, three ventral radials, five hypurals and a urostyle, all of which are arranged in a fan-like pattern at the tip of the vertebral column. The epurals have been found to remain separate from the caudal fin skeleton, a variation which appears to be due to the presence of a large dorsal fin and the deep incision separating it from the caudal fin.