DISCUSSION
DISCUSSION

Canal Bones:

Few cases of teleosts are on record dealing with a comprehensive study of the development of the lateral line system in relation with the bones of the skull. The modification of the latero-sensory system in the light of evolution has been admirably summarised by Cole (1898), Allis (1904, 1934, 1935), Goodrich (1909, 1930), Holmgren (1942), Lekander (1949) and Ommarkhan (1949). Pehrson (1922, 1940, 1944) on Amia and Esox, Hammerberg on Polypterus (1937), Acipenser (1944) and Allis (1904) on Lepidosteus have made praise worthy investigations in the Ganoids. Lekander (1949), Holmgren and Pehrson (1949) have made valuable contributions in this field by their researches on Ostariophysi and Dipnoi respectively. Kapoor (1962a, 1970) made observations on the development of the sensory canal bones in Ophicephalus and Wallago attu.
Two categories of dermal bones were recognized as early as 1889 by Allis and later elaborated by Devillers (1944) which develop along with the various sensory canals. One of these comprised of tubular canal bones or ossicles which lack a membranous component and the other includes the two component type of bones which are composed of a membranous and a latero sensory component. The two components of the latter type of bones are fused with each other from the beginning in *Ambassis range* (*Chanda range*) as in *Ophicephalus* and *Wallago* examined by Kapoor (1970).

The significance of the canal bones and their ontogenesis has been the subject of many investigations. Vrolik (1873) was probably, one of the first to discuss the significance of the canal bones in *Esox*. According to him the primary purpose of the bones was to protect the canals and the neuromast sense organs lodged in them. Walther (1882) who, likewise, dealt with *Esox*, opposed this view, maintaining that the protection of the canals was a secondary function as the membranous part of the frontal bone formed first, and has obtained practically its full development before the canal component began to appear. Only secondarily the bone developed into a protection for the canal. The difference between dermal bones and canal protection, thus indicated by Walther, was more distinctly discernible in *Amiurus* (Mc Murrich, 1884; Kindred, 1919). In *Amiurus*, the nasal, the infraorbital and the supraperioperculum are formed as
cylindrical bones round the canals. All of these bones remain unchanged in the adult, except the nasal, where bone lamellae develop. The frontal bone is formed first as a normal dermal bone. The separate canal bones that, secondarily, fuse with the lamellar bone appear only later. De Beer (1937) has paid much attention to these conditions, however, he does not seem to be absolutely convinced of the correctness of the Kindred's account. He states, "The frontal is of considerable interest if Kindred's description is correct". Pehrson (1944a) also calls his data in question, stating that his examination does not definitely prove that the frontal bone is formed as described above. According to Lekander (1949) from the description of the development of the canal bones in Phoxinus, Tinfo and Nemachilus, it is, however, perfectly clear that the lamellar and latero sensory components may form separately from each other. This confirms the correctness of Kindred's view. In A. ranga (C. ranga) also the lamellar component of the frontal bone is formed first and obtains practically its full development. Only secondarily the latero sensory component develops around the canals. So this also supports the views of Kindred and Lekander.

In more primitive fishes (Westoll, 1937; Lekander, 1949) the canal bones form in connection with the neuromasts. First a tube like bone appears round the canals, and only later it develops into a lamellar bone. In these fishes the primary
purpose of the canal bones seems to protect the canals. In more differentiated teleosts the two components are formed in different ways. The membranous component is formed like an ordinary dermal bone while the other component appears in connection with the canal system. In these fishes the canal bones have specialized into different directions viz. as a dermal bone and as a protective bone for the canal, that this contention is correct is evident from the conclusion. In such fishes which lack canals for example Cobites taenia (Sato, 1959), if there is no canal no latero sensory component of the bone develops which shows that its formation is dependent on the presence or absence of the canals. Its function is, most probably, to protect the canals. On the other hand, in spite of the disappearance of the canals the membranous part remains in the form of a dermal bone. According to Pehrson (1922, 1940, 1944 a, b) the bone owes its origin to the neuromast of the future canal and there is no correlation between the invagination of these neuromasts and the ossification of the bones. The point which attracts attention is that the latero-sensory as well as the membranous component invariably develop in close vicinity of the sensory canals. Kapoor (1970) also confirmed this fact while investigating the development of the sensory canal bones in Ophicephalus and Wallago.

According to Moodie (1922) the nature of the influence of the lateral line canals on the formation of the peripheral osseous elements is mechanical because it furnishes the dense connective
tissue which is an inactive substance and compose the canals, and the neuromast organs are not trophic for dermal bones of head. The canals develop before the formation of bones. He states that they are 'preossious structure' which create disturbing factors of a mechanical nature to which the peripheral osseous elements in their formation must respond. Westoll (1937) believes that in primitive bony fishes the bone was quite probably passive in its method of origin, depending on the physico-chemical conditions set up by the sensory organs or nerve endings. The present author supports the opinion of Kapoor (1970) who find difficulty to accept the views of Moodie (1922) and Westoll (1937) as both consider the invagination of the canal as the cause of creating disturbing factors of a mechanical nature (Moodie, 1922) or 'physico-chemical conditions' (Westoll, 1937) which are responsible for initiating bone development. Now it should be clear that the membranous component of the two component type of bones in *Ambassis ranga* (*Chanda ranga*) develops in the vicinity of the neuromasts at a time when they are freely exposed at the surface of the epithelium and there is no sign of any disintegration of the connective tissue below the neuromast sense organs. So now it can be concluded that the invagination of the neuromast has nothing to do with the formation of the membranous component of the bone. All these facts can be supported by the works of Pehrson (1944a) on *Esox*, Lekander (1949) on Ostariophysi, Kapoor (1969, 1970) on *Ophicephalus* and *Wallago*, etc.
In judging the nature of the canal bones, there is special significance of the origin and derivation of the blastemas, from which the bones are developed. Authors like Hammarbergh (1937), Klaatsch (1894), Pehrson (1922, 1940, 1944 a,b), Lekander (1949) and Kapoor (1970) reported the origin of blastema from ectoderm. Pehrson (1922 and 1940) states that in Amia at a certain stage the basal membrane breaks below the neuromasts and their adjoining areas. This is followed by a proliferation of osteoblasts from the epithelial cells in the neighbourhood. These osteoblasts migrate into the mesenchyma where they spread along the course of the future canal. According to Devillers (1958) the neuromasts act as inductors in the dermogenesis. During his study on Salmo he did not find any connection between the epithelium and the osteoblasts. According to Lekander (1949) the osteoblasts originate from the lateral line placode which are left in the form of connective strands after the primary neuromasts have been differentiated along them. Kapoor (1970) worked on Ophicephalus punctatus and does not agree with the ectodermal origin of the osteoblast and the origin of canal bones due to the morphogenetic activity of the neuromasts. He further stated that in Ophicephalus the membranous part of the two component type of bones, as also the blastema which precede it, develop in close vicinity of neuromasts at a stage when they lie at the surface of the epithelium, and when the connective tissue below them is still intact. Further, the neuromasts start invaginating only after the
membranous part of the bone has been formed and it is important to note that no blastema is formed below the neuromasts at the time of invagination. And finally, the latero-sensory component of most of the two component type of bones in this fish develops a considerable time after the neuromasts have got enclosed in canal and not at the time of their invagination. He does not find any migration of osteoblasts from the epithelium to the growing lamellae representing the latero-sensory component. The present author agrees with the views of Kapoor as the observations on the development of canal bones in A. range (C. range) give the same results as were found in Ophicephalus punctatus. Thus inclined to accept de Beer's contention (1937) like Kapoor that the neuromasts of the lateral line serve not to cause the bone to arise, but to determine the localization of its rudiment and that they seem to stimulate ossification in their neighbourhood by exerting some trophic influence associated with their presence. This view is also supported by Moy-Thomas (1941) and Stensio (1947) etc.

The latero-sensory and the lamellar, the two components, of the two component type of canal bones show variations in their relationship with each other. There are three possibilities:

(a) They may be united from the very beginning.

(b) They may develop separately and secondarily fuse with each other, and

(c) They may remain entirely separate.
These interrelationships of the membranous and the latero-sensory components can be explained in the light of the works of Lekander (1949) and Kapoor (1970). According to Lekander the bones such as frontal, preopercle, antorbital etc. develop in two stages. First the lamellar component develops and then the latero-sensory component appears. *Leuciscus* and *Abramis* (Lekander, 1949) are the examples of first possibility of the interrelationship of the two components, as the two components are united with each other from the very beginning, while *Phoxinus* and *Alburnus* (Lekander, 1949) represent the second possibility where the two components develop separately and unite with each other only secondarily. *Nemachilus* (Lekander, 1949) represents the third possibility as the two components remain separate even in the adult. *Tinca* shows a somewhat different condition where the two components of most of the bones secondarily fuse with each other but the splenials remain independent of the dental and angular even in the adult. Thus it stands intermediate in between the *Phoxinus* and *Nemachilus*. In *Cobitis taenia* (Sato, 1959) the latero-sensory component of the canal bones like sub-orbitals, extra-scapulars, nasals etc. are lacking. In *A. ranga* the two components are united with each other from the very beginning as in *Ophichthys* and *Wallago* (Kapoor, 1970).

Another important point which attracts one's attention is the interrelationship of the appearance of the latero-sensory
component and the time of invagination of the neuromasts. Walther (1882) reported that in *Esox* the lamellae of the latero-sensory component grow out only after the formation of the canal but not at the time of starting of its invagination. Pehrson (1944a) has vehemently criticized the work of Walther (1882), according to him in *Esox* a pair of lamellae develop from the membranous plate of frontal at the time of the invagination of the neuromasts, and they subsequently arch over the canal and fuse with each other to form the usual bone tube around the canal. According to Kapoor (1961, 1970) in *Ophicephalus punctatus* excepting the preopercle and post-temporal all the two component type of bones develop in a manner exactly similar to that described by Walther (1882) for frontal in *Esox* while the preopercle and post-temporal develop in the usual manner as advocated by Pehrson (1944a). In *Wallago attu* also the latero-sensory component of the two component type of bones arises at the time of invagination of the neuromasts. The views of Pehrson are supported by Devillers (1947) and Lekander (1949). In *A. range* (*G. range*) most of the two component type of canal bones develop in a manner exactly similar to that described by Walther (1882) and Kapoor (1961, 1970).

Allis (1935) supposed that the canal bones in *Polyodon* and *Acipenser* are made up of two components. He speaks of "a latero-sensory component" and "a membranous component", a terminology
that has been adopted here also. Pehrson (1947) found free splenial bones in Polypterus. Sagemehl (1885, 1891) reported that in Gymnotus, certain Murenids and Cyprinids, the canal lie enclosed in separate bony cylinders. His explanation is that the epidermis in these fishes was thick and the underlying dermal bones for this reason were deeply sunk in the skin. According to Lekander (1949) the canals must not sink too deep in the dermis, if they have to perform their function, according to Sagemehl (1885, 1891) they must not sink too deep in the epidermis. On this account the canal cylinders occupy a more superficial position. Free cylindrical bones are reported in Nemachilus and to a certain extent in Tinca also. As compared to others, these fishes possess a comparatively thick epidermis. He further stated that in Tinca, it is possible to ascertain that, in the canal bones which lie close to the epithelium, the two components fuse together while bones which lie deeper down remain separate. This supports the Sagemehl's theory, that the thickness of the epidermis is a determining factor in this respect. Observations on Ambassia ranga (Chanda ranga) also support the theory of Sagemehl as in this fish the canals and the neuromasts lodged within them along with the canal bones have not sunk too deep in the dermis and the epidermis is not thick. The two components of the canal bones are united with each other from the very beginning.
The interrelationship of the different canal bones and the lateral line canals in the head of *Ambassis ranga* (*Chanda ranga*) can be conveniently discussed as under:

The supraorbital canal passes through the nasal and the frontal bones, and after leaving the frontal enters into the sphenotic where it joins the infraorbital canal and the temporal canal. This point is marked by a pore (compound pore of Kapoor, 1962). The anterior portion of the supraorbital canal lodges two neuromast sense organs which are located in the nasal bone. The nasal in *Ambassis ranga* (*Chanda ranga*) is a narrow tubular bone. The nasal in *Polypterus* (Pehrson, 1922) is represented by three elements, the terminale, nasal and the adnasal but in *Amia* (Pehrson, 1940) a single nasal containing three neuromasts is present denoting the fusion of three elements. Aumonier (1942) reported its absence in *Lepidosteus* but shows the presence of adnasal. According to Hammerberg (1937) in *Lepidosteus*, three elements of the nasal are fused. In *Esox* (Pehrson, 1944a) only one nasal bone appears. In a number of primitive fishes, a row of independent nasal bones is a common feature. Lekander (1949) stated that "in the great majority of examined recent Teleosts, there is, as a rule, only one nasal bone, but the embryological development shows that, from the beginning, several separate elements may form. In all likelihood these free nasal primordia, represent the separate nasal
bones in more primitive fishes, though, now in living fishes, they have, generally fused into one bone. In Ambassis range the nasal is a single paired bone.

According to Lekander (1949) in Alburnus, Abramis, Tinc, Nemachilus, Leuciscus, Phoxinus and Cobitis the nasal bone when present consists exclusively of the latero-sensory component and the lamellar component is missing. According to Sagemehl (1891) in Cyprinids without exception the nasal is a very small bone in contrast with the conditions in the Characinids which possess a well developed nasal bone with a lamellar component. In Silurids there are variable conditions. In Clarice and Amiurus (Kindred, 1919) the bone has a well developed lamellar component. In Amiurus in the beginning a tube like bone is formed which later fuses with the underlying lamellar component which develops in the connective tissue, while in Chrysichthys only the latero sensory part exists and Corydoras shows its absence as it lacks the canals. In Wallasso attu (Kapoor, 1970) only the latero-sensory component is present but in Ophicephalus punnatus (Kapoor, 1970) both the lamellar as well as the latero sensory components are well developed. In A. range (C. range) the nasal bone consists of only the latero-sensory component, the lamellar component is absent.

In Amia (Pehrson, 1940) the canal lodges three neuromast sense organs within the nasal bone. But in Ophicephalus,
Wallago and Heteropneustes (Kapoor, 1960 a, b, 1961) it lodges only two neuromast sense organs. According to Lekander in Cobitis (1949) the nasal is absent and in Nemachilus the canal in the nasal bone lodges two neuromast sense organs, but in Abramis, Alburnus, Leuciscus and Tinca the canal in the nasal bone lodges three neuromast sense organs. In Phoxinus he reported two neuromasts in the nasal bone, but Manigk (1933) reported three neuromasts in Phoxinus. Gupta (1970) reported four to five neuromasts in Xenentodon cancila. In Ambassis range the anterior portion of supraorbital canal in the region of the nasal bone lodges only two neuromast sense organs.

As examined by Lekander (1949) even in very closely related fishes the frontal bone is formed in an extremely variable manner. Both the lamellar and the latero-sensory components of the bone are formed in several ways. He stated that "In Nemachilus the lamellar part originates in a blastema with some relationship to the supraorbital neuromasts. In this blastema the lamellar part forms, in the form of three separate bone elements, each connected with a neuromast of its own. Soon the different bone lamellae will fuse with one another". In Esox (Pehrson, 1944a) also similar type of formation of the lamellar part of the frontal bone is present. In Leuciscus and Phoxinus (Lekander, 1949) on the other hand, the lamellar part of the frontal is formed in a different way. There is no perceptible blastema and the
bone forms in a very irregular manner. The latero-sensory component also shows variations in its formation, and its connection with the lamellar part varies from species to species. In most of the cases the lamellar part appears first which is sooner or later followed by the latero-sensory part. In fishes like Leuciscus, Esox etc. the two components are united from the very beginning and the latero-sensory portion grows from the lamellar portion. On the other hand in Phoxinus and Tinca etc. these two components are formed independently but fuse later on. In Nemachilus (Lekander, 1949) the two components never fuse with each other. Pehrson (1944b) in Acipenser, however, does not say anything about the origin of the two separate bone primordia of frontal. He (1940, 1941a) does not make a distinction between the membranous and the latero-sensory parts (a view shared by Westoll, 1937, 1941). Thus, what one might be inclined to regard as the membranous part of frontal in Esox is designated by him as the latero-sensory portion of the complex 'rostro-frontal'. Stensio (1947) made out the distinction and termed them as 'sensory line component' and the 'anamastic component'. He does not agree with the interpretations of Pehrson on Amia (1940) and Acipenser (1944b). The concept of a composite bone with two components has recently been shared by Branson and Moor (1962), Reno (1966) and Kapoor (1970). In Amiurus (Kindred, 1919) the frontal develops in two parts. First a membranous part develops and then later on a
tube like part around the canal which fuses with the membranous part only secondarily. The same condition has been reported by Mc Murchie (1883, 1884) and Moodie (1922) on the same fish. Allis (1935) stated that, "the frontal is primarily a membrane bone and is known to occur as such in early embryos of Acipenser and the adults of Polyodon, the fossil Dipnoi and the Coelacanthidae. In all other fishes considered excepting possibly certain of Arthrodira, it fuses with one or more of the latero sensory ossicles developed in relation to the supraorbital canal and may possibly fuse also with certain of the supra orbitals". The present study of A. range (C. range) provides an example where the frontal develops in a manner exactly similar to that of Heterax (Walter, 1882) and Ophicephalus punctatus (Kapoor, 1970).

The frontals form the roof of the skull in the anterior half of the cranium. Amongst Mormyridae, Hyodontidae and Osteoglossidae (Ridewood, 1904) the frontals are short and broad but in Arapaima (Ridewood, 1904) they are elongated and amongst the Percoids in Pagrosomus (Kesteven, 1920) they are in the form of tongue-shaped masses by the deposition of heavy bony tissue. The frontal in A. range is a broad and elongated bone.

The supraorbital canal in its relation with the frontal bone exhibits a number of variations as regards the number of neuromast sense organs. In Ophicephales and Wallago (Kapoor, 1960, 1961)
the canal in its frontal region lodges three neuromast sense organs, but in *Heteropneustes* (Kapoor, 1960) it lodges four neuromast sense organs. In fishes like *Nemachilus* and *Phoxinus* (Lekander, 1949) it lodges four neuromast sense organs. In *Amia* (Pehrson, 1922) and in *Notopterus* (Omarkhan, 1949; Kapoor, 1964) it lodges three neuromasts in each. In *A. ranga* (*C. ranga*) it lodges four neuromast sense organs during its course in the frontal bone.

The infraorbital canal runs through the lachrymal, a series of infraorbital (including the post-orbital) bones. Generally in teleostes the lamellar and the latero-sensory components of the lachrymal bone are united with each other from the very beginning, but in some cases they are formed separately and fuse only secondarily. In *Bhavana* (Ramaswami, 1948) and *Nemachilus* (Lekander, 1949) the lamellar and the latero-sensory components remain separate; but in *Leuciscus*, *Alburnus*, *Abramis* and *Tinca* (Lekander, 1949) the lamellar and the latero-sensory components arise separately and fuse later. But the observations of *A. ranga* (*C. ranga*) have shown that unlike all the above mentioned fishes it is an example of general teleost. In this fish the lamellar and the latero-sensory components of the bone are united with each other from the very beginning and the latero-sensory component grows out from the lamellar component after the formation of the canal, and then arch over the canal to form a bone tube.
The number of neuromast sense organs in the infra-orbital canal during its course in the lachrymal bone varies from fish to fish. In *Heteropneustes* (Kapoor, 1960) and *Wallago* (Kapoor, 1961) the infraorbital canal in its course in lachrymal bone lodges only one neuromast sense organ in each, while in *Ophicephalus* (Kapoor, 1960) it lodges three neuromasts. In *Amia* ((Pehrson, 1922) the lachrymal contains three to six neuromast sense organs, but Westoll (1937) is of the opinion that the third and the fourth organs belong to the rostral commissure. In *A. range* (*G. range*) the canal in the lachrymal bone lodges three neuromast sense organs — the first, second and the third organs of the line.

The infraorbital canal after leaving the lachrymal bone passes into a series of infraorbital (sub-orbital) bones. These infraorbital ossicles are broad in *Rasbora, Ptychidio* and *Cyprinus*, and tubular in *Ophicephalus, Wallago, Heteropneustes* and Ostariophysi fishes studied by Lekander (1949). In *A. range* (*G. range*) also the infraorbital ossicles are tubular. In Cyprinids like *Leuciscus, Alburnus, Abramis* and *Tinca* (Lekander, 1949) these ossicles are formed in the same way as the lachrymal bone. The bone arises without any sign of serial formation, appears first in connection with the infraorbital neuromasts and then the latero sensory component is added serially. In *Nemachilus* (Lekander, 1949) the infraorbital bony elements are present as the lamellar, and the latero-sensory components remain separate. In *Cobitis taenia, Coryderas* and other fishes that lack an infraorbital canal, the
infraorbital bones also are missing. According to Kapoor (1961, 1970) in Ophicephalus and Wallago the sub-orbitals consist of purely the sensory component and the lamellar component is missing. In A. ranga (C. ranga) the infraorbital ossicles consist of only the latero-sensory component.

The infraorbital canal, in its course in the infraorbital ossicles lodges variable number of neuromast sense organs in different fishes. In Ophicephalus (Kapoor, 1960) it lodges four neuromast sense organs, one in each of the second, third, fourth and fifth sub-orbitals. In Wallago and Heteropneustes (Kapoor, 1960, 1961) each of the first, second and third sub-orbital lodges only one neuromast. In Xenentodon cancila (Gupta, 1970) the sub-orbital ossicles are missing as the middle portion of the infraorbital canal is absent. The canal traverses through the supraorbital in the anterior region and post-orbital in the posterior region. In A. ranga (C. ranga) the canal in its course in the infraorbitals, lodges six neuromast sense organs, two in the first, two in the second, one in the third and one in the post-orbital ossicle.

The preoperculo mandibular canal follows the usual Teleostean pattern in A. ranga (C. ranga) and is located in the dentary, angular and the preopercular bones. According to Pehrson (1922) the development of dental and splenial in Amia 'does not follow phylogenetical lines' and 'the first developed plates, respectively
of the dentary and the angular in \textit{Amia} are phylogenetically products of the sensory canal in the same way as the frontal. He speaks of the dentary in \textit{Amia} (Pehrson, 1922, 1940) as composed of two components; a canal component and a tooth bearing or the dental component, both of which are fused together. He further writes in his work on \textit{Esox} (1944a), "Generally the ontogeny of the latero-sensory canal bones is simplified and abbreviated in comparison with the condition in \textit{Amia}. The splenials, for instance, which even in \textit{Amia} do not develop entirely independently have lost their individuality altogether during the ontogeny. Only a strip of blastematic tissue, which later ossifies as a lamella along the dental, is what remains of this series of once independent bones". Kapoor (1970) argues in the light of the above statement that the latero-sensory ossicles which once develop independently around the neuromasts of various canals have also met the same fate as these splenial bones and that in most of the modern Teleosts these ossicles are represented by the bone-tubes which develop from the composite bones (two component type of bones) and which encircle the sensory canals in the region of these bones. In \textit{Phoxinus} (Lekander, 1949) the morphological picture of dentary and angular entirely agrees with the majority of Teleosts. The number of dental splenial varies from specimen to specimen. Lekander (1949) found one splenial in one of the two oldest, specimens and two splenials in the other specimens while Manigk (1933) found three neuromasts in
this part of canal and therefore probably there are three splenial bones. In case of angular splenial first a cylindrical bone is formed round the canal and only then does this bone fuses with the underlying angular bone. In Polypterus (Pehrson, 1947) the splenials are separate cylindrical bones round the mandibular canal but later fuse with the underlying dental and angular bones; but in Amia (Pehrson, 1940) they are not separate, while the blastema form independently at an early stage, the splenials are only partly fused with the dental bone. Some authors like Stensio (1936), Holmgren (1942), Pehrson (1944a) and others, the dental bone is regarded as a dental-splenial mento-mandibular bone. However, in the teleosts so far examined, no separate splenial elements have proved ascertainable. From the first, they have fused with the dental bone, so that some authors have doubted in the composition of dental by dental and splenial elements. Thus de Beer (1937) writes regarding the dentary in Salmo that, "In the absence of evidence of separate ossification of the bone surrounding the canal, the whole bone cannot be called a dento-splenial but must be regarded as a dentary, which has acquired relations with the lateral line canal, or a splenial which has taken the dentary's place". In Esox Pehrson (1944a) did not find any separate splenial element but along the ventro-medial side of dental comparatively sparse-blastematic tissue was found only in 18.8 mm specimen. This blastema is homologous to the sphenial primordia which are comparatively independent in Amia
(Pehrson, 1940). In *Phoxinus* (Lekander, 1949) the development of dental and splenial shows that these two elements develop independently, the former as dermal and the latter as a latero-sensory canal bone, but only at a late stage the two will fuse and finally the result will be as in *Salmo* and *Esox*, which supports the conception of Pehrson.

In *Ambassia ranga* (*Chanda ranga*) the dentary and angular develop in the same way as the frontals or any two component type of bone described by Walter (1882) and Kapoor (1961, 1970). The two components are fused together from the very beginning so that the latero-sensory component develops from the lamellar part after the formation of the latero-sensory canal.

As regards the number of neuromast sense organs in the mandibular portion of the preoperculo mandibular canal which passes through the dentary and angular bones, there are a number of variations. In *Ophicephalus* (Kapoor, 1960) the canal in the dentary and angular lodges three and one neuromast sense organs, while in *Heteropneustes* (Kapoor, 1960) four and one and in *Wallago* (Kapoor, 1961) it lodges eight and one neuromast sense organs respectively. In *Phoxinus* (Lekander, 1949) there are one or two in the dentary and one in the angular bone, but according to Manigk (1933) there are three neuromasts in the dentary bone. In *Nemachilus* (Lekander, 1949) a mandibular line in proper sense is missing thus no dental splenial bone is
to be seen and the angular-splenial contains two neuromast sense organs. In *Leuciscus, Alburnus* and *Abramis* (Lekander, 1949) the canal in the region of dentary and angular contains six each, in *Tinca* ten, in *Nemachilus* two and in *Plotosus* five neuromast sense organs (Lekander has not mentioned the number of organs in dentary and angular bones separately). In *Amia* (Pehrson, 1922) there are seven organs in dentary and one in angular bone, while in *Notopterus* (Omarkhan, 1949; Kapoor, 1964) there are four organs in dentary and one in angular bone. In the present fish the mandibular portion of the preoperculo-mandibular canal lodges four neuromast sense organs, three in the dentary and one in the angular bone.

The canal after leaving the angular bone runs further as the preopercular canal in the preopercular bone. In the mode of development the preopercular bone shows variations in different Teleosts. According to Lekander (1949) in Cyprinids the preopercular develops in the same manner as the antorbital. He states, "a blastema appears, immediately underneath the sense organ in the preopercular line. Several organs participate in its formation. A single bone is formed from the beginning. No indication of a binary or serial origin can be traced. Far later during the development, the latero-sensory component forms, likewise in a direct contact with the sense organs. However, these bones form serially one in connection with each neuromast". In *Leuciscus* (Lekander, 1949) the two components are fused with
each other from the very beginning but in *Phoxinus* and *Tinca* (Lekander, 1949) the two components form separately and join only later. In *Phoxinus* the preopercular canal is very short, thus the canal bones are restricted to only the horizontal part of the bone, while in *Nemachilus* the two components remain separate. In *Cobitis* the latero-sensory part is completely missing. The preopercle in *Ophicephalus* and *Wallago* (Kapoor, 1970) is unquestionably a two component bone, the latero-sensory component of which arises at the time of invagination of the neuromast sense organs. In *A. ranga* (*G. ranga*) the lamellar and the latero-sensory components of the preopercular bone develop in the same manner as the frontal.

The number of neuromast sense organs in the preopercular portion of the preoperculo-mandibular canal in the preopercular bone varies in different fishes. In *Ophicephalus*, *Heteropneustes* and *Wallago* (Kapoor, 1960 a, b, 1961) the canal lodges six, three and three neuromast sense organs respectively. Lekander (1949) reported twenty neuromasts in this canal in *Tinca*, fourteen in *Abramis*, ten in *Leuciscus*, six in *Phoxinus* five in *Nemachilus* and three in *Plotosus*. In *Amia* (Pehrson, 1922) there are five neuromasts located in the preopercular bone, however, in *Notopterus* (Omärkhan, 1949; Kapoor, 1964) and *A. ranga* (*G. ranga*) their number is six.

In some cases the preoperculo-mandibular canal after leaving the preopercular bone, but before joining the temporal
canal, passes through a small ossicle; the supra-preopercular, which has been discussed earlier. In case of Sisor (Mahajan, 1966) the preopercular canal from its junction with the mandibular canal runs through four to six tubular ossicles; the infra-preopercular ossicles and after leaving the preopercle bone and before joining the temporal canal again passes through a couple of bone ossicles, the supra-preopercular ossicles. In Alburnus and Anguilla (Lekander, 1949) this bone is a latero-sensory one without any membranous component. Lekander (1949) states that "In fishes with a short lamellar preoperculum these canals components become free, in the shape of supra-preopercular bones providing they do not secondarily fuse with underlying operculum as in Alburnus and Leuciscus." Thus these bones constitute an independent continuation of the latero-sensory parts in the preoperculum. In A. ranca (C.ranca) this bone is altogether absent.

The temporal canal starts from the junction of supra and infraorbital canals behind the eye in the anterior region of the sphenotic bone, and traverses through-out its length, and then runs back through the pterotic, extra-scapular and the post-temporal bones. In Cyprinidae (Ramaswami, 1955b) the sphenotic bone is generally associated with the latero-sensory system, its sensory component (the intertemporal) becoming indistinguishably fused with the sphenotic bone. In Wallago attu (Kapoor, 1970) the portion of the temporal canal in the region of
the dermosphenotic runs in a gutter and is not protected by bone from above (Kapoor, 1961b). In *Ophicephalus*, Kapoor (1970) stated that the section of the canal enclosed in the region of the inter-temporal-dermosphenotic is devoid of any neuromast sense organ. Obviously therefore, a full latero-sensory unit or ossicle of bone in connection with this section of the canal should be expected to be absent. It is probable, therefore, that the bone tube which develops around the section of the canal represents a detached anterior portion of the adjoining latero-sensory component the inter-temporal (squamosal latero-sensory ossicle of Allis's description). Allis (1904) reported that in one of the skulls of *Pleuronectes* the canal was found to be in a groove of the sphenotic and on one side of another skull, a portion of the canal was enclosed within this bone. Further in *Hippoglossus* he found that besides the presence of sphenotic the canal pass directly from frontal to pterotic, so he believes that the canal becomes secondarily enclosed in the sphenotic in *Pleuronectes* as well as in the same bone in *Amiurus*, *Ophicephalus* and *Hexarchonemastes* (Kapoor, 1960). In *Clupisoma* as also in *Silonia* and *Eutrophiichthyes* (Khandelwal and Sharma, 1965) the canal in the sphenotic is enclosed within the bone tube. However, Allis (1904) in *Silurus* reported the absence of the bone tube in the sphenotic and found that the canal simply lies in a groove without bony covering. In his account of *Amiurus*
**nebulosus** Allis (1904) refers to the sphenotic as a bone occurring between the frontal and squamosal. This bone corresponds to the one which has been identified by Kapoor (1960, 1961) as sphenotic in *Heteropneustes* and *Wallago*. The only difference is the presence and absence of the bony covering over the canal. In the present fish the canal runs in the gutter of the bone and the bony covering over the canal is missing.

In some fishes the canal in its course in the sphenotic is devoid of any neuromast organ as in *Ophicephalus* (Kapoor, 1960), *Amiurus nebulosus* (Allis, 1904), *Wallago attu* and *Heteropneustes* (Kapoor, 1961, 1960) but in *A. range* (*C. range*) the section of the canal in the region of sphenotic lodges one neuromast sense organ like *Perca fluviatilis*, *Micropterus dolomieu*, *Pomatomus saltatrix*, *Archosargus brobatocephalus*, *Cottus octodecimospinosus* and *Cottus geneus* (Allis, 1904).

The temporal canal from sphenotic passes into the pterotic bone which in *Leuciscus*, *Abramis*, *Alburnus* and *Tinca* (Lekander, 1949) is a true cartilage bone in association with the dermal lamellae (dermo-pterotic) of the latero-sensory system. In *Salmo reedus* (Devillers, 1944) and *Esox* (Pehrson, 1944) the membranous component is formed in relation with the neuromast sense organs of the temporal latero-sensory canal. In *Salmo* (Pehrson, 1944) there is only one primordium which fuses with the underlying opisthotic followed by the addition of the
supra-temporal bone along with the lateral line canal with it. Kapoor (1970) named this bone as 'inter-temporal membranopterotic' in Wallago. According to him in Ophicephalus "the membrano-pterotic is also fused ab initio with the inter-temporal and is therefore, to be regarded as an inter-temporal membranopterotic". In the same fish, first a bone plate develops under the organ which is on surface and as the development proceeds further and the organ becomes enclosed within the canal, a lamella develops from the bone plate, which by gradual growth in successive stages, flanks the newly formed canal on its dorsal side and eventually joins the outwardly curved ventral edge of the bone plate to form a bone tube around the canal. The bone tube represents the inter-temporal component of the bone. A supra-temporal component is absent but it is present in Wallago around the second and third neuromasts of the line. In A. ranga the pterotic bone is fused with the supra-temporal component of the latero-sensory canal system but the supratemporal does not form the complete bone tube. The development of the bone is similar to that of Ophicephalus but in A. ranga (C. ranga) unlike Ophicephalus the canal is in the gutter-shaped bone.

Generally in teleosts the section of the temporal canal lodges a single neuromast sense organ in the pterotic bone but in Wallago (Kapoor, 1961b) it lodges three neuromast sense organs. Unlike Perca fluviatilis, Micropterus dolomieu,
**Pomatomus saltatrix**, *Archosargus probatocephalus*, *Cottus octodecimospinosus* and *Cottus aeneus* (Allis, 1904) and like *Ophicephalus* (Kapoor, 1960), in *A. ranga* the pterotic bone lodges a single neuromast sense organ. The preopercular canal joins the temporal canal in the region of the pterotic bone.

The canal from pterotic passes into the extra-scapular bone. In having the supra-temporal diverticulum inside the extra-scapular bone *A. ranga* (*Chanda ranga*) resembles *Ophicephalus* (Kapoor, 1960) and *Perca fluviatilis*, *Micropterus dolomiea*, *Pomatomus saltatrix*, *Archosargus probatocephalus*, *Cottus octodecimospinosus* and *Cottus aeneus* (Allis, 1904) like Aeaontliopterygian fishes where the supra-temporal cross commissural canal runs through one or more extra-scapular ossicles but in *A. ranga* the supra-temporal canal (diverticulum) like *Ophicephalus* runs through a single extra-scapular bone which ossifies at three centres. According to Kapoor (1960 b) these three ossifications quite possibly correspond to the three extra-scapular ossicles of Allis's description in *Polypterus* (1900) and in *Muraenida* (1903) etc. none of them evidently fuses with the parietal, while in the case of *Cottus* (Bodenstein, 1882) the mesial ossicle fuses with the parietal, and the supra-temporal cross-commisural canal passes through the compound parieto-extra-scapular bone (Allis, 1904). In *A. ranga* there is a single extra-scapular bone which has a lateral and a median arm, the former enclosing the main temporal canal and the latter
the diverticulum. The extra-scapular in this case also develops from three ossification centres and encircles the canal within it. The extra-scapular in *Ophicephalus* lodges three neuromasts, two of these are placed in the supra-temporal diverticulum enclosed by the median arm and have been referred to as the first and second neuromasts, while the third is lodged in the region of the canal enclosed by the lateral arm of this bone and has been designated as the third neuromast. In *A. range* the extra-scapular bone lodges four neuromast sense organs, two of these are lodged in the supra-temporal diverticulum enclosed by the median limb and the other two are lodged in the main temporal canal enclosed by the lateral limb, which are the third and the fourth organs of the main temporal canal.

After leaving the extra-scapular bone the canal passes into the post-temporal bone which is also a two component type of bone. In *Wallago* and *Ophicephalus* (Kapoor, 1970) it ossifies as a thin plate of bone at an early stage when the organ is lying freely exposed at the surface, and represents the lamellar component, then the organ starts invaginating and the paired lamellae representing the latero-sensory component of the bone develops from the underlying plate and as the organ becomes enclosed in a canal the lamellae also grow simultaneously and arch over the canal and fuse with each other to form a bone tube around the canal. In *A. range* also the lamellar
component of the bone develops first in the form of a thin plate-like bone under the fifth temporal neuromast sense organ which is at the surface and does not show any invagination. Subsequently it invaginates and gets enclosed within the canal and then only the latero-sensory component develops from the underlying lamellar component and finally arches over the canal to form the bone tube around it.

Generally in fishes like Ophicephalus, Heteropneustes, and Wallago (Kapoor, 1960a, b, 1961), Clupisoma garua (Agrawal, 1966) and other teleosts the temporal canal lodges a single neuromast sense organ in the post-temporal bone. In Ambassis ranga (Chanda ranga) also it lodges a single neuromast.