DEVELOPMENT OF THE LATERO-SENSORY CANALS
AND ASSOCIATED NEUROMAST SENSE ORGANS
IN THE HEAD OF AMBASSIS RANGA

(CHANDA RANGA)
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In the present account the development of the neuromast sense organs has been followed in embryos starting from 4.5 mm in length but the latero-sensory canals start developing much later than the neuromast sense organs. The neuromast sense organs have been described as they would have become finally associated with the respective canals. The neuromast sense organs have been numbered not in accordance with their order of development but in order in which they are found in the adult, starting from the anterior region.

1. 4.5 mm Stage

Figures 1-6

At this stage there is no differentiation of the epidermis, indicating the formation of the neuromast sense
organs in the region of the future infraorbital and the temporal canals. In the supraorbital, however, the neuromast sense organs are represented by two patches of slightly enlarged epidermal cells which form the entire thickness of the epidermis in these areas. These patches correspond to the third and fourth organs of the adult. Similarly there are three areas of slightly enlarged epidermal cells, as in the preceding case, which correspond to the second, third and sixth organs of the preoperculo-mandibular canal of the adult.

2. **5.0 mm Stage**

Figures 7-13

At this stage also no trace of neuromast sense organs is seen in association with the infraorbital and the temporal canals. The third and the fourth supraorbital neuromast sense organs have now reached the surface and taken the form of elongated epidermal cells arranged in the form of shallow depressions.

Six preoperculo-mandibular neuromast sense organs can be made out at this stage, three in the mandibular portion corresponding to the second, third and fourth, and three in the preopercular portion corresponding to the fifth, sixth and
seventh organs of the future canals found in the adult. All these organs are still in the form of areas of slightly enlarged epidermal cells which form the entire thickness of the epidermis. The second, third and sixth are somewhat more prominent than others, and all of them show a vacuolar space at the top called an apical cavity.

3. **6.0 mm Stage**

Figures 14-21

At this stage neuromast sense organs associated with the infraorbital canal have made their appearance but still there is no trace of any neuromast sense organ associated with the temporal canal.

In the supraorbital line, all the six neuromast sense organs found in the adult can be made out. The third and fourth have now partially sunken down below the surface, while the first is represented by a patch of slightly enlarged epidermal cells which form the entire thickness of the epidermis in this area. Now the second, fifth and sixth have also reached the surface and show an apical cavity, and take the form of elongated epidermal cells arranged in the form of a shallow depression.

In the infraorbital line the first three neuromast sense
organs have made their appearance. The first and second show an apical cavity. The third is less developed and is represented by an area of enlarged epidermal cells which form the entire thickness of the epidermis.

In the preoperculo-mandibular line one more neuromast sense organ can be made out. Thus, now there are three in the mandibular portion corresponding to the second, third and fourth, and four in the preopercular portion corresponding to the fifth, sixth, seventh and eighth of the adult. Out of these organs the second, third and sixth have become more enlarged than in the previous stage, but still show an apical cavity. The fourth, fifth, seventh and eighth are represented by patches of slightly enlarged epidermal cells which form the entire thickness of the epidermis.

4. **8.0 mm Stage**

Figures 22-35

In the supraorbital line, the first neuromast sense organ has now reached the surface and shows an apical cavity. The second and sixth have become somewhat enlarged but still show the apical cavity on the surface. The third, fourth and fifth have now sunk down below the surface and show a shallow depression on the surface. The depression being
shallowest in the case of the fifth.

In the infraorbital line in addition to the first three neuromast sense organs seen in the previous stage, six more can now be made out and thus all the nine seen in the adult stage have now made their appearance. The first and second have now begun to sink below and show a shallow depression on the surface. The third has now reached the surface and shows an apical cavity. The fourth, fifth, sixth and seventh have also reached the surface and show small apical cavities. The eighth and ninth, each is represented by an area of slightly enlarged epidermal cells which form the entire thickness of the epidermis in the areas.

In the preoperculo-mandibular line the first as well as the ninth and tenth neuromast sense organs can now be made out. Thus the full complement of ten as found in the adult have now made their appearance; four in the mandibular portion and six in the preopercular portion. The first, fourth, seventh, eighth, ninth and tenth have reached the surface and show small apical cavities. All the remaining ones i.e. the second, third, fifth and sixth have sunken down below and each one of them shows a shallow depression on the surface, which is most pronounced in the case of the sixth organ.

At this stage four neuromast sense organs in the temporal
line also have made their appearance. These correspond to the first four neuromast sense organs found in the main part of the temporal canal of the adult and are represented by areas of enlarged epithelial cells which form the entire thickness of the epidermis.

Two neuromast sense organs have made their appearance in the supra-temporal line also and they correspond to the two neuromast sense organs found in the supra-temporal canal on the diverticulum of the adult. These organs are in the form of patches of enlarged epithelial cells forming the entire thickness of the epidermis.

5. 10.0 mm Stage

Figures 36-47

This stage shows the first indication of the formation of the preoperculo-mandibular line as a canal for a short distance, enclosing the sixth neuromast sense organ of the line. The other latero-sensory canals, however, are still undeveloped.

In the supra-orbital line the first neuromast sense organ still remains on the surface with an apical cavity. In addition to the third, fourth and fifth organs, the second and sixth have now sunken deep down in the dermis and each
one lies at the base of a gutter-shaped depression which opens widely on the surface.

In the infraorbital line, the first and second neuromast sense organs have sunken deeper down but their depressions on the surface are still shallow. The third, fourth, fifth, sixth and seventh organs have become somewhat enlarged but still remain on the surface and each one is provided with an apical cavity. The eighth and ninth organs are still without any apical cavity.

In the preoperculo-mandibular line the first, fourth, ninth and tenth organs still remain at the surface and each one of them shows an apical cavity but the seventh and eighth have sunken down below the surface and each one of them shows a shallow depression. The second, third, fifth and sixth have now sunken down deeper below the surface. At this stage the depression in which the neuromast organs are situated becomes continuous from the fifth up to the eighth organ, and over the sixth organ the edges of the depression fuse together to form a complete canal. On either side of the canal the depression gradually gets shallower. The ninth and tenth organs, however, are still on the surface, each with an apical cavity.

In the temporal line the fifth neuromast sense organ can now be made out and thus the full complement of five, as
found in the adult have made their appearance. The first organ is more developed than the rest and has sunken below the surface showing a shallow depression. The second, third and fourth have now reached the surface and each one shows an apical cavity. The fifth one is represented by an area of enlarged epithelial cells forming the entire thickness of the epidermis.

The two neuromast sense organs found in the supra-temporal line or diverticulum of the adult are still in the form of patches of enlarged epithelial cells, which form the entire thickness of the epidermis, but have become more prominent than in the previous stage.

6. **12.0 mm Stage**

Figures 48-61

At this stage a little more development of the lateral sensory canals in the head can be made out. It shows the first indication of the formation of the supraorbital as well as the preoperculo-mandibular canal as continuous canals, each enclosing more than one neuromast sense organs.

In the supraorbital line the first organ has also now partially sunken down below the surface and shows a very shallow depression. The second organ has sunken deeper down,
and its depression on the surface is more pronounced. The third, fourth, fifth and sixth organs now lie deep down in the dermis at the base of a continuous depression (invagination). The edges of the depression over the third, fourth and fifth neuromast sense organs, however, have fused together to form a canal, but an opening is left in the canal in between the two successive neuromast sense organs. At either end the canal is continued into the depressions, at the bases of which, the second and sixth organs are situated.

In the infraorbital line, in addition to the first and second neuromast sense organs the third has also now sunk down below the surface. The depression being most pronounced in the case of the third neuromast sense organ. By now the eighth and ninth organs have also reached the surface. All the neuromast sense organs from fourth to ninth, however, still remain on the surface and each one shows an apical cavity.

In the preoperculo-mandibular line the first and fourth organs have now sunk down below the surface and show small depressions. The second and third organs show depressions on their surfaces and the depression of the third organ is more pronounced. The fifth organ has now sunken deeper down in the dermis and the edges of the depression have fused to form a canal, which becomes continuous
with the part of the canal which encloses the sixth organ. A wide opening, however, remains in the canal in between the two neuromast sense organs. The seventh and eighth organs have sunken further down than in the previous stage. The ninth and tenth organs, however, still remain on the surface, each with an apical cavity.

In the temporal line, the first, third and fourth neuromast sense organs have now sunken down below the surface and each one shows a shallow depression. The second organ still remains on the surface showing an apical cavity. The fifth organ has now reached the surface and it also shows an apical cavity.

The two neuromast sense organs found in the supra-temporal line also have now reached the surface and each one has an apical cavity.

7. **14.0 mm Stage**

Figures 62-74

The development of the sensory head canals has now proceeded much further than in the previous stage. This stage gives the first indication of the formation of the infraorbital line as a canal enclosing only a single organ within it.
In the supraorbital line the canal shows its further extension towards the posterior direction. The first and second neuromast sense organs have sunken down deeper still than in the previous stage and are placed at the bases of shallow gutter-shaped depressions (shallow gutter-shaped invaginated canal). This depression extends further back and finally gets converted into the closed canal. The third, fourth and fifth neuromast sense organs were already enclosed in the canal in the previous stage and the sixth organ which was placed in the open canal now gets sunken still deeper down into the dermis and finally gets enclosed within the canal. Thus, at this stage the supraorbital canal is enclosing four neuromast sense organs within it. The canal is gutter-shaped having wide openings above in between every two successive neuromast sense organs.

In this stage for the first time the infraorbital line is seen in the form of a canal enclosing a single neuromast sense organ. The first organ has sunken deeper down and shows slightly larger depression above the surface than in the previous stage. The second neuromast is now better developed and sunken deepest down the dermis to get enclosed within the canal. The canal in between the second and the third organs is shallow and gutter-shaped. The third organ also has sunken deeper down the dermis and is
placed in an open canal with a wide opening above. Rest of the six neuromast sense organs are in the same condition as they were in the previous stage.

In the preoperculo-mandibular line, the canal has proceeded further anteriorly as well as posteriorly. The first organ shows a little larger depression on the surface, as it has sunken deeper in the dermis but is not associated with the canal. The second, third and fourth organs have sunken deepest into the dermis and get enclosed within the continuous canal. Thus, this is the stage where we find the first indication of the formation of mandibular portion of the preoperculo-mandibular canal as a continuous canal enclosing more than one neuromast sense organs which was only gutter-shaped in the previous stage. The fifth and sixth organs were already enclosed within the canal in the previous stage, and now seventh and eighth organs have developed much more and sunken deepest down in the dermis and get enclosed, within the canal. The ninth and tenth organs have also sunken further below the surface and show slightly larger depressions on the surface than in the previous stage. Thus, the preoperculo-mandibular canal at this stage encloses seven neuromast sense organs within it, three in its mandibular portion and four in the preopercular portion. The mandibular and preopercular portions become continuous. The canal is gutter-shaped in between every two
successive neuromast sense organs. But this open area is slightly reduced in comparison to the previous stage.

In the temporal line the first, third and fourth neuromast sense organs have sunken further below the surface than in the previous stage. The second and fifth organs still remain on the surface, each with an apical cavity.

The two neuromast sense organs found in the supra-temporal canal or the diverticulum of the adult are in the same condition as they were in the previous stage.

8. **16.0 mm Stage**

**Figures** 75-88

This stage shows only further extension of the different canals. In the supraorbital line the canal does not show many developmental changes as from the previous stage. The first neuromast sense organ is as it was in the previous stage, but the second organ is better developed and sunken deeper down in the dermis and is placed at the base of an open canal with a wide opening above. The third, fourth, fifth and sixth organs were already enclosed within the continuous canal, in the previous stage. Just after the fourth neuromast sense organ the canal gives off the
indication of frontal commissure of the adult in the form of very small projections from both sides. The large open areas in between every two successive neuromast sense organs are now getting reduced to get converted in the form of openings. The open areas in between the fourth and fifth, and fifth and sixth have become very much reduced than in the previous stage, while in between the third and fourth it is still quite large.

In the infra-orbital line the canal shows a little more development than in the previous stage. It has further extended towards the anterior side. The first organ has sunk deepest into the dermis and got enclosed within the canal. The second organ was already enclosed within the canal in the previous stage. The third organ has also sunk down in the dermis but it is still not enclosed in the canal. It is placed in an open canal with a small opening above. The rest of the six neuromast sense organs are still unassociated with the canal and are as in the previous stage. The infraorbital canal has reached up to the anterior end of the lachrymal bone, in front of the first neuromast sense organ of the line. It gives out a small projection from its dorsal side in front of the first organ. The canal has a terminal pore at its anterior end, and remains open in between the first and second organs for a long interval.
In the preoperculo-mandibular line one more neuromast sense organ is now enclosed within the continuous canal. The first organ has sunken down a little more than the previous stage. The second, third, fourth, fifth, sixth, seventh and eighth organs are already associated with the canal and now the ninth organ has sunken lowest down in the dermis and got enclosed within the canal. The tenth organ is just the same as it was in the previous stage. The open area of the canal, in between every two successive neuromast sense organs is reduced to some extent and at some places tends to convert into tubular openings.

In the temporal line the first neuromast sense organ has sunken down in the dermis. The second organ has partially sunken below the surface. The third and fourth are again sunken down in the dermis and are placed in the open canal with wide openings above. The fifth organ is still on the surface with an apical cavity.

In the first neuromast sense organ of the supra-temporal canal or diverticulum of adult there is no change and it is as it was in the previous stage, but the second has partially sunken down below and shows a very small depression on the surface.
9. **18.0 mm Stage**

**Figures 89-98**

At this stage in the supraorbital line the canal extends further towards the anterior side. The first neuromast organ has sunken deeper into the dermis and lies at the base of the canal with a narrow opening above. The second organ has also sunken down into the dermis and lies at the base of the continuous canal. The third, fourth, fifth and sixth were already associated with the canal in the previous stage. All the six organs associated with the canal have become quite large in size. The openings are slightly reduced and the projection which will form the frontal commissure in the adult does not show any further development.

In the infraorbital line the canal does not show any remarkable change. The first and second neuromast sense organs lie at the base of the closed canal and the third is still in the open canal. The remaining fourth, fifth, sixth, seventh, eighth and ninth organs are still on the surface. Though the canal starts with the first terminal pore, yet the opening in between the first and the second organ is not converted into the pore of the adult.
In the preoperculo-mandibular line the first neuromast sense organ is still in the gutter-shaped depression. The second, third, fourth, fifth, sixth, seventh, eighth and ninth organs were already in the canal, now the tenth organ has also sunk deeper down into the dermis but still lies at the base of the open canal. The canal has a narrow opening on the upper side. The opening in between the fourth and fifth, fifth and sixth, and sixth and seventh organs are still quite large, but very small tubular openings are formed in between the seventh and eighth and eighth and ninth organs which are the eighth and ninth pores of the adult.

In the temporal line the development of the neuromast sense organs is as in the previous stage except that the second has sunk deeper in the dermis than in the previous stage. The third and fourth have also sunk deeper down into the dermis but the fourth organ still lies in the open canal with a small opening above, while the third is now enclosed within the canal. The fifth organ is still on the surface.

Both the neuromast sense organs of the supra-temporal diverticulum of the adult have sunk still deeper than in the previous stage.
10. **22.0 mm Stage**

**Figures 99-107**

This is the stage when the temporal line gives the first indication of the formation of the continuous main temporal canal as well as its supra-temporal diverticulum, enclosing more than one neuromast sense organs.

The supraorbital canal has advanced over the previous stage. The edges of the depression of the first organ have also fused together to form a canal. Thus the full complement of six neuromast sense organs of the adult is now associated and enclosed within the canal which is nearly fully formed. Except the first terminal pore the pores found in the adult have not yet been formed, as the canal in between every two successive neuromast sense organs is still open for fairly long intervals. The lumen of the canal is not the same throughout its length. It is wider in the middle and narrower in its anterior and posterior ends. The processes arising from the canal, which will form the frontal commissure of the adult are now better developed than in the previous stage.

In the infraorbital line the canal further extends back to enclose the third neuromast sense organ. Thus at this
stage the first three organs lie within the continuous canal. The rest of the six organs have sunken partially below the surface and show small depressions. The lumen of the canal is very wide in its anterior region and gradually becomes narrower towards its posterior part. Only the first terminal infra-orbital pore is formed.

The preoperculo-mandibular canal is still not fully formed. The development of the first organ is the same as it was in the previous stage, but the tenth organ has sunken deepest down into the dermis, and the canal has extended back to enclose it. The third and fourth pores are formed in between the second and third, and third and fourth neuromast sense organs (primary pores, Kapoor, 1963). In addition to these the seventh, eighth, ninth and tenth pores placed at the tips of the tubular processes or canaliculi of the adult are also formed. The lumen of the canal is narrower in its mandibular portion and wider in its preopercular portion.

In the temporal line, the first, second, third and fourth organs have sunken down in the dermis and the two lateral edges of the depressions fuse together to form a complete and continuous canal enclosing all these four organs. The fifth organ has also sunken down into the dermis and lies at the base of an open canal with a wide opening above. The openings in between every two organs are not yet
converted into the form of pores as they are still wide.

Both the organs of the supra-temporal line have sunken deepest into the dermis and the edges of the depression fuse together to form the canal over both the organs. The temporal diverticulum is given off from the main canal in between the second and the third neuromast sense organs of the main canal.

11. 28.0 mm Stage

Figures 108-112

The condition of the supraorbital canal is the same as in the previous stage. The processes which will form the frontal commissure of the adult have further developed. The first terminal pore along with the second and sixth pores of the adult have been formed, of which the sixth is placed at the tip of a small tubular process or canaliculus. The lumen of the canal is variable in its different regions.

In the infraorbital line the fourth, fifth, sixth, seventh, eighth and ninth neuromast sense organs have invaginated deep below the surface in the dermis and show depressions, which are deeper over the ninth and tenth organs. The first and second pores of the adult have been formed, of which the first is terminal and the second is at the end of
a very small outwardly directed tubular process arising
from the outer margin of the canal.

The preoperculo-mandibular canal shows the same condition
as found in the previous stage. The first neuromast sense
organ is lying in the open canal with a small opening above.
In addition to the third, fourth, seventh, eighth and ninth
pores the sixth, tenth and eleventh pores are also formed.
The tenth and eleventh pores are placed at the tips of small
tubular processes arising from the outer margin of the canal.

In the temporal line the canal has further extended back
to enclose the fifth neuromast sense organ and now it has
attained its full length. Almost from its middle it gives
out the supra-temporal diverticulum. The main canal has developed
only two pores up to this stage, i.e. the first and the second
pores of the adult. The supra-temporal diverticulum opens
out by two pores; the first is placed at the tip of a small
tubular process while the second is terminal.

12. 34.0 mm Stage

Figures 113-124

At this stage the supra-orbital canal is fully formed with
all the six neuromast sense organs and openings present in
the adult. The frontal commissure is also completely formed by
the union of the two processes arising from the supraorbital canals of the two sides. It connects them transversely. Each half of the commissure opens out by a single pore placed at the tip of a small caudad directed tubular process as in the adult. The canal starts with the first terminal pore. The second pore is simple and placed in between the first and the second neuromast sense organs. The third pore is placed at the end of a small tubular process or canaliculus in between the second and the third neuromast sense organs. The fourth pore is against the fourth organ and is tubular. The fifth pore is again tubular and placed a little anterior to the fifth neuromast sense organ. The sixth pore is placed in between the fifth and the sixth neuromast sense organs and it is also at the tip of a small tubular process.

The infraorbital canal now shows a little further development over the previous stage. The seventh, eighth and the ninth neuromast sense organs have now sunken deepest into the dermis so that the edges of the depression join together to form a continuous canal over them. The fourth, fifth and the sixth organs are still placed in the open canal. The opening above the sixth is narrower than above the fourth and fifth organs. The canal joins the supraorbital canal after the ninth neuromast sense organ behind the eye. At this stage only a few of the pores have been formed, namely the first, second, third, eighth and the ninth pores of the adult. Each of these pores except
the first terminal pore, is placed at the tip of a very small tubular process. The second pore is very close to the first neuromast sense organ. Third pore is in between the second and the third organs. The eighth and ninth pores are placed in between the seventh and eighth and eighth and ninth organs respectively.

In the preoperculo-mandibular canal now the first organ has also become enclosed within the anterior portion of the mandibular portion of the preoperculo-mandibular canal, so that all the ten organs are now associated with the canal and all the eleven openings found in the adult have also been formed. The canal has joined with the main temporal canal, almost in its middle. The preoperculo-mandibular canal communicates with the exterior by eleven pores throughout its full length. Out of these eleven pores last five are placed at the tips of canaliculi or the tubular processes. The first five pores are found in the mandibular portion of the canal while the rest of the six in the preopercular portion.

The temporal canal and the supra-temporal diverticulum with their pores and canaliculi as found in the adult are fully formed. The main part of the temporal canal has developed five pores along its full length. The first pore is placed at its starting point, where the canal meets with the supra and infraorbital canals. The second pore is placed a little behind the first neuromast sense organ. The third pore is
adjacent to the supratemporal diverticulum. The fourth and the fifth pores are placed opposite to the fourth and the fifth organs. The supratemporal diverticulum opens out by two pores. The first tubular pore is in between the first and second neuromast sense organs and the second pore is terminal and at the tip of the free end of the diverticulum.
MORPHOLOGY
MORPHOLOGY

Figures 125-126

In the adult *Ambassis ranga* (*Chanda ranga*) the latero-sensory canal system in the head region consists of a number of large tunnel-like canals which are symmetrically disposed off on either side of the skull and they open to the outside by several pores. The lumen of the canals varies in size and extent in various regions of the system. The disposition of the sensory canal system follows the generalized pattern. These canals of the system are as follows:

(a) Supra-orbital latero-sensory canal,

(b) Infra-orbital latero-sensory canal,

(c) Preoperculo-mandibular latero-sensory canal, and

(d) Temporal latero-sensory canal.
(a) Supraorbital Latero-Sensory Canal:

The supraorbital canal runs along the dorsal side of the skull and is enclosed in the nasal and frontal bones throughout its length. Anteriorly, it lies in the nasal bone and then runs further back through the frontal and after leaving the frontal enters into the sphenotic bone. Just behind the eye it is joined by the infraorbital canal in the anterior portion of the sphenotic bone. The supraorbital canals of the two sides are connected with each other by a frontal commissure in the region of the middle of the frontal bone, just opposite to the fourth tubular opening of the canal. Each supraorbital canal communicates with the exterior by six openings. The first pore is terminal and placed at the anterior end of the nasal bone. All the pores except the second are placed at the ends of small tubular processes or canaliculi. The second opening is simple and situated almost in the anterior half of the nasal bone, while the third is placed at the anterior end of the frontal bone. In the anterior most region of the frontal bone the supraorbital canals of the two sides, run very close to the mid-dorsal line, and extends backwards and opens out by fourth opening placed on small canaliculi. Now the canal moves towards the outer margin of the frontal bone, runs up to the hinder limit and in due course opens out by fifth and sixth canaliculi or
tubular openings. Now the canal enters into the sphenotic bone, where it joins the infraorbital and the temporal canals. This point is marked by an opening which is the first temporal opening. The lumen of the canal is variable in its different regions. It is narrowest in its posterior region where it lodges the fifth and the sixth neuromast sense organs. Each half of the frontal commissure communicates with the exterior by a single large caudad canaliculus.

On either side of the head, the main part of the supraorbital canal contains six neuromast sense organs. The first two are associated with the nasal bone, and of these the first organ lies in between the second and the third openings. The third, fourth, fifth and sixth are situated in the region of the frontal bone, the fourth one is opposite to the fourth opening, the fifth is opposite to the fifth opening but the sixth one lies a little above the posterior extremity of the frontal in between the sixth opening and the first temporal opening. The supraorbital canal is unbranched throughout its length.

(b) Infraorbital Latero-Sensory Canal:

The infraorbital canal starts from the anterior end of the lachrymal bone and runs back along the inferior margin of the eye through the four sub-orbital bones and then enters the sphenotic bone, where as already mentioned, the canal joins
the supraorbital canal and this point is marked by an opening. The infraorbital canal communicates with the exterior throughout its length by nine pores, including the first terminal pore. Each one of these pores, except the first is placed at the end of a very small tubular process arising from the outer margin of the canal. The first three pores are placed in the lachrymal bone and the rest of the six in the sub-orbital bones.

The infraorbital canal lodges nine neuromast sense organs. The first, second and third are lodged in the anterior portion of the canal passing through the lachrymal bone. The fourth and fifth organs are situated in the first, sixth and seventh in the second, eighth in the third suborbital bone, and the ninth in the fourth sub-orbital (post-orbital) bone.

(c) **Preoperculo-mandibular Latero-Sensory Canal:**

The preoperculo-mandibular latero-sensory canal is divisible into two portions; an anterior mandibular and the posterior preopercular portion. The anterior mandibular part of the canal starts with an opening and runs along the entire ventral margin of the dentary bone and extends back into the angular bone. After leaving the angular bone, the canal runs further as the preopercular portion of the
preoperculo-mandibular canal into the preopercular bone. The preopercular portion of the canal runs along the outer margin of the preopercular bone and after leaving it, finally joins the temporal canal. This point of junction is marked by an opening. The lumen of the canal varies in its different parts. It is narrow in its mandibular portion but is of variable width in its preopercular portion. This preoperculo-mandibular canal communicates to the exterior by eleven openings. Out of these the first five are located in its mandibular portion and the remaining six in its preopercular portion. Each of the seventh, eighth, ninth, tenth and eleventh pore is placed at the tip of a tubular process or canaliculus arising from the outer margin of the canal. The first pore is terminal and placed at the anterior region of the dentary bone. The first four pores are placed in the dentary and the fifth in the angular bone. After leaving the angular bone the mandibular canal becomes continuous with the preopercular canal and this point is marked by an opening. The canal in its further course in the preopercular bone opens out by five tubular pores.

The preoperculo-mandibular canal contains the ten neuromast sense organs within it. The mandibular portion of the canal lodges the first four neuromast sense organs of which the first three are associated with the dentary and the fourth with the angular bone, while the posterior preopercular
portion of the canal lodges rest of the six neuromasts. Each neuromast sense organ is placed in between every two successive openings of the canal.

(d) **Temporal Latero-Sensory Canal:**

The temporal canal starts with an opening placed at the junction of the supra- and infraorbital canals behind the eye and extends back along the lateral part of the posterior half of the head. During its course it passes through the sphenotic, pterotic, extrascapular and the post-temporal bones, and finally enters into the trunk region as the main body lateral line canal. In the region of the pterotic bone it receives the preoperculo-mandibular canal and in the transverse limb of the extrascapular bone it gives off a characteristic Acanthopterygian supratemporal canal, which is in the form of a diverticulum. The diverticulae of the two sides do not meet with each other in the mid-dorsal line to form the supratemporal cross-commissure. The supratemporal diverticulum of each side communicates to the exterior by two openings of which the first one is placed at the tip of the small tubular process caudad directed and opposite to the first neuromast sense organ, while the second is the terminal one. The main part of the temporal canal communicates to the exterior throughout its length by five openings. Except the first and the second pore each of the hinder three pores
is placed at the end of short tubular processes. The first and the second pores are placed in the sphenotic bone while the third and fourth in the extra-scapular and the fifth in the post-temporal bone.

The main portion of the temporal canal lodges five neuromast sense organs of which the first is placed in between the first and the second pore, the second is placed just after the meeting point of the preoperculo-mandibular canal with the temporal canal; the third just after the place, where the main canal gives off the supratemporal diverticulum, while the fourth and fifth are situated in its further course. The supratemporal diverticulum also lodges two neuromast sense organs in its course in the transverse limb of the extra-scapular bone.

Thus from the above account it is clear that the system in *Ambassis renqa* is an open system and represents the generalized teleostean system. All the canals and openings are unbranched. Each pore except the terminal pore is placed in between every two successive neuromast sense organs or in other words the pores and neuromast sense organs are placed alternately.

**Structure of the Neuromast:**

The histological structure of the neuromast is practically the same and uniform in the different groups of fishes. The
structure of neuromast in *A. ranga* (*C. ranga*) is same as in other teleosts. It consists of a group of sensory cells placed on the basal epithelial lining. This group of cells consist of two kinds of cells; supporting cells in which the nuclei are located near the base of each cell; the other, the sensory cells whose nuclei are placed in the middle of the cells. From these sensory cells, sensory hair or cilia project into the lumen of the canal. A noncellular cupula is attached to the distal ends of the cilia of each neuromast enclosed within the canal system of the head region.

The cilia are very small so that the cupula is more or less in close association with the neuromast. Associated bones lie surrounding the base of the neuromast. There is connective tissue in between the canal and the bone. The wall of the canal is lined internally by very thin membrane consist of extremely flattened cells.
DISCUSSION
DISCUSSION

The general pattern of the lateral line system in the head of Teleostei is represented by:

(i) Supraorbital latero-sensory canal, (ii) infraorbital latero-sensory canal, and (iii) temporal and the preoperculo-mandibular latero-sensory canals. Typically the supra and infraorbital canals join the anterior end of the temporal canal behind the posterior margin of eye, and the preoperculo-mandibular canal joins the temporal canal somewhat farther back. Posteriorly the temporal canals of the two sides are usually connected with each other by a supratemporal cross commissure or the occipital commissure. These canals contain within them a number of neuromast sense organs and communicate with the outside by a number of pores. This generalized pattern, however, is subject to modifications in the different members of the group, both as regards the disposition of the canals as well as to the number of pores and neuromast sense organs.
association with them.

The development of the latero-sensory canals in Teleostei was first described by Allis (1889) in his classical work on *Amia*. Later on in 1904 he distinguished two types with regard to the formation of the sensory canals, the plagiostomian type and the teleostean type. According to him the plagiostomian canal is the result of dehiscence or deliquescence in the central portion of the solid cord of cells formed by an involution of the deeper layers only of the ectoderm, while the teleostean canal is the result of a much larger involution which involves the entire ectoderm and includes within it the ectodermal region that gives origin to the plagiostomian type which is found in Selachoids and Batoids and probably also in Chondrostei while the former type in Teleosteii and Holosteii. Omarkhan (1949) has dealt with the development of the latero-sensory canal system in Teleostei and states that the works of Allis (1839), Wilson (1889) and Locity (1895) may be summarised as follows:

1. In the neighbourhood of the ultimate position of the auditory organ, a small ectodermal sensory dorso-lateral placode arises. The differentiation of which gives rise both the auditory organ and the latero-sensory canal system.

2. This rudiment soon occupies a position in the deeper
layers of the epidermis and begins to grow as a nonsegmental cord of cells. By the extension and branching of this cord, other cords are formed in lines indicating the future pattern of the canals.

3. A localized thickening of the cord gives rise to each organ, which at first lies embedded in the epidermis, but soon pushes through the overlying epidermal cells and thus its upper central portion becomes exposed.

4. Each sense organ now begins to sink down carrying the surrounding epidermis with it, so that it ultimately lies at the bottom of the groove.

5. The tips of the groove fuse, leaving a pore at each end. Each sense organ now lies in a short tube opening at each end to the surface by a pore ("half-pore" of Allis, 1889).

6. Each tube extends both ways and fuses with the two adjacent tubes, adjacent "half-pores" fusing to form a single "primary pore". Each sensory canal therefore is formed by end-to-end fusion of small tubes which are formed by epidermal invaginations and not by conversion into hollow tubes of a solid cord of cells derived from the epidermis.

Omarkhan (1949) says "in Notopterus the lateral line sense organs in the head region do not ever open on the surface, and that no invagination of the epidermis takes place for the
formation of tubes. The tubule is formed by the sinking down and direct conversion of an ectodermal solid cord of cells into a shallow cylinder.

According to Lekander (1949) normally the canals in Teleostei will originate from an invagination of the epithelium into a broad furrow which will then close and thus a canal with a wide lumen will form. In Phoxinus, however, he found that the canals which appear first, like the mandibulo-preopercular canal, develop somewhat differently. In these, just before the canal is about to sink in, the deeper parts of the epithelium assume the shape of a small massive ridge and secondarily a lumen will appear. According to Lekander, 1949 "the canals that form later, e.g. the infraorbital will develop in an entirely normal way through a wide invagination". Thus in Phoxinus, the latero-sensory canals develop in both ways while in Notopterus, they develop entirely in the plagiodontian way. Lekander (1949) further states "Generally a first sign of the formation of the canals can be traced as a clearly marked epithelial thickening projecting towards underlying tissue. Later, however, the development may turn out differently. Either this epithelial ridge will remain for a considerable time, a lumen being formed only secondarily, through a breaking down of the central cells, or the canal formation may take place quite normally, through an invagination
of a broad strip of epithelium* (p. 35). He also mentions that in other Cyprinids examined by him, the first or plagiostomian type of development appear rather frequently, though more or less distinctly developed.

It will not be out of place to mention in this connection that much earlier Beard (1885-86), had stated that the lateral line in the embryos of Salmon develops as a cord of cells by the splitting off of certain cells in the inner layers of the epiblast which corresponds to the linear streaks of modified epidermis in Scylium (Balfour, 1881). Similarly in Batrachus also Clapp (1889) had mentioned that the sense organs of the lateral-line system arise from special cord of cells formed in the lower layer of the epidermis, and it follows the same process of formation of the canal as described by Allis (1889) in Amia, but in this fish the growing edges of the pits do not meet and fuse over the majority of the neuromasts which therefore, remain in this condition (i.e. lying in pits) even in the adult. Denny (1937) also has referred briefly about a strand of non-sensory epithelium in the lower layers of the epidermis connecting the sense organs of the lateral line in the head of Fundulus, recalling the condition described by Wilson (1889) in Serranus in which in between the sensory organs, the sensory tissue condenses into a solid connecting strand. Kapoor (1963) has discussed in detail the classification of the
latero-sensory canals into plagiostomian and teleostean types as advocated by Allis (1904), that the canals in these two divisions of fishes have fundamentally different morphological nature and are, therefore, not homologous structures.

The present author feels that considering all the above facts the classification of canals according to the development into plagiostomian and teleostean types, though generally true, cannot now be considered as strictly applicable as both types of development take place not only in some Teleostei but even in the same fish as happens in *Phoxinus*.

Among the acanthopterygians and cyprinids very little work has been done on the development of the latero-sensory canals in the head, while a fairly good amount of work has been done in Siluroids. Among the acanthopterygians only the work of Allis (1889) is available.

In *Ambassis rança* (*Chanda rança*) the development of the latero-sensory canal system follows the usual teleostean pattern i.e. to begin with each neuromast lies at a level with the epithelium. At a subsequent stage it starts invaginating and in doing so it more or less, drags with it, the adjoining layer of ectoderm. This naturally results in the disintegration of the underlying layer of
the connective tissue. A gutter is eventually formed, at the base of which lies the invaginated neuromast. The process of invagination continues further and the aforementioned gutter gradually becomes deeper. Another change which takes place simultaneously is the inward growth of both the edges of this gutter. These growing edges subsequently meet each other above the invaginated neuromast and finally fuse so as to form a small section of the canal with two openings (half pores of Allis) one on either end.

In Teleostei, the order of formation of canals varies considerably. Lekander (1949) has drawn special attention to the formation of the canals in several fishes at different times. The Table 1 shows the same as studied by Lekander (1949) in 14 different fishes and in Ambassis range (Chanda range) by the present author.

As compared to other Teleostei the canals seem to be practically always earlier in acanthopterygians, and in cyprinids the formation of canals occurs very late. Further, the canals develop in a certain order. According to Lekander (1949), "As a rule, the anterior part of the preopercular canal forms first. After that, or simultaneously part of the supraorbital and mandibular canals appear. Every time the infraorbital canal develops last. Invariably part of the
<table>
<thead>
<tr>
<th>Name of the fish</th>
<th>Length of Fish</th>
<th>Canal Formed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clupea</td>
<td>29 mm</td>
<td>Preopercular canal</td>
</tr>
<tr>
<td>Clupea</td>
<td>32 mm</td>
<td>All canals</td>
</tr>
<tr>
<td>Coregonus lavaretus</td>
<td>21 mm</td>
<td>Only preopercular canal indicated</td>
</tr>
<tr>
<td>Salmo salar</td>
<td>20 mm</td>
<td>All canals except the infraorbital indicated</td>
</tr>
<tr>
<td>Salmo salar</td>
<td>27 mm</td>
<td>All canals, except the infraorbital indicated</td>
</tr>
<tr>
<td>Galichthys</td>
<td>15.3 mm</td>
<td>Frontal and mandibular canals</td>
</tr>
<tr>
<td>Galichthys</td>
<td>17 mm</td>
<td>Antorbital and preopercular canals</td>
</tr>
<tr>
<td>Galichthys</td>
<td>22.5 mm</td>
<td>Temporal canal</td>
</tr>
<tr>
<td>Galichthys</td>
<td>32 mm</td>
<td>Infraorbital canal</td>
</tr>
<tr>
<td>Esox lucius</td>
<td>18.2 mm</td>
<td>Frontal canal. Anterior part of preopercular canal indicated.</td>
</tr>
<tr>
<td>Esox lucius</td>
<td>20.5 mm</td>
<td>Nasal canal. Antorbital canal indicated</td>
</tr>
<tr>
<td>Esox lucius</td>
<td>32 mm</td>
<td>Temporal canal</td>
</tr>
<tr>
<td>Esox lucius</td>
<td>40 mm</td>
<td>Slightly developed infraorbital canal</td>
</tr>
<tr>
<td>Lebistes</td>
<td>23 mm</td>
<td>Mandibulo-preopercular canal only</td>
</tr>
<tr>
<td>Spinachia spinachia</td>
<td>28 mm</td>
<td>Only supraorbital, antorbital and preopercular canals</td>
</tr>
<tr>
<td>Belone acus</td>
<td>25 mm</td>
<td>Invagination of the anterior part of the preopercular canal indicated</td>
</tr>
<tr>
<td>Belone acus</td>
<td>43 mm</td>
<td>The anterior part of the mandibular and the entire preopercular canal</td>
</tr>
<tr>
<td>Belone acus</td>
<td>62 mm</td>
<td>The frontal canal, the antorbital part of the infraorbital canal, temporal and anterior body canals indicated</td>
</tr>
<tr>
<td>Ammodytes tobianus</td>
<td>23 mm</td>
<td>The frontal and the pre-opercular canals. The anterior part of the body canal</td>
</tr>
<tr>
<td>Ammodytes tobianus</td>
<td>35 mm</td>
<td>All canals</td>
</tr>
<tr>
<td>Gadus merlanus</td>
<td>15 mm</td>
<td>All canals</td>
</tr>
<tr>
<td>Perce flavatilis</td>
<td>29 mm</td>
<td>All canals</td>
</tr>
<tr>
<td>Labrus spec.</td>
<td>10 mm</td>
<td>Supraorbital, antorbital, mandibular and temporal canals only</td>
</tr>
<tr>
<td>Trachurus trachurus</td>
<td>17 mm</td>
<td>All canals</td>
</tr>
<tr>
<td>Bothus spec.</td>
<td>8.5 mm</td>
<td>Antorbital, preopercular and body canals only</td>
</tr>
<tr>
<td>Ambassis ranga</td>
<td>10 mm</td>
<td>Preoperculo-mandibular canal</td>
</tr>
<tr>
<td>Ambassis ranga</td>
<td>12 mm</td>
<td>Supraorbital canal</td>
</tr>
<tr>
<td>Ambassis ranga</td>
<td>14 mm</td>
<td>Anterior portion of the infraorbital canal</td>
</tr>
<tr>
<td>Ambassis ranga</td>
<td>18 mm</td>
<td>Middle portion of the temporal canal</td>
</tr>
</tbody>
</table>

The term frontal canal is here applicable to the part of the supraorbital canal that lies in or on the frontal bone.
infraorbital canal forms first. In many fishes, there is no invagination of the middle and posterior parts of the canal. The anterior part of the main canal of the body mostly forms early". He further added that in Cyprinids also the canals form in the same order. In Phoxinus (Lekander, 1949), however, the mandibular canal is formed first and then the preopercular one; as to the supraorbital the frontal part appears first, then the nasal part and after that the posterior prolongation or 'canal anterieur'. Throughout the infraorbital canal develops last, mostly a considerable time after others. In Namachilus (Lekander, 1949), however, the order is reversed and the 'canal anterieur', the infraorbital and the temporal canals are formed far in advance of the other canals (p. 113). Among Siluroids, there seems to be no record of the order in which the different canals are formed. Even Kapoor (1963) has described only the development of the supraorbital canal in Wallago attu and has not described the canals as they are formed in the different stages studied by him.

The present fish follows the typical acanthopterygian order in the formation of the canals, i.e. the anterior part of the preopercular canal is formed first, which is followed by the middle part of the supraorbital canal and
then the mandibular canal appears. The infraorbital and the temporal canals are the last to be formed.

The different canals normally open to the outside by pores but in some cases, they are closed and do not communicate to the exterior by any pore in the adult (Sinusoid type) as in *Lota* (Allis, 1904; Omarkhan, 1948) and *Notopterus* (Omarkhan, 1949). Such a condition, however, has not been reported in any other teleostei. In cyprinids namely *Leuciscus*, *Alburnus* etc., according to Lekander (1949) the supra- and infraorbital canals are not connected behind the eye but according to Khandelwal (1963) in *Cirrhina*, *Catla* and *Labeo* the supra- and infraorbital canals meet with each other behind the eye. Bhargava (1972) also reported their union behind the eye in *Rasbora daniconius*. In addition as in *Nemachilus barbatula* (Lekander, 1949) the supra-orbital and preoperculo-mandibular canals may not form continuous canals; but they are continuous canals in *Cirrhina mirgala*, *Catla catla* and *Labeo gonius* (Khandelwal, 1963), and *Rasbora daniconius* (Bhargava, 1972). Further, the canals may be restricted to only the anterior part of the body as in *Misgurnus anquillicaudatus*, *M. decemcirrosus* and *Cobitis biwae* or may be entirely wanting as in *Lefua echigonia* (Miyadi, 1929, quoted by Lekander, 1949, p.58), *Cobitis taenia* and *Coryderus* (Lekander, 1949).
In Siluroïds, the canal system is very well developed and the canals open to the exterior by pore tubes, some of which may be specially long and even branched.

In Perciformes according to Allis (1904), Jakubowski (1963 and 1966) and Moor (1956a, b) the canal system is well developed. All the canals are complete and continuous canals. The supra- and infraorbital canals meet each other behind the eye, and the temporal canal after leaving the post temporal bone extends back as the main lateral line canal of the trunk region. Ambassius ranga (Chanda ranga) shows the typical Perciform type of canal system.

In Teleostei, in general the supraorbital canal passes through the nasal, frontal and sphenotic (dermo-sphenotic) bones and in the sphenotic joins the infraorbital canal. A similar condition is found in Perciformes also, and in a few cyprinids, indigenous to India and studied by Khandelwal (1963) and Bhargava (1972) the supraorbital canal receives and joins the infraorbital canal in the sphenotic bone; but in a few other cyprinids like Leuciscus, Alburnus and Tinca (Lekander, 1949) it is not connected with the infraorbital canal. In Notopterus chitala (Omarkhan, 1949 and Kapoor, 1964) the supraorbital canal remains quite independent from the rest of the canals. The important features with regard to the supraorbital canal, which need
special mention, are the presence or absence of a posterior or mesial branch from the hinder end of the canal, and the presence or absence of a frontal commissure. In the Siluroideos (Pollard, 1892), the supraorbital canal just before joining the infraorbital canal gives off mesially a small branch which runs inwards and backwards; in Heteropneustes (Kapoor, 1960-61) also, a similar branch is present but it runs abruptly backwards. According to Allis (1889), Nielson (1942) and Devillers (1944 and 1947), the lengthened posterior part of the canal is homologous with the anterior pit line of Amia (Allis, 1889). It also corresponds to the much longer 'canal anterier' of the Characinidae like Erythrinus (Sagemehl, 1985) and Cyprinids like Leuciscus Alburnus, Tinca and Phoxinus (Lekander, 1949) and Cirrhina, Catla and Labeo (Khandelwal, 1963) in which it extends back up to the parietals but in R. daniconius (Bhargava, 1972) it is absent. In Siluroideos this canal contains a single neuromast sense organ while in Cyprinids it contains usually two. This extension of the supraorbital canal is absent in Polypterus (Allis, 1900; Jarvick, 1947), Ophicephalus (Kapoor, 1961) and all the other groups of Teleostei including the Perciformes.

In Ambassis ranga this 'canal anterier' is totally absent like other Perciform fishes.
In Siluroids the frontal commissure joining the
two supraorbital canals may be either absent or present.
In Wailago and Heteropneustes (Kapoor, 1957b, 1960a, 1961),
a tube leaves the supraorbital canal behind the third
neuromast organ, but the tubes of the opposite sides do not
unite to form a commissure but open separately close to
each other along the mid-dorsal line. A vestige of a
commissure has been recorded in Monopterus javaneusis
(Yih, 1948). Pollard (1892) has described a commissural
connection behind the third neuromast organ in Chaetostomus,
and Collinge (1895b) has described a similar connection in
Clarias magur and an imperfectly developed commissure, in
Pimelodus. In Sisor rhabdophorus Mahajan (1966) has also
described the frontal commissure behind the third neuromast
organ. From near the middle of this commissure arises a tube
which runs anteriorly and opens outside by a pore. In
Plotosus also, Friedrich-Freksa (1930) has described a
pore-tube commissure between the two canals. In Cyprinids
(Lekander, 1949; Khandelwal, 1963; Bhargava, 1972), however,
this commissure is altogether absent.

In Perciform fishes the frontal commissure joining the
two supraorbital canals is usually present, but sometimes
absent. According to Moor (1956) in Aphredoderus sayanus
(Pirate perch) it is in the form of an anastomosis, the two
supraorbital canals are joined by a broad anastomosis and its posterior median portion opens by a median coronal pore. Moor (1956b) further reported its presence in Leopomis (sun fish) also, where the commissure gives off a single median caudad canaliculus through which it opens out. Its presence has been also reported in Cottus (Bodestein, 1882; Allis, 1904), Acerina cernua, Leucioperca leucioperca, Mullus barbatus (Jakubowski, 1963, 1966) and Perca fluviatilis (Jakubowski, 1966; Allis, 1904) but in different forms. According to Jakubowski (1963) in Acerina, the so called frontal commissure is absent but above the middle of the eyes the supraorbital canals communicate with each other by a broad anastomosis which sends out an unpaired spacious sac like canaliculus caudad. In Leucioperca (Jakubowski, 1966) the supraorbital canals of the two sides give off long canaliculi which are directed caudad and usually communicate with each other but in some specimens measuring 35 mm there is no such communication. The frontal commissure as such is present in Perca fluviatilis (Allis, 1904; Jakubowski, 1966) and connects the supraorbital canals of the two sides. It gives off a median canaliculus and a small canaliculus on either side from its anterior margin. In Spicara smaris (Jakubowski, 1966) the commissure is absent and instead two well developed canaliculi corresponding to the position of the frontal commissure, tend backwards
and produce a very dense network and join with the canaliculi arising from the terminal portions of the supra-temporal canal. Kapoor (1957) also reported its presence in *Ophicephalus punctatus*.

In the fish studied by the writer the frontal commissure as such is present and connects the supraorbital canals of the two sides. It gives off a single large caudad tubular process bearing an opening at the tip from each half of the commissure.

In Teleostei in general the infraorbital passes through the lachrymal and the series of sub-orbital bones (including the post-orbitals) and then enters the sphenotic, where it joins the supraorbital canal. It shows no special variations except the presence of an ethmoid commissure in some cases and in some it is not joined by the supraorbital canal. In Cyprinids worked out by Lekander (1949) the infraorbital canal does not join the supraorbital canal while in the Indian Cyprinids studied by Khandelwal (1963) and Bhardwaj (1972) the infraorbital canal joins the supraorbital canal behind the eye. In Siluroids like *Sisor* (Mahajan, 1966) and Acanthopterygians (Allis, 1904) also the supra- and the infra-orbital canals meet each other behind the eye.
In *Amia* (Pehrson, 1922) the sub-orbital (infraorbital) canal is enclosed in the antorbital, lachrymal, sub-orbital 1 and 2, post-orbital 1 and 2 and the dermo-sphenotic bones. Mostly in Teleostei, however, this antorbital bone seems to be absent. In *Amia*, *Polypterus*, and *Lepidosteus* (Pehrson, 1922) etc. anteriorly the infraorbital canal joins its counter part of the opposite side infront of the anterior nasal aperture to form an ethmoid commissure, but in all Teleostei, this pre-nasal part is absent and consequently there is no trace of an ethmoid commissure.

In *A. ranga* (*Chanda ranga*) the canal passes through the lachrymal and the series of four sub-orbital bones and finally gets joined to the supraorbital and the temporal canals behind the eye. Like other Teleostei the pre-nasal part and the ethmoid commissure are absent.

Generally in Teleostei, the preoperculo-mandibular canal passes through the dentary, angular and the preopercular bones to join the temporal canal in the pterotic (squamosopterotic). In some fishes in which the preopercular bone is absent as in *Phavania*, *Gasteromyzon* and *Aphyocypris* (Ramaswami, 1948, 1955b) the mandibular canal is carried by a number of ossicles. In many teleostei, as in *Salmo* (Collinge, 1895b; Allis, 1904), *Leuciscus* (Devillers, 1947) and *Anguilla* (Lekander, 1949), the mandibular canal passes
from the preopercular bone into the supra-preopercular bone, before joining the temporal canal. Allis (1903) also has described the presence of such a bone in Muraenidae. According to Ramaswami (1955a) in some Gobiidinae the opercular bone carries the sensory canal leading to the lower jaw. In his figure 8, he has shown that the canal passes through the antero-dorsal portion of the opercular bone and it is just possible that this part of the bone represents the supra-preopercular element which has become fused with the opercular during development. In Siluroids, however, the preoperculo-mandibular canal is well developed and after passing through the dentary, angular and preopercular joins the temporal canal in the squamoso-pterotic bone. Herrick (1901) has mentioned that in Amiurus melas and some other North American Siluroids, a small portion of the canal extending between the pre-opercular and pterotic is enclosed in a small 'supra opercular' bone which is tubular or ring-shaped. In Clupisoma (Agrawal, Sharma and Khandelwal, 1965) the canal before joining the temporal canal passes through the supra-preopercular ossicle. Kapoor (1961) found a similar tubular ossicle in Wallago attu and Heteropneustes and has called it as 'supra-preopercular', a term which seems to be more appropriate. According to him the canal in this bone does not contain any neuromast sense organ and represents the detached portion of the adjoining
latero-sensory unit belonging to the preoperculum and is not homologous with the supra-preopercular found in a similar position in other teleosts like Muraenidae. In *Leuciscus* (Devillers, 1947) *Alburnus* and *Anguilla* (Lekander, 1949), a similar ossicle, in which the portion of the canal is passing through the bone, lodges a neuromast sense organ. Pollard (1892) has mentioned that in 30 mm long specimens of *Callichthys*, a short preopercular canal is present but does not communicate with the temporal canal. According to him no such ossicle is present in *Auchenaspis bissulcatus* but writes "the last portion of the canal lies in dermis outside the dilator opercular muscle".

The preoperculo-mandibular canal, however, shows variations in the different teleostei. In most of the cases, the two mandibular portions of the canal are quite separate from each other, but in a few exceptional cases like *Clarias* (Collinge, 1895) and *Ophicephalus* (Kapoor, 1960b) the two mandibular portions of the preoperculo-mandibular canal are connected with each other anteriorly, but this connection is a purely secondary one. Allis (1904) stated that in *Moxostoma* the mandibular canal is entirely wanting. Andres (1899) and Allis (1904) had stated that the mandibular canal is absent in *Tinca*, but according to Lekander (1949) a well developed mandibular canal exists in
this fish. Similarly in *Chaetostomus*, the mandibular portion is absent and in 25 mm long specimens of *Trichomycterus* the entire preoperculo-mandibular canal is absent, but this statement of Pollard (1892), however, cannot be applicable to the adults also because his account is based on small specimens only and as pointed out by Kapoor (1961), in Siluroids like *Wallago* the connection between the preopercular portion and the temporal canal is not formed in the specimens as large as 33 mm in length, though in the adult the two are connected. However, in *Sisor* (Mahajan, 1966) the connection between the preopercular portion and the temporal canal is present.

In many other Teleostei, specially in some Cyprinids (Lekander, 1949) the mandibular portion of the preoperculo-mandibular canal, is not continuous with the preopercular portion of the canal, but in other Cyprinids studied by Khandelwal (1963) and Bhargava (1972) the mandibular portion of the canal is continuous with the preopercular portion of the canal like other teleosts. Further according to Lekander (1949) the posterior portion of the preopercular canal in Cyprinids like *Leuciscus*, *Alburnus*, *Tinca* and *Phoxinus*, is incomplete and never reaches up to the temporal canal. In *Aphyocypris* (Ramaswami, 1955b) the preopercular canal is absent.
In Perciform fishes (Jakubowski, 1963, 1966; Moor, 1956a, b; Allis, 1904) the course of the preoperculo-mandibular canal is the same as found in other teleost fishes. It passes through dentary, angular and the preopercular bone. After leaving the preopercular bone the canal joins the main temporal canal. The mandibular portions of the two sides do not meet each other and they are continuous with the preopercular portion of the canal. In general the preoperculo-mandibular canal joins the main temporal canal but some variations are still there. In some fishes like Aphredoderus (Moor, 1956a) Lepomis (Moor, 1956b), Mullus and Spicara (Jakubowski, 1966) the preoperculo-mandibular canal joins the temporal canal while in others like Acerina (Jakubowski, 1963), Leuciperca and Perca (Jakubowski, 1966) it does not join the temporal canal. In Acerina it does not join the temporal canal but terminates at the height of the upper pupil. In Leuciperca also it does not join but the upper end of the preopercular canal lies very close to the middle part of the temporal canal so that the condition found in Acerina and Leuciperca is almost similar.

In the present fish, the preoperculo-mandibular canal follows the typical Perciform course and joins the main temporal canal almost in its middle. The canal does not pass through the 'supra preopercular' ossicle and the
mandibular portion of the canal is continuous with that of the preopercular portion. The anterior ends of the two mandibular canals do not join with each other.

The temporal canal starts from the junction of the supra- and infraorbital canals behind the eye, and runs backwards up to the hinder end of the head, where it becomes continuous with the lateral line canal of the trunk region, but according to Omarkhan (1949) and Kapoor (1964) in *Notopterus* the temporal canal is prolonged anteriorly above the eye up to the posterior nostril and it dilates into a large sinus at the point where the preopercular canal opens into it. The temporal canal in general teleostei, during its course passes through the sphenotic, pterotic (squamoso-pterotic), extra specular (-tubular or post-parietal) and post-temporal (supra cleithrum) bones.

In *Amia* (Pehrson, 1922), most of the Acanthopterygii, *Salmo, Conger* (Collinge, 1895b) and many Ostariophysi like *Phoxinus, Albunus, Abramis, Tine* and *Nemachilus* etc. (Lekander, 1949) the two temporal canals are connected with each other posteriorly by an occipital or supra-temporal cross-commissural canal. According to Lekander (1949), Khandelwal (1963) and Bhargava (1972) this cross-commissural canal connecting the two temporal canals is well developed in Cyprinids. Among Siluroids this commissure is absent
except in *A. caudus* in which its presence has been reported by Wright (1884) and Collinge (1895b), but Herrick (1901) has denied its presence in *A. nebulosus*. In some other fishes like *Ophicephalus* (Kapoor, 1957 and 1959) it is represented by a mesially directed diverticulum from each of the two temporal canals, but they fail to unite with each other to form a commissure.

In Perciformes there is variation about the presence and position of the supra-temporal cross-commisural canal. Bodenstein (1882) reported its presence in *Cottus*. In *Perca fluviatilis* (Allis, 1904 and Jakubowski, 1966) it is well developed and connects the temporal canals of the two sides. In *Spicara varisi* (Jakubowski, 1966) the commissure as such is not present but the two canals communicate with each other in a different way. The canaliculi arising from the terminal portions of the supra-temporal canals join the canalicular network of the two well developed canaliculi, corresponding to the position of the frontal commissure, arising from the supraorbital canal. In *Aphredoderus* (Moor, 1957a), *Lepomis* (Moor, 1957b) *Acerina* (Jakubowski, 1963), *Leucoperca* and *Mullus* (Jakubowski, 1966) the supra-temporal canals of the two sides fail to unite with each other so they do not form the commissure and remain in the form of a diverticulum as in *Ophicephalus* (Kapoor, 1960b).
In *A. ranga* (*Chanda ranga*) the temporal canal starts from the junction of the supra and the infraorbital canals behind the eye and passes through the sphenotic, pterotic, extrascapular and the post-temporal bones. From its middle temporal canal of each side gives out a mesially directed supra-temporal canal, which fail to unite with each other to form the supra-temporal cross-commissure and each diverticulum remains as such and is called the supra-temporal diverticulum.

The number of neuromast organs in Teleostei has been described by a number of authors. Pehrson (1922) has stated the canals contain a number of sensory organs, which always occur in a fixed number for each species (p. 38). The following table shows the number of neuromast organs in the different canals in some teleosts. The list, however, should not be considered as exhaustive and is given only to show the great variation in the different members of the group (Table 2).

Thus from the table it is clear that the number of the neuromast sense organs is fairly large in *Amia* (47) and greatly reduced in *Polypterus* (27). In the Cyprinids, their number is usually large and varies from 30 in *Phoxinus* to 85 in *Tinca*. Among the Siluroids, the number is comparatively much smaller and seems to vary between 22 and 27.
<table>
<thead>
<tr>
<th>Author, Year and Fish Described</th>
<th>Supra-orbital canal</th>
<th>Infra-orbital canal</th>
<th>Mandibular canal</th>
<th>Preopercular canal</th>
<th>Temporal canal</th>
<th>Supra-temporal cross-commussural canal</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pehrson</strong> 1922 Amia</td>
<td>7</td>
<td>14</td>
<td>10</td>
<td>6</td>
<td>7</td>
<td>3</td>
<td>47</td>
</tr>
<tr>
<td>1958 Polypterus</td>
<td>6</td>
<td>8</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>27</td>
</tr>
<tr>
<td><strong>Omarkhan</strong> 1949 Notopterus</td>
<td>10</td>
<td>8</td>
<td>5</td>
<td>6</td>
<td>8</td>
<td>1</td>
<td>35</td>
</tr>
<tr>
<td>Lekander 1949 Leuciscus</td>
<td>10</td>
<td>15</td>
<td>6</td>
<td>10</td>
<td>3</td>
<td>6</td>
<td>50</td>
</tr>
<tr>
<td>Phoxinus</td>
<td>5</td>
<td>11</td>
<td>4</td>
<td>6</td>
<td>3</td>
<td>1</td>
<td>30</td>
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<tr>
<td>Albumus</td>
<td>9</td>
<td>11</td>
<td>6</td>
<td>9</td>
<td>3</td>
<td>4</td>
<td>42</td>
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<tr>
<td>Abramis</td>
<td>15</td>
<td>18</td>
<td>6</td>
<td>14</td>
<td>3</td>
<td>5</td>
<td>61</td>
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<tr>
<td>Tinca</td>
<td>15</td>
<td>24</td>
<td>10</td>
<td>20</td>
<td>3</td>
<td>7</td>
<td>85</td>
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<tr>
<td>Politosus</td>
<td>5</td>
<td>7</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>22</td>
</tr>
<tr>
<td>Namachilus</td>
<td>6</td>
<td>11</td>
<td>2</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>28</td>
</tr>
<tr>
<td>Kapoor 1960a Heteropterus</td>
<td>6</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td></td>
<td>2</td>
<td>22</td>
</tr>
<tr>
<td>fossils</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1960b Ophicephalus punctatus</td>
<td>5</td>
<td>7</td>
<td>4</td>
<td>6</td>
<td>(4) 2</td>
<td>2</td>
<td>26</td>
</tr>
<tr>
<td>1961 Wallago attu</td>
<td>5</td>
<td>5</td>
<td>8-10</td>
<td>3</td>
<td>4</td>
<td>-</td>
<td>25-27</td>
</tr>
<tr>
<td>1963 Acrina</td>
<td>5</td>
<td>9</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>31</td>
</tr>
<tr>
<td>Lucioperca</td>
<td>5</td>
<td>11-12</td>
<td>-</td>
<td>-</td>
<td>4</td>
<td>4</td>
<td>31</td>
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<tr>
<td>Perca fluviatilis</td>
<td>5</td>
<td>9-10</td>
<td>5</td>
<td>6</td>
<td>4</td>
<td>3</td>
<td>31</td>
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<tr>
<td>Mulus</td>
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<td>10</td>
<td>4</td>
<td>6</td>
<td>5</td>
<td>2</td>
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<td>5</td>
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<td>4</td>
<td>6</td>
<td>7</td>
<td>2</td>
<td>33</td>
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<tr>
<td>Harbora</td>
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<td>4</td>
<td>6</td>
<td>6</td>
<td>2</td>
<td>33</td>
</tr>
<tr>
<td>Bhargava 1973 Ambassis ranga</td>
<td>6</td>
<td>9</td>
<td>4</td>
<td>6</td>
<td>5</td>
<td>2</td>
<td>32</td>
</tr>
</tbody>
</table>
Kapoor (1963) reported 26 organs in *Ophicephalus*. Among Perciformes the number is larger and varies from 31 to 34. Collinge (1895b) has mentioned that two neuromast sense organs are present in the frontal commissure of *Clarias*, but as pointed out by Kapoor (1961), Pollard (1892) has not shown any such organ in the figure given by him for *Clarias* and that no such organ is present either in *Chaetostomus* or *Plotosus*. Thus it is necessary to investigate *Clarias* to find the presence or absence of neuromast sense organs in the frontal commissure and till then no conclusions can be drawn from the conflicting observation of Pollard (1892) and Collinge (1895b).

In *Ambassis ranqa* (*Chanda ranqa*) the total number of neuromast sense organs present in the lateral line system in the head in each half is 32. Out of these, six organs are lodged in the supraorbital canal, nine in the infraorbital canal, ten in the preoperculo-mandibular canal (of which four in its mandibular and six in its preopercular portion), five in the main temporal canal and two in its supra-temporal diverticulum. The frontal commissure lodges no neuromast sense organ.

In Teleostei the different canals communicate to the exterior by a number of pores some of which are placed at
the ends of small tubular processes or canaliculi, but the system in *Notopterus* (Omarkhan, 1949; Kapoor, 1964) is without any pores whatsoever. The whole system is closed and shut off from the external aqueous medium. In Siluroids in general the latero-sensory canal system is well developed and opens to the outside by pore-tubes which divide into branches and sub-branches before opening to the outside. Among the Cyprinids also the system is an open system so that the different canals communicate to the exterior by a number of pores, which may be simple or tubular.

Several types of canaliculi are found in the different members of the group Perciformes. In *Aphredoderus* (Moor and Burris, 1956) *Lepomis* (Moor, 1956), *Acerina* (Jakubowski, 1963) and *Perca* (Allis, 1904; Jakubowski, 1966) the different canals communicate with the exterior by pores placed on simple and unbranched canaliculi, but in *Perca* (Allis, 1904; Jakubowski, 1966) the canaliculi of the temporal and upper section of the infraorbital canal and on the dorsal side of the head are comparatively very dense while in *Lucioperca*, *Mullus* and *Spicara* (Jakubowski, 1966), the canaliculi are very much branched. The peculiarity of *Spicara* (Jakubowski, 1966) is the large number of much branched canaliculi of different canals, specially of the supraorbital canal. In *Mullus* (Jakubowski, 1966) also, all the canals have a large number of canaliculi; which on the top of the head, lachrymal and
lower part of the preopercular bones are quite large and have several branches. The canaliculi of *Ophicephalus* (Kapoor, 1957) are simple and unbranched.

In *Ambassis ranga* (*Chanda ranga*) all the different canals communicate to the exterior by a number of pores, some of which are placed at the ends of small tubular processes or canaliculi, which are simple and unbranched as in *Acerina*, *Leptomis*, *Perca* etc. There is no secondary ramification of pores and pore-tubes.

The various canals in different fishes communicate to the exterior by a different number of pores. In *Ophicephalus* (Kapoor, 1960a) the supraorbital canal communicates to the exterior by four pores, and the infraorbital by seven. The preoperculo-mandibular canal starts with a single median pore and communicates to the exterior by four pores in its mandibular portion and then joins the preopercular portion of the canal and this junction point is marked by a pore 'y' (Kapoor, 1960) and opens out by a total number of five pores in its preopercular portion and then finally passes out of it to join the temporal canal. The junction between these two canals is marked by a pore 'z'. The temporal canal starts with a pore and runs back through the sphenotic and the pterotic bones without opening out and communicates to the exterior by a pore at the place from
where the canal leaves the extrascapular and enters the post-temporal bone. The frontal commissure opens out by a single dorso median pore and the supra-temporal diverticulum by two pores. In *Heteroneustes* (Kapoor, 1960b) the supra-orbital canal starts with a pore and opens out by five pores, the infraorbital by six pores, mandibular by five and preopercular by three pores; the junction point between the mandibular and preopercular is marked by a pore 'y'. The temporal canal does not start with a pore as the junction point of supra and infraorbital canals with temporal is not marked with a pore. It communicates to the exterior by two pores. In case of *Wallago* (Kapoor, 1961) the junction point of supra and infraorbital canals is not marked by any pore but the junction points of mandibular with preopercular and preopercular with temporal are marked by 'y' and 'z' pores respectively. The supraorbital canal opens out by five, infraorbital by six, mandibular by nine, preopercular by three and the temporal canal by three pores. In *Mystus* (Khandelwal and Rastogi, 1965) the 'x' pore is absent but the 'y' and 'z' pores are present. The supraorbital canal communicates to the exterior by six, infraorbital by three, mandibular by eight, preopercular by one and the temporal by two pores, but in *Clupisoma garua* (Agrawal, Khandelwal and Sharma, 1966) only the presence of 'y' pore is reported, the 'x' and 'z' pores are absent. There
are four pores present in the supraorbital canal, one in infraorbital canal, seven in preoperculo-mandibular and two in the temporal canal. Khandelwal and Sharma (1966) reported the absence of 'x' and 'z' pores and presence of 'y' pore in *Silonica*. They have reported three pores in supraorbital canal, two in infraorbital, seven in mandibular, four in preopercular and three in temporal canal.

In *A. rangea* (*Chanda rangea*) the lateral line canals of the head communicate to the exterior by 33 pores on either side. Each of the supraorbital, infraorbital and the preoperculo-mandibular canal starts with an anteriorly placed terminal pore (half-pore of Allis; 1889). Each supraorbital canal communicates with the exterior by six pores of which all except the first and second, are placed at the ends of small tubular processes. The second pore is the primary pore (Kapoor, 1962). The infraorbital canal opens to the outside by nine pores, each of which except the first, (terminal, half-pore of Allis, 1889) is placed at the end of very small canaliculi. The preoperculo-mandibular canal communicates to the exterior by eleven pores of which the first five are located in the mandibular portion and the remaining six in the preopercular portion of the canal. All the five pores of the mandibular and the first pore of the preopercular portion are simple, but the
remaining five pores of the preopercular canal i.e. the seventh to eleventh pores of the preoperculo-mandibular canal are placed at the ends of tubular processes or canaliculi. The temporal canal opens to the outside by five pores, of which the first one is placed at the junction of the supra and infraorbital canals with the temporal canal, which is a compound pore of Kapoor (1962). Each of the third, fourth and fifth pores are placed at the free end of a short tubular process. The temporal diverticulum of each side opens to the exterior by two pores of which the first is tubular and the second is terminal. Each half of the frontal commissure communicates with the exterior by a single, large, caudad pore tube.