CHAPTER - I

OSTEOL O G Y
OBSERVATION

The cranium of the fishes under the present study can be divided into three principal subdivisions namely neurocranium, branchio- cranium and epicranium. The neurocranium is further discernible into four distinct regions such as olfactory, orbital, otic and basicranial. The branchio cranium, on the other hand, is composed of oromandibular, hyoid and branchial regions. The epicranium, a peculiar feature of these fishes, is in fact an extension of the dorsal fin over the head.

In order to provide a comprehensive idea of the different bony elements of the head region as well as for ready references, a classified list of the same is presented below. The said list will also serve as an index to the description of cranial bones.

LIST OF CRANIAL BONES

//Neurocranium//

/Olfactory region/

1. Ethmoid
2. Lateral ethmoid
3. Prevomer

/Orbital region/

4. Frontal
5. Lacrymal

/Otic region/

6. Autosphenotic
7. Autopterotic
8. Prootic

9. Epiotic
10. Opisthotic
11. Exoccipital
12. Supraoccipital
13. Parietal
14. Posttemporal

/Basicranial region/

15. Basidiphtalic
16. Parasphenoid
//Branchiocranium//

/Oromandibular region/
17. Autopalatine
18. Ectopterygoid
19. Endopterygoid
20. Metapterygoid
21. Quadrate
22. Dentary
23. Angular
24. Retroarticular
25. Maxilla
26. Premaxilla
27. Upper jaw - dentary cartilage

/Hyoid region/
28. Hyomandibular
29. Symplectic
30. Interhyal
31. Epiphyal

//Branchial region/
32. Ceratohyal
33. Upper hypohyal
34. Lower hypohyal
35. Basihyal
36. Urohyal
37. Branchiostegal
38. Preopercle
39. Opercle
40. Interopercle
41. Subopercle

//Epicranium//
47. Brisma
48. Interneural spine
49. Anterior pterygiophore
50. Posterior pterygiophore
51. Anterior pseudointerneural spine
52. Posterior pseudointerneural spine
This is the anterior most region of the neurocranium which provides articulation to different elements of the oromandibular region. The different bones of this region are as follows:

1. Ethmoid

In C. arel (Figs. 7, 9, 11, 15) it is a small funnel shaped bone placed at the anterodorsal angle of the neurocranium and lies above the prevomer. It is postero-laterally flanked by the two lateral ethmoids. In profile, the anterior border of the ethmoid descends in a concave arc to become continuous with the anterior border of the prevomer below. However, a cartilaginous bridge is present between them. The anterior border of ethmoid provides space for the attachment of maxilla-ethmoid ligament whereas the dorsal concavity provides space for the attachment of ethmoid-anterior pseudointernuclear spine ligament.

It is similar in the rest of the fishes investigated.

2. Lateral ethmoid

These paired elements are present over the prevomer and parasphenoid and are capped anteriorly by the ethmoid.

The lateral ethmoid of the ocular side of C. arel (Figs. 7, 9, 11, 12, 16) is an irregular shaped bone with the apex projecting laterally. Anterolaterally and posteroventrally it articulates with the prevomer and lateral ethmoid of the blind side respectively. Posterodorsally it has a small prong on which rests the anterior end of the frontal of the same side. The bone bears a pore in its basal region for the exit of olfactory nerve.
On the blind side (Figs. 8, 10, 11, 12, 17) it is relatively a large bone having a long postero-ventral prolongation which becomes narrow distally and runs along the inner aspect of the parasphenoid. Anteroventrally and posterodorsally it has firm interdigitation with the prevomer and the anterior end of the frontal of the blind side respectively. Anterodorsally the lateral ethmoid possesses a relatively a small aperture in comparison with the ocular side for the exit of the olfactory nerve of the blind side. Anterolaterally, on the outer aspect there is a disc-like structure which provides place for the attachment of autopalatine.

This bone is identical in the rest of the fishes studied.

3. Prevomer

In C. arel (Figs. 7, 8, 9, 10, 11, 12, 18, 19) the median, unpaired, prevomer consists of an edentulous inverted irregular shaped head with its posterior end much drawn out to a long pointed shaft. The latter is sutureally inserted into a ventral depression on the anterior end of the parasphenoid. The head of the prevomer is directed downward and slewed round to the blind side. Dorsally the head is covered by the ethmoid. The anterolateral profile of the head remains continuous with the anterior aspect of the ethmoid and a cartilaginous bridge intervenes between them. The head of the prevomer provides an area on which lies the median rostral cartilage. Dorsolaterally the head is attached to the lateral ethmoids on both the sides but the ala for articulating with the lateral ethmoid is larger on the blind side.

This bone is similar in rest of the fishes studied presently.

/Orbital region/

The bones of this region are generally paired and contribute to the rim of the orbit. However, the frontal bones of this region
exhibit extreme asymmetry so as to accommodate both the eyes on left side. A detail account of the bones of this region is given below.

4. Frontal

The paired frontals of *C. areol* (Figs. 7, 8) are large elongated bones whose posterior halves are connected with each other and forms the anterior roof of the skull. Dorsally the frontals are connected to each other more towards the ocular side as the frontal of the blind side is larger. Posteriorly the frontals are connected by sutures to the parietals and the latter extends laterally over the former. Posteroventrally they are connected with the autosphenotic and to some extent overlaps the anterodorsal part of the latter. Anteriorly both the frontals form a facet to which is loosely attached the anterior pseudointerneural spine.

The frontal of the ocular side (Figs. 7, 9, 11, 20) is thin and becomes narrow and curved anteriorly. On its inner aspect it carries the sensory canal along its length in its body proper. The anterior end of the frontal rests upon a posterodorsal prong of the lateral ethmoid of the ocular side and almost touches the ethmoid in front. Laterally it bears an aperture for the exit of supra orbital trunk of the trigemino facial nerve.

The frontal of the blind side (Figs. 8, 10, 11, 21) is a straight and stout bone, which is attached to the lateral ethmoid on its anterior end in a digitate manner. It possesses a lateral groove on its outer aspect and relatively a large aperture for the exit of supra orbital trunk of the trigemino facial nerve complex. Dorsally the frontal possesses a ridge over which passes the posterior pseudointerneural spine.
Further, it may be mentioned that the nature and disposition of this bone is similar in rest of the fishes investigated presently.

5. Lacrymal

In *C. arel* (Figs. 22, 86, 87) it is a small, roughly cone shaped bone located in front of the lower orbit. The bone possesses three faces for the attachment of different ligaments which have been described in chapter III.

On the blind side it is relatively large and is located at a position corresponding to that of the ocular side.

In *C. bilineatus* this bone is lacking on the ocular side. However, the above bone is similar in *C. lingua*, *P. blochii* and on the blind side of *C. bilineatus* (Fig. 89).

/Otic region/

This is the posterior region of the skull consisting of all paired bones except one i.e. supraoccipital. The bones of this region forming the otic capsule provide protection for brain, cranial nerves and sensory equilibrating apparatus. The branchiocranium, vertebral column and the pectoral girdle are also afforded foothold for their attachment.

The constituent bones are as follows:

6. Autosphenotic

In *C. arel* (Figs. 7, 8, 9, 10, 23) this bone is present in a position corresponding to the posterodorsal rim of the lower orbit. Anterodorsally and posterodorsally it is attached suturally to the frontal and parietal respectively and remains partly overlain by the frontal. Posteriorly it articulates with the autopterotic and posteroventrally with the prootic with which it shares the anterior
hyomandibular fossa. The spinous autosphenotic ridge which projects downwards lateroposteriorly from the autosphenotic provides a suitable area for the origin of m. levator arcus palatini.

On the blind side the autosphenotic ridge is relatively large.

In rest of the fishes the bone is similar to that of C. arel.

7. Autopterotic

It is roughly a disc shaped bone with a lateral ridge and forms the dorsolateral wall of the brain case of C. arel (Figs. 7, 8, 9, 10, 14, 24). It articulates, anteriorly with the autosphenotic, anterodorsally with the parietal, posterodorsally with the epiotic and posteriorly it is capped by the exoccipital. Ventrally the autopterotic articulates with the prootic and posteroventrally with the opisthotic with which it shares the posterior hyomandibular fossa. Autopterotic of the blind side is similar to that of the ocular side.

The nature and disposition of this bone is similar in rest of the fishes presently investigated.

8. Prootic

In C. arel (Figs. 7, 8, 9, 10, 25) it is an expanded bone which contributes to the formation of auditory capsule. Each prootic unites anterodorsally with the autosphenotic with which it forms the anterior hyomandibular fossa and posterodorsally with autopterotic with which it shares the posterior hyomandibular fossa. At the posteroventral corner the prootic remains separated from the basioccipital by a cartilaginous block. However, such a condition is absent in P. blochii (Fig. 13). Subventrally from each prootic, a flange extends horizontally to meet its fellow of
the other side. The prootic lodges two foramina for the facial (VIIth) nerve and jugular vein.

This bone is identical on the blind side except for the fact that the foramen (Fig. 10) for the facial nerve is relatively large.

It is identical in the rest of the fishes.

9. Epiotic

It is a hollow, cone shaped bone capping the posterodorsal corner of the skull of \textit{C. arel} (Figs. 7, 8, 9, 10, 11, 14, 26). It joins medially with the supraoccipital, anteriorly with the parietal, posteriorly with the exoccipital and ventrally with the autopterotic. On the dorsal side a shallow groove is present which receives the superior limb of posttemporal.

This bone is symmetrical on both the sides.

In rest of the fishes it is similar to that of \textit{C. arel}.

10. Opisthotic

It is the smallest bone of the otic series in \textit{C. arel} (Figs. 9, 10, 27). It is present below the exoccipital and autopterotic and takes part in the formation of the posterior hyomandibular fossa. The body of the bone possesses a depression which receives the inferior limb of posttemporal.

This bone is identical on the blind side as well as in the rest of the fishes studied.
11. Exoccipital

These are irregular shaped bones present at the rear end of the skull surrounding the foramen magnum of *C. arel* (Figs. 9, 10, 11, 14). Each exoccipital makes natural contact with the basioccipital ventrally and the prootic anteriorly. It articulates antero-dorsally with the epiotic and anterolaterally with the autopterotic and opisthotic. The foramen magnum is roofed by paired wing like expansion of the dorsal surface of the exoccipital, each wing curving dorsomesially to meet its fellow of other side. The two exoccipitals, together with the basioccipital condyle, form the tricondylar articulation with the atlas. On either side of foramen magnum the exoccipital lodges two apertures for the exit of glossopharyngeal (IXth) and vagus (Xth) nerve. However, the foramen for the vagus nerve is relatively large on the blind side. It is similar in the rest of the fishes observed.

12. Supraoccipital

This unpaired bone, of *C. arel* (Figs. 11, 14, 28), caps the cranium posterodorsally, flanked anterolaterally by the perietals and articulates posteriorly with the epiotic. Posteriorly, it forms a supraoccipital spine which remains separated from the lateral lamellae of the exoccipital by a cartilaginous bridge. The base of the posterior pseudointerneural spine which passes over it gets almost fused with the latter. In *C. lingua* and *C. bilineatus* it is similar to that of *C. arel*.

However, in *P. blochii*, the supraoccipital bears a mid dorsal groove into which fits the distal end of erisma.
13. Parietal

In C. arel (Figs. 7, 8, 9, 10, 11, 29, 30) each parietal is suturally united to the frontal anteriorly, supraoccipital medially and epiotic posteriorly. The autopterotic and the autosphenotic form its ventral border. It has dorsolateral ridge, which anteriorly overlaps the frontal partially.

The parietal of ocular side is identical with that of blind side excepting a feebly developed dorsal ridge.

This bone is similar in the rest of the fishes studied presently.

14. Posttemporal

In C. arel (Figs. 7, 8, 31) this bone is secondarily fused with the cranium and connects the pectoral girdle with the cranium. Anteriorly the bone is bifurcated producing two limbs, a superior and an inferior. The superior limb is long, pointed and fits into a lateral groove present on the epiotic. The short inferior limb has a blunt tip and fits into a depression on the opisthotic. The projected lower end of the posttemporal articulates with the supracleithrum.

The posttemporal of the blind side (Fig. 8) is relatively strong than that of the ocular side.

This bone is alike in the rest of the fishes studied.

Basicranial region/

This region constitutes the posteroventral region of the skull and contributes to the formation of auditory capsule, roof of the mouth and the floor of the myodome. It also bridges the anteriorly
placed ethmoid region with the posteriorly placed vertebral axis. The bones of the basicranial region are unpaired and are as follows:

15. Basioccipital

In C. arel (Figs. 7, 8, 9, 10, 12, 14, 32) this stout median bone forms the posteroventral floor of the neurocranium. Ventrally it joins the parasphenoid by suture. Dorsally the basioccipital is firmly attached to the exoccipital and the opisthotic. Posteriorly the bone forms a circular concavity which forms an articulating surface for the centrum of the first vertebra. Below the posterior concavity, on either side, there is a ventral projection. The projection of the ocular side is relatively small and anteriorly placed than its counter part of the blind side. Anteroventrally basioccipital remains separated from the prootic by a cartilaginous block and forms the pharyngeal apophysis from which hangs the os pharyngeus superior of the respective side. The joint between pharyngeal apophysis and the os pharyngeus superior is synovial in nature offering controlled mobility to the latter.

The nature and disposition of this bone is similar in C. lingua and C. bilineatus. However, in P. blochii (Figs. 13, 33) the basioccipital directly articulates with the prootic, the cartilaginous bridge being absent. Anteroventrally it possesses a cup like structure on either side containing cartilaginous blocks thus forming the pharyngeal apophysis.

16. Parasphenoid

In C. arel (Figs. 7, 8, 9, 10, 12, 34) this is a prominent, long, median bone underlying the cranium from the ethmoidal to the basioccipital region. On the posteroventral aspect, the parasphenoid meets the basioccipital obliquely, where the two bones project downward and the former fits deeply into the latter. The middle part of the parasphenoid on either side possesses an
ascending laminar process or lateral wing. The lateral wing of the blind side is larger than that of the ocular side. The anterior part of the parasphenoid receives the pointed shaft of the prevomer in a ventral recess and little bit twisted on its long axis towards the blind side.

It is identical in rest of the fishes studied.

//Branchiocranium//

It is divided into three regions: (1) Oromandibular region, (2) Hyoid region and (3) Branchial region.

/Oromandibular region/

The bones of this region contribute to the lower wall of the orbit and roof of the mouth. Attachment with the neurocranium is accomplished by the autopalatine and posteriorly by the hyomandibular. The different component of this region are as follows:

17. Autopalatine

It is a small piece of bone present between the prevomer and ectopterygoid and endopterygoid. It is the anterior most bone of the palatoquadrate arch and posteriorly it joins the ectopterygoid and endopterygoid to form the bony palate.

In C. arel (Fig. 7) on the ocular side, the anterior end of autopalatine is bifurcated and fits to the lateral groove of the prevomer. Posteriorly it gets broadened and produces two articulating surfaces, of which the dorsal one articulates digitately with the anterior end of endopterygoid and the ventral one with the ectopterygoid. However, a strip of cartilaginous bridge is present near the joint of autopalatine with the ectopterygoid and endopterygoid. On the blind side (Fig. 8), the head of the autopalatine is almost rounded and is articulated with the lateral
ethmoid. Posteriorly it becomes wide and is divided by a sharp notch to produce two articulating arms for the articulation with the ectopterygoid and endopterygoid. Both the articulations are interdigitate in nature and a small cartilaginous strip is also present between them.

In C. lingua though the shape is like that of C. arel it is relatively long on the blind side. In C. bilineatus (Fig. 72) on the ocular side, the autopalatine is flat and almost rectangular with a small posterodorsal elongation. Posteriorly the autopalatine articulates with the ectopterygoid and endopterygoid by digitating processes. On the blind side (Fig. 73) it is a small narrow piece of bone having a disc like head for the articulation with the lateral ethmoid.

In P. blochii though the nature of the bone is similar to that of C. arel, it is relatively thick on the blind side.

18. Ectopterygoid

In C. arel (Fig. 7) it is a boomerang shaped bone. Its longer anterior arm articulates anteriorly with autopalatine while the posterior shorter arm bends ventrad along the anterior edge of the quadrate and attached to it. Dorsally it is fused with the endopterygoid.

On the blind side (Fig. 8), the ectopterygoid is relatively long and thick.

The posterior end is placed in a groove, present at the anteroventral part of the quadrate. In C. bilineatus (Fig. 73) however, the anterior arm possesses a finger like lateral projection. In C. lingua and P. blochii the condition of the bone is similar to that of the C. arel.
19. Endopterygoid

In C. arel (Fig. 7) on the ocular side, it is a thin plate of bone resting above the inner margin of ectopterygoid and is very closely apposed to the latter. Anteriorly it articulates with the autopalatine and its posterior end is attached to the quadrate. The posterior part of the endopterygoid remains covered by the metapterygoid and the quadrate.

On the blind side (Fig. 8) it is relatively large and thick. The bone is of similar nature in rest of the fishes under the present study.

20. Metapterygoid

It is a large irregular shaped thin plate of bone placed almost vertically to the long axis of the skull. This bone is lodged in between quadrate, endopterygoid and the hyomandibular.

In C. arel (Figs. 7, 8) the metapterygoid remains separated from the hyomandibular and quadrate by a cartilaginous bridge. Antero-ventrally and posterovertrally the metapterygoid overlaps the endopterygoid and the anterior wing of the symplectic respectively.

This bone is relatively large on the blind side.

The nature and disposition of metapterygoid is identical in C. lingua. In C. bilineatus (Figs. 88, 89) this bone of the ocular side is similar to that of the C. arel. However, the posterovertral end of this bone of the blind side is lodged in between the two anterior wings of symplectic. The metapterygoid of the blind side is identical in size with that of ocular side.
The nature and disposition of this bone in *P. blochii* is similar to that of *C. bilineatus*.

21. Quadrate

In *C. arel* on the ocular side (Figs. 7, 86), it is a flat, roughly triangular bone placed anterior to the preopercle and ventral to the hyomandibular. At the lower end, a wide transverse condyle articulates with the corresponding fossa in the angular. The condyle is strengthened by the thickened posterodorsal margin of the bone. Along the posterior margin of the quadrate the preopercle is placed. The dorsal margin of the quadrate is connected to the ectopterygoid and endopterygoid. The anterodorsal corner of the quadrate overlaps a part of endopterygoid. Dorsally the quadrate remains separated from the symplectic end of hyomandibular and the metapterygoid by a cartilaginous bridge. On the posterior-dorsal margin there is a deep notch which extends below as a groove on the inner side into which extends the narrow end of symplectic. On the blind side (Figs. 8, 87) the quadrate is relatively strong and large. The posterior end of the ectopterygoid is lodged in a groove present on the anteroventral part of quadrate.

The nature of this bone is similar in the rest of the fishes studied.

22. Dentary

In *C. arel* on the ocular side (Figs. 7, 37), it is a curved elongated bone which forms the anterior element of the lower jaw. Near the anterior end there is a constriction, behind which it becomes gradually wide. On the posterior side there is a "<" shaped (inclined V-shaped) notch for the reception of the anterior end of angular. The "<" shaped notch extends forward as a tubular canal inside which the anterior end of Meckel's cartilage is lodged. The elevation of the dorsal arm of the notch is known
as the ascending process of dentary. The dentaries of both the sides meet each other anteriorly. It is interesting to note that the dentary of the ocular side is edentulous.

Dentary of the blind side (Figs. 8, 38) is much more wide and an irregular shaped structure. The dentary being wider and larger, the mouth opening lies at a higher level than that of the ocular side. The anterior and ventral border of dentary is convoluted. The ascending process of dentary is more developed and larger than its counterpart of the ocular side. Dorsal border of dentary is curved and provided with large number of pointed teeth arranged in many irregular rows. The patch of teeth is wider in the middle and becomes gradually narrow towards the ends. The teeth of the middle part are the largest. Below the dorsal border of dentary is present a foramen for the exit of a branch of r. mandibularis trigeminus internus. There is also another foramen present towards the lower posterior part of dentary for the exit of a branch of r. mandibularis facialis. Posteriorly, the dentary articulates with the angular as in the case of its counterpart of the ocular side.

The bone is very much similar in the rest of the fishes investigated.

23. Angular

In C. arel (Figs. 7, 39) on the ocular side, it is present in the posterior region of the lower jaw behind the dentary. It is an elongated bone becoming thin and pointed anteriorly. The anterior part of it remains overlapped by the dentary. On the inner anterior aspect, it lodges the remnant of the Meckel's cartilage as a rod inside an elongated cavity. Anterodorsally it possesses an ascending process which remains united along its entire length with the ascending process of the corresponding dentary. On the posterodorsal end it bears a fossa that receives the condyle of the quadrate. Posteroventrally, the angular is capped by the retroarticular. The common aponeurosis of m. adductor
mandibularis, II, III is inserted on the inner aspect of angular posterior to its ascending process.

The angular of blind side (Figs. 8, 40) is architecturally similar to its counterpart of ocular side but is relatively large and strong and its ascending process is also better developed. Anterior to the articulating fossa of angular, there is a small foramen for the exit of externus branch of r. mandibularis trigeminus and some branchlets of r. mandibularis facialis.

The shape and size of this bone is identical in rest of the fishes studied presently.

24. Retroarticular

In G. arel on the ocular side (Fig. 39), it is a small piece of bone which is attached to the posterior end of angular. It lies close to the articular facet of angular but does not take part in its formation. Rather it is ligamentously attached to the interopercle.

It is relatively large on the blind side (Fig. 40).

The above bone is alike in the rest of fishes studied presently.

25. Maxilla

The maxilla of the ocular side of G. arel (Figs. 7, 43) is an elongated and slightly arched bone present posterior to the premaxilla. Approximately the posterior half of it takes part in the formation of the upper gape of mouth. Anteriorly the head gets bifurcated and looks roughly like 'Y'. The inner limb is the elongation of the cranial condyle and is comparable to the premaxillary process of maxilla of the blind side. The small outer
limb is also comparable to the maxillary spine of the maxilla of blind side. While the anterior part of cranial condyle lies in contact with the median rostral cartilage, the posterior part remains covered by a cartilaginous strip which on the other hand rests on the lateral side (ocular side) of the head of prevomer. Maxilla of the ocular side is edentulous.

On the blind side (Figs. 8, 44) it is an elongated, edentulous and more curved bone which never takes part in the formation of the upper gape of mouth. Anteriorly it possesses a greatly expanded head with a prominent cranial condyle. The head has an anteriorly directed premaxillary process on its inner aspect and a maxillary spine on its outer aspect. The head of maxilla fits in such a way over the head of premaxilla that the latter remains in between the maxillary spine and premaxillary process of the former. This type of articulation while allows the movement of both maxilla and premaxilla, prevents lateral dislocation of the premaxilla. The dorsal part of head of maxilla forms a condylar surface whose anterior part remains apposed to the lateral side of median rostral cartilage and the posterior part of the condyle is capped by a piece of cartilage which ultimately articulates with the lateral (blind) side of prevomer. Maxilla of the blind side is stronger than its counter part of the ocular side.

This bone is of similar nature in the rest of the fishes presently studied.

26. Premaxilla

In G. arel it is the outer most bone of the upper jaw. The premaxilla of the ocular side (Figs. 7, 41) is a small piece of bone which extends to about the middle along the length of maxilla. As a result, the anterior and posterior parts of the upper gape of mouth is formed by the premaxilla and maxilla respectively. The labial limb of premaxilla becomes gradually narrow and pointed.
posteriorly, and lodges itself in a ventrolateral groove of maxilla of the same side. The head of premaxilla is greatly modified to form a cup like structure with the concavity facing internally, and into this concavity fits a cartilaginous block (median rostral cartilage) whose other end rests on the prevomer. As a result the upper jaw completely rests over the prevomer. The premaxilla is edentulous in nature.

On the blind side (Figs. 8, 42) the premaxilla forms the total upper gape of mouth unlike the ocular side. The head of the premaxilla is laterally flattened and possesses feebly developed articular and ascending processes. Its long labial limb is highly arched with its concave side facing the corresponding dentary. The ventrally directed concave side of it is provided with large number of small pointed teeth, which, on closing the mouth bites against the teeth of the corresponding dentary. The patch of teeth becomes narrow anteroposteriorly.

The nature and disposition of this bone is similar in C. lingua, C. bilineatus and P. blochii.

27. Upper jaw - dentary cartilage

It is interesting to mention here that the above element seems to be a new record, as because such element has not yet been reported in the teleosts. Thus it may be termed upper jaw - dentary cartilage depending upon its attachment.

In C. arel (Fig. 8) it is a cartilaginous structure present only on the blind side, which connects the upper and lower jaws near the angle of the mouth. It is a spatulated structure having a narrow dorsal part and a broad ventral part. Dorsally it is connected to the maxilla and premaxilla and ventrally with the dentary below its dorsal border with the help of connective tissue.

It is identical in the rest of the fishes investigated presently.
It consists of two halves which meet each other on the midventral line with a median basihyal. Each half has two portions, the dorsal which includes the hyomandibular and symplectic and the ventral comprises the hyoid cornu (interhyal, epihyal, ceratohyal, the two hypohyals and basihyal in a descending series). The hyomandibular is one of the most important bones of the hyoid arch providing attachment to the hyoid cornu and the opercular bones directly and the jaws indirectly. The palatoquadrate arch is suspended from the skull through the intermediation of this bone, giving rise to the hyostylic (methyostylic) type of jaw suspension. Besides hyomandibular the bones of the hyoid region also give skeletal support to the tongue, anchor the gill arches, and take part in the respiratory and feeding action of the fish. The details of the bones of this region are as follows:

28. Hyomandibular

In C. arel (Figs. 7, 8a), it is somewhat a flat, roughly 'Y' shaped bone. The upper edge has two prominent condylar heads of which one is anteriorly and the other is posteriorly directed. The condylar heads are present at the extremities of two distinct rod like arms which meet the main shaft of the hyomandibular posteriorly. The posterior arm is stouter than the anterior one. Each of anterior and posterior condylar heads possesses a lens shaped disc of cartilage and fits into the anterior and posterior hyomandibular fossa respectively. The third prominent condyle is situated on the postero-medial edge of the bone at about 1/3rd distance below its upper edge. The condyle has also a lens shaped cartilage which articulates with the opercle. Anteriorly the hyomandibular gives rise to an expanded flange. The main shaft or body of hyomandibular extends below and becomes gradually broad. There runs a groove along the dorsal side of hyomandibular into which fits the pre-opercle. The anterior border of the hyomandibular is bounded by the
metapterygoid. However, both are separated by a cartilaginous bridge. The symplectic end of the hyomandibular is fastened to the symplectic and interhyal with the help of a cartilaginous strip. There is a small foramen present below the base of postero-medial condyle for the exit of the hyomandibular trunk of the seventh cranial nerve.

On the blind side (Fig. 8), the hyomandibular is of similar nature but the main body is relatively strong than that of the ocular side.

It is identical in the rest of the fishes studied.

29. Symplectic

It is a small elongated bone (Fig. 7) present between the symplectic end of hyomandibular and the quadrate. Ventrally it becomes narrow and is placed in a notch in the quadrate. The notch extends below as a groove on the inner side of quadrate into which extends the narrow ventral part of symplectic. The dorsal end of symplectic is attached to the symplectic end of hyomandibular with the help of a cartilaginous bridge.

In C. arel on the ocular side (Fig. 86), the symplectic has a thin wing like anterolateral projection which remains covered by the metapterygoid and quadrate.

On the blind side (Figs. 8, 87), in addition to the anterolateral wing, the symplectic bears a posterolateral wing which also remains covered by the quadrate. The symplectic is relatively large on this side.

In C. lingua the above bone is identical with that of C. arel. In C. bilineatus the symplectic of ocular side (Fig. 88) possesses two anterolateral wings. The posterior part of metapterygoid is lodged in between these two wings. On the blind side (Fig. 89)
the posterolateral wing of the symplectic is prominent. In *P. blochii* on the ocular side, the symplectic is devoid of wings. But on the blind side it has a posterolateral wing.

30. Interhyal

In *C. arel* on the ocular side (Fig. 56), it is a tiny rod shaped bone present between the hyomandibular and the epihyal. The interhyal remains below the preopercle and quadrate. Proximally the interhyal is attached to the symplectic end of hyomandibular where the symplectic is also attached. However, a cartilaginous block is present between them. Distally the interhyal articulates by its swollen base to the cup shaped facet of the epihyal, thus linking the hyomandibular with the ventral hyoid element.

On the blind side (Fig. 56) it is relatively thick.

It is similar in the rest of the fishes.

31. Epihyal

In *C. arel* on the ocular side (Fig. 56), it is a laterally flattened bone situated between the interhyal and ceratohyal. Its posterior end is convex and becomes little bit narrow anteriorly. Anteriorly it is attached immovably to the ceratohyal through jagged margin, overlapping each other. However, there is a cartilaginous bridge on the ventral side of epihyal and ceratohyal. On the postero-dorsal side it has a concavity to which interhyal is movably articulated. The posterior most branchiostegal loosely articulates with the epihyal on its ventral side.

The nature of the bone is similar on the blind side.

The above bone is similar in the rest of the fishes studied presently.
32. Ceratohyal

In *C. arel* on the ocular side (Fig. 56), it is a long, compressed bone extending anteriorly from the epiphyal. Anteriorly it is excavated and forms two facets for articulation with the upper and lower hypohyal. The hypohyals are suturally connected to it. Four branchiostegals are attached to its ventral side by connective tissue.

It is similar on the blind side as well as in the rest of the fishes.

Hypohyal

There are two hypohyals on each side, an upper and a lower, situated anterodorsal and anterior to the ceratohyal respectively. These bones are symmetrical on both the sides.

33. Upper hypohyal

In *C. arel* (Fig. 56) it is an elongated rectangular bone which becomes broad towards posteriorly and caps the anterodorsal margin of ceratohyal. Ventrally it is articulated with the lower hypohyal. The junction of basihyal and first basibranchial is interposed between dorsomedial tips of the converging upper hypohyals.

It is identical in the rest of the fishes.

34. Lower hypohyal

In *C. arel* (Fig. 56), it is roughly a cone shaped bone which caps the lower anterior end of ceratohyal. Dorsally it articulates with the upper hypohyal.

It is similar in the rest fishes.
35. Basihyal

In *C. arel* (Figs. 58, 59) basihyal is a median rod like bone forming the anterior most element of the copula. It becomes slightly narrower posteriorly. Anteriorly it is capped by a cartilaginous structure and posteriorly it rests over the anterodorsal prolongation of first basibranchial. Postero-laterally it is bounded on both the sides by the convergence of upper hypohyals.

The nature and disposition of this bone is similar in the rest of the fishes studied presently.

36. Urohyal

It is a thin, laterally compressed bone, placed vertically below the floor of the mouth cavity. The elongated anterior portion of the bone is the main part which remains near the angle of the cornu and gets attached to the hypohyal by urohyal-hypohyal ligament. The broader posterior portion comprises a cardiac apophyse and a sciatic part. M. cleithrohyoideus is inserted on the either side of the cardiac apophyse and the sciatic part of urohyal.

In *C. arel* (Fig. 52) the cardiac apophyse bends slightly upward and is denticulated. The sciatic part consists of two spinous projections.

In *C. lingua* (Fig. 53) the cardiac apophyse is almost similar to that of the former but its end is somewhat wavy. The sciatic part consists of a single downwardly projected spinous structure.

In *C. bilineatus* (Fig. 54) the cardiac apophyse is relatively broad and the sciatic part is almost similar to that of *C. lingua*. 
In P. blochii (Fig. 55) the sciatic part resembles the shape of a thumb and is bend downward and the cardiac apophyse is like that of the former.

37. Branchiostegal

In C. arel on the ocular side (Figs. 56, 57), there are six branchiostegals which are attached to the ventral side of epiphaly and ceratohyal. The rays are curved, pointed posteriorly and broader towards their anterior extremities. But the middle part of anterior most ray or the sixth ray is laterally flattened. The length of branchiostegals decreases from behind forward. The posterior most one is the longest and is attached to the epiphaly. The preceeding one is attached to the junction of epiphaly and ceratohyal. The third and fourth are attached to the ceratohyal. All these rays are attached to their respective segment on the outer ventral side. Unlike the preceeding rays the fifth one is attached to the inner lateroventral side of ceratohyal.

The attachment of the sixth or anterior most ray is very peculiar in the sense that though its proximal end remains on the inner ventral side of ceratohyal, it is attached only by a long thread like ligament to the lower hypohyal of the respective side. The anterior most two branchiostegals of both the sides are closely apposed to each other on the midventral line.

Branchiostegal rays are symmetrical on the blind side. It may be further mentioned here that the nature and disposition of these bones are similar in the rest of the fishes studied.

38. Preopercle

Preopercle of the ocular side of C. arel (Fig. 7) is a crescentic bone placed posterior to the hyomandibular and the quadrate. While both its dorsal and ventral ends are pointed, the middle part is
broad. The dorsal end fits into a groove present over the hyomandibular. The remaining portion of the preopercle curves downward, contacting in turn a cartilaginous block present below the symplectic end of hyomandibular and quadrate. Ventrally it overlaps the interhyal and a part of epihyal.

The preopercle of the blind side (Fig. 8) is architecturally similar to that of the ocular side but is relatively long, broad and thick.

This bone is identical in the rest of the fishes investigated.

39. Opercle

In C. arel (Figs. 7, 45) on the ocular side, it is a thin roughly triangular bone having a concave posterior border and is placed posterior to the preopercle. The anterodorsal border of the opercle is thick and gradually narrows as it descends. The dorsal border is also thick and becomes obtusely pointed posteriorly. Both the dorsal and the anterodorsal borders are interconnected by a thin membranous part. Anterodorsally the opercle has a small narrow elongation, below which lies a facet for its articulation with the hyomandibular. Near the base of the anterodorsal process there is a small spine like elevation where the opercle-hyomandibular ligament is attached. The opercle partly overlaps the subopercle.

Though the opercle of the blind side (Fig. 8) is architecturally similar with that of the ocular side, the former is larger in size.

In C. lingua and C. bilineatus the shape of opercle is quite similar to that of C. arel. But unlike C. arel the opercle is symmetrical on both sides.
In *P. blochii* the condition is similar to that of *C. arel*.

40. Interopercle

In *C. arel* on the ocular side (Figs. 7, 46), it is roughly a rectangular shaped bone with a narrow anterior end. It is placed posterior to the lower jaw and below the quadrate. The anterior end of interopercle is notched and bony rays pass from its antero-dorsal aspect to the posterior end. The interopercle is attached ligamentously to the lower jaw, epiphysal and opercle.

Though the interopercle of the blind (Fig. 8) side is similar in shape with that of the ocular side the former is relatively large. The nature of the bone is identical in the rest of the fishes.

41. Subopercle

In *C. arel* on the ocular side (Figs. 7, 47), it is a thin irregular shaped bone placed below the opercle and posterior to the interopercle. The subopercle is broad ventrally and becomes narrow dorsally. The anterior side remains partly covered by the opercle and the interopercle. Thin branched bony rays radiate out from the anterior side to the posterior and posteroventral side.

The structure of the subopercle of the blind side (Fig. 8) is similar to that of the ocular side but is relatively small. The nature of the bone is identical in the rest of the fishes.

/Branchial region/

Immediately behind the hyoid cornu are situated five branchial arches, which together form the branchial basket supporting the gills, respiratory and masticatory musculature and pharyngeal teeth. Of these only the anterior four bear gills on their
posterior convex faces. The fifth is thickened and modified to bear the pharyngeal teeth for mastication. Each typical gill arch consists of a median basibranchial element, joined on either side by hypobranchial, ceratobranchial, epibranchial, and pharyngobranchial arranged in a usual circumpharyngeal series.

Instead of each arch being described separately, the corresponding segments from different arches are treated serially in the following account.

It may also be mentioned here that the osteological structure of this region neither exhibit an asymmetry nor any variation among the presently studied fishes.

42. Basibranchial

Basibranchials (Figs. 58, 59) are three in number, situated mid-ventrally one behind the other between the hypobranchials and act as a copula for uniting the right and left loops of the branchial arches. The hypobranchials are attached to them laterally from both the sides in horizontal level.

The three basibranchials, along with the three hypobranchials and the basihyal form a strong and firm floor for the buccal cavity.

The first basibranchial appears to be a small piece of flattened bone from above, whose middle portion is slightly constricted. Anteroventrally it has an elongated process over which lies the basihyal. Posteriorly the first basibranchial articulates with the second basibranchial by interdigitating processes. Posteroventrally it possesses an elongation which passes below the second basibranchial and covers about half of the latter.

The second basibranchial is dorsally flattened, elongated bone whose posterior end is enlarged. It articulates anteriorly with
the first basibranchial by interdigitations, anterolaterally with
the first pair of hypobranchials and posteriorly with the third
basibranchial by a cartilaginous intercommunication.

The third basibranchial is an elongated inverted cone shaped bone
which articulates anteriorly with the second basibranchial by a
cartilaginous intercommunication and anterolaterally with the
second pair of hypobranchials. Its posterolateral surface is
attached to the lateral surface of the third hypobranchial by a
cartilaginous bridge.

43. Hypobranchial

Hypobranchials (Fig. 58) are represented by only three pairs,
attached to the second and third basibranchials.

The first hypobranchial is a stout rod shaped bone whose ends are
slightly broader and has a shallow ventral groove through which
passes the branchial blood vessels. While distally it articulates
with the anterolateral side of second basibranchial, proximally
it articulates with the first ceratobranchial.

The second hypobranchial is essentially the same as the first, but
shorter. Proximally, it articulates with the second ceratobranchial
and distally, its head fits to the anterolateral side of third
basibranchial.

The spatulate third hypobranchial lies longitudinally, flanking the
posterior part of the third basibranchial. It narrows anteriorly,
with its anterior tips extending to below the second hypobranchial.
Proximally, the third hypobranchial joins the third ceratobranchial.

The fourth hypobranchial is absent.
44. Ceratobranchial

Ceratobranchials (Fig. 58) are the most prominent and also the largest part of the branchial skeleton. The first four are elongated and slightly curved, rod-like structures on the lateral wall and the floor of the pharynx, and are provided with cartilaginous tips. Proximally they are attached to the epibranchials at the lateral margin of the pharynx. Immediately behind this point of attachment they bend sharply inwards to meet the corresponding hypobranchials. However, the distal end of fourth ceratobranchial is embedded in a cartilaginous matrix nearly in contact with the third hypobranchial as the fourth hypobranchial is absent.

The fifth ceratobranchial or 'inferior pharyngeal bone' constitutes the only element of the fifth branchial arch. It is expanded medially and thickly studded with pointed teeth on its dorsal side, projecting into the pharynx. The teeth are present in longitudinal rows. The distal ends of the bones remain embedded in the cartilage behind the fourth ceratobranchial. It has a ventral process to which are attached the m. depressor os pharyngeus inferior and m. protractor os pharyngeus inferior.

45. Epibranchial

Epibranchials (Fig. 58) are present only in the first four arches. The four epibranchials sharply bend anterodorsally from the tips of their corresponding ceratobranchials.

The first epibranchial is a slender, gently curved rod. Anterodorsally its proximal end remains embedded in a cartilaginous matrix, along with the proximal ends of second epibranchial and third pharyngobranchial. This cartilaginous matrix is suspended from the pharyngeal apophysis of the neurocranium.
The second epibranchial is architecturally similar to that of the first but is relatively shorter and more curved. On the dorsal side towards its distal end there is a small elevation to which is attached the m. transversus dorsalis anterioris.

The third epibranchial is short but broad and flat. While its narrow distal end articulates with the proximal end of the third ceratobranchial, its proximal end is broad and articulates with the third pharyngobranchial.

The fourth epibranchial is a curved rod-like structure and runs along the inner side of the third epibranchial. It has a small elevation on its dorsal side which is attached tightly to a similar elevation present on the third epibranchial by a cartilaginous substance. Proximally it articulates to a notch present on the third pharyngobranchial.

Pharyngobranchial

Pharyngobranchials (Fig. 58) are the dorsal most segments of the branchial arches. In the fishes under present study the first and second pharyngobranchials are lacking. The third and fourth are fused to form a large flattened bone known as os pharyngeus superior. The os pharyngeus superior is provided with two tooth-patches on its ventral surface and projects inside the throat from the roof of the pharynx. It has two distinct articular surfaces to which are attached the third and fourth epibranchials. The presence of two patches of teeth and two articulating facets for third and fourth epibranchials indicate the probable fusion of third and fourth pharyngobranchials. Anteriorly the os pharyngeus superior becomes narrow and attached to the pharyngeal apophysis along with the proximal ends of the first and second epibranchials by a synovial joint. The os pharyngeus superior of both the sides meet in the middorsal line, but they do not fuse, instead
some transverse muscular tissue is present between them. The pharyngeal teeth are prominent and work against the teeth of the os pharyngeus inferior on the floor of the throat and thus help in mastication.

//Epicranium//

The anterior extension of the dorsal fin onto the head beyond the eyes comprises a system of bones which constitutes the epicranium. The different components of the epicranium is described below:

47. Erisma

It is roughly a rod shaped bone lying nearly parallel to the neurocranium (Figs. 7, 8, 35). While the posterior end of the bone is pointed and extends to a point slightly beyond the first neural arch, the anterior end is broad and strongly bent ventrally. Dorsally the erisma supports few anterior interneural spines and two pterygiophores. This bone is considered as a modified first interneural spine (Norman, 1934).

It is identical in C. lingua and C. bilineatus. In P. blochii (Fig. 36) the anterior bent portion is relatively strong.

48. Interneural spines

These are (Figs. 7, 8) roughly paddle shaped bones which lie in the median plane closely connected with the neural spines of the vertebrae. They form the framework and support the dorsal fin. Each interneural spine has a long slender shaft and a flattened bifurcated head containing a cartilaginous block. While the ends of the shafts are placed towards the neural spines, the heads project outwards. However, a few anterior interneural spines are inclined forward to carry the dorsal fin to the required place and
the ends of their shafts lie along the dorsal side of the erisma. The number of interneural spines which are carried forward by the erisma varies in different species and has been presented below in a tabular form.

Table 1. Number of interneural spines carried forward by the erisma in the present group of fishes.

<table>
<thead>
<tr>
<th>Name of the fish</th>
<th>Number of interneural spines</th>
</tr>
</thead>
<tbody>
<tr>
<td>C. arel</td>
<td>12 - 13</td>
</tr>
<tr>
<td>C. lingua</td>
<td>14 - 15</td>
</tr>
<tr>
<td>C. bilineatus</td>
<td>6 - 8</td>
</tr>
<tr>
<td>P. blochii</td>
<td>9 - 10</td>
</tr>
</tbody>
</table>

49. Anterior pterygiophore

It has been modified to form an axe shaped rostral cartilage (Figs. 7, 8), devoid of any fin rays. The rostral cartilage is strong and it is blunt anteriorly.

50. Posterior pterygiophore

In C. arel (Figs. 7, 8), it is an elongated, conical structure situated above the erisma and is placed posterior to the rostral cartilage. Dorsally it is bifurcated and possesses a cartilaginous block within the fork.

It is identical in the rest of the fishes studied presently.
51. Anterior pseudointerneural spine

In *C. arel* (Figs. 7, 8, 48), it is roughly a sword shaped bone, whose base lies loosely over the frontals and the broader anterior portion extends forward. There runs a groove along the dorsal side of the bone, inside which the posterior limb of erisma is placed. Ventrally the anterior pseudointerneural spine is strongly attached to the ethmoid by a ligament.

This bone is identical in *C. lingua* (Fig. 49). However, in *C. bilineatus* (Fig. 50) the dorsal side of the bone is flat, the groove being absent. In *P. blochii* (Fig. 51) the bone is relatively wide and strong.

52. Posterior pseudointerneural spine

In *C. arel* (Figs. 9, 10, 11, 28), it is a long spinous structure which extends from the anterodorsal part of the supraoccipital, runs forward over a ridge present on the frontal of the blind side, and finally extends into the dorsal groove of the anterior pseudointerneural spine below the erisma and gets fused with the anterior pseudointerneural spine.
EXPLANATION OF FIGURES (7,8) AND ABBREVIATION USED

Lateral views of skull of *C. a£el* (Body length 320 mm).

Fig. 7 - Ocular side

Fig. 8 - Blind side

/Abbreviations/

ais - anterior pseudointerneural spine
ang - angular
ang.iop.lig - angular-interopercle ligament
ant.a.hyo - anterior arm of hyomandibular
ap - autopalatine
ass - autosphenotic
boo - basioccipital
chb - cartilaginous bridge
d - denticary
e - ethmoid
e.ais.lig - ethmoid-anterior pseudointerneural spine ligament
eept - ectopterygoid
enpt - endopterygoid
epi.iop.lig - epihyal-interopercle ligament
epo - epiotic
es - erisma
ex.f.hyo - expanded flange of hyomandibular
f - frontal
hyo - hyomandibular
in.s - interneural spine
iop - interopercle
i.e - lateral ethmoid
m.r.c - median rostral cartilage
mpt - metapterygoid
mx - maxilla
op - opercle
op.hyo.lig - opercle-hyomandibular ligament
op.iop.lig - opercle-interopercle ligament
op.pop.lig - opercle-preopercle ligament
p - parietal
p.ptg - posterior pterygiophore
pm - premaxilla
pop - preopercle
post.a.hyo - posterior arm of hyomandibular
post.n.q - posterodorsal notch of quadrate
pro - prootic
ps - parasphenoid
pt - posttemporal
pto - autoplerotic
pv - premaxilla
q - quadrate
r.c - rostral cartilage
ret.iop.lig - retroarticular-interopercle ligament
s.hyo - symplectie end of hyomandibular
sop - subopercle
sy - symplectic
t - teeth
up.d.c - upper jaw dentary cartilage
EXPLANATION OF FIGURES (9-14) AND ABBREVIATIONS USED

Neurocranium of C. arel (Bl. 320 mm) and P. blochii (Bl. 260 mm).

Fig. 9 - Lateral view of ocular side of C. arel
Fig. 10 - Lateral view of blind side of C. arel
Fig. 11 - Dorsal view of C. arel
Fig. 12 - Ventral view of C. arel
Fig. 13 - Ventral view of P. blochii
Fig. 14 - Posterior view of C. arel

/Abbreviations/

aso - autosphenotic
boc - basioccipital
boc.p - ventral projection of basioccipital
c.b - cartilaginous bridge
e - ethmoid
eoc - exoccipital
eo - epiotic
f - frontal
f ais - facet for articulation with anterior pseudo-interneural spine
f.m - foramen magnum
fac.f - forament for facial nerve
g.f - foramen for glossopharyngeal nerve
hm.an.f - anterior hyomandibular fossa
hm.post.f - posterior hyomandibular fossa
j.v.f - foramen for jugular vein
l.e - lateral ethmoid
opo - opisthotic
p - parietal
p.a - pharyngeal apophysis
pis - posterior pseudointerneural spine
pro - prootic
ps - parasphenoid
pto - autopterotic
pv - prevomer
s.o.t.f - foramen for supraorbital trunk
soc - supraoccipital
v.f - foramen for vagus nerve

l.s - lateral ethmoid
EXPLANATION OF FIGURES (15-36) AND ABBREVIATIONS USED

Disarticulated skull bones (Figs. 15-32, 34, 35) of C. arel (Bl. 320 mm) and (Figs. 33, 36) of P. blochii (Bl. 260 mm).

Bones of the blind side have been designated as Bli.

Fig. 15 - Ethmoid, 16-Lateral ethmoid, 17-Lateral ethmoid (Bli), 18-Dorsal view of prevomer, 19-Anterior view of prevomer, 20-Frontal, 21-Frontal (Bli), 22-Lacrimal, 23-Autosphenotic, 24-Autopterotic, 25-Prootic, 26-Epiotic, 27-Opisthotic, 28-Supraoccipital, 29-Parietal (Bli), 30-Parietal, 31-Posttemporal, 32-Basioccipital, 33-Basioccipital (P. blochii), 34-Parasphenoid, 35-Erisma, 36-Erisma (P. blochii).

/Abbreviations/

a.b - anterior border
a.e.f - end for articulation with frontal
a.e.p - end for articulation with parietal
ais.f - facet for anterior pseudointerneural spine
al.a.le - ala for articulation with lateral ethmoid
asp.a - area for articulation with autopalatine
aso.r - autosphenotic ridge
boc.a.e - end for articulation with basioccipital
boc.p - ventral projection of basioccipital
i.c - dorsal concavity
d.i.pt - depression for inferior limb of posttemporal
dr - dorsal ridge
f.o.l.n - foramen for olfactory nerve
gr.pst - groove for posttemporal
hm.an.f - anterior hyomandibular fossa
hm.post.f - posterior hyomandibular fossa
l.r - lateral ridge
l.ac - lower end for articulation with supraclavithrum
l.w - lateral wing
le.ae - lateral ethmoid articulating end
p.a - pharyngeal apophysis
p.p - posteroventral prolongation
pis - posterior pseudointerneural spine
post.a.f - posterior articulating facet
ps.a.d - anteroventral depression for paraphenoid
pt.i.l - inferior limb of posttemporal
pt.s.l - superior limb of posttemporal
pv.a.d - anterior depression for prevomer
pv.a.e - prevomer articulating end
pv.h - head of prevomer
s.a - sensory canal
sh - shaft
soc.a - supraoccipital spine
EXPLANATION OF FIGURES (37-47) AND ABBREVIATIONS USED

Disarticulated skull bones of C. arel (Bl. 320 mm).

Fig. 37-Dentary of ocular side, 38-Dentary of blind side, 39-Angular of ocular side, 40-Angular of blind side, 41-Premaxilla of ocular side, 42-Premaxilla of blind side, 43-Maxilla of ocular side, 44-Maxilla of blind side, 45-Opercle of ocular side, 46-Interopercle of ocular side, 47-Subopercle of ocular side.

/Abbreviations/

a.p - ascending process
ar.p - articular process
b.r - bony rays
c.c - cranial condyle
c.pm - concavity of premaxilla
con.f - facet for the condyle of hyomandibular
fac.f - foramen for r. mandibularis facialis
m.s - maxillary spine
me.p - membranous part
p.p.m - premaxillary process of maxilla
q.a.f - facet for articulation with quadrate
ret - retroarticular
s.e - spinous elevation
t - teeth
tri.f - foramen for r. mandibularis trigeminus internus
tri.fac.f - foramen for trigeminal and facial nerve
v.g - ventrolateral groove
EXPLANATION OF FIGURES (48-55) AND ABBREVIATIONS USED

Lateral view of anterior pseudointerneural spine and urohyal of the presently studied fishes.

Figs. 48 and 52 - Anterior pseudointerneural spine and urohyal respectively of C. arel (Bl. 320 mm).

Figs. 49 and 53 - Anterior pseudointerneural spine and urohyal respectively of C. lingua (Bl. 320 mm).

Figs. 50 and 54 - Anterior pseudointerneural spine and urohyal respectively of C. bilineatus (Bl. 320 mm).

Figs. 51 and 55 - Anterior pseudointerneural spine and urohyal respectively of P. blochii (Bl. 260 mm).

/Abbreviations/

c.a - cardiac apophyse
d.g - dorsal groove
f.a.f - facet for articulation with the frontals
m.p - main part
s.p - sciatic part
EXPLANATION OF FIGURES (56-59) AND ABBREVIATIONS USED

Different view of hyoid and branchial arches of C. arel (Bl. 320 mm) showing the bones, ligaments and muscle.

Fig. 56 - Dorsal view
Fig. 57 - Ventral view
Fig. 58 - Branchial region
  i) Left side of figure – adpharyngeal view
  ii) Right side of figure – abpharyngeal view
Fig. 59 - Diagramatic presentation to exhibit the nature of attachment between the basihyal and basibranchials.

/Abbreviations/

ab.br - m. abductor branchio-stegalis
bb - basibranchial
bb₁, bb₂, l - basibranchial₁, basibranchial₂ ligament
bh - basihyal
bh, hh, l - basihyal hypohyal ligament
cb - ceratobranchial
cb - ceratohyal
eh - epihyal
ep - epibranchial
ep₂, cb, l - epibranchial₂, ceratobranchial ligament
hh₁, hh₂, l - hypobranchial₁, hypobranchial₂ ligament
hh₁, hb₁, l - hypobranchial₁-hypobranchial₂ ligament
hh₂, hb₁, l - hypobranchial₂-hypobranchial₁ ligament
hh₂, hb₂, l - hypobranchial₂-hypobranchial₂ ligament
hh, br, l - hypobranchial-sixth branchiostegal ligament
hh₁, l - hypobranchial₁ ligament
hh₂, l - hypobranchial₂ ligament
ih - interhyal
ih, eh, l - interhyal - epihyal ligament
ih, hy, l - interhyal-hyo-mandibular ligament
ih, mt, l - interhyal-meta-pterigoid ligament
ihb, l - inter hypo-branchial ligament
ihh₁, l - inter lower hypohyal ligament
ihh₂, l - inter upper hypohyal ligament
uh - lower hypohyal
uh, hh, l - urohyal-hypo-branchial ligament
uh₁, l - urohyal-hypo-branchial₁ ligament
uh₁, l - upper hypohyal
uhh - upper hypohyal
DISCUSSION

The skull not only forms a hard protective covering around the brain and other sense organs but also its plan and pattern of osteological architecture, when meticulously examined provide very important clue in the determination of the nature of food and feeding habit of the organism. So the study of cranial osteology is an essential prerequisite to have a better understanding on the food and feeding habit of the organisms. A vast wealth of knowledge has been accumulated on the cranial osteology of different groups of teleosts due to the contribution of many workers of which worth mentioning are Owen (1866), Starks (1910, 1911, 1926), Hubbs (1920), Goodrich (1930), Gregory (1935, 1951), Norman (1934), Dharmarajan (1936), Blake (1945), Kulkarni (1948), Ramaswami (1948, 1952a, b, c, d; 1953, 1955a, b; 1957), Harrington (1955), Gosline (1961), Weitzman (1962), Smith and Bailey (1962), Jollie (1962), Liem (1963, 1967a, b; 1970, 1979), Nelson (1967a, b; 1969), Greenwood (1968), Topp and Cole (1968) and Rosen (1973). Although the above contributions provide a solid theoretical framework of the present study but it is worth mentioning here that these were primarily preoccupied with the questions pertaining to structural peculiarities, homology and phylogenetic trends of different osteological elements. Osteological studies as such although is important enough from comparative anatonic standpoint but it is sincerely felt that it would be more interesting if such studies could be made in relation to biology of the organism concerned. The present undertaking is an attempt to achieve the objective mentioned above. Perhaps it would be worthwhile to mention that the material of the present study is peculiar enough to exhibit extreme adaptation culminating to asymmetry of structure disabling the golden rule of the bilateral symmetry of the vertebrates in general.
Cranial asymmetry of the flatfishes has drawn the attention of many earlier workers. Autenrieth (1800), one of the oldest workers, while working on the anatomy of the plaice remarked that "The examination of the skeleton shows us that the entire left side of the fore part of the cranium is, in reality, wanting, and that nature, in order not to lose an eye, was necessitated to put it into the hollow of the right check under the single remaining orbit". Rosenthal (1812-1822) opined that the upper eye of the Flounder to be that of the eyeless side and postulated that the eye passes though the head from left to the right side.

Meckel (1824) recognized correctly the homology of the various cranial bones with those of the symmetrical fish and supported the earlier theory that two eyes of the flatfishes are brought round to one side by a twisting process. Steenstrup (1865) revised the theory of Rosenthal and viewed that "The eyes, at an early stage, must have quit its primitive position, and directing itself upwards and towards the inferior, pierced the vault of the cranium constituted above the eye by the frontal bone, and formed for itself a new orbit, whether on the interior region of the frontal bone of the same side or between the two frontals". Traquair (1865) made a detailed study of the osteological asymmetry of the Pleuronectidae (Turbot, Halibut, and Plaice) and explained the reasons of asymmetry. Cunningham (1890) described the osteology of Soles in his book 'A treatise on the common sole'. Kyle (1923) studied the asymmetry, metamorphosis and the origin of different groups of flatfishes. Wu and Wang (1933) in their supplementary notes on the fishes of Heterosomata also threw light on their osteology. Chabanaud (1934, 1940) studied the osteology of some flatfishes. Dobben (1937) studied the jaw mechanism of Turbot, Plaice and common sole. Block (1957) studied the osteological asymmetry of the skull of Pleuronectes platessa. Ochiai (1966) made a comparative study of the morphology and ecology of the Japanese soles. Yazdani (1969) observed the adaptation of the jaws of the flatfishes. But till now there is hardly any study on
the osteology in relation to food and feeding habit of the fishes belonging to the family Cynoglossidae. So the present worker has studied the osteological architecture and its asymmetry to correlate them with the feeding habit of the fishes concerned. Keeping this in mind, in the discussion given below, emphasis has been laid on the osteological elements which play some role in the process of feeding. Besides, an attempt has also been made to examine the extent of asymmetry between the ocular and blind side.

The present finding that the pterygoid is skewed round to the blind side upon which the upper jaw lies, draws support from the earlier findings of Traquair (1865) and Yazdani (1969). Frontals are the most distorted bones of the skull. The present author is of the opinion that the frontal of the ocular side is curved downwards to accommodate the displaced upper eye.

Yazdani (1969) reported the presence of first infraorbital only on the blind side of Cynoglossus sp. However, the present investigation has revealed the presence of first infraorbital on both the sides of the head of C. ariel, C. lingua and P. blochii. But the first infraorbital has been found to be lacking on the ocular side of C. bilineatus.

Unlike the bones of the anterior region of the skull, the bones of the otic region except the posttemporal are least asymmetrical.

The present findings is concurrent with the earlier findings of Kyle (1923) who stated that in Cynoglossus the parasphenoid and the basioccipital meet at an angle due to the downward bulging of the cranium and also as a rule the parasphenoid bends to the blind side after it leaves the basioccipital.

The most peculiar asymmetry and the specialization in the skull are found in the jaws and the suspensory apparatus. Traquair (1865)
reported that the jaws of the blind side of Halibut and Flounder are stronger, and on opening point towards the eyeless side. But in Turbot the jaws are symmetrical and the mouth opens straight. The present investigation has revealed that the gape of mouth on the ocular side is longer than on the blind side (Table 2). The lower jaw of the ocular side is also longer and as a result the jaw articulation on the ocular side is posterior in position than that of blind side. The mandible of the blind side is broad (Fig. 8), strong and provided with numerous small teeth on its dorsal edge. The mandible being broad on the blind side, the mouth opening of that side is situated at a higher level.

Dobben (1937) and Yazdani (1969) have reported that in the common sole and tongue sole the mouth parts of the ocular side is used for respiration and that of the blind side is used for feeding. So it is expected that the lower jaw of the blind side should have a stronger osteological architecture, more mobility than on the ocular side as the former is expected to receive more stress and strain. A meticulous examination of the bones of the lower jaw has revealed that the angular is thicker (Table 2) on the blind side and as a result the jaw is considerably strengthened. Yazdani (1969) observed in the common sole and tongue sole that during the opening of the mouth on the blind side, the lower jaw moves around an axis through the quadrate articulation and the symphysis and thus the mouth projects to the blind side. The present investigation reveals that the area of the articulating facet of the angular on the blind side is more than twice than that of the ocular side (Table 2). This allows a greater mechanical advantage and mobility between the angular and quadrate and thus provides sufficient freedom for outward rotation of the lower jaw. The present author is of similar opinion with Yazdani (1969) that the projection of the mouth opening towards blind side helps the fish to pick up the bottom living organisms like molluscs, crustaceae and polychaetes etc. on which it feeds (Figs. 110, 111, 112, 113). The contention of Dobben (1937) and Yazdani (1969) regarding the role of blind...
side for feeding and ocular side for respiration in flatfishes is supportable from the present anatomical observations, morphometrics of jaw apparatus and as well as by statistical analysis (Table 2). While feeding by ocular side seems improbable as is evident from the jaw armature (jaws are edentulous) and feeding habit, the role of blind side in respiration cannot entirely be ruled out since feeding is also accompanied by water intake and the same may subserve respiration to some extent.

Retroarticular (Table 2), which caps the angular posteriorly, is larger and provides a greater surface area on the blind side for the attachment of a stronger interopercle-retroarticular ligament.

Thus it can be said with emphasis that the asymmetry which is met with in the lower jaw, is meant for strengthening and modifying the lower jaw of the blind side for the feeding activities.

In accordance with the anatomical make-up of the lower jaw of the blind side, the upper jaw of the blind side is also expected to possess a stronger osteological foundation with well marked articulation than that of the upper jaw of the ocular side as the former will have to forbear more stress and strain during feeding activities. Meticulous observation of the upper jaw bones have revealed that the edentulous premaxilla of the ocular side is small, becomes gradually pointed posteriorly and does not articulate with mandible. However, the same bone of the blind side is large, strong and its posterior end is articulated with the dorsal process of the mandible. It is also more arched and provided with large number of teeth on the ventral side so as to effectively bite against the convex dorsal surface of the mandible of the same side.

Traquair (1865) also observed premaxilla-mandible articulation only on the blind side of Pleuronectidae and viewed that this type of
arrangement makes the bite much more effective. The present author shares the above view of Traquair (1865). In addition to it as revealed from the present study there is an upper jaw - dentary cartilage which connects the maxilla and premaxilla with the dentary on the blind side. This type of arrangement perhaps reinforces the binding between the upper and lower jaws on the blind side.

The suspensory apparatus also exhibits wellmarked asymmetry in keeping with other cranial elements. Kyle (1923) pointed out a correlation between the asymmetry of the mandibular and hyomandibular arches of S.olea. According to the above author, the side (eyed side) having larger rami, the bones of the hyomandibular arch are shorter and stouter than those of the other side. However, an indepth analysis of the different components of the hyomandibular arch reveals, that due to more anterior position of the articulation of the lower jaw of blind side the bones of the hyomandibular arch of that side are elongated with the notable exception of hyomandibular (Table 2).

Hyomandibular links the cerebral skull with the rest of the bones of the suspensorium. Since the symplectic end of the hyomandibular forms a knot from where hangs the rest of the bones of the suspensorium, and interhyal linking in series the various bones of the jaws and branchial apparatus, the former plays a vital role in the suspensorium. In the fishes under the present study, as the process of feeding is carried out by the blind side so the suspensory apparatus of that side should be stronger and more rigid so as to provide more strength to the jaws. The present investigation has revealed that though both the hyomandibulars are equal in length, the cross sectional area of symplectic end is larger on the blind side (Table 2). This modification provides more area for attachment of hyomandibular with the rest bones of the suspensorium and thus makes the binding stronger.
Traquair (1865) reported the presence of a larger preopercular on the eyed side of some Pleuronectidae. Contrary to this, the present investigation records the presence of a larger preopercle on the blind side. Preopercle, which reinforces the hyoid arch by connecting the myomandibular with the quadrate is thicker and wider on the blind side and thus helps in strengthening the hyoid arch of the blind side. Quadrate plays a great role in the suspensorium of the jaws as the latter hangs from below the former. Besides the quadrate being longer, the area of the articulating facet is large on the blind side (Table 2). This increase in the articulating area makes the articulation with the angular more effective on the blind side.

The pterygopalatine arch serves as a buttress to the ethmoid region of the skull with its base resting on the quadrate (Kyle, 1923). Traquair (1865) observed a considerable flattening of the palate, entopterygoid and ectopterygoid bones of the blind side in some Pleuronectidae. Kyle (op. cit) observed the pterygopalatine arch of the ocular side to be more horizontal and that of the blind side more vertical and shorter in Solea and Cynoglossids. The present investigator though agrees with the Kyle (1923) regarding the orientation of the pterygopalatine arches, but disagrees with him regarding their size. A careful measurement of the bones of the pterygopalatine arches revealed that the palate of either side is equal in length and thickness, metapterygoids are also of equal size but the pterygoid (ectopterygoid and endopterygoid) is longer and thicker on the blind side and thus the said arch is longer and stronger on the blind side (Table 2). The articulation of pterygoid with the quadrate also exhibits asymmetry. While the pterygoid of the ocular side is attached to the lateral side of the quadrate, the former of the blind side is attached inside a lateral groove of the quadrate and thus, the attachment between the two is stronger on the blind side.
The present findings indicate that the anterior two branchioostegal rays are attached to the inner side of the ceratohyal and thus the view of Hubbs (1920) that in the higher group of teleosts the anterior two branchioostegals are always attached to the inner side of ceratohyal is corroborated.

Present study further indicates that the urohyal does not show any asymmetry but its different shape of cardiac and sciatic parts may be used as a taxonomic criterion (Figs. 52 - 55).

Traquair (1865) viewed that in the pleuronectidae (Turbot, Halibut and Plaice), due to more anterior position of the hyomandibular of the ocular side the opercle and preopercle are larger on that side as they have to cover a larger area. However, the opercle and subopercle are found to be symmetrical in the presently studied fishes except in S. arel where the subopercle has been found to be larger on the ocular side (Table 2). In contrast to the earlier findings of Traquair (1865) in the pleuronectidae (Turbot, Halibut and Plaice), that the interopercle is large on the ocular side due to the more anterior position of the lower jaw on that side, the present investigation reveals just the opposite condition, i.e., the interopercle is larger on the blind side due to more anterior position of the lower jaw articulation (Table 2).

Cunningham (1890) observed in Solea the presence of four pharyngobranchials on each side. However, the present study records the presence of only third and forth pharyngobranchials which are fused on both the sides.

The extension of the dorsal fin on to the head is a peculiar feature of these fishes. This has been achieved by the forward inclination of the first few anterior interneural spines. The modified first interneural spine which lies horizontally and carry the anterior few interneural spines forward has been called erisma by Norman (1934). But nobody has mentioned the number of interneural spines disposed on the erisma. The number of interneural spines which are
carried forward by the erisma varies in the fishes under the present investigation (Table 1). In addition to carry the dorsal fin rays over to head, the erisma bears a rostral cartilage anteriorly to strengthen the snout. A stronger snout enables these fishes to plough the sandy bottom to secure their food as well as to hide themselves therein (Menon, 1977). Among the fishes under the present investigation, the snout of P. blochii is more pointed and possesses a better developed erisma and thus can be considered to be better adapted in the sandy habitat.

To put the whole discussion in nutshell it can be said that the cranium is well adapted for the bottom living habit. The asymmetry of the jaw and suspensory apparatus is mainly meant to strengthen them as well as to meet the functional requirements. Virtually the osteological design of blind side is such that it can withstand a greater thrust generated by the biting of the jaws.