

# SKELETON OF CYPRINOID FISHES IN RELATION TO PHYLOGENETIC STUDIES.

## 5. THE SKULL AND THE GASBLADDER CAPSULE OF THE COBITIDAE

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### INTRODUCTION.

Having reported on the skeletal structure and its bearing on the inter-relationship of the Cyprinoid families Gyriinocheilidae (Ramaswami, 1952*a*), Psilorhynchidae (Ramaswami, 1952*b*), Homalopteridae (Ramaswami, 1952*c*) and Gastromyzonidae (Ramaswami, 1952*d*), I am now reporting on the Cobitid skeleton. The Cobitidae, unlike other families studied, show certain distinguishing skeletal characters which are, however, not noticed in any other Cyprinoid family studied so far.

Regan (1911) described the osteological characters of the Cobitidae as follows:

Premaxillae excluding the maxillaries from gape; pharyngeal teeth uniserial, often rather numerous, on the inner and posterior edges of sub-triangular laminar expansions of the pharyngeal bones, which are scarcely falciform; pharyngeal process of basioccipital sometimes very small, sometimes larger and meeting below the aorta, but *never* united and not supporting a horny pad. Subtemporal fossa shallow; a lateral occipital foramen on each side of foramen magnum. Preorbital and suborbital unossified.

He divided the family into two taking into consideration the nature of the mesethmoid.

The two divisions are:

- (1) Mesethmoid firmly united to frontals; skull depressed; anterior part of air-bladder nearly divided into two, the lateral halves of the capsule connected by a narrow bridge; no spine.—Nemachilinae.

Examples: *Nemachilus*, *Diplophysa*, etc.

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\* Now at Natural History Museum, Stanford University, California.

(2) Mesethmoid movably articulated with frontals; skull compressed, air-bladder undivided.—Cobitidinae.

(a) No spine. *Misgurnus*.

(b) Lateral ethmoid a movable spine. *Botia*, *Acanthopsis*, *Lepidocephalichthys*, *Cobitis*, etc.

Sagemehl (1891) described the skull structure of six genera of Cobitidae, viz., *Misgurnus*, *Nemachilus*, *Cobitis*, *Diplophysa*, *Botia* and *Acanthophthalmus*. In describing the bones of the skull, the nomenclature adopted by Sagemehl is now obsolete. He has figured the skulls of *Cobitis* and *Botia*.

Berg (1940) who followed the descriptions of Chranilov (1927) divided the family Cobitidae into three subfamilies, viz., Cobitini, Botini and Nemachilini. In the Nemachilini the mesethmoid, prevomer and the lateral ethmoid bones are immovably connected with the frontals and orbitosphenoid, and the lateral ethmoid bears no spine; the pharyngeal processes unite below the aorta. In the Botini, the mesethmoid is immovable while the lateral ethmoid is movable and possesses a suborbital spine. In the Cobitini the mesethmoid, prevomer and the lateral ethmoid are movable and the latter bears a spine; the metapterygoid has a large foramen.

I have examined the following species with a view to study the skeletal features of the Cobitidae:

- |             |  |
|-------------|--|
| Cobitini    | .. <i>Cobitis taenia</i> L., <i>C. biwae</i> (Jordon & Synder), <i>Misgurnus angullicaudatus</i> (Cantor), <i>M. fossilis</i> (Linn.); <i>Acanthopsis chaerorhynchus</i> Bleeker, <i>Acanthophthalmus pangia</i> (Ham. Buch.), <i>Lepidocephalichthys guntea</i> (Ham. Buch.), <i>Somileptes gongota</i> (Ham. Buch.). |
| Botini      | .. <i>Botia lohachata</i> Chaudhuri, <i>B. hymenophysa</i> Bleeker, <i>B. birdi</i> Chaudhuri.   |
| Nemachilini | .. <i>Nemachilus dayi</i> Hora, <i>N. botia</i> (Ham.), <i>N. rupicola</i> (McClelland), <i>N. barbatulus</i> L., <i>N. microps</i> (Steind.), <i>Nemachilichthyes rüppelli</i> (Sykes), <i>Diplophysa stewarti</i> Hora, <i>D. papilloso-labiata</i> Kesslr., <i>Adiposia macmohni</i> Chaudhuri.                     |

*Cobitis biwae* and *Botia birdi* did not yield good preparations of the skeleton. From the above list, it could be seen that I have examined genera belonging to all the three cobitid subdivisions of Berg.

#### OBSERVATIONS.

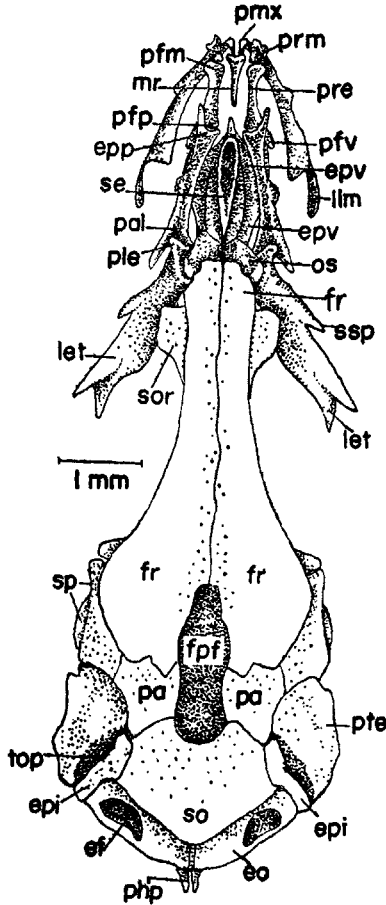
*Cobitini*.—For the sake of convenience, I shall take up the subfamily Cobitini first and describe the skeletal characters of one important genus and then compare the features of the other genera studied by me.

In the ethmoid region of *Cobitis*,—the family and subfamily being named after this genus, the supraethmoid portion is slightly broad and the ethmoid portion forms a vertical septum separating the two olfactory sacs. In the anterior end of the supraethmoid portion, there is a slight depression.

Ventrally the prevomer is united with the ethmoid to form a composite bone,—the ethmoprevomer, a unique feature noticed among the Cyprinoidea. From this united bone, anteriorly there are apophyses looking more like prevomerine projections with which the preethmoid articulates by a process (Text-fig. 1, *pfv*). The preethmoid (*pre*) is a three-pronged bone, situated on either side in front of the united ethmoprevomer (*epv*). It articulates anteriorly by a facet (*pfm*) with a similar facet (*prm*) on the maxilla; posteriorly it has two facets. The flat dorsal

one (*pfp*) articulates with the elongated ethmoid process (*epp*) of the palatine (*pal*) while the ventral one (*pfv*) articulates with a round prevomerine facet.

The premaxilla (Text-fig. 1, *pmx*) shows a large rostral process and a lateral limb. The maxilla exhibits a prominent anterior premaxillary process, a posterior facet for articulating with the preethmoid, a ventral rostral process and a process from the broad lateral limb for the insertion of the ligament of the adductor mandibulae muscles.



TEXT-FIG. 1. Dorsal aspect of the skull of *Cobitis taenia* Linn. (The sensory canal ossicles are omitted.)

The lateral ethmoid<sup>1</sup> (Text-fig. 1, *let*) is a well developed elongated bone with quite a few processes: one of these processes (*ssp*) is usually described as the sub-orbital spine. Mesially the bone articulates by means of a prominent head with the orbitosphenoid.

The lacrimojugal (not drawn in Text-fig. 1) is a flat strip of bone in front of the lateral ethmoid. As there is no anterolateral process from the lateral ethmoid, the lacrimojugal does not come in contact with it. There are a number of sensory

<sup>1</sup> Prefrontale (ectethmoid), according to Chranilov (1927a).

canal ossicles lying laterally to the lacrimojugal forming a part of the suborbital series.

The median rostral (Text-fig. 1, *mr*) is an obliquely vertical bone whose dorsal end is enlarged to receive the two rostral processes of the premaxilla.

I shall consider the palatine here though it belongs to the upper jaw. The edentulous palatine (Text-fig. 1, *pal*) while articulating at its middle with the ethmoprevomer, shows anteriorly a prominent process (*epp*) with which a prominent process (*ppf*) of the preethmoid (*pre*)<sup>1</sup> comes in contact. Laterally to this articulation, the palatine has a prominent pointed process.

The orbitotemporal region: In *Cobitis*, there is a large supraorbital bone (Text-fig. 1, *so*)<sup>2</sup>. The large frontals and the small parietals bound anteriorly and laterally the fronto-parietal fontanel (*ppf*). Each frontal laterally shows a ventral shelflike extension. Peculiarly the frontals do not disclose laterally the passage of the supraorbital sensory canal; however, the canal passes through independent ossicles on the frontal and anteriorly, there is a very small nasal bone.

A reference to the orbitosphenoid has already been made; it is noticed on either side of the ethmoprevomer (Text-fig. 1, *os*) dorsally in front of the frontals. Ventrally the united orbitosphenoid is noticed just posterior to the ethmoprevomer mesially to the anterior articulations of the lateral ethmoid. The orbitosphenoid extends below the frontals as two posterior limbs and ventrally, above the parasphenoid, there is a median posterior limb of the same. Since the orbitosphenoid is limited to the anterior end of the orbitotemporal region, the orbit is very large and there is usually a membranous interorbital septum. The pleurosphenoid<sup>3</sup> is a small ossification relegated to the posterior wall of the orbit, mesially to the large sphenotic. The parasphenoid does not show any peculiarity.

The infraorbital sensory canal is composed of a series of independent ossicles, ending anteriorly as a large rostral in *Cobitis*.

The auditory region: The sphenotic<sup>4</sup> (Text-fig. 1, *sp*) and pterotic (*pte*) form the lateral ossifications and posterolaterally there is a small epiotic (*epi*) bone. In the anteromesial region of the pterotic, there is a depression in the bone and this is the temporal opening.\* It should, however, be noted that not in all the Cobitini examples is this temporal opening noticed. The occipital bones are well developed. The two exoccipitals bound the foramen magnum dorsally and in each, there is a large lateral fenestra. The basioccipital shows two prominent pharyngeal processes (*php*) disunited below the aorta.

I shall give a description of the jaws and hyobranchial skeleton under *Acanthopthalmus* as there is not much difference noticed among the members of Cobitini.

The skull of *C. biwae* resembles that of *C. taenia* closely and a separate description of it is therefore, unnecessary.

I shall now describe the skull of *Acanthopthalmus* which shows quite a few differences from that of *Cobitis*.

In the ethmoid region of *Acanthopthalmus* (Text-fig. 2a), a supraethmoid portion is absent and the ethmoprevomer forms a vertical septum separating the olfactory sacs.

Ventrally the united ethmoprevomer (Text-fig. 2a, *epv*) is noticed, from whose anterior end, there are prevomerine projections (*ppv*) with which the preethmoids articulate. The preethmoid also articulates by a facet (*ppf*) with a similar facet (*epp*) of the palatine.

The maxilla exhibits an anterior premaxillary (Text-fig. 2a, *apm*), a pre-ethmoid (*prm*), a ventral rostral (*rpm*) and a lateral ligamentary (*plm*) processes.

The lateral ethmoid of *Acanthopthalmus* resembles that of *Cobitis*.

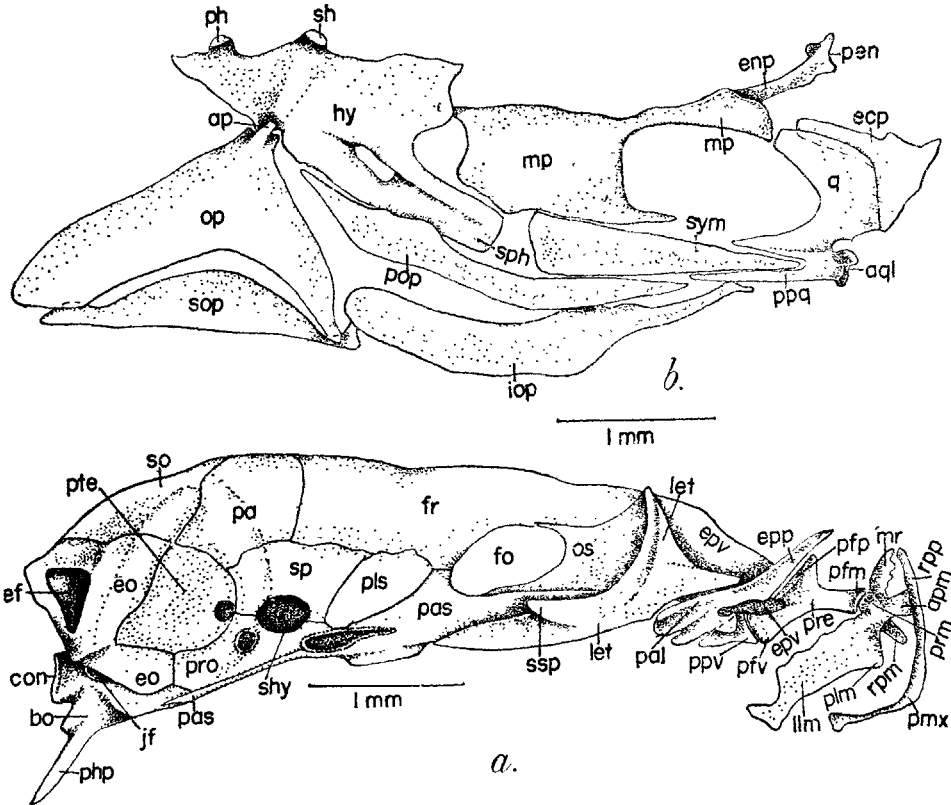
<sup>1</sup> Submaxillare, <sup>2</sup> orbitale, <sup>3</sup> alisphenoid, <sup>4</sup> postfrontale, according to Chranilov (1927a).

\* Chranilov (1927a) does not show a temporal opening in his figure (6, above) of *C. taenia*.

In the orbitotemporal region, there is a bowl-like supraorbital bone in *Acanthophtalmus*.

In the auditory region, there is a frontoparietal fontanel. Peculiarly in *Acanthophtalmus*, the frontal instead of merely extending laterally, arches downwards to form a sutural contact with the parasphenoid (*pas*), pleurosphenoid (*pls*) and sphenotic (*sp*) so that the skull is rounded in this region.

The orbitosphenoid is single and the small pleurosphenoid (Text-fig. 2a, *pls*) is posteriorly situated showing no contact with the orbitosphenoid; in *Acanthophtalmus*, the extensions of the frontal (*fr*) and parasphenoid (*pas*) meet in front of the pleurosphenoid (*pls*) and exclude the latter from the orbit. Thus in this



TEXT-FIG. 2. (a) The lateral aspect of the skull of *Acanthophtalmus pangia* (Ham. Buch.). (b) The upper jaw of *Acanthopsis chaerorhynchus* Bleeker. (Palatine omitted).

example, there is a large optic fenestra roofed by the frontal and floored by the parasphenoid and by the posterior spinous extension of the orbitosphenoid dorsally to the parasphenoid. Into the membranous interorbital septum dorsally, there is also a short projection of the orbitosphenoid.

The auditory region: In *Acanthophtalmus* (Text-fig. 2a), the skull is perfectly rounded in the auditory region, as in the orbitotemporal, without any gaps or temporal fossae and the extension of the frontal (*fr*) coming in contact with the parasphenoid (*pas*) one, as already said, keeps the small lateral pleurosphenoid (*pls*) away from the orbit. Moreover, there is no epiotic bone and the exoccipital (*eo*) is very large showing a large fenestra (*ef*). Probably, the epiotic has united

with the exoccipital. The supraoccipital (*so*) is large and does not show any membranous processes and the two exoccipitals bound the foramen magnum dorsally, keeping out the supraoccipital from forming the roof in this region. The basioccipital (*bo*) gives rise to the pharyngeal processes (*php*) which do not unite below the aorta.

In the upper jaw of *Acanthopthalmus* and *Acanthopsis* (Text-fig. 2b), the metapterygoid (*mp*) is arched in front with a deep indentation towards the quadrate (*q*) and the quadrate also shows a similar indentation towards the metapterygoid. The preopercle (*pop*) is fairly long and does not carry a sensory canal in it. The hyomandibula (*hy*) has a rectangular orifice in it and shows a long symplectic process (*sph*). The symplectic (*sy*) itself is a long wedge-shaped bone. The operculum (*op*) shows an articular process (*ap*) and the lower edge is indented. The entopterygoid (*enp*) is rod like and has a facet for the articulation of the palatine.

In the lower jaw of *Acanthopthalmus*, the dentary and angular are practically of the same size articulating with each other loosely. *Cobitis* also shows a similar condition. The dentary shows a prominent dorsal process. The retroarticular occupies the ventral portion below the angular near the articulation with the quadrate. Mesially there is a canal between Meckel's cartilage and the investing angular which is probably a sensory canal. No other canal is noticed leading the sensory canal in the angular or dentary. At any rate in my previous papers, I have labelled such a mesial canal as a sensory canal. A sesamoid angular is peculiarly absent.

In the hyobranchial apparatus of *Acanthopthalmus*, there are four copulae, two pairs of hypohyals and the basihyal is rodlike with the anterior end slightly enlarged.

The other genera, viz., *Lepidocephalichthys*, *Acanthopsis*, *Somileptes* and *Misgurnus* are similar to *Cobitis* and *Acanthopthalmus* in many features. A supraethmoid is absent in *Acanthopsis* and *Lepidocephalichthys* while in *Somileptes* and *Misgurnus* there is a slight enlargement as in *Cobitis*. The premaxilla and maxilla of *Lepidocephalichthys*, *Acanthopsis*, *Somileptes* and *Misgurnus* resemble those of *Acanthopthalmus* and *Cobitis* but in *Somileptes*, there is a large lateral process from the maxilla extending laterally to the preethmoid in addition to the other processes.

In the auditory region, the sphenotic, pterotic and epiotic bones are arranged in a line one behind the other; in *Misgurnus* the epiotic also shows a small membranous portion. The supraoccipital in *Misgurnus* and *Lepidocephalichthys* does not show any projecting processes, while in *Somileptes* they are present. The two pharyngeal processes of the basioccipital are large in *Misgurnus* and the similar processes of *Somileptes* are fenestrated; they do not unite ventrally to enclose the dorsal aorta. The subtemporal fossa in *Lepidocephalichthys* and *Misgurnus* is insignificant while it is quite distinct in *Somileptes*. A temporal opening is absent in *Lepidocephalichthys*, *Acanthopsis*, *Somileptes* and *Misgurnus*.\*

The upper jaw of *Lepidocephalichthys*, *Acanthopthalmus* and *Somileptes* resembles that of *Acanthopsis* in all important characters. There are a number of small and large orifices in the metapterygoid of *Somileptes*. The hyomandibula of *Somileptes* shows a prominent spine laterally at its middle. The entopterygoid is rodlike and possesses a facet for the palatine.

The lower jaw is the same in all the genera; a glance at figure 4a of the lower jaw of *Somileptes* shows the similarities in structure with that of *Acanthopthalmus*.

The nature of the gasbladder of the Cobitini is very well seen in that of *Somileptes* (Text-fig. 7a). The pleural ribs of the second (*pl2*) and the dorsal (*dr4*, *pr4*) and pleural ribs (*oss*) of the fourth vertebrae contribute towards the

\* Chranilov (1927a) also does not show in his figure (6, below) *M. fossilis* a temporal opening.

formation of the single capsule with its lateral openings; however, the dorsal ribs of the second vertebra (*dr2*) are free. There is a posterior opening (*po*) in the capsule for establishing a connection between the anterior and posterior portions of the gasbladder. Of the first vertebra, the projecting centrum (*cl*) and its dorsal ribs are seen; of the second vertebra, the neural arch (*na2*), the dorsal (*dr2*) and pleural (*pl2*) ribs with prominent ventral processes from the latter (*pr2*) are noticed. The neural spines of the second and third vertebrae appear to have fused into a single one (*ns23*). Of the fourth vertebra, the neural arch (*na4*), the neural spine (*ns4*) and the dorsal (*dr4*) and pleural ribs (*oss*) are seen. Of the weberian ossicles, the tripus needs special mention. It has retained its triangular shape resembling very much that in the Cyprinidae.

*Botini*.—I shall now describe the skull of *Botia*, the only genus that I have studied under *Botini*.

In the ethmoid region, the supraethmoid part (Text-fig. 3a, *se*) is slightly broadened out with a deep gully in it. The supraethmoid projects in the form of a short process (Text-figs. 3a, 3b, *p*) in between the ethmoprevomerine projections. The ethmoprevomer (*epv*) is firmly articulated with the orbitosphenoid and the bone does not come in contact with the anterior end of the frontals (*fr*).

The prepalatine (Text-figs. 3a, 3b, *ppa*) and the first preethmoid (*pre*) are elongated rodlike bones articulating anteriorly with independent facets (*ppm*, *prm*) of the maxilla. Peculiarly, there is a large oval bone (*sb*), probably a sesamoid, sitting on the articular region of the maxilla and the preethmoid. As I am unable to discover the exact homology of it, I have simply called it an 'oval' bone.

The premaxillae are peculiar in *Botia*. The rostral process (Text-figs. 3a, 3b, *rpp*) of the premaxilla (*pmx*) takes its origin not at the anterior end as in other examples of Cobitidae, but at the middle of the bone so much so, there is a semi-circular arch of the premaxilla formed in front for supporting the tuft of maxillary barbels.

The maxilla of *Botia* shows all the characteristic processes: the rostral (Text-figs. 3a, 3b, *rpm*), the dorsal (*dpm*), the preethmoid (*prm*), the prepalatine (*ppm*) process and the process (*plm*) for the attachment of a ligament. The lateral limb (*llm*) is very short.

The lateral ethmoid (Text-figs. 3a, 3b, *let*) is well developed and shows at least five processes: mesially, it comes in contact with the large orbitosphenoid (*os*). Anteriorly, there is a process and from the lateral aspect of this, there is a small process (*llj*) articulating with the lacrimojugal (*lj*). A prominent suborbital spine (*ssp*) is seen and the posterior spinous process articulates with the lateral edge of the frontal (*fr*).

The lacrimojugal<sup>1</sup> (Text-figs. 3a, 3b, *lj*) is a thin piece of bone with the posterior end of which, the lacrimojugal process (*llj*) articulates; the rostral (*ros*) is free anteriorly and behind the rostral, there are ten suborbital canal ossicles (*sc3*, *sc9*, *sc10*).

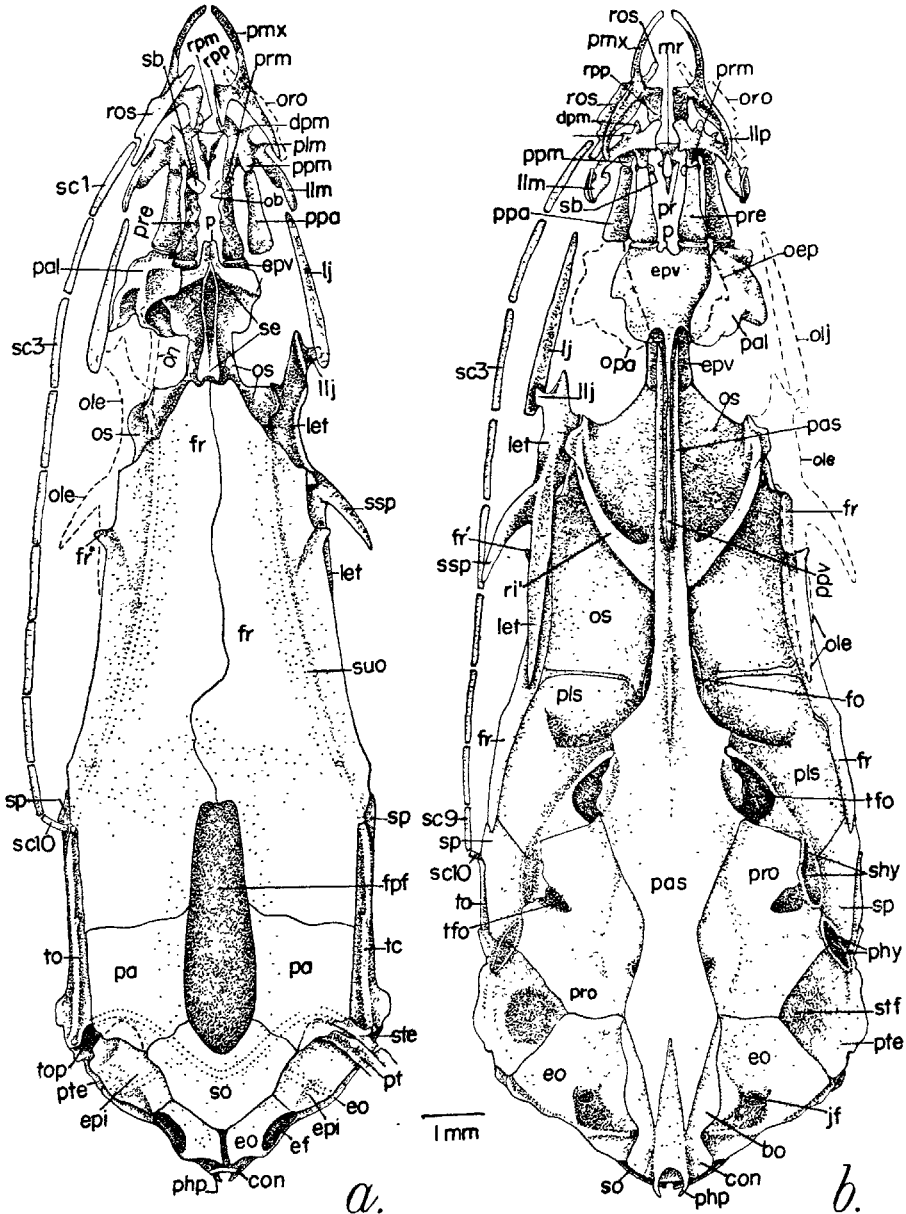
In *Botini*, the median rostral (Text-figs. 3a, 3b, *mr*) is an obliquely vertical bone whose dorsal end is enlarged; at the middle there are two projections (*pr*), one on either side for the attachment of a ligament. The ventral end is pointed.

The palatine (Text-figs. 3a, 3b, *pal*) while mesially articulating with the ethmoprevomer, shows anteriorly a prominent facet for the prepalatine (*ppa*). Posteriorly the entopterygoid articulates with a palatine facet.

In the orbitotemporal region, the frontals (Text-fig. 3a, *fr*) are large covering bones; each frontal shows a lateral spinous projection (*fr'*), a short distance from its anterior end. Also the passage of a lateral sensory canal is noticed in each bone. The orbitosphenoid (*os*) projects in front as far as the ethmoprevomer so that there is a small gap between the supraethmoid and the frontals. The bone

<sup>1</sup> Preorbitale (Chranilov 1927a).

also gives articulation to the lateral ethmoid (Text-fig. 3b, *os*) and ventrally, the large size of the bone could be easily made out; it also shows a large ridge (*ri'*). Posteriorly, it comes in contact with the pleurosphenoid (*pls*) which is also fairly



TEXT-FIG. 3. The skull of *Botia hymenophysa* Bleeker.  
(a) Dorsal aspect. (b) Ventral aspect.

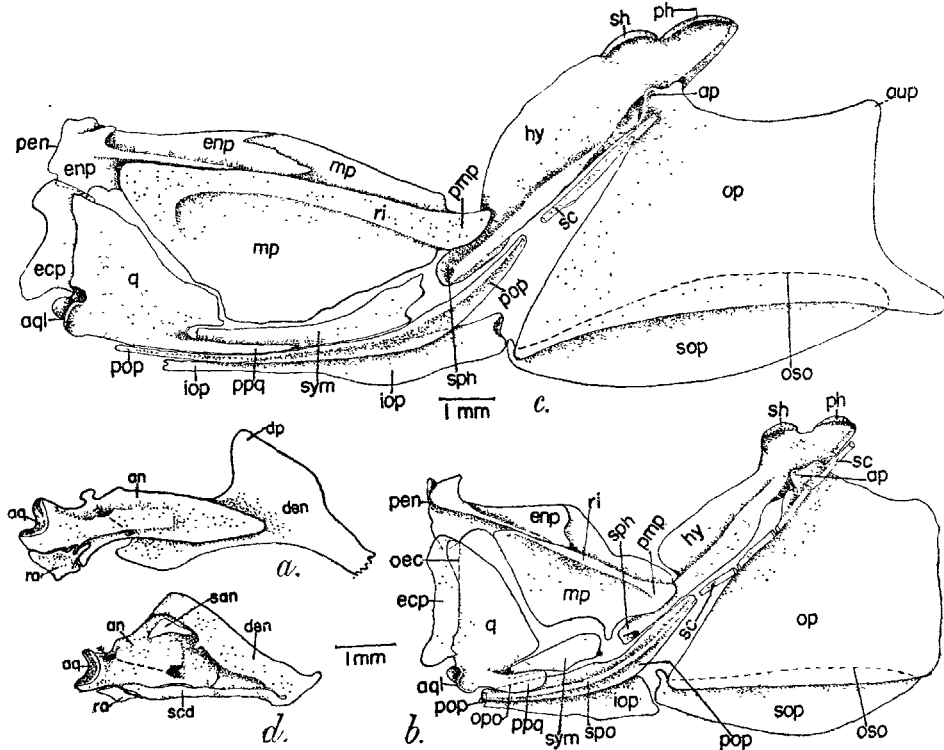
large. The optic foramen (*fo*) is quite small. A part of the orbitosphenoid anteriorly or in front of the optic foramen dorsally to the parasphenoid (*pas*) forms the interorbital septum, which however, is not visible in the ventral view.



There are two sclerotic bones in the bulbus oculi.

In the auditory region, *Botia* exhibits certain peculiarities. The sphenotic (Text-fig. 3b, *sp*) and pterotic (*pte*) are fairly large ossifications and ventrally, the sphenotic (*sp*), the prootic (*pro*) and the pleurosphenoid (*pls*) contribute towards the formation of the anterior facet (*shy*) for the articulation of the hyomandibula. Between the mesial part of the epiotic (Text-fig. 3a, *epi*), lateral pterotic (*pte*) and the anterior temporal ossicle (*to*), there is a small temporal opening (*top*) for the attachment of a few muscles. The occurrence of a single temporal sensory canal ossicle (*tc*) in front of the supratemporal (*ste*) one in *Botia* is noteworthy.

In the upper jaw of *Botia*, the hyomandibula (Text-figs. 4b, 4c, *hy*) shows a fairly large symplectic process (*shy*) with a short (Text-fig. 4b) or long (Text-fig. 4c)



TEXT-FIG. 4. The skull of Cobitid Fishes (continued).  
 (a) Mesial view of the left ramus of lower jaw of *Somileptos gongota* (Ham. Buch.).  
 (b) The upper jaw of *Botia lohachata* Chaudhuri. (Palatine omitted).  
 (c) The upper jaw of *Botia hymenophysa* Bleeker. (Palatine omitted).  
 (d) Mesial view of the left ramus of lower jaw of *Botia hymenophysa* Bleeker.

symplectic (*sym*) in front. The metapterygoid (*mp*) does not show an indentation towards the quadrate (*q*) and along with the entopterygoid (*enp*), they disclose a prominent ridge (*ri*). The metapterygoid (*mp*) comes in contact with the hyomandibula by a short posterior process (*pmp*) which, however, is laterally disposed to the symplectic process of the hyomandibula. The preopercular (*pop*) is slender and long and carries a sensory canal (*spo*) in it which is connected with the temporal canal by a series (*sc*, *B. lohachata*) or a single (*B. hymenophysa*) canal ossicle. The opercle (*op*) is large with its lower border entire and dorsally shows an articular (*ap*) and an auricular process (*aup*).

The lower jaw of *Botia* (Text-fig. 4d) is compactly built. The angular<sup>1</sup> and dentary show ventrally the united sensory canal (*scd*) and mesially also one (indicated by the arrow). The sesamoid angular (*san*) is a fairly large bone.

In the hyobranchial apparatus of *Botia*, the number of copulae is reduced to two and there are present three pairs of hypobranchs and two pairs of pharyngobranchs. Between the two pairs of hypohyals, there is intercalated a piece on which the hypohyals can rotate. This middle piece has its upper and lower surfaces enlarged into button-shaped prominences. I do not know if this is a part of the basihyal; the basihyal proper is feebly expanded anteriorly.

In the two species of *Botia* examined by me, the gasbladder capsule is a pearshaped bony chamber. The dorsal ribs (Text-fig. 7b, *dr2*) of the second vertebra are disposed anteriorly to the apertura magna (*ape*) or the lateral openings and do not take part in the formation of the capsule while the extensions of the pleural ribs (*pl2*) form ridges on the anterior wall of the capsule. The dorsal ribs (*dr4*) of the fourth vertebra form the dorsal boundary of the lateral openings and also extend laterally as projections over the capsule and end as spines (*pr4*). The gasbladder capsule (*gbc*) itself is formed by the pleural ribs (*oss*) of the fourth vertebra and the capsule does not show a posterior opening as in *Somileptes* for connecting the posterior portion of the gasbladder. The first centrum (*cl*) shows a pair of short dorsal ribs (*dr1*); the second vertebra also exhibits the dorsal (*dr2*) and pleural ribs (*pl2*), a neural arch and a short neural spine (*ns2*). The neural arch (*na3*) and neural spine (*ns3*) of the third vertebra are comparatively larger. The fourth vertebra discloses a neural arch and neural spine (*ns4*) and the dorsal (*dr4*) and pleural ribs (*oss*).

With regard to the weberian ossicles, the four ossicles are typically noticed and the tripus is triangular without a transformator process.

*Nemachilini*.—I shall now describe the skull and gasbladder capsule of *Nemachilus* as an example under the *Nemachilini*.

In *Nemachilus* (Text-figs. 5, 6a), the supraethmoid (*se*) is represented by a slight enlargement of the septum and this posteriorly, comes firmly in contact with the frontals (*fr*); in *N. barbatus* (Text-fig. 6a), at the region of sutural contact with the frontals (*fr*), the supraethmoid (*se*) is broad. The anterior portion of the supraethmoid projects as a short blunt or long (Text-fig. 6a) process (*p*). In *N. dayi*, *botia* and *rupicola* there is a slight depression in the anterior supraethmoid portion; in *N. microps* and *barbatula* such a depression is absent and the anterior region shows slight enlargement in the former species.

As in the two previous subfamilies, the ethmoid and prevomer have united together to form a composite ethmoprevomer in *Nemachilus* (Text-figs. 5, 6a, 6b, *epv*); the posterior portion of the prevomer (*ppv*) is long in all the nemachiline genera studied. From this ethmoprevomer in *N. dayi* (Text-fig. 5) and *rupicola*, anteriorly there are two apophyses-like prevomerine projections with which the preethmoids (*pre*) articulate. In *N. microps* and *botia*, a second preethmoid is developed with which the rodlike first preethmoid articulates.

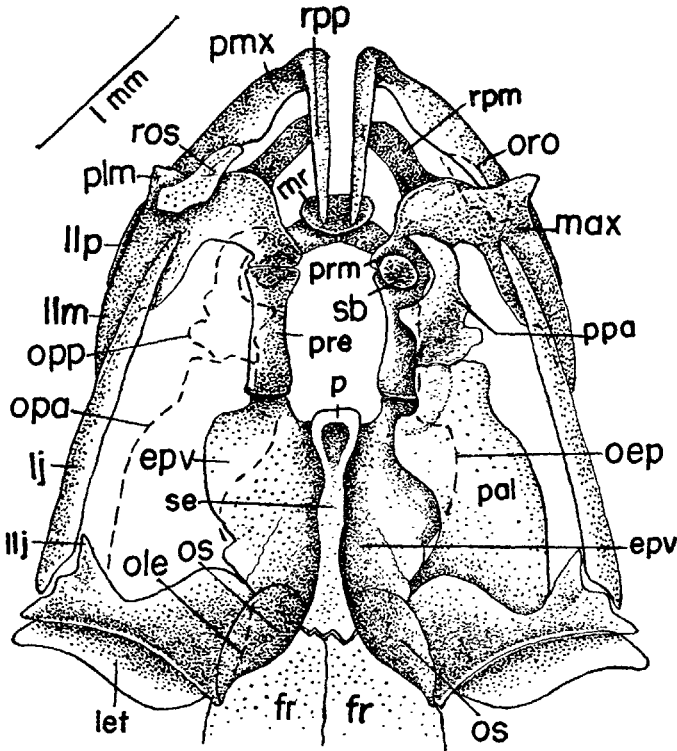
*Nemachilus* (Text-figs. 5, 6a, 6b) shows a rodlike first preethmoid (*pre*); the prepalatine shows difference in shape in the several species of *Nemachilus*. In *N. dayi* the prepalatine (Text-fig. 5, *ppa*) is sickle-shaped and there is no special facet for articulation with the maxilla in this species; so also in *rupicola*. In *N. microps* and *botia* the prepalatine articulates with the maxilla by a facet. Sitting on the first preethmoid in *N. dayi*, there is a rounded sesamoid bone (Text-fig. 5, *sb*).

The premaxillae of *Nemachilus* (Text-figs. 5, 6a, *pmx*) show a large rostral process (*rpp*) coming in contact with the rostral (*mr*), and a lateral limb (*lm*).

<sup>1</sup> Articulare (Chranilov, 1927a).

The maxillae of *Nemachilus* (Text-figs. 5, 6a, *max*) show the usual processes, viz., the anterior rostral process (*rpm*), a prominent facet (*prm*) for articulation with preethmoid and a process (*plm*) for the attachment of a ligament. There is no special facet of the maxilla for articulation of the prepalatine (*ppa*) in *N. dayi* but in *microps* and *botia*, it is present. The lateral limb in *N. dayi* (Text-fig. 5, *llm*) is fairly long.

In *Nemachilus*, the lateral ethmoid shows variation: in forms like *N. dayi* (Text-fig. 5, *let*), *rupicola* and *barbatulus* (Text-fig. 6a, *let*), it is a small ossification in the lamina orbitonasalis. In *N. microps*, which is a larger animal, the bone is also comparatively larger. Laterally the bone shows a lacrimojugal process (Text-figs. 5, 6a, *llj*). Ventromesially the bone articulates with the unpaired orbitosphenoid (Text-fig. 6b, *os*). In *N. botia*, the lateral ethmoid and the broad



TEXT-FIG. 5. Dorsal aspect of the ethmoid region of the skull of *Nemachilus dayi* Hora.

lacrimojugal are in close contact and a lacrimojugal process of the lateral ethmoid is thus absent.

The lacrimojugal (Text-fig. 5, *lj*) is a thin strip of bone in front of the lacrimojugal process of the lateral ethmoid in *N. dayi* and *rupicola*; in *microps* there is a broad posterior portion and in continuation with this one anteriorly, there is a small projecting portion. In *N. barbatulus* (Text-fig. 6a) the lacrimojugal and rostral are united into a single ossification (*ljr*). In *N. botia* the lacrimojugal is broad and projects in front of the lateral limb of the lateral ethmoid.

In *Nemachilus* the median rostral (Text-figs. 5, 6a, *mr*) is disposed as in the two previous subfamilies; in the middle of the bone there are two lateral projections for the insertion of ligaments.

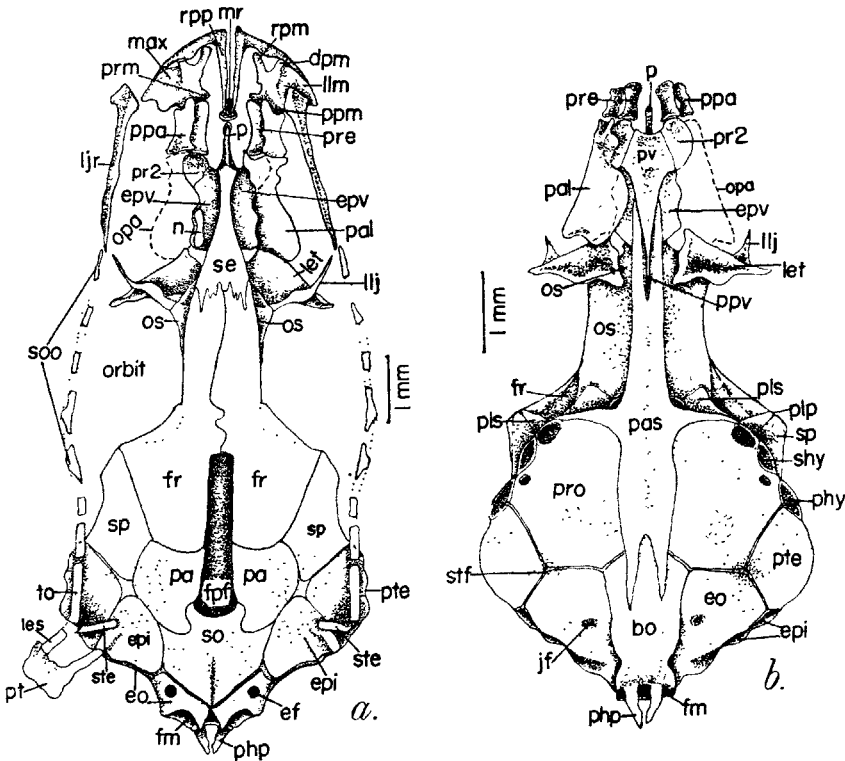
The palatine of *Nemachilus* resembles very much that of *Botia*. It possesses a facet (Text-figs. 6a, 6b, *pal*) for articulation with the prepalatine (*ppa*) and mesially articulates with the large ethmoprevomer and has posteriorly a facet for the entopterygoid.

In the orbitotemporal region, a supraorbital bone is absent in *Nemachilus*.

The frontals (Text-fig. 6a, *fr*) are large bones and between them, the parietals (*pa*) and the supraoccipital (*so*), there is a large frontoparietal fontanel (*fpf*). In the frontals, the passage of the supraorbital sensory canal is not noticed.

The supraorbital sensory canal ossicles are independent of the frontals and end anteriorly as the nasal ossicle in the olfactory region.

Ventrally, the large orbitosphenoid (Text-fig. 6b, *os*) extends posteriorly and meets the large pleurosphenoid (*pls*), the optic foramen (*fo*) being very small. In



TEXT-FIG. 6. The skull of *Nemachilus barbatulus* Linn. (a) Dorsal aspect. (b) Ventral aspect.

*Nemachilus* the orbitosphenoid has winglike extensions on either side of the ethmoprevomer in front of the frontals, and the lateral ethmoid comes mesially in contact with them.

The parasphenoid (Text-fig. 6b, *pas*) shows a narrow portion anteriorly and a broad portion in the auditory region of *Nemachilus*. A lateral limb from the posterior portion of it delimits the trigeminofacial opening.

In each eye, there are two cupshaped sclerotic bones.

The auditory region of *Nemachilus* shows some interesting features. In *N. barbatulus* (Text-fig. 6b, *sp*) the sphenotic shows a winglike process and a similar process from the pleurosphenoid comes in contact with it. In other species of *Nemachilus*, the pleurosphenoid projection is absent. The epiotic (Text-fig. 6b,

*epi*) is posteromesial and the supraoccipital (*so*) does not show any posterior process. The exoccipitals are small and the lateral fenestrae are hardly visible in *N. dayi*, while in other species of *Nemachilus*, they are clearly seen. The basioccipital (Text-fig. 6b, *bo*) shows the pharyngeal processes which have united below the aorta.

There is one peculiarity noticed in the dorsal sphenotic-pterotic region of Nemachilini, i.e., the presence of a temporal opening developed on account of the nonextension of the parietal laterally and of the pterotic mesially to meet the parietal. Laterally to this cavity, the independent temporal sensory canal ossicles are noticed on the pterotic bone; the floor of the cavity is formed mostly by the pterotic posteriorly, in front by the sphenotic and mesially by the sphenotic and pterotic; there is, however, a slight extension of the parietal as roof. The mesial limb of the supratemporal and posttemporal lie over the temporal opening so that the muscles from this temporal cavity pass below these bones.

On the ventral aspect of *Nemachilus* (Text-fig. 6b), the pterotic-protic-exoccipital junction discloses a clearly demarcated shallow subtemporal fossa.

In the upper jaw of *Nemachilus* (Text-fig. 7c), the hyomandibula (*hy*) is broad and the symplectic process (*syh*) is comparatively short; there is a prominent process (*pho*) of the hyomandibula towards the operculum (*op*) in *N. dayi*. The metapterygoid (*mp*) and entopterygoid (*enp*) are broad and the former shows a ridge (*ri*) on it. The metapterygoid also shows a short posterior process (*opm*) towards the hyomandibula in all the species of *Nemachilus* examined by me. The opercle (*op*) shows only an articular process (*ap*). The preopercle (*pop*) does not show a sensory canal in it except in *N. botia*. However, sensory canal ossicles are noticed by the side of the preopercle.

In the lower jaw, *Nemachilus* shows the usual four bones, viz., the angular, the dentary, the retroarticular and the sesamoid angular. A mesial sensory canal is also noticed.

In the hyobranchial apparatus of *Nemachilus*, there are three copulae, three pairs of hypobranchs and two pairs of pharyngobranchs. Between the two pairs of hypohyals, there is a bony piece intercalated. The basibranchial is anteriorly forked assuming a Y-shape.

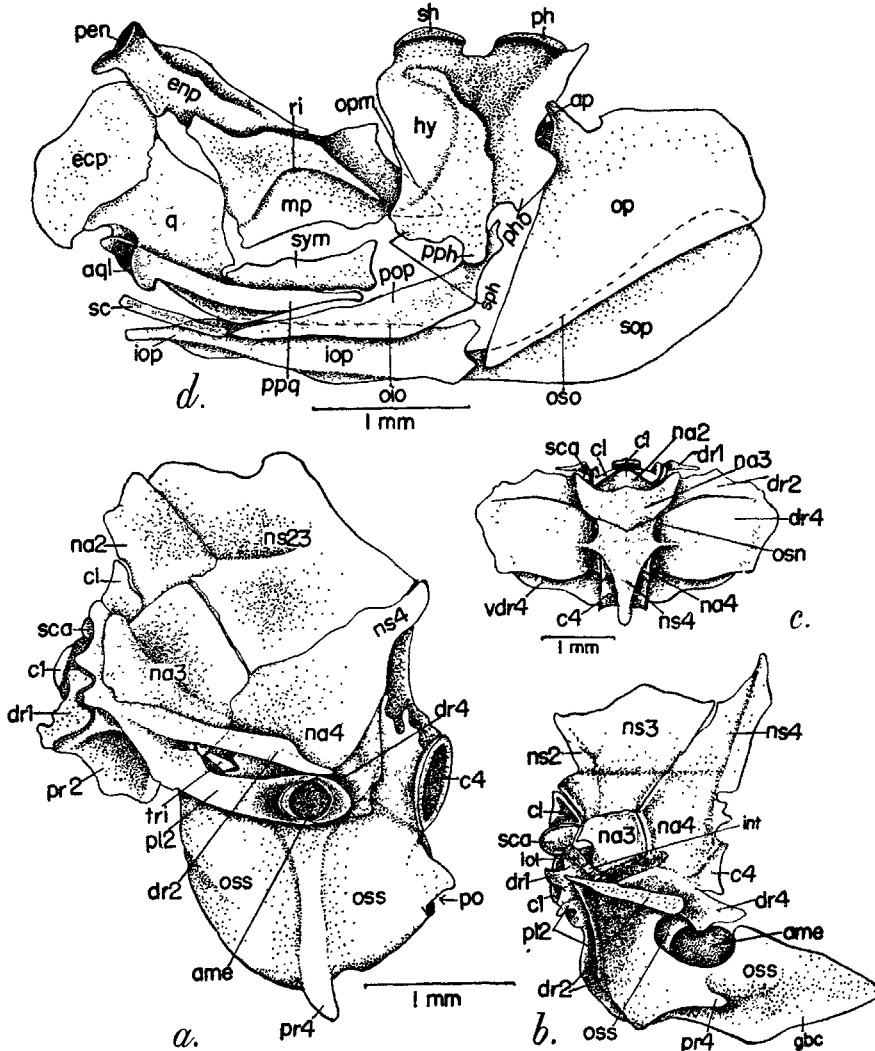
In *Nemachilus*, the gasbladder capsule is double, connected together by a posterior commissure following roughly the contour of the bladder itself. There is also a posterior portion of the bladder free of any osseous covering. In *Nemachilus dayi* (Text-fig. 7c), the anterodorsal and anteroventral portions of the gasbladder capsule appears to be formed by the dorsal (*dr2*) and pleural ribs respectively of the second vertebra; the posterodorsal and postero-ventral portions of the capsule are formed by the dorsal ribs (*dr4*) of the fourth vertebra. The region of the capsule near the united centra of the second and third vertebrae is probably formed by the pleural ribs (ossa suspensoria) and I am not able to follow this in my preparation on account of the absence of any demarcations. The centrum of the first vertebra with its dorsal ribs (*dr1*), and the neural arches of the second (*na2*), third (*na3*) and fourth (*na4*) vertebrae are clearly made out; however, the lateral openings are not seen in the view drawn.

The characteristic ossicles are noticed: the claustrum, scaphium, intercalarium and the tripus. The tripus is Y-shaped with the lateral limb of the fork short and this represents the processus anterior; the other limb comes in contact with the centrum as processus articularis. The posterior limb is also short and comes in contact with the gasbladder and there is no transformator process.

The second example that I have studied under Nemachilini is *Adiposia*. I shall only refer to the important characters in which the second genus resembles or differs from *Nemachilus*.

In the ethmoid region of *Adiposia*, the supraethmoid shows anteriorly a depression. The prepalatine articulates with the maxilla by a special facet. Sitting on the preethmoid, there is a small rounded sesamoid bone as in *N. dayi*;

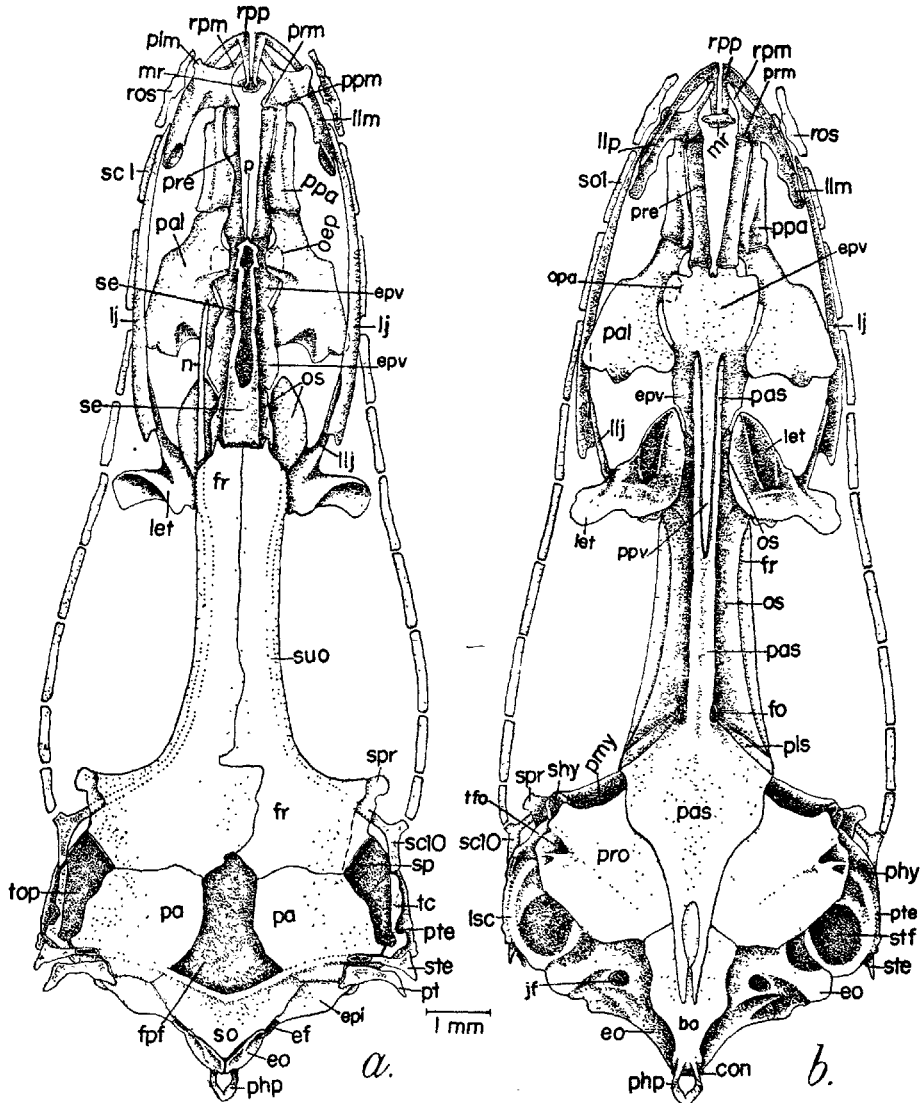
a second preethmoid is also not developed in *Adiposia*. The lacrimojugal is a thin slender bone. Like *Nemachilus*, a supraorbital bone is also absent in *Adiposia*. In the supraorbital region of the frontals of *Adiposia*, where the independent sensory canal ossicles are located, oval orifices are seen in the frontal bones.



TEXT-FIG. 7. The Vertebrae, Gasbladder and Jaw of Cobitid Fishes.  
 (a) Left view of the first four vertebrae and gasbladder capsule of *Somileptes gongota* (Ham. Buch.).  
 (b) Left view of the first four vertebrae and gasbladder capsule of *Botia lohachata* Chaudhuri.  
 (c) Dorsal view of the first four vertebrae and gasbladder capsule of *Nemachilus dayi* Hora.  
 (d) The upper jaw of *Nemachilus dayi* Hora. (Palatine omitted).

I shall now take up the description of the skeleton of the other genera, viz., *Diplophysa* and *Nemachilichthys* that I have studied under the subfamily *Nemachilini*.

Of the two species of *Diplophysa*, *stewarti* is smaller than *papilloso-labiata*. In the ethmoid region, the supraethmoid is slightly developed in *D. stewarti* and *Nemachilichthys* (Text-fig. 8a, *se*); there is also a depression anteriorly in it. In *D. papilloso-labiata* the supraethmoid is broad (Text-fig. 9, *se*) with winglike



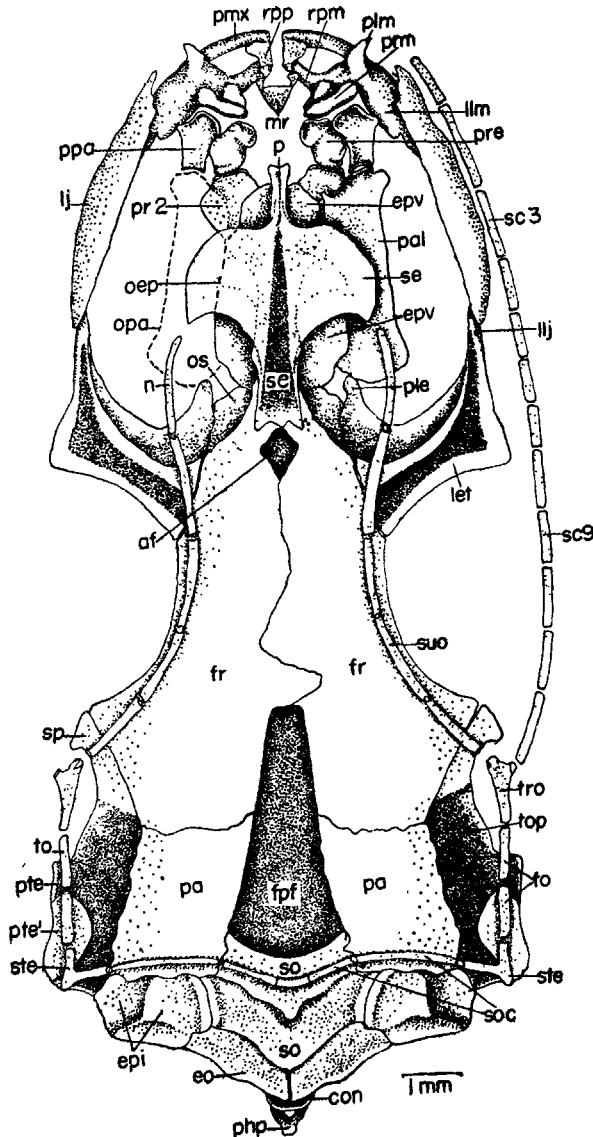
TEXT-FIG. 8. The skull of *Nemachilichthys ruppelli* (Sykes).  
 (a) Dorsal aspect (nasal is shown on one side only).  
 (b) Ventral aspect (nasals are not shown).

extensions anterolaterally and there is a large process (*p*) anteriorly. There is a median depression in the bone.

The preethmoid does not articulate with a prevomerine projection as in *N. dayi* and *Nemachilichthys* (Text-fig. 8a) but with a second preethmoid (Text-fig. 9, *pr2*)

in *Diplophysa*. The occurrence of a second preethmoid is noticed in *Diplophysa* as in some species of *Nemachilus* examined.

The maxillae and premaxillae (Text-fig. 8a) show the usual processes; in *Diplophysa* (Text-fig. 9) the single facet (*prm'*) of the maxilla for the prepalatine and preethmoid is obliquely elongated.



TEXT-FIG. 9. Dorsal aspect of the skull of *Diplophysa papilloso-labiata* Kessler. (The sub-orbital sensory canal is shown on one side only).

The lateral ethmoid (Text-fig. 9, *let*) in *D. papilloso-labiata* is large; mesially it comes in contact with the orbitosphenoid (*os*) and there is also an anterior projection (*ple*) of the lateral ethmoid in this region. There is a short process (*lj*) towards the lacrimojugal (*lj*). In *Nemachilichthys* (Text-figs. 8a, 8b) this process



(*llj*) is very long. In these two genera, the sensory canal bones are separate from the lacrimojugal.

In the orbitotemporal region, a supraorbital is absent in *Nemachilichthys* and *Diplophysa*.

Between the large frontals and the small parietals, there is the large frontoparietal fontanel (Text-figs. 8a, 9, *fpf*) in both *Nemachilichthys* and *Diplophysa*. In *D. papilloso-labiata* there is also an anterior fontanel (Text-fig. 9, *af*) between the two frontals just posterior to the supraethmoid articulation.

On the ventral aspect, the broader posterior portion of the parasphenoid gives rise to the lateral limbs to delimit the openings for the trigeminofacial nerves in *Diplophysa*; such a lateral limb is absent in *Nemachilichthys* (Text-fig. 8b).

In the auditory region, the sphenotic has a blunt sphenotic process (Text-figs. 8a, 8b, 9, *spr*) and dorsally, the posterior portion of the sphenotic along with the pterotic shows a depression in *Diplophysa* and *Nemachilichthys*; this depression is the temporal opening or fossa (Text-figs. 8a, 9, *to*). In *D. papilloso-labiata* a portion of the pterotic (*pte'*) extends over the fossa below the temporal sensory ossicles forming a part of the roof for the fossa. This fossa, as already said, is for the attachment of muscles. The epiotic of *D. papilloso-labiata* also shows a deep depression towards the fossa in the pterotic. On the ventral aspect the pterotic discloses a subtemporal fossa, poorly developed in *Diplophysa* but very well formed in *Nemachilichthys*, (Text-fig. 8b, *stf*) resembling the cyprinid condition.

In the jaws of *Diplophysa* and *Nemachilichthys*, the hyomandibula shows a prominent symplectic and a preopercular process; an opercular process is, however, wanting. In the lower jaw, *Nemachilichthys* is peculiar in having a ventral sensory canal in the dentary.

## DISCUSSION.

### *Skull and the Associated Characters.*

It is well established that the family Cobitidae falls into two very sharp groups with reference to the movability or otherwise of the ethmoid region over the frontals as recorded by Regan (1911). The Cobitidinae (Cobitini plus Botini) comes under the first category while in the Nemachilinae, the ethmoprevomer is firmly united with the frontals.

A supraethmoid is just indicated in *Cobitis* while in examples like *Acanthopsis*, *Acanthophthalmus*, *Lepidocephalichthys*, *Somileptes* and *Misgurnus*, it is not at all developed; in Botini there is a slight enlargement of the median septum to indicate a supraethmoid with a gully in it resembling more *Cobitis*. Sagemehl (1891) described that in *B. M'Clellandi*, the supraethmoid part was reduced. In *Nemachilus* and *Nemachilichthys*, a supraethmoid part could be clearly made out with an anterior depression; however, in *N. barbatulus* and *microps*, this depression is absent. In the latter species of *Nemachilus*, the supraethmoid shows anteriorly slight wing-like extensions. In *D. papilloso-labiata* the supraethmoid is very broad and wing-like anteriorly and there is a prominent median process. In the other cyprinoid families, viz., Cyprinidae, Gyrinocheilidae, Psilorhynchidae and Homalopteridae the ethmoprevomer septum enlarges dorsally into a platelike supraethmoid which forms a mesial roof for the olfactory organs.

The most remarkable feature in the ethmoid region of the Cobitidae is the union of the ethmoid with prevomer to form a composite bone, a feature also recorded by Sagemehl (1891). I have called this united bone the ethmoprevomer. There are two projections from the anterior end of the prevomerine portion of the bone for articulation with a pair of preethmoids. This union of the ethmoid and the prevomer is probably an environmental adaptation for obtaining a certain amount of rigidity of the ethmoid region, for, these fish live among pebbles and shingles. Peculiarly such a union of the ethmoid and prevomer is not noticed

among the Homalopteridae and Gastromyzonidae (Ramaswami, 1948) dwelling in fast-running brooks, where obviously a certain amount of flexibility of the anterior region is necessary.

The preethmoid presents a peculiar condition. In the Cobitini like *Acanthopsis*, *Acanthophtalmus*, *Somileptes*, *Misgurnus* and *Lepidocephalichthys* there is a bone on either side of the ethmoprevomer; anteriorly, it articulates with the maxilla and posteriorly with the palatine by a large facet and with the prevomerine projection by another. In Botini and Nemachilini, there are two pairs of bones in the region occupied by the single preethmoid of the Cobitini. Of these, one is dorsal and spans between the maxilla and palatine and is called the prepalatine; the other extends between the maxilla and the prevomerine facet and this is the preethmoid. However, in a few examples like *N. barbatula*, *microps*, *botia* and *D. stewarti* and *papilloso-labiata*, the arrangement of bones in this region is different from what is noticed in Botini and other Nemachilini. In the above examples there are two preethmoids: a posterior smaller one which articulates with the lateral aspect of the ethmoprevomer (the 'septomaxilla' of Sagemehl, 1891) and the second anterior rounded rod which connects the second preethmoid and the maxilla (the 'submaxillary' of Sagemehl). Between the palatine and the maxilla, sitting on the first preethmoid is the prepalatine. I have pointed out elsewhere (Ramaswami, 1952c, 1952d) that it is very likely that the preethmoid found in the Cobitini has given rise, by a process of splitting, to the condition found in the above two genera and also to that in the Botini and other Nemachilini. However, in the Botini and Nemachilini examined (with the exceptions mentioned above) a second preethmoid is *not* developed and the prevomerine portion of the united ethmoprevomer gives articulation to the elongated preethmoid. It is interesting to note that in the Homalopteridae (Ramaswami, 1952c) and Gastromyzonidae (Ramaswami, 1952d), a second preethmoid is always developed.

The premaxillae of the Botini are different from those of the rest of the Cobitidae. The rostral process of the premaxilla arises not from the anterior end of the bone but from the middle, so much so there is an archlike process of the bone in front for supporting the tuft of barbels.

In the orbitotemporal region, the lateral ethmoid again shows difference in structure. While the bone is well developed in the Cobitini and Botini, it is generally small and always without a suborbital spine in Nemachilini; in the larger species like *N. microps* and *D. papilloso-labiata* the bone is quite large. However, the Cobitid *Misgurnus* also lacks a spine. The lateral ethmoid articulates with the orbitosphenoid ventrally and also with the frontal in the Cobitidae. While the lateral ethmoid gives rise anterolaterally to a small or large lacrimojugal process with which the lacrimojugal comes in contact, in *N. botia*, a lacrimojugal process of the lateral ethmoid is absent and the broad lacrimojugal comes in intimate contact with the lateral ethmoid by its posterior edge. Generally, in front of the lacrimojugal there is a sensory canal ossicle,—the rostral. In *N. barbatulus*, the lacrimojugal and rostral have united into a single ossification.

The Cobitini show a broad or a thin archlike supraorbital; the bone is absent in Botini and Nemachilini. Chranilov (1927, 1927a) also did not delineate a supraorbital in *N. barbatulus* described by him; however, a tiny supraorbital (orbitale) is drawn by him in *Lefua costata* (1927a, fig. 4, below). A supraorbital is also absent in the majority of Gastromyzonidae (Ramaswami, 1952d) while it is prominently present in the Homalopteridae (Ramaswami, 1952c).

In the Cobitidae the orbitosphenoids have united together into a single bone, a unique feature noticed nowhere else among the Cyprinoids. Moreover, it projects anteriorly on either side of the ethmoprevomer and peculiarly in Botini, the lateral ethmoid gains articulation with a special facet of the orbitosphenoid. The occurrence of a united orbitosphenoid appears to be as distinguishing a character of the Cobitidae as that of the united ethmoprevomer.

In some examples of Cobitini (*Acanthopsis*, *Acanthophthalmus*), the frontal and parasphenoid extend in front of the pleurosphenoid and keep the latter out of the orbit. In the other Cobitini (*Lepidocephalichthys* etc.) the pleurosphenoid is noticed in the posterior wall of the orbital region differing thereby from the above Cobitini.

In the auditory region, the Cobitini show peculiarities. In *Acanthopsis*, *Acanthophthalmus* and *Lepidocephalichthys* an epiotic is wanting and in the former two examples, the subtemporal fossa is also absent. In the other Cobitini, an epiotic is developed and the subtemporal fossa may be poorly developed (except *Somileptes*) as in Botini and a number of Nemachilini; however, the subtemporal fossa is well developed in the nemachiline *Nemachilichthys*. In this feature it resembles the Gyrinocheilidae (Ramaswami, 1952) and Homalopteridae (Ramaswami, 1952c). While in the Homalopteridae the subtemporal fossa is well developed, in the majority of the Gastromyzonidae (Ramaswami, 1952d) it is a shallow depression. In the Cobitini and Botini the pharyngeal processes do not unite below the aorta; in Nemachilini, there is union.

In the Cobitini, the members show such extraordinary variation in their skull structure that the group appears to be polyphyletic. Among the genera examined by me, *Acanthopsis*, *Acanthophthalmus* and *Lepidocephalichthys* show a conical skull with the posterior portion somewhat cylindrical and the skull lacks epiotics and the subtemporal fossae. In *Cobitis*, *Somileptes*, and *Misgurnus* the skull is depressed and the epiotics and subtemporal fossae are present. It may not be possible to explain these differences in skull structure in the Cobitini unless it is assumed that the group is polyphyletic; of the examined genera, *Acanthopsis*, *Acanthophthalmus* and *Lepidocephalichthys* have to be treated separately from *Cobitis*, *Somileptes* and *Misgurnus*.

Sagemehl (1891) referred to a 'temporalhöhle' in the dorsal pterotic region of Botini and some Nemachilini. He recorded (p. 552) that the temporal opening referred to above was absent in the genera *Nemachilus*, *Misgurnus*, *Cobitis* and *Acanthophthalmus*. Chranilov (1927, 1927a) also did not show the 'temporalhöhle' in his figure of *N. barbatus* and the same figure has been copied by Berg (1940, p. 267, fig. 155). In my preparation of the several species of *Nemachilus* and *Cobitis taenia*, the temporal opening is, however, clearly seen. This is a depression in the pterotic roof mostly for the attachment of certain muscles and is roofed by the mesial limb of the supratemporal ossicle and the posttemporal. In *Acanthopsis*, *Acanthophthalmus*, *Somileptes*, *Misgurnus* and *Lepidocephalichthys*, this depression is wanting.

*Misgurnus* differs from the other Cobitini in two important features. Firstly it lacks a suborbital spine so characteristically seen in other Cobitini. In the upper jaw of *Misgurnus* the metapterygoid is large showing a large foramen in it as delineated in Fig. 158 (p. 270) by Berg (1940) which is a reproduction from Chranilov (1927, 1927a). But in his description, Berg stated that the foramen was between the quadrate and the metapterygoid. In the other Cobitini like *Lepidocephalichthys* and *Acanthopsis*, the metapterygoid is deeply indented towards the quadrate and the latter bone also shows an indentation and this large gap between the bones is probably the foramen referred to by Berg (1940) between metapterygoid and quadrate.

In the Cobitini the supraorbital, suborbital and temporal sensory canal ossicles are all independent and disunited with the bones on which they rest and they can be easily taken off from the skull; a mandibular sensory canal is also seen. The first ossicle of the supraorbital series is the nasal situated on the mesial aspect of the nares. In Botini, in the orbital region of the frontal bones, the supraorbital canal passes within the bone and the occipital canal also passes similarly. In the Nemachilini, the supraorbital and suborbital canal ossicles are independent of the skull bones. However, in *Nemachilichthys* the supraorbital sensory canal passes

through the frontals and the temporal ossicle is fused with the pterotic; the occipital canal is also intraosseous.

The bones of the lower jaw of Cobitidae, apart from showing difference in shape, also differ in disposition. In the Cobitini the angular and dentary are loosely articulated and the mesial sesamoid angular is absent. In the Botini and Nemachilini, the angular and dentary are firmly articulated and there is a mesial sesamoid angular. Generally a set of sensory canal bones run by the side of the lower jaw bones.

*Gasbladder capsule and the weberian ossicles.*

Chranilov (1927) described the gasbladder capsule and the weberian ossicles in a number of genera belonging to the three subfamilies. According to him, the structural arrangement of parts falls into two types. In the first the gasbladder capsule may show an upper smaller and a lower larger-portion as in *Misgurnus*, *Cobitis*, *Lepidocephalichthys* etc., where the capsule is built by the dorsal ribs [= transverse processes, parapophyses (Chranilov, 1927); parapophyses (Berg, 1940)] and ossa suspensoria (pleural ribs) of the fourth vertebra. In the second type, the gasbladder capsule is divided into right and left parts as in *Nemachilichthys*, *Nemachilus* and *Diplophysa* where the capsule is built by the ribs (dorsal and pleural) of the second and fourth vertebrae. Chranilov (1927) also pointed out that the structure of the capsule in a form like *Leptobotia* gave a clue as to how the second type could have evolved from the first.

I have been able to confirm the observations of Chranilov (1927) in the case of *Cobitis*, *Misgurnus* and *Lepidocephalichthys*; the same arrangement is also noticed in the other Cobitini examined by me like *Acanthopsis*, *Acanthophthalmus* and *Somileptes*.

Having examined three species of *Botia*, I am also able to confirm the observations of Chranilov (1927) with regard to Botini. In *Leptobotia* (Chranilov, 1927), the posterior portion of the gasbladder capsule is membranous while in *Botia*, the capsule is a pearshaped bony chamber.

I shall now describe the structure of the gasbladder capsule and the weberian ossicles which show differences in the three subfamilies of the Cobitidae. In the Cobitini, the dorsal ribs of the second vertebra are large and free; the pleural ribs may bound anteriorly the large lateral opening (= 'introitus' or apertura magna externa). The dorsal ribs of the fourth vertebra form the roof of the lateral opening and partly extend on the sides as spines, the gasbladder capsule being formed by the ossa suspensoria (pleural ribs). In the Botini, while the second pair of dorsal ribs are free, the pleural ribs take part in bounding the capsule wall anteriorly; the dorsal ribs of the fourth vertebra project over the large lateral fenestra and also extend laterally to end as spines as in Cobitini. The ossa suspensoria form the walls of the capsule. In *Leptobotia* the capsule is membranous posteriorly but in *Botia*, it is completely osseous and no opening is noticed posteriorly as in *Somileptes* or *Lepidocephalichthys* for connecting the posterior portion of the gasbladder. In both Cobitini and Botini, the capsular gasbladder is single. In the Nemachilini, it is divided into right and left halves and connected together by a posterior commissure. Chranilov's figure (1927, Fig. 11) of the gasbladder capsule of *Diplophysa strauchii* also copied by Berg (1940, Fig. 156) and labelled as that of *Nemachilus strauchii* gives an impression that the anteroventral portion of the gasbladder capsule is formed by the pleural ribs of the second vertebra while the more mesial portion of the same region is formed by the projections of the second pair of dorsal ribs; the remaining portion of the covering is formed by the dorsal ribs of the fourth vertebra and near the united centra of the second and third vertebrae, by the pleural ribs of the fourth vertebra (ossa suspensoria). But my examination of the gasbladder capsule of *Diplophysa stewarti*, *D. pailloso-labiata*, *Nemachilus dayi*, *N. botia*, *N. rupicola*, *N. microps* and *Nemachilichthys* has disclosed that dorsally the osseous

covering of the gasbladder capsule is composed of two parts separated by a suture; the anterior part appears to be formed by the second pair of dorsal ribs while the larger posterior is formed by the dorsal ribs of the fourth vertebra. Similarly, on the ventral aspect, the anterior part is formed by the second pair of pleural ribs and the posterior part by the dorsal ribs of the fourth vertebra and the mesial wall of the capsule near the centra being formed by the pleural ribs or ossa suspensoria, though the demarcations are not visible.

The first centrum is free in the Cobitidae and is generally opisthocoelous. It carries a small or large pair of dorsal ribs. Peculiarly, the dorsal ribs of the first vertebra unite at their tips with the gasbladder capsule in some Gastromyzonidae (Ramaswami, 1952*d*).

The centra of the second and third vertebrae are fused in the Cobitidae. While it may be possible to distinguish the outlines of articulations of the centra in some (*Leptobotia*), in others it is not possible (*Botia* etc.). The centrum of the second vertebra carries a pair each of dorsal and pleural ribs. The dorsal ribs are free in Cobitini and Botini while in Nemachilini, they form the anterodorsal wall of the osseous capsule. The pleural ribs may form the anterior boundary of the lateral opening (Cobitini) or they may help to form the capsule wall (Botini and Nemachilini).

The third centrum does not bear any ribs or parapophyses.

The fourth centrum is independent and is amphicoelous. The dorsal, and pleural ribs (ossa suspensoria) of this vertebra take part in the formation of the remaining portion of the osseous capsule wall.

That the so-called 'transverse processes' alluded to by workers on the Ostariophysian gasbladder capsule are not really those, is undoubted. A true transverse process is a diapophysis from the neural arch while the so-called 'transverse process' of the fishes is a basiventral projection plus the dorsal rib of the segment (Watson, 1939). The transverse process as described by Chranilov (1927), probably represents an united parapophysis and the dorsal rib. Mookerjee and Mookerji (unpublished thesis, 1950)\* confirmed the observation of Watson in stating that the so-called transverse process in the carp-minnow (*Esomus*) which they studied, was the united basiventral and the dorsal rib. The other structure which has been labelled 'rib' by Chranilov (1927) and Berg (1940) represents the pleural rib. In the fourth vertebra, the pleural ribs are modified into the ossa suspensoria and Watson (1939), however, considered these as haemapophyses. Nelson (1948) described in the Catostomidae and also in the Cyprinidae, the large ventrolateral projection from the fourth centrum as pleural rib while all previous workers like Chranilov (1927), Sarbahi (1933) and Berg (1940) do not consider it so and both Chranilov and Berg regard the ossa suspensoria as pleural derivatives.

The weberian ossicles of Cobitidae has been described by Chranilov (1927). While the structure of the first three ossicles (claustrum, scaphium and intercalarium) are almost the same in the three subfamilies, that of tripus differs. In the Cobitini and Botini, the tripus is broadly triangular with the anterior and articular processes differing in size. In the Nemachilini, the tripus is Y-shaped with one of the anterior limbs short and this represents the processus anterior; the other limb comes in contact with the centrum as processus articularis. The posterior limb is very short and comes in contact with the gasbladder and there is no transformator process.

I am unable to comment upon the derivation of the ossicles, as I have not been able to study their developmental history.

*Adiposia* was made the type of a suborder Adiposidae by Jordon since the fish showed an adipose dorsal but was subsequently merged in the genus *Nemachilus*. Berg (1940) also treated the genus *Adiposia* as congeneric with *Nema-*

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*chilus* (Hasslt.). A study of the skeletal characters of *Adiposia* has shown that it resembles *Nemachilus* very closely and therefore, it is rightly merged in *Nemachilus*.

Similarly, *Cobitis barbatulus* in its cranial organisation resembles *Nemachilus* and therefore, cannot be treated as a member of Cobitini and is correctly described by systematists as *N. barbatulus*.

With regard to the species of *Diplophysa* and *Nemachilus* that I have studied, *Diplophysa* shows an arrangement of bones in the skull similar to *Nemachilus*. I have noticed only two differences in the ethmoid region of the examined species of *Diplophysa* and *Nemachilus*. In the latter genus, only two species (*microps*, *botia*) show the occurrence of a second preethmoid and only one species (*microps*) shows the broadening of the anterior supraethmoid region. Berg (1940) treated *D. struachi* as a synonym of *N. struachi* (Kessl.) and it is very likely that other species of *Diplophysa* may also be merged under those of *Nemachilus*. In fact Berg (1940, p. 270) treated the entire genus *Diplophysa* as a synonym of *Nemachilus* as was previously done by Hora (1930). As far as I could judge from a study of the skull and gasbladder capsule of the examined species of *Diplophysa* and *Nemachilus*, I find that the two genera resemble each other in all important characters.

In assessing the relationship of the Cobitidae with the Homalopteridae and Gastromyzonidae, it is noticed that the former differs from the latter two in the possession of (1) a united ethmoprevomer, (2) a united orbitosphenoid, and (3) the pharyngeal processes united or disunited below the aorta. But all the Homalopteridae and Gastromyzonidae resemble the Nemachilini cobitids in the structure of their gasbladder capsule and the weberian ossicles. Moreover the gastromyzonids resemble the nemachilini cobitids generally in the poorly developed supraethmoid portion and the subtemporal fossae, in the ento-meta-pterygoid ridge and in the linear elongation of the operculum. The Bornean Gastromyzonid *Glanioptis* also shows the sensory canal ossicles disunited from the bones on which they are located. Peculiarly, a few species of *Nemachilus* and of *Diplophysa*, in addition to the resemblances enumerated above, also show the occurrence of the second preethmoid commonly met with in the Gastromyzonidae. Therefore, it is clear that the Gastromyzonidae resemble more the nemachiline subdivision of the Cobitidae but the differences, few as they may be, are so poignant that the Gastromyzonidae cannot be derived directly from Cobitid ancestors. The Gastromyzonidae (Ramaswami, 1952*d*) has already been shown to be diphyletic in origin, the Bornean genera evolving independently of the mainland or Chinese forms. The Bornean *Glanioptis* (Gastromyzonidae) in showing a number of internal and external nemachiline features (Hora and Jayaram, 1951; Ramaswami, 1952*d*) has probably taken its origin from the same ancestral stock as that of the Cobitidae, and both *Glanioptis* and the Nemachilini genera have evolved parallelly. As the mainland fauna had no geographical continuity with the Bornean, the Chinese genera of the Gastromyzonidae must have evolved from a different ancestor, probably from a Crossostomid one. This ancestor also probably took its origin from the same stock. As already indicated by me (Ramaswami, 1952*d*), it is not possible to derive the Gastromyzonidae from a Cyprinid ancestor and therefore, the Gastromyzonidae must have taken their origin from a stock common to the Cyprinidae and the Cobitidae, and must have evolved parallelly with the Nemachilini (Cobitidae) as did the Homalopteridae with the Cyprinidae.

#### SUMMARY.

1. The skull and the gasbladder capsule of eleven genera belonging to the three subfamilies of Cobitidae have been studied and described.
2. The Cobitid genera show in their skull uniformly a united ethmoprevomer and a united orbitosphenoid.
3. The ethmoid region of Cobitini differs from that of Botini and Nemachilini. In the Cobitini, on either side of the ethmoprevomer, a preethmoid articulates anteriorly with the

maxilla and posteriorly with the ethmoprevomer and palatine independently; in Botini and Nemachilini there are in this region two bones. The dorsal one is the prepalatine, while the other is the preethmoid. It is argued that the single preethmoid of Cobitini has given rise, by a process of splitting, to the two bones seen in Botini and Nemachilini.

4. The lateral ethmoid is built on a common plan in Cobitini and Botini. In the two subfamilies, a number of spinelike processes are noticed and one of them is the suborbital spine which is of great systematic importance. *Misgurnus* is peculiar in lacking a suborbital spine. In Nemachilini, the bone is smaller and is devoid of a spinelike process.

5. The lacrimojugal may be well or poorly developed. In *Nemachilus botia*, the bone is very broad and articulates with the lateral ethmoid. In *N. barbatus*, the lacrimojugal is united with the anterior rostral to form a lacrimojugal-rostral.

6. The premaxillae of Botini differ from those of the other two subfamilies. In *Botia* the rostral processes arise from the middle of the premaxilla instead of the anterior tip.

7. The supraorbital bone is present generally in Cobitini (however it is not shown by Chranilov (1927a) in his fig. 6 above); it may be broad as in *Cobitis* or like a bow as in *Acanthopsis*, *Acanthophthalmus*, etc.

8. The supraorbital, suborbital and temporal sensory canal ossicles are disunited with the underlying bones in Cobitini and Nemachilini; however, in *Nemachilichthys*, the supraorbital, temporal and occipital canals run within the bones in those regions. In Botini also the supraorbital and occipital canals run within bones and there is a single elongated temporal ossicle in front of the supratemporal.

9. The Cobitini appear to be polyphyletic. *Acanthopsis*, *Acanthophthalmus* and *Lepidocephalichthys* do not show in the auditory region the epiotics and subtemporal fossae; in *Cobitis*, *Somaleptes* and *Misgurnus*, they are developed.

10. In the structure of the jaws, the Cobitini show peculiarities. There is a large gap between the metapterygoid and quadrate and the entopterygoid is rodlike. A sesamoid angular is absent in the lower jaw of Cobitini; it is well developed in Botini and Nemachilini.

11. The pharyngeal processes are disunited in Cobitini and Botini while in Nemachilini, they unite below the aorta.

12. The gasbladder capsule is single in the Cobitini and Botini. In the Cobitini, there is a posterior opening in the capsule; this is absent in *Botia*. In the Nemachilini, the gasbladder capsule is divided into right and left portions connected by a commissure. In the Cobitini and Botini, the capsule is formed by the fourth pair of dorsal ribs and ossa suspensoria (= pleural ribs of the fourth vertebra). In Nemachilini the capsule is formed by the dorsal and pleural ribs of the second and fourth vertebrae. The tripus is broadly triangular in the Cobitini and Botini while in Nemachilini, it is triradiate.

13. *Adiposia* and *Diplophysa* are closely allied to *Nemachilus* and craniology supports the merging of the two in *Nemachilus*.

14. The study of Cobitid skeleton amply supports the division of the family into three subfamilies, viz., Cobitini, Botini and Nemachilini.

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## KEY TO LETTERING.

*af* = anterior fontanel; *ame* = apertura magna externa; *an* = angular; *ap* = articular process; *apm* = anterior process of maxilla; *aq* = articular facet of lower jaw for quadrater *aql* = articular facet of quadrater for lower jaw; *aup* = auricular process; *ao* = groove for passage of aorta; *bo* = basioccipital; *cl* = claustrum; *con* = condyle; *cl,ca* = centra of first and fourth vertebrae; *den* = dentary; *dp* = dorsal process of dentary; *dpm* = dorsal process of maxilla; *dr1*, *dr2*, *dr4* = dorsal ribs of first, second and fourth vertebrae; *ecp* = ectopterygoid; *ef* = exoccipital fenestra; *enp* = entopterygoid; *eo* = exoccipital; *epi* = epiotic; *epv* = ethmoid process of palatine; *fm* = foramen magnum; *fo* = foramen opticus; *fpf* = frontoparietal fontanel; *fr* = frontal; *fr'* = lateral process of frontal; *gbc* = gasbladder capsule; *hy* = hyomandibula; *int* = intercalarium; *iol* = interopercular; *jf* = jugular foramen; *les* = lateral extrascapular; *let* = lateral ethmoid; *lj* = lacrimojugal; *ljr* = lacrimojugal-rostral; *lj* = lateral ethmoid process towards lacrimojugal; *llm* = lateral limb of maxilla; *lp* = lateral limb of premaxilla; *lsc* = lateral semicircular canal enlargement; *mp* = metapterygoid; *mr* = median rostral; *n* = nasal; *na2*, *na3*, *na4* = neural arch of second, third and fourth vertebrae; *ns2*, *ns3*, *ns4* = neural spine of second, third and fourth vertebrae; *ns23* = united second and third neural spines; *ob* = outline of sesamoid bone; *oec* = outline of ectopterygoid; *oep* = outline of ethmoprevomer; *oio* = outline of interopercular; *ole* = outline of lateral ethmoid; *olj* = outline of lacrimojugal; *on* = outline of nasal; *op* = opercular; *opa* = outline of palatine; *opm* = outline of posterior process of metapterygoid; *opo* = outline of preopercular; *opp* = outline of prepalatine; *oro* = outline of rostral; *os* = orbitosphenoid; *osn* = orifice for spinal nerve; *oso* = outline of subopercular; *oss* = ossa suspensoria; *p* = ethmoprevomerine process; *pa* = parietal; *pal* = palatine; *pas* = parasphenoid; *pen* = articular facet of entopterygoid for palatine; *pfm* = preethmoid facet for maxilla; *pfp* = preethmoid facet for palatine; *pfv* = preethmoid facet for ethmoprevomer; *ph* = hyomandibular facet for pterotic articulation; *pho* = hyomandibular projection towards the operculum; *php* = pharyngeal process; *phy* = pterotic facet for hyomandibula; *ple* = lateral ethmoid projection towards palatine; *plm* = process of maxilla for adductor ligament; *plp* = process of pleurosphenoid towards sphenotic process; *pls* = pleurosphenoid; *pl2* = pleural rib of second vertebra; *pmp* = posterior process of metapterygoid; *pmx* = premaxilla; *pmv* = posterior myodome; *po* = posterior opening in gasbladder; *pop* = preopercular; *ppa* = prepalatine; *pph* = hyomandibular facet towards preopercular; *ppm* = maxillary facet for prepalatine; *ppq* = posterior process of quadrater; *ppv* = posterior process of prevomerine portion of ethmoprevomer; *pr* = lateral process of median rostral; *pre* = preethmoid; *prm* = facet of maxilla for preethmoid and prepalatine; *pro* = prootic; *pr2* = process



from the second dorsal rib; *pr2'* = second preethmoid; *pr4* = process from the fourth dorsal rib; *pt* = posttemporal; *pte* = pterotic; *pte'* = pterotic roof over temporal opening; *pv* = prevomerine portion of ethmoprevomer; *q* = quadrate; *ra* = retroarticular; *ros* = rostral; *rpm* = rostral process of maxilla; *rpp* = rostral process of premaxilla; *ri* = ridge on the metapterygoid; *ri'* = ridge on the orbitosphenoid; *san* = sesamoid angular; *sb* = sesamoid bone; *sc* = sensory canal ossicle; *sca* = scaphium; *scd* = sensory canal in dentary; *sc1*, *sc3*, *sc9* = first, third and ninth suborbital sensory canal ossicle; *sc10* = tenth sensory canal ossicle; *se* = supraethmoid; *sh* = sphenotic facet of hyomandibula; *shy* = facet in sphenotic for hyomandibula; *so* = supraoccipital; *soc* = supraoccipital sensory canal ossicles; *soo* = suborbital ossicles; *sop* = subopercular; *sor* = supraorbital; *sp* = sphenotic; *sph* = symplectic process of hyomandibula; *spo* = sensory canal in preopercular; *spr* = sphenotic process; *ssp* = subocular spine of lateral ethmoid; *ste* = supratemporal; *stf* = subtemporal fossa; *suo* = supraorbital sensory canal; *sym* = symplectic; *tc* = temporal canal; *tfo* = trigeminofacial opening; *to* = temporal sensory ossicle; *top* = temporal opening; *tri* = tripus; *tro* = triradiate temporal ossicle; *vdr4* = ventral portion of the roof of gasbladder capsule formed by the fourth pair of dorsal ribs.

## ADDENDUM.

## SYSTEMATICS OF THE FISHES OF THE FAMILY COBITIDAE.

As a result of the investigations reported above, the following observations may be recorded as regards the Systematics of the Cobitidae:

- (1) The Cobitidae, in spite of divergences necessitating grouping in three divisions, is a monophyletic family.
- (2) The Section Cobitini forms a composite group in which *Acanthopsis*, *Acanthophthalmus* and *Lepidocephalichthys* differ from *Cobitis*, *Somileptes* and *Misgurnus* in lacking epiotics and subtemporal fossae.
- (3) The genus *Adiposia* Annandale and Hora is craniologically a *Nemachilus* though in the development of an adipose dorsal it shows a physiological adaptation to the conditions under which it lives.
- (4) The genus *Diplophysa* Kessler is, like *Adiposia*, craniologically a *Nemachilus* though in the development of a second free air-bladder it shows an adaptation to the conditions of life in deeper waters.
- (5) As the presence or absence of a dorsal fin is a generic character among the Siluroids and other groups of fishes, *Adiposia* should not be suppressed but retained as a distinct genus under *Nemachilini*. There is, however, no justification to raise it to the rank of a family as was done by Jordon.
- (6) *Diplophysa* should also be regarded as a separate genus on the character of a second air-bladder free in the abdominal cavity besides the original bladder enclosed in bone.

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