

OBSERVATIONS ON THE OSSIFICATION CENTRES OF *TRICHOPODUS TRICHOPTERUS* (PALL.)

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INTRODUCTION

THE study of the ossification centres in fish skulls has been practically neglected in India. Hence, the present investigation was undertaken to examine the centres of ossification in the skull of *Trichopodus trichopterus* (Pall.), a freshwater fish, belonging to the family Anabantidæ. The development of the chondrocranium of the same fish has been worked out by the authors (1957).

MATERIAL AND METHODS

The fish was bred in the laboratory and the successive stages of fish-fry were fixed in acetic alcohol, and 3-5% formalin. The serial sections of different stages were cut at 10 micra and stained with Delafield's hæmatoxylin. The stages in which the bones had appeared were decalcified before sectioning. Alizarine transparencies of the various stages were made for noting the ossification centres.

OBSERVATIONS

Stage 1 (Total length 2.5 mm.).—The nasal sacs and a distinct ventral mouth have appeared. Some of the chondrocranial cartilages are laid down in this stage but there is no trace of any centre of ossification.

Stage 2 (Total length 4.0 mm.) (Fig. 1, a-d).—The ethmoid region does not show any ossification in this stage. In the orbito-sphenoidal region an elongated parasphenoid is noticed. In a lateral view the parasphenoid (*pasp*) shows a characteristic dorsal flexure and extends ventrally to the trabecula communis. In the auditory region the ossification centres of the pro-otic and sphenotic are seen. The pro-otic (*pro*) is large and the sphenotic (*sph*) very small. These are perichondral ossifications. In the occipital region, the basioccipital (*boc*) and exoccipitals (*exo*) are developed as perichondral ossifications.

The premaxilla (*pmx*) and the maxilla (*mx*) have appeared as thin, elongated dermal ossifications. The maxilla is slightly longer than the pre-

maxilla. The palatine and the different pterygoid ossifications have not yet appeared. The quadrate (*qu*) appears as a small ossification centre which is in the form of a triangular bony piece with a posteriorly directed process, reaching the anterior end of the symplectic. In the lower jaw the dentary (*den*) develops as a dermal ossification and anteriorly bears a few dermal denticles. A slender perichondral ossification centre is noticed behind the dentary and it is the articular (*ar*). Behind this is seen a very small centre of ossification of the retroarticular (*rar*).

In the hyoid arch the following centres of ossification are noticed—hyomandibular, symplectic, epi- and cerato-hyals and basihyal. The hyomandibular (*hym*) is being ossified and it shows the characteristic foramen (*fh*) for the exit of the hyomandibular branch of the facial. Its anterior and

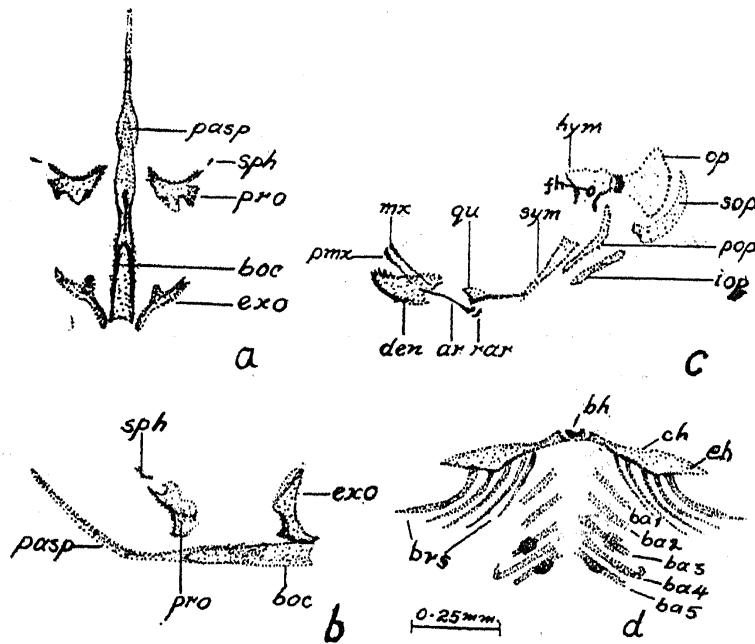


FIG. 1. (a) Dorsal aspect of the cranium of *Trichopodus trichopterus* (Pall.), 4 mm. long, showing ossification centres. The visceral arches are not shown.

(b) Lateral aspect of the same.

(c) Lateral, outer view of the jaws, hyopalate and opercular regions of *T. trichopterus*, showing ossification centres.

(d) Ventral view of the hyobranchial skeleton of *T. trichopterus*. The hyomandibular and symplectic are not shown.

posterior margins are better ossified. The symplectic (*sym*) appears as a conical perichondral ossification in the lower part of the hyosymplectic cartilage. The epi- and cerato-hyals (*eh* and *ch*) are uniformly ossified, and are not yet separated from each other. They together bear five characteristic

branchiostegal rays which are purely dermal structures. A small perichondral ossification gives rise to the basihyal (*bh*) situated between the two ceratohyals.

There appear four centres of dermal ossification in the opercular region. The preopercular (*pop*) seen behind the symplectic is an elongated centre of ossification. The opercular (*op*) is large and is already attached to the hyomandibular. The subopercular (*sop*) and interopercular (*iop*) are small.

No centre of ossification is seen in the region of the basibranchials. The ossification centres of the first four ceratobranchials (*cb* 1-4) and of the pharyngeum inferius (*cb* 5) along with its dentigerous pad have appeared.

Stage 3 (Total length 6.0 mm.).—As seen from the transverse sections the centres of ossification are better developed in this stage. In the sphenoidal region the frontals and the parietals have appeared. In the auditory region the epiotic and the pterotic make their appearance as perichondral ossifications. The pro-otic is better ossified in this stage, and the cartilage of the lateral and the anterior basicapsular commissures is ossified, forming a part of the pro-otic bone. The pro-otic exhibits a foramen for the passage of the VII cranial nerve. The sphenotic has slightly increased in size. The synotic tectum is being ossified perichondrally. In front of it is seen a dermal ossification, covering the brain. These two centres of ossification go to form the supraoccipital bone.

The premaxilla develops the small median ascending process, extending over the ethmoid cartilage. Palatine has made its appearance. It is the autopalatine and the ossification starts on the ventral side of the cartilaginous pterygoid process. The ectopterygoid also appears as a single centre of ossification. The ceratohyal is better ossified and the hypohyal is making its appearance in front of it. The basihyal is noticed as a ring-like perichondral ossification around the basihyal cartilage. The parahyoid appears as a small dermal ossification below the common copula but is not connected to it.

Stage 4 (Total length 7.0 mm.) (Fig. 2, a-c).—In the ethmoid region the lateral ethmoids (*let*) appear as small perichondral ossifications in the laminae orbitonasales. The vomer (*vo*) appears as a small centre of ossification at the tip of the parasphenoid. The nasals are just appearing. In the sphenoidal region the frontals (*fr*) have increased in size and are posteriorly joined to the sphenotics (*sph*). The parietals (*p*) are better ossified along their anterior margin. The parasphenoid (*passp*) has developed the lateral processes, which do not reach the pro-otics in this stage. In the auditory region all the four

otic bones of the adult fish are seen and the pro-otic (*pro*) is the largest. In the occipital region the basioccipital (*boc*) is better developed and is anteriorly produced into two processes. The supraoccipital (*so*) still exhibits its two centres of ossification, the anterior one situated in front of the parietals and the posterior near the epiotics.

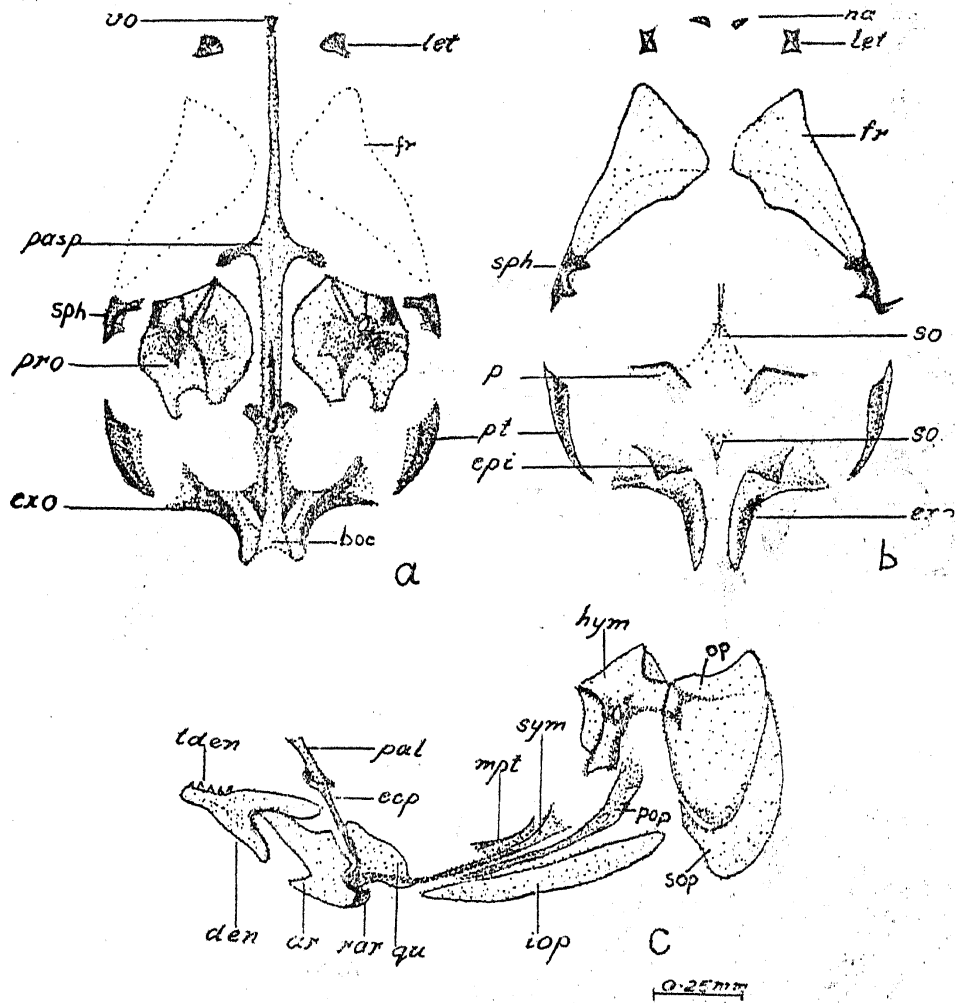


FIG. 2. (a) Ventral view of the cranium of *T. trichopterus*, 7 mm. long, showing ossification centres.

The visceral arches are not shown.

(b) Dorsal view of the same.

(c) Lateral view of the jaw, hyopalate and opercular regions of the same, showing ossification centres.

The metapterygoid (*mpt*) appears as an elongated centre of ossification situated close to the symplectic. The stylohyal appears as a small perichondral ossification and is ventrally united with the epihyal. The epihyal and the ceratohyal are differentiated. The basihyal has developed into an elongated cylindrical piece. The preopercular (*pop*) has increased in size

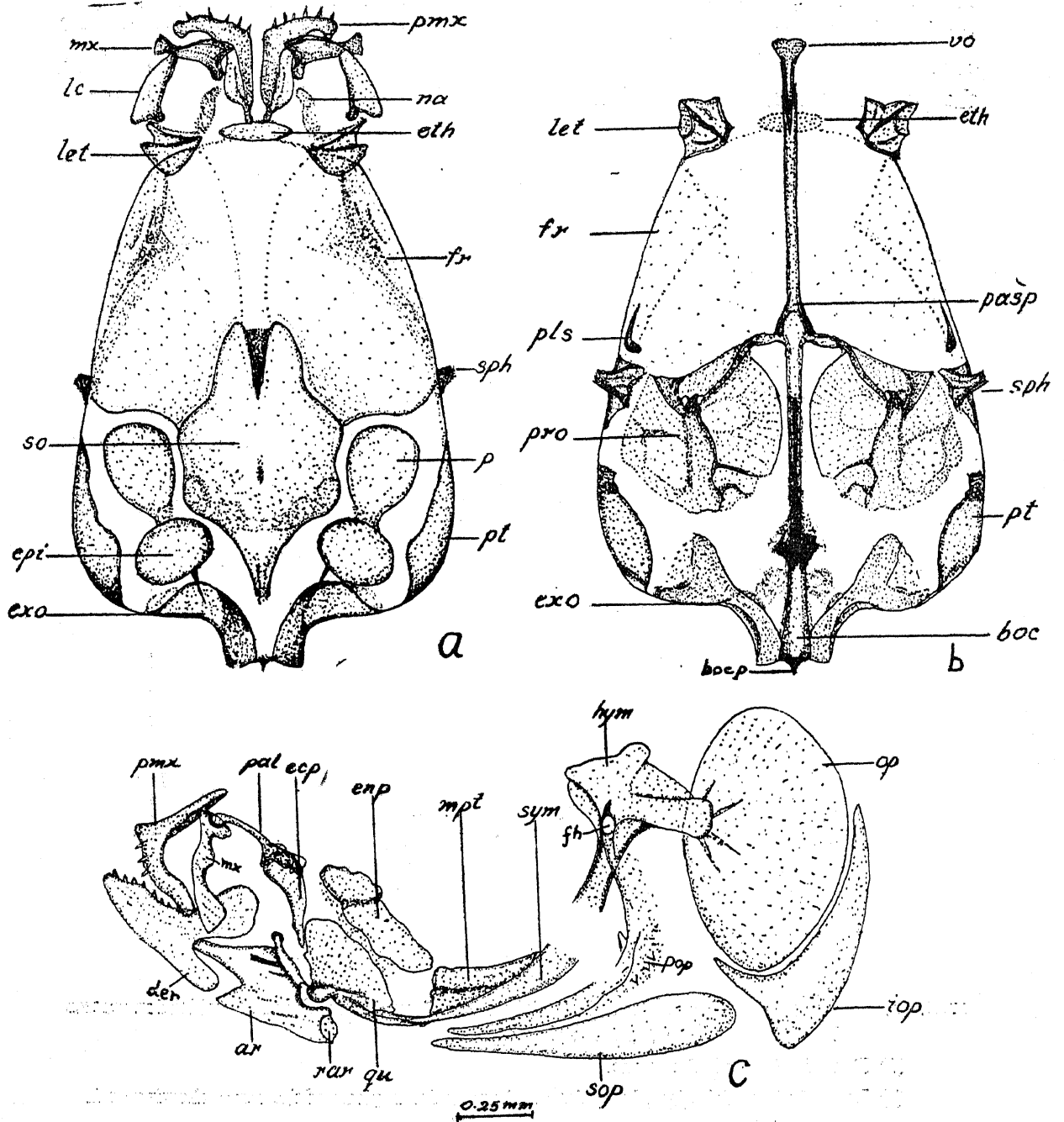


FIG. 3. (a) Dorsal view of the cranium of *T. trichopterus*, 10 mm. long, showing the ossification centres. The visceral arches are not shown.

(b) Ventral view of the same.

(c) Lateral view of the jaws, hyopalate and opercular regions of the same, showing the ossification centres.

and bears a few denticles. Three centres of ossification are seen in the basi-branchial region. The anterior centre is in contact with the basihyal. The middle gives attachment to the first pair of branchial arches and the posterior to the second and third. The first three pairs of hypobranchials are being ossified. The three pharyngobranchials have appeared.

Stage 5 (Total length 10.0 mm.) (Figs. 3, a-c and 4).—In addition to the centres of ossification already described, the ethmoid region shows the median ethmoid (*eth*) for the first time. It appears as an ovoid centre of perichondral ossification, situated dorsally between the two lateral ethmoids. The dermal centre of ossification of the nasal (*na*) is better represented. The lachrymal (*lc*) or the first orbital is well developed. The remaining orbital bones are appearing. The frontals and the parietals have increased in size. The pleurosphenoid (*pls*) appears as a small centre of ossification situated in front of the sphenotic. The parasphenoid is very well represented, exhibiting the characteristic features of the adult skull. Its lateral processes meet the pro-otics. The epiotic (*epi*) exhibits its characteristic posterior lamella. The occipital bones are well represented. The basioccipital (*boc*) has developed posteriorly a small blunt process, as seen in the adult skull. The centres of ossification of the supratemporal and the post-temporal have appeared.

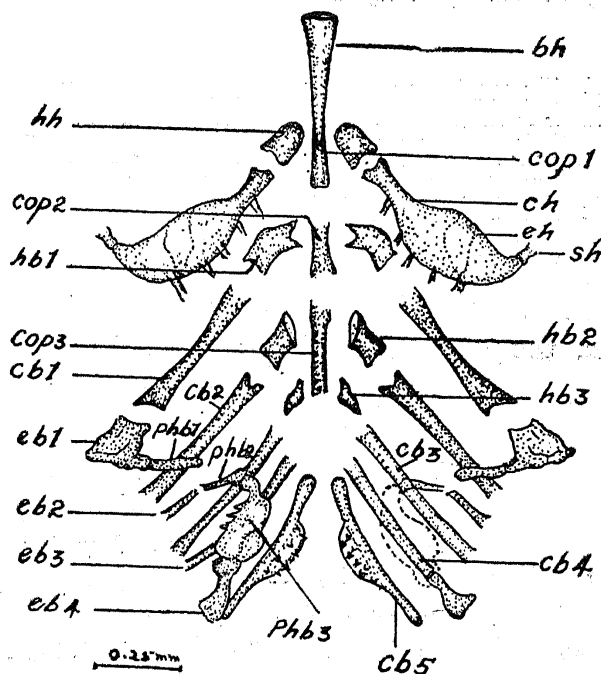


FIG. 4. Dorsal aspect of the hyobranchial skeleton of *T. trichopterus*, 10 mm. long, showing the ossification centres. The hyomandibular and the symplectic are not shown.

The entopterygoid (*enp*) appears for the first time and is situated dorsal to the quadrate. The anterior part of the symplectic (*sym*) is wedged into the quadrate (*qu*). In the branchial skeleton, the four epibranchials (*eb* 1-4) are added in this stage. The remaining branchial elements increase in size. The first epibranchial is large and is taking up the characteristic shape found in the adult skull.

SUMMARY

The ossification centres in the skull of *T. trichopterus* have been studied in five stages.

(a) In stage 1 (2.5 mm.), the centres of ossification have not yet appeared.

(b) In stage 2 (4 mm.), the parasphenoid, the pro-otics, the exoccipitals and the basioccipital have appeared in the cranium. The premaxilla, maxilla, quadrate, dentary, articular and retroarticular are seen in the jaws and palate region. In the hyoid arch and opercular region all the bones are seen excepting the stylohyal, the hypohyal and the parahyoid. In the branchial region, centres of ossification of the ceratobranchials, and the pharyngeum inferius are noticed.

(c) In stage 3 (6 mm.) the frontals, parietals, pterotics, epiotics and supra-occipital are added to the cranium. The palatines (autopalatines), ectopterygoids, hypohyals and parahyoid are added to the visceral skeleton in this stage.

(d) In stage 4 (7 mm.) the lateral ethmoids, vomers and nasals have appeared. The remaining centres are—the metapterygoid, the stylohyal and the three basibranchials. The first three hypobranchials and the three pharyngobranchials are being ossified.

(e) In stage 5 (10 mm.) the following centres of ossification have appeared—The median ethmoid, the orbitals, the pleurosphenoids, the supratemporals, the post-temporals, the entopterygoids, and the four epibranchials.

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KEY TO ABBREVIATIONS

<i>ar</i>	.. articular	<i>lc</i>	.. lachrymal or first orbital
<i>bh</i>	.. basihyal	<i>let</i>	.. lateral ethmoid
<i>ba 1-5</i>	.. branchial arches 1-5	<i>mpt</i>	.. metapterygoid
<i>boc</i>	.. basioccipital	<i>mx</i>	.. maxilla
<i>bocp</i>	.. basioccipital process	<i>na</i>	.. nasal
<i>brs</i>	.. branchiostegal rays	<i>op</i>	.. opercular
<i>cb 1-5</i>	.. ceratobranchials 1-5	<i>p</i>	.. parietal
<i>ch</i>	.. ceratohyal	<i>pal</i>	.. palatine
<i>cop 1-3</i>	.. basibranchials or copulæ 1-3	<i>pasp</i>	.. parasphenoid
<i>den</i>	.. dentary	<i>phb 1-3</i>	.. pharyngobranchials 1-3
<i>eb 1-4</i>	.. epibranchials 1-4	<i>pls</i>	.. pleurosphenoid
<i>ecp</i>	.. ectopterygoid	<i>pmx</i>	.. premaxilla
<i>eh</i>	.. epihyal	<i>pop</i>	.. preopercular
<i>enp</i>	.. entopterygoid	<i>pro</i>	.. pro-otic
<i>epi</i>	.. epiotic	<i>pt</i>	.. pterotic
<i>eth</i>	.. median ethmoid	<i>qu</i>	.. quadrate
<i>exo</i>	.. exoccipital	<i>rar</i>	.. retroarticular
<i>fh</i>	.. foramen for the hyomandibularis branch of the facial	<i>sh</i>	.. stylohyal
<i>fmg</i>	.. foramen magnum	<i>so</i>	.. supraoccipital
<i>fr</i>	.. frontal	<i>sop</i>	.. subopercular
<i>hb 1-3</i>	.. hypobranchials 1-3	<i>sph</i>	.. sphenotic
<i>hh</i>	.. hypohyal	<i>sym</i>	.. symplectic
<i>hym</i>	.. hyomandibular	<i>tden</i>	.. teeth or denticles on dentary
<i>iop</i>	.. interopercular	<i>vo</i>	.. vomer