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Osteology of *Trypauchenichthys sumatrensis* Hardenburg

Christine Parrish Baer
Old Dominion University

OSTEOLOGY
OF
TRYPAUCHENICHTHYS SUMATRENSIS HARDENBURG

CHRISTINE PARRISH BAER

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SUPERVISORY COMMITTEE

(Thesis Advisor)
Ray S. Birdsong

Harold G. Marshall

ABSTRACT

The osteology of a Malaysian goby was examined in detail and compared to other gobioids. Results indicated that *Trypauchenichthys sumatrensis* is a specialized, but definite member of the Gobioidei. Some osteological characteristics of a related fish, *Trypauchen vagina*, were also discussed.

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Key to Abbreviations

ANG	angular
AR PMX	articular process of premaxilla
ART	articular
ASC PMS	ascending process of premaxilla
BB	basibranchial
BH	basihayal
BO	basioccipital
BR	branchiostegal
C	centrum
CB	ceratobranchial
CH	ceratohyal
CL	cleithrum
COR	coracoid
D	dentary
DH	dorsal hypohyal
DPTG	distal pterygiophore
EB	epibranchial
EH	epihyal
EO	exoccipital
EPO	epiotic
EPR	epipleural rib
EPU	epural
F	frontal
HB	hypobranchial
HS	haemal spine
HYO	hyomandibular
HYP	hypural
IH	interhyal
INT	intercalar
IOP	interopercle
LAC	lacrymal
LE	lateral ethmoid
ME	median ethmoid
MPT	metapterygoid
MPTG	medial pterygiophore
MX	maxilla
MX PAL	maxillary process of palati
NA	neural arch
NS	neural spine
OP	opercle
PAL	palatine
PAP	parapophysis
PB	phryngobranchial
PCC	procurrent cartilage
PHYP	parhypural
PMX	premaxilla
POP	preopercle
PPTG	proximal pterygiophore
PR	pleural rib
PRO	prootic
PS	parasphenoid
PT	ectopterygoid
PTG	pterygiophore
PTM	posttemporal
PTO	pterotic
PTS	pterosphenoid
QU	quadrate
RAD	radials
SCA	scapular cartilage
SCL	supracleithrum
SES	sesmoid articular
SOC	supraoccipital
SOP	subopercle
SPH	sphenotic
STF	subtemporal fossa
SYM	symplectic
UH	urohyal
US	urostylar vertebra
V	vomer
VH	ventral hypohyal
VT	vertebra

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INTRODUCTION

Of all the tropical marine fishes, the gobies are among the most speciose and ecologically diverse. With the exception of the oceans lying within the Arctic and Antarctic circles, gobies are distributed in all the oceans of the world. The Suborder Gobioidei has over 400 nominal genera with more than 2,000 nominal species; most of which are small carnivorous fish.

The family Trypauchenidae, a small group of eel-like Indo-Pacific gobies, is one of the more specialized Gobioidei groups. They are sedentary and inhabit mud burrows up to six feet deep at the mouths of rivers along the coastlines of India, Africa, and Malaysia making them difficult to collect (Hora, 1924; Tomiyama, 1936). Available information in the literature on trypauchenid osteology and specific information on other gobioids is scarce. Among the more significant works are those of Regan (1911), Gregory (1933), Tomiyama (1936), Lele and Kulkarni (1938 and 1939), Takagi (1950), Gosline (1955), Akihito (1963, 1967, 1969, and 1971), Miller (1973), and Birdsong (in press). Confusing and insufficiently detailed information has greatly inhibited progress in the understanding of the systematics and relationships of the gobioids.

The objective of this study was to examine, in detail, the osteology of *Trypauchenichthys sumatrensis* in an effort to provide information which will eventually (it is hoped) lead to the clarification of phylogenetic relationships in this large and complex suborder.

METHOD AND MATERIALS

Specimens were cleared with a trypsin-borax solution using the methods described by Taylor (1967) and stained with Alizarin Red-S. Specimens were stored in 100% glycerin. The eventual dissection and examination of the specimens were performed while they were immersed in 100% glycerin or in 60% isopropyl alcohol. The cranium of the female *Trypauchenichthys sumatrensis* was disarticulated by heating in a strong KOH solution.

Detailed examinations, dissections and drawings were made using a Wild M-5 dissecting microscope with camera lucida attachment.

The following materials were examined in this study: *Trypauchenichthys sumatrensis* USNM uncat.; UM-SI Project Indian Ocean Survey, Sta. 69-76; Locality 5° 11' N lat. and 100° 10' E long.; south of Pu Kendri Island south of Penang Island; Malaysia drainage; mud bottom; captured at 12 ft depth with 30 ft otter trawl 6 May 1969; F. J. Schwartz collector. Specific specimens examined: male 59.5 mm SL, and female 55.6 mm SL. *Trypauchen vagina* USNM 86958 Foochow, China; collected Sept.-Nov. 1923; Arthur de C. Sowerby collector (no other information given). Specific specimens examined: male 97.8 mm SL and female 94.2 mm SL.

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Head Region

Vomer (Figs. 3, 4, 5, 6, 7, 8A). The dorsoventrally flattened vomer is paddle shaped in ventral view and narrows abruptly posteriorly. Two pairs of processes extend posterodorsally from the vomer. The lateral ethmoid processes, the larger more posterior pair, attach to the anteroventral portion of their respective lateral ethmoids. The smaller more medial pair, the ethmoid processes, are thin pieces of bone which extend parallel to and above the lateral ethmoid processes and attach to the latero-anterior surface of the median ethmoid. The vomer is toothless.

Median ethmoid (Figs. 2, 3, 5, 6, 7, 8B, 9). Lying at the anterodorsal extent of the cranium, the median ethmoid is rectangular in dorsal view. The anterior face is cup shaped with a pair of extensions projecting ventrally from the latero-anterior face. An anteromedial recess of the median ethmoid holds the ethmoid cartilage. Laterally, the median ethmoid is synchondrally joined to the paired lateral ethmoids. The median ethmoid process of the palatine articulates in a fossa on the anterolateral surface of the median ethmoid. A pair of ligaments attach to the anterolateral surfaces of the median ethmoid and extend to the dorsomedial surfaces of the maxillaries. The frontals overlap the posterodorsal portion of the median ethmoid. The nasals are apparently absent.

Lateral ethmoid (Figs. 2, 3, 4, 5, 6, 7, 8C, 8D, 9). The paired lateral ethmoids are the anterolateral most extension of the cranium. Each lateral ethmoid consists of several processes. A dorsomedial process joins with the frontal dorsomedially and the median ethmoid medially to form an arch that bridges the olfactory nerve. Ventral to the olfactory foramen, the lateral ethmoid process of the vomer joins to the anteroventral surface of the lateral ethmoid. Ventrally, the lateral ethmoid is joined to the parasphenoid by a band of cartilage. A cylindrical process which extends anterolaterally is ligamentously attached to the lacrymal. Anterior to the lateral ethmoid process of the lacrymal, the lateral ethmoid fossa for the palatine attachment is found. A small process extends dorsally from the dorsal surface of the lateral ethmoid.

Frontal (Figs. 3, 4, 5, 6, 7, 9, 10A). The frontals are paired bones that form the dorsal-most portion of the cranium. They form a synostosis medially and possess a dorsally projecting serrated crest along the midline of their posterior half. The fused frontals are narrow anteriorly and widen abruptly posteriorly. At the point where the frontals widen, they send down ventral bilateral extensions which are laterally overlapped by dorsal extensions of the parasphenoid. The frontals overlap the median ethmoid anteriorly, the medial edge of the sphenotic anterolaterally, the median edge of the pterotic laterally and meet the median edge of the pterosphenoid ventrolaterally. Posteriorly the frontals overlap the anterior edge of the epiotics and most of the anterior half of the supraoccipital.

Sphenotic (Figs. 3, 4, 5). The paired sphenotics form the lateral most extensions of the cranium. The large anterolateral projection of each sphenotic is a fan shaped bone which narrows medially and widens again at the base. The sphenotic synchondrally joins the pterosphenoid anteromedially and is overlapped dorsomedially by the frontal. The pterotic and the prootic are synchondrally joined posteriorly to the sphenotic. The sphenotic posteriorly extends as a small thin shelf of bone under the anterodorsal portion of the prootic. The anterodorsal condyle of the hyomandibular articulates in a rounded fossa on the ventrolateral face of the sphenotic.

Pterotic (Figs. 3, 4, 5). The paired pterotics lie posterior to the sphenotics to which they are synchondrally joined. Anteriorly the pterotic is overlapped by the frontal and posteriorly it synchondrally joins the prootic. Ventrally, it forms the lateral margin of the subtemporal fossa.

The lateral most edge of the pterotic extends as a wing-like extension. The posterodorsal extension of the hyomandibular articulates in a shallow fossa located on the ventral surface of the shelf.

Epiotic (Figs. 3, 4, 5). The paired epiotics form the lateral posterodorsal corners of the cranium. Anteriorly, each epiotic synchondrally joins with the pterotic and is overlapped dorsoanteriorly by the frontal and posterolaterally by the supraoccipital. Each epiotic has a small process to which the dorsal arm of the posttemporal is ligamentously attached.

Supraoccipital (Figs. 3, 5, 10B). The supraoccipital forms the dorsoposterior margin of the cranium and extends posteriorly as a spinous process. It is overlapped by the frontals anteriorly and overlaps the epiotics lateroventrally and the exoccipitals ventrally.

Exoccipital (Figs. 3, 4, 5, 11A, 11B). The paired exoccipitals form most of the posteromedial wall of the cranium and synchondrally join each other posteromedially. Each exoccipital joins synchondrally with each epiotic and is overlapped by the supraoccipital anteriorly. Anterolaterally the exoccipital forms the posterior margin of the subtemporal fossa. Ventral to the subtemporal fossa, the lateroposterior portion of the exoccipital is slightly overlapped by the intercalar. The ventral edge of the exoccipital synchondrally joins with the basioccipital.

The exoccipital extends posteroventrally to form a condyle which articulates with the apophysis of the first vertebra. The large glossopharyngeal foramen can be seen immediately ventral to the vertebral condyle. Dorsomedial to the condyle the exoccipital is pierced by the vagal formen.

Basioccipital (Figs. 3, 4, 5, 11C, 11D). The basioccipital extends shelf-like to form the ventroposterior portion of the cranium. Anteriorly, the basioccipital is overlapped for more than half its length by the parasphenoid and the intercalar. Internal to the parasphenoid and intercalar, the basioccipital joins synchondrally with the prootic. The basioccipital also joins synchondrally to the ventral margin of the exoccipital. Posteriorly the basioccipital forms an extension which articulates with the first vertebral centrum and forms the floor of the foramen magnum.

Intercalar (Figs. 3, 4). The paired intercalars are thin rectangular bones applied to the surface of the ventral part of the cranium. The intercalar overlaps the prootic anteriorly, the basioccipital medially, the epiotic posteriorly, and forms the posteromedial margin of the subtemporal fossa. Posteriorly the intercalar has a projection to which the ventro-anterior arm of the posttemporal is ligamentously attached.

Subtemporal fossa (Figs. 3, 4). The subtemporal fossae are large areas of cartilage in the ventro-lateral walls of the brain case. Each fossa is bounded by the prootic anteriorly, the pterotic dorsally, and the exoccipital posteriorly. The ventromedial edge of the subtemporal fossa is overlapped by the dorsolateral margin of the intercalar.

Prootic (Figs. 3, 4, 12B, 12C). The paired prootics occupy most of the ventromedial portion of the cranium. Each prootic is synchondrally joined to the pterosphenoid anteriorly, the sphenotic anterolaterally, the pterotic dorsally, and the basioccipital ventroposteriorly. It is overlapped by the parasphenoid ventromedially, the intercalar posteriorly and forms the anterior margin of the subtemporal fossa. The trigeminal-facial foramen is formed in the space between the frontal-pterosphenoid overlap and the posterior prootic-pterosphenoid joint. The large facial foramen of the prootic lies immediately posterior to the lateral extension of the sphenotic.

Lacrymal (Fig. 2). The paired lacrymals are ligamentously attached by their dorsal portions to the anterior extension of the lateral ethmoid. Each very thin laterally flattened lacrymal broadens ventrally.

Pterosphenoid (Figs. 4, 12D). The small paired pterosphenoids are found medial to the lateral extensions of the sphenotics. The dorsal portion of each of the pterosphenoids are slightly overlapped by the frontal. The pterosphenoid meets the parasphenoid anterolaterally and the medial posterior margin of the pterosphenoid meets the prootic. The pterosphenoid joins with the prootic posteriorly and the sphenoitc laterally.

Parasphenoid (Figs. 3, 4, 6, 12A). The parasphenoid forms the medial portion of the floor of the cranium. The parasphenoid extends anteriorly to each of the lateral ethmoids via a band of cartilage and overlaps the posterior portion of the vomer. The parasphenoid and the frontals form a synchondral joint at the base of the narrow portion of the parasphenoid. The parasphenoid meets the pterosphenoid anterolaterally and it laterally overlaps the entire ventromedial margin of the prootic. The posterior portion of the parasphenoid overlaps the basisphenoid posteriorly. Two foramina, one on each side, are found medial and ventral to the sphenotics. These foramina provide the passage for the internal carotid arteries.

Upper jaw (Figs. 2, 9, 13B, 14A, 14B). Anteriorly each premaxilla has a large ascending process that forms a symphysis with its fellow along the entire median edge of the jaw. The premaxilla ascending process and a smaller process located posteriorly are overlapped and ligamentously attached to the maxilla. The paired maxillae lie immediately above the premaxillae and parallel them along their length. Posteriorly each premaxilla and maxilla ligamentously attach to the lateral face of the coronoid dentary. The premaxilla has 6-7 large and posteriorly curved caninoid teeth and 39-42 smaller caninoid teeth. The smaller caninoid teeth are more numerous posteriorly, but are found between the larger anterior caninoid teeth. The bases of most of the smaller caninoid teeth are ensheathed in continuous connective tissue, while the bases of some of the smaller caninoid and all of the large caninoid teeth are ensheathed in bone.

Lower jaw (Figs. 2, 13A, 15B). The dentary consists of three processes: a small anterior process, a larger ventrally extended process and the coronoid dentary. On its medial surface under a small ridge the dentary articulates with the entire dorsal edge of the articular. The dentary has 8-11 large posteriorly curved caninoid teeth and 36-39 smaller caninoid teeth that lie between the larger caninoid teeth. The larger teeth are more anteriorly located. The attachment of these teeth to the dentary is the same as in the premaxilla.

The anterior extension of the articular inserts into a narrow concavity on the medial surface of the dentary. Posterodorsally the articular articulates with the articular process of the quadrate by means of a shallow notch-like joint. The ventral portion of the articular is poorly ossified.

A sesamoid articular bone is firmly applied to the medial surface of the anterior portion of the articular.

The angular bone is located immediately below the articular-quadrate articulation and is firmly applied to the medial surface of the articular.

A large ligament originates on the medial surface of the facial connective tissue, blending with it just below the eye. Another ligament originates on the medial surface of the angular and attaches to the anterodorsal edge of the interopercle.

The cylinder of Meckel's cartilage lies in a narrow concavity between the articular-quadrate articulation and the sesamoid articular on the medial surface of the articular.

Hyomandibular and palatine arch (Figs. 2, 9, 15A, 15C, 16). Each of the paired hyomandibular bones is a roughly oval laterally flattened bone with three cylindrical processes radiating dorsally and posteriorly. The anterodorsal process articulates with the sphenotic and the posterodorsal process articulates with the pterotic. The posterior-most process articulates with an anteriorly directed process of the opercle. Ventrally the hyomandibular articulates by its ventroposterior edge to the interhyal. The anterodorsal portion of the preopercle is ligamentously attached to the ventrolateral surface of the hyomandibular. The interhyal-hyomandibular articulation is covered by the preopercle. The anterolateral surface of the hyomandibular is ligamentously attached to the posterior portion of the metapterygoid. Ventral to the metapterygoid-hyomandibular attachment the hyomandibular anteroventral edge joins the cartilage capped symplectic. On the medial surface of the hyomandibular, facial nerve VII is located immediately below the anterodorsal process (Fig. 15C).

Each of the paired symplectic bones is oriented approximately horizontally along its long axis. The posterior margin of the symplectic is separated from the hyomandibular by cartilage. Anteriorly the symplectic is overlapped and firmly bound to the medial surface of the quadrate. The dorsal edge of the symplectic is firmly bound to the ventral edge of the metapterygoid.

The paired metapterygoid bones are joined anteriorly through cartilage to the dorsoposterior margin of the quadrate; the ventral edge of each metapterygoid is bound to the symplectic; and the posterior portion of each metapterygoid joins the anterolateral surface of the hyomandibular. A shelf of bone projects laterally along the posterolateral surface of the metapterygoid. The symplectic-metapterygoid combination comprises the central strut of the suspensorium.

Each of the paired ectopterygoid bones articulates with a palatine to form the anterior strut of the suspensorium. They are ventrally bound to the quadrate and dorsally bound to the palatine. The mesopterygoid is absent.

The paired quadrate bones form the tip of the suspensorium. Each quadrate overlaps and is joined to the ectopterygoid dorsally, the symplectic posterodorsally and the preopercle posteriorly. The quadrate overlaps and is bound to the anterior end of the symplectic. The anterior-most extent of the quadrate articulates in a shallow notch-like joint of the articular.

The paired palatine bones each have five processes: a maxillary process, a vomer process, a median ethmoid process, a lateral ethmoid process, and an ectopterygoid process. The maxilla process of the palatine articulates with a shallow notch on the dorsal surface of the maxilla. The short vomer process articulates through a ligament to the lateral margin of the vomer. The median ethmoid process articulates in a shallow fossa on the anterolateral surface of the median ethmoid. The lateral ethmoid process articulates in a shallow fossa on the anteroventral surface of the lateral ethmoid. The ectopterygoid process of the palatine articulates ligamentously with the ectopterygoid.

Opercular Series (Figs. 2, 15C, 16). The triangular opercle bears an anteriorly directed process which articulates with the opercle process of the hyomandibular. The opercle overlaps most of the dorsal margin of the subopercle. The subopercle is overlapped laterally by the posterior portion of the interopercle and branchiostegal number five. The dorsal edge of the opercle and the ventral and posterior edge of the subopercle consist of poorly ossified bone.

The preopercle overlaps the ventral portion of the hyomandibular and is ligamentously joined to it. The ventral portion of the preopercle overlaps, is ligamentously joined to the lateral surface of the interopercle and is firmly bound to the posterior arm of the quadrate. The anteroventral edge of the subopercle covers the ligamentous attachment of the interhyal and the epihyal. The anterior edge of the preopercle has a sheet of very thin bone, the symplectic process, extending to, but not touching, the symplectic.

The interopercle is a large thin bone which is overlapped and joined to the preopercle and the posterior arm of the quadrate and posteriorly overlaps the ventro-anterior edge of the subopercle. Medially, the interopercle hides the ceratohyal and the bases of the branchiostegals from view. The interopercle has two ligaments which originate on its medial surface; one attaches to the anterior lateral of the subopercle and the other attaches to the lateral surface of the epihyal. The ventral edge of the interopercle consists of poorly ossified bone.

Hyoid arch (Figs. 2, 15C, 16, 17A, 18). The short interhyal is ligamentously attached by its dorsal end to the ventral edge of the hyomandibular. This attachment is hidden from exterior view by the preopercle. A ligament joins the interhyal and epihyal. The dorsal and ventral ends of the interhyal are capped with cartilage.

The epihyal synchondrally joins the ceratohyal along its entire anterior edge. The epihyal articulates on its posterolateral surface with the epihyal process of branchiostegal number five.

The ceratohyal is broadest at its posterior end and narrows abruptly anteriorly. The anterior portion of the ceratohyal joins with the dorsal hypohyal dorsally and the ventral hypohyal anteriorly. The ceratohyal articulates anteriorly with branchiostegal one followed by branchiostegal two, three, and four which articulate along the lateroventral face of the broader portion of the ceratohyal.

The dorsal and ventral hypohyals are synchondrally joined to the anterodorsal and anteroventral surfaces respectively of the ceratohyal. The dorsal and ventral hypohyals join synchondrally to the posterolateral surface of the basihyal. The ventral hypohyal articulates with its fellow medially, ventral to the anterior portion of the basihyal.

Posteriorly, the funnel shaped basihyal is ligamentously joined to the laterally flattened urohyal.

The urohyal is ligamentously attached to and lies between and below the basihyal and basibranchial two. The dorsal edge of the urohyal is slightly thickened and flattened. Below the dorsal edge the urohyal thins and, in lateral view, is seen as a half-circle. Connective tissue joins most of the hyoid apparatus together.

Branchial arches (Figs. 18, 19). Pharyngobranchials two and three are joined medially with their fellows by connective tissue.

Pharyngobranchial two articulates with the forked epibranchial one (posterior arm) and epibranchial two. Pharyngobranchial three articulates with the proximal ends of epibranchials three and four.

The four epibranchials articulate with their respective ceratobranchials, except for epibranchial three which articulates by its anterior arm to ceratobranchial three. The posterior arm of epibranchial three articulates with a small anteriorad process of epibranchial four.

Ceratobranchials one, two, three, and four join by connective tissue anteromedially to hypobranchials one, two, three and the cartilagenous basibranchial four, respectively. Basibranchials two and three are laterally flanked by the paired hypobranchials two and three, respectively. The urohyal is joined anteriorly to the basihyal and laterally to hypobranchial one by connective tissue. The lower pharyngeal tooth plates appear unfused but firmly bound by ligamentous tissue. Most of the branchial apparatus is loosely joined by connective tissue. Basibranchial one and bony gill rakers are absent.

Pectoral girdle and paired fins (Figs. 2, 20). Each pectoral girdle is composed of a posttemporal, supracleithrum, cleithrum, coracoid, scapular cartilage and the radials. The posttemporal has two arms and a posteroventral projection. The dorsal arm is ligamentously bound to the epiotic, the ventral arm to the intercalar and the posteroventral projection to the dorsolateral surface of the supracleithrum. The medial surface of the supracleithrum joins with the dorsolateral surface of the cleithrum.

The cleithrum is bifid at its dorsal end and attached ligamentously to its fellow at its ventral end. Ventroposteriorly the cleithrum bears a laterally flattened process that is ligamentously attached to the pelvic.

The triangular coracoid is synchondrally joined to the posterior surface of the cleithrum. The scapular cartilage attaches to the posterior edge of the coracoid and runs dorsally along part of the posterior edge of the cleithrum. There is no evidence of ossification or of a foramen in the scapular cartilage.

The four rectangular radials are surrounded by cartilage and lie posterior to the scapular cartilage. The pectoral rays are much shorter on the ventral portion of the radials than on the dorsal portion.

The pectoral rays (18 to 19 in number) articulate with the radials posteriorly along the cartilagenous border. The pectoral ray bases of rays 3-7 are bilaterally asymmetric and dorsally produce small bony flaps.

Pelvic girdle and fins (Fig. 17B). The pelvic girdle is composed of two fused pelvic bones. Fusion of the pelvic bones is unreported for other gobies. Each pelvic articulates with its respective cleithrum.

A pelvic spine and three rays attach ligamentously along the posterolateral margin of each pelvic bone. The inner most ray is vestigial. The pelvic spine base consists of three process: the two ventral processes wrap around the posterolateral margin of the pelvic and the dorsal process articulates with the dorsolateral surface of the pelvic.

Vertebral column and unpaired fins (Figs. 21A, 21B, 22). There are 10 precaudal and 21 caudal vertebrae including the urostyle.

The first precaudal vertebra articulates by lateral processes with the exoccipital condyles. The first two precaudal vertebrae bear only epipleural ribs. All vertebrae, except the urostyle, have a well developed neural spine. Vertebrae 9-30 bear poorly developed postzygopophyses. Vertebrae 3-10 have short broad extensions of the parapophysis. The pleural ribs on vertebrae 3-9 are fused with the epipleural ribs. The base of each fused pair of ribs articulates in a small concavity on the posterior surface of the parapophysis.

The pleural rib on vertebra 10 is short and unfused with its epipleural rib and articulates loosely with its parapophysis.

Some of the vertebrae have a large foramen near the base of the neural spine while other vertebrae have a second (smaller) foramen just above the centrum. A few vertebrae have no foramina at all. Vertebrae 11-28 each bear a long haemal spine that reaches almost to the medial radial of each respective anal pterygiophore.

The dorsal pterygiophores begin posterior to neural spine number three with the radials of the first six pterygiophores fused into single units, each supporting a spine. The pterygiophores of the spinous dorsal fin insert into the interneural spaces as follows: one in space 3, two in space 4, two in space 5 (closely applied) and one in space 6. Pterygiophore seven supports the first branched ray and consists of fused proximal and medial radials with a separate distal portion. Dorsal pterygiophores eight through forty-six are unfused and consist of proximal, medial and distal radials. The dorsal pterygiophores lie either singly or paired in the interneural spaces.

The first three ventral pterygiophores converge at their proximal ends and insert anterior to the first haemal spine. Each of the first two pterygiophores bear fused radials and an anal ray. There is no anal spine. The third pterygiophore is composed of a proximal, medial and distal radial. This arrangement continues through pterygiophore 36. Anal pterygiophores lie either singly or paired within the interneural spaces.

Caudal fin (Fig. 23). Vertebra 30 is involved in the support of the caudal fin. The short neural spine of vertebra 30 articulates with the single elongate epural. Two cylindrical cores radiate toward the dorsal margin from near the anteroventral corner of the epural. The upper procurrent cartilage lies along the dorsal margin of the epural. Hypural 5 lies between the epural and the fused hypurals 3-4. The urostyle is fused with hypurals 3-4 at its posterior end. In a concavity in the posteroventral surface near the point of fusion of the urostyle with hypurals 3-4, fused hypurals 1-2 articulate with the urostyle. All the hypurals are posteriorly capped with cartilage. The parhypural lies between the fused hypurals 1-2 and the last (bifid) haemal spine. The ventral margin of the bifid haemal spine bears the lower procurrent cartilage.

The upper and lower procurrent cartilage each bear three small vestigial procurrent rays. The epural and last haemal spine each bear one segmented, but unbranched, ray. All caudal rays between these two are both segmented and branched. The parhypural bears one ray, the fused hypurals 1-2 seven rays, the fused hypurals 3-4 six rays, hypural 5 a cap of cartilage and one ray.

Discussion

The family Trypauchenidae is a small distinctive group of gobioids composed of four, apparently closely related, nominal genera. The genera are not well defined, are controversial and have been described primarily using meristic differences in the fins and scales, the degree of fusion of the pelvic fins and the presence or absence of canine teeth.

Comparison of *Trypauchenichthys* and *Trypauchen*. Table 1 shows the major osteological differences between *Trypauchenichthys sumatrensis* and *Trypauchen vagina* and Table 2 the similarities of these species.

Trypauchenichthys has pelvic fins separate to the base, with one spine and three rays in each. *Trypauchen* has united pelvic fins, with one spine and five rays in each.

Trypauchenichthys has one epural composed of two cylindrical struts while *Trypauchen* has two separate epural bones. In gobioids the number of epurals varies from group to group with the occurrence of some intraspecific variation. Most species have either one or two (Birdsong, in press). *Rhyacichthys* is the only known gobioid form with three epurals.

Comparison of *Trypauchenichthys* with Other Gobioids. The basic characteristics of the trypauchenids make them firm members of the Gobioidei, differing little from the other gobioids in most osteological features.

The major difference between *Trypauchenichthys* and other gobioids is the organization of the anterior portion of the suspensorium and the snout region.

Trypauchenichthys and *Trypauchen* differ from the described condition in other gobioids by having two processes of the vomer and five processes of the palatine. For example, *Microgobius signatus* has one process of the vomer and three processes of the palatine (Birdsong, in press). The palatines of some other gobioids differ in having two distinct processes on the dorsal portions which usually articulate with the maxillary process and one of the following: the median ethmoid, the vomer or the lateral ethmoid (Gosline, 1955; Regan, 1911; Gregory, 1933; Lele and Kulkarni, 1938). The palatine of *Trypauchenichthys* and *Trypauchen* may be unique to trypauchenids.

Modifications of the snout and suspensorium of *Trypauchenichthys* have had the total effect of strengthening the support of the upper jaw. This may relate to the burrowing tendancies of *Trypauchenichthys*.

Trypauchenichthys has a symplectic process of the preopercle which is narrowly separated from the symplectic. This character is variable in gobioids (Miller, 1973). The symplectic process of the preopercle is well removed from the symplectic in *M. signatus* (Birdsong, in press), *Mistichthys* (Gregory, 1933), and *Periophthalmus* (Lele and Kulkarni, 1938); while in some eleotrids, *Eleotris marmorata* (Regan, 1911) and *Eleotris pisonis* (Gregory, 1933), it lies next to or touches the symplectic.

Trypauchenichthys has an enlarged fifth branchiostegal ray, a character shared with *Periophthalmus* (Lele and Kulkarni, 1938).

Fused epipleural-pleural ribs is another condition *Trypauchenichthys* shares with *Periophthalmus* (Lele and Kulkarni, 1939). The significance of this specialization in a mud burrower is not obvious.

There are no bony gill rakers or branchial tooth patches in *Trypauchenichthys*, a condition unusual in a gobioid.

In *Trypauchenichthys* the specialized scapular cartilage has no foramen. A scapular foramen is found in the bony scapula of *Periophthalmus* (Lele and Kulkarni, 1939) and in the cartilagenous scapula of *M. signatus* (Birdsong, in press). This character appears to be variable.

Trypauchenichthys has neither ventral nor dorsal postcleithra, both variable characters in gobioids.

The pelvic bones of *Trypauchenichthys* are fused into a single unit, a condition unreported in other gobioids. It has been recognized that in gobioids the character of united pelvics varies from group to group. *Trypauchenichthys* and *Trypauchen* are two obviously related genera that differ greatly in this character. *Trypauchenichthys*, with reduced pelvic fins, and *Trypauchen*, with a fully formed pelvic disk, call attention to the overall variability in gobioid classification of split versus united pelvics. The trypauchenids demonstrate the unreliability of this character better than any other example.

Conclusion

It has been shown that *Trypauchenichthys sumatrensis* and *Trypauchen vagina* are firm, yet distinct, members of the Gobioidei. They are obviously related to each other, sharing many characters.

These species possess many characters which appear to be variable within the Trypauchenidae and the Gobioidei.

This osteological study will, hopefully, further the understanding of gobioid phylogeny.

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-----. 1938. The skeleton of *Periophthalmus barbarus* (Linn.) (I). The skull. J. Univ. Bombay, 6(5): 76-91.

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APPENDIX A

TABLE 1

Comparison of *Trypauchenichthys* and *Trypauchen*

	Character	*Trypauchenichthys*	*Trypauchen*
1.	Vomer	2 poserior processes	1 posterior process
2.	Lacrymal	much larger than *Trypauchen* with flattened ventral portion	small
3.	Frontals	well developed sagittal crest	poorly developed sagittal crest
4.	Pelvic fins	Separate to base; 1 spine and 3 rays	united; 1 spine and 5 rays
5.	Pelvic bones	fused	unfused
6.	Anal pterygiophores	1 or 2 within an interneural space; 3 precede first haemal spine	2 or 3 within an interneural space; 4 precede first haemal spine
7.	Caudal vertebrae	21	19
8.	Vestigial PCC rays	3	2
9.	Last haemal spine	bifid ventrally	not bifid ventrally
10.	Epurals	1; composed of two cylindrical cores	2; separate with cylindrical cores

Table 2

Similarities of *Trypauchenichthys sumatrensis* and *Trypauchen vagina*

Character	*Trypauchenichthys* and *Trypauchen*
1. Palatine processes	5: ethmoid process, lateral ethmoid process, vomer process, ectopterygoid process, maxilla process.
2. Preopercle	narrowly separated form symplectic
3. Epiotics	joined under the supraoccipital
4. Branchiostegal rays	5
5. Interopercular	large when compared to many other gobioids
6. Scapula	cartilagenous
7. Scapular foramen	absent
8. Precaudal vertebrae	epipleural and pleural ribs fused
9. Anal spine	absent
10. Procurrent cartilage rays	vestigial
11. Parhypural and hypural 5	with cylindrical strut

Figure 1. *Trypauchenichthys sumatrensis* Hardenburg.

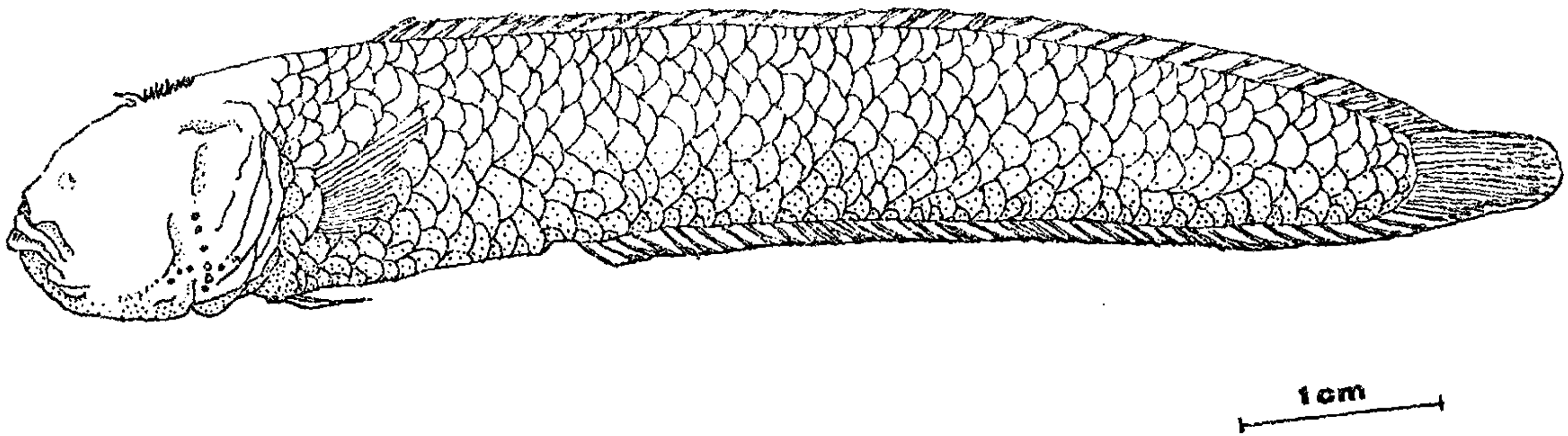

1cm

Figure 2. Articulated skull (lateral view) of *Trypauchenichthys sumatrensis*.

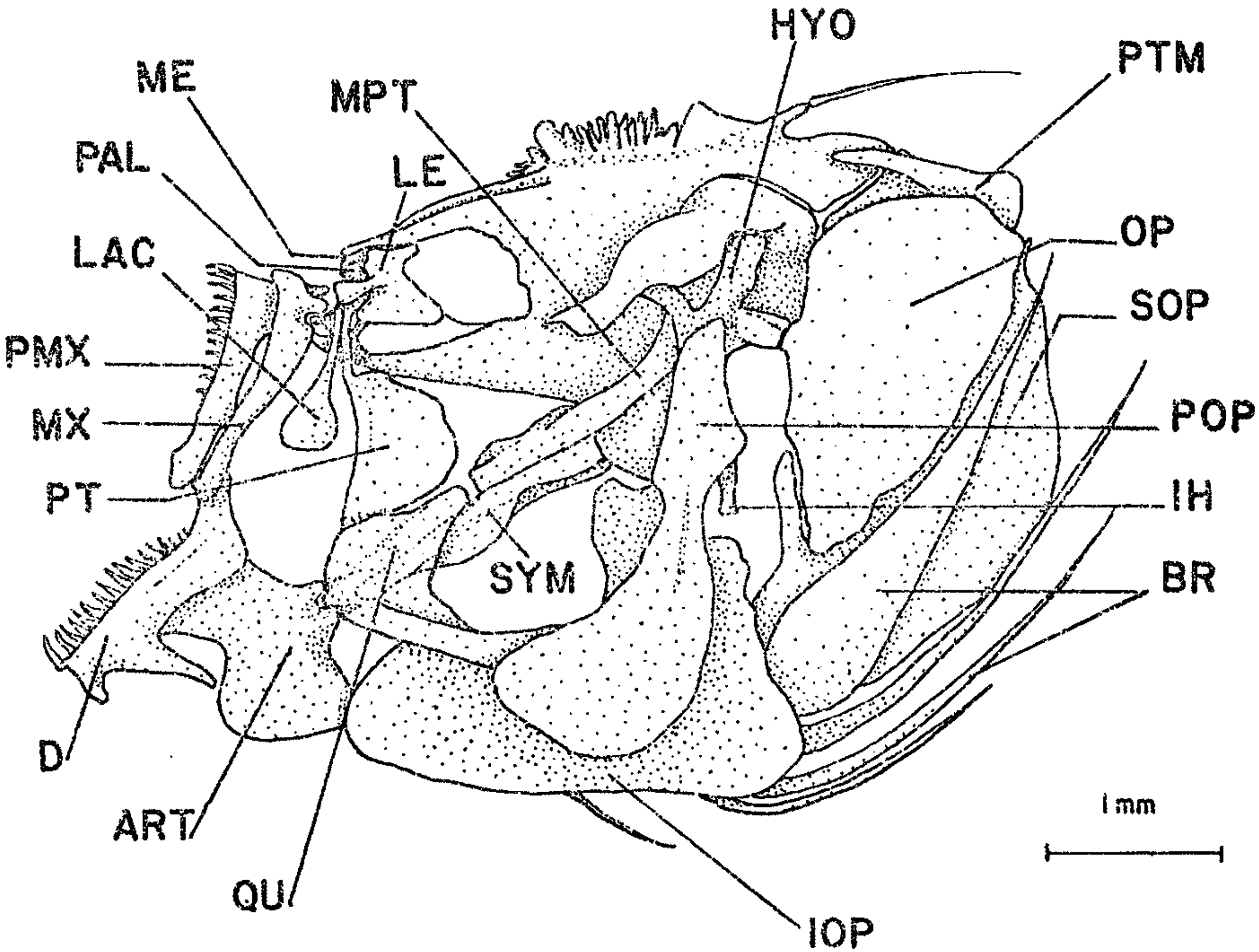

HYO
PTM
ME
MPT
PAL
LE
LAC
OP
SOP
PMX
MX
POP
PT
IH
SYM
BR
D
ART
QU
IOP
1 mm

Figure 3. Cranium (lateral view) of *Trypauchenichthys sumatrensis*.

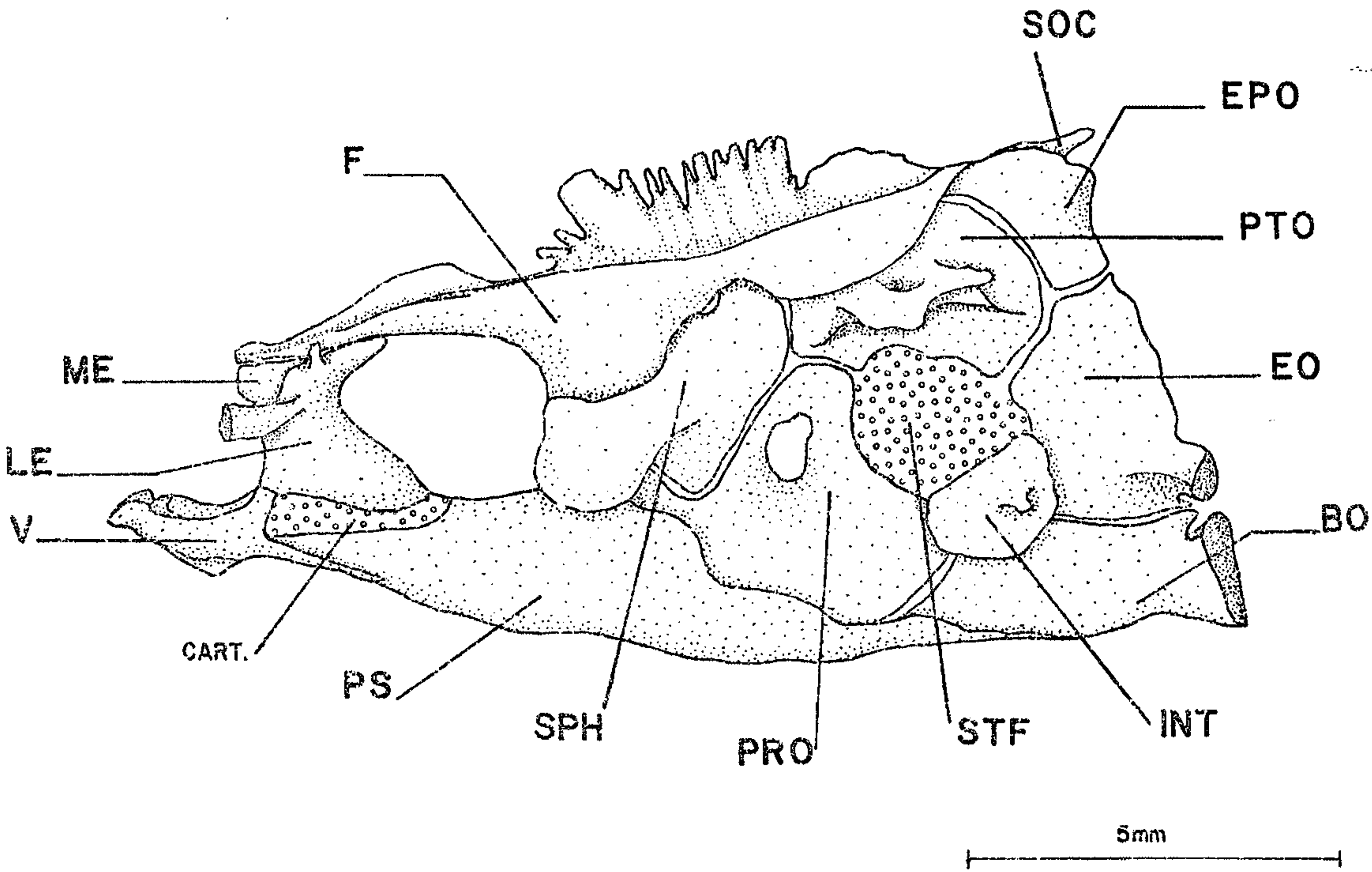

SOC
EPO
F
PTO
ME
EO
LE
V
BO
CART.
PS
SPH
PRO
STF
INT
5mm

Figure 4. Cranium of *Trypauchenichthys sumatrensis* lateral view.

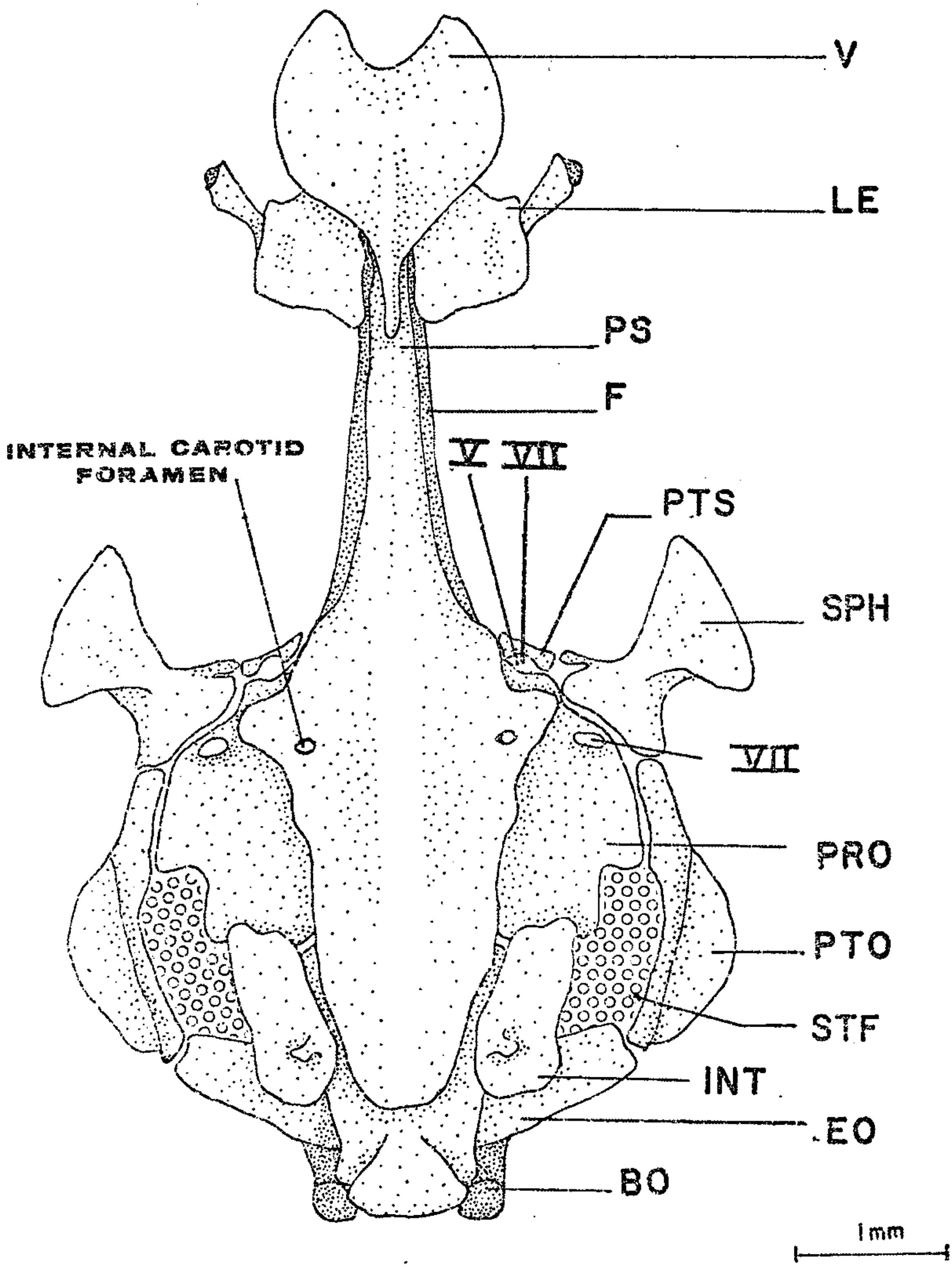

V
LE
PS
F
INTERNAL CAROTID FORAMEN
V
VII
PTS
SPH
VII
PRO
PTO
STF
INT
EO
BO
1mm

Figure 5. Cranium of *Trypauchenichthys sumatrensis* dorsal view.

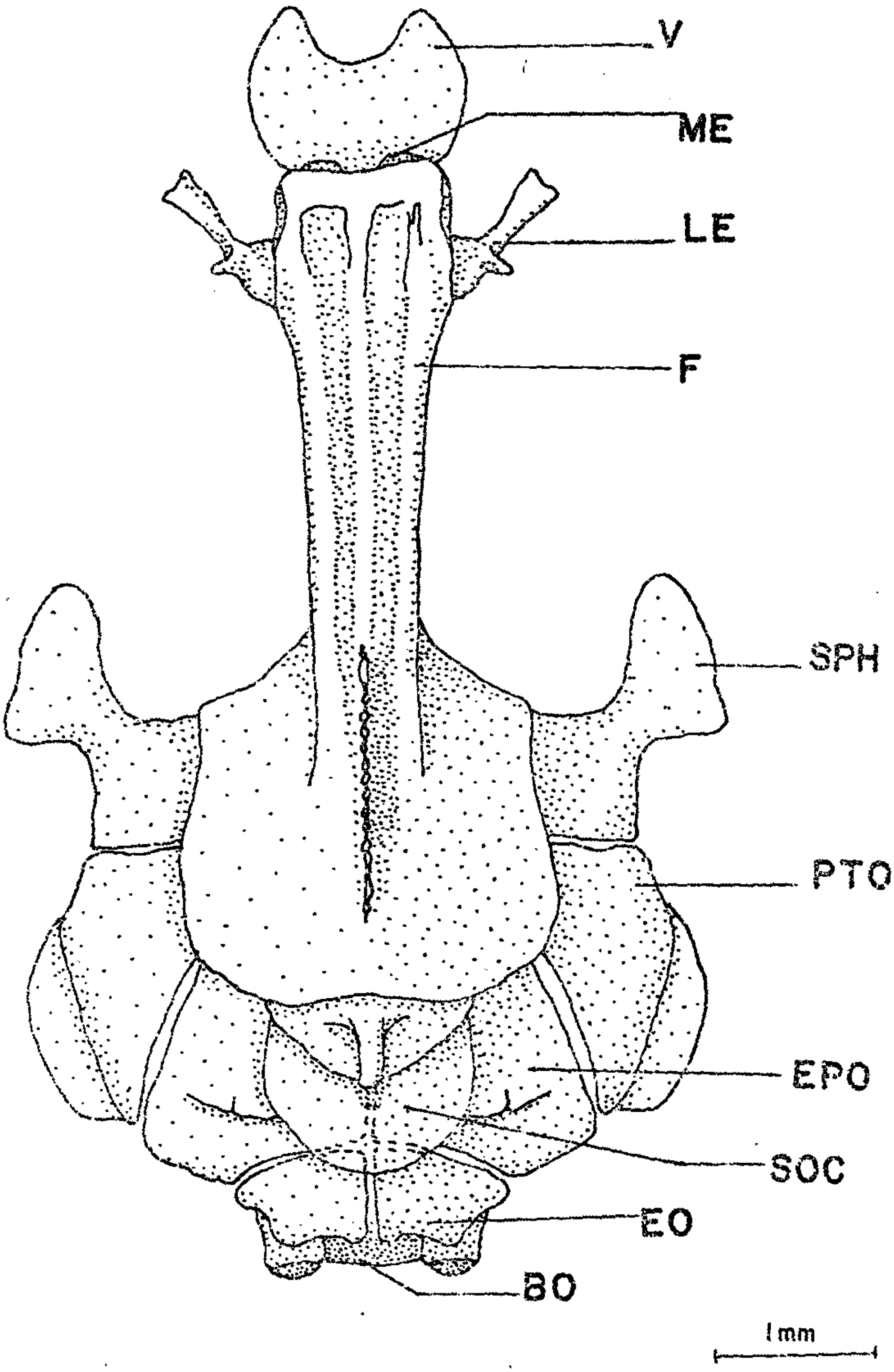

V
ME
LE
F
SPH
PTO
EPO
SOC
EO
BO
1mm

Figure 6. Snout region of *Trypauchenichthys sumatrensis* lateral view.

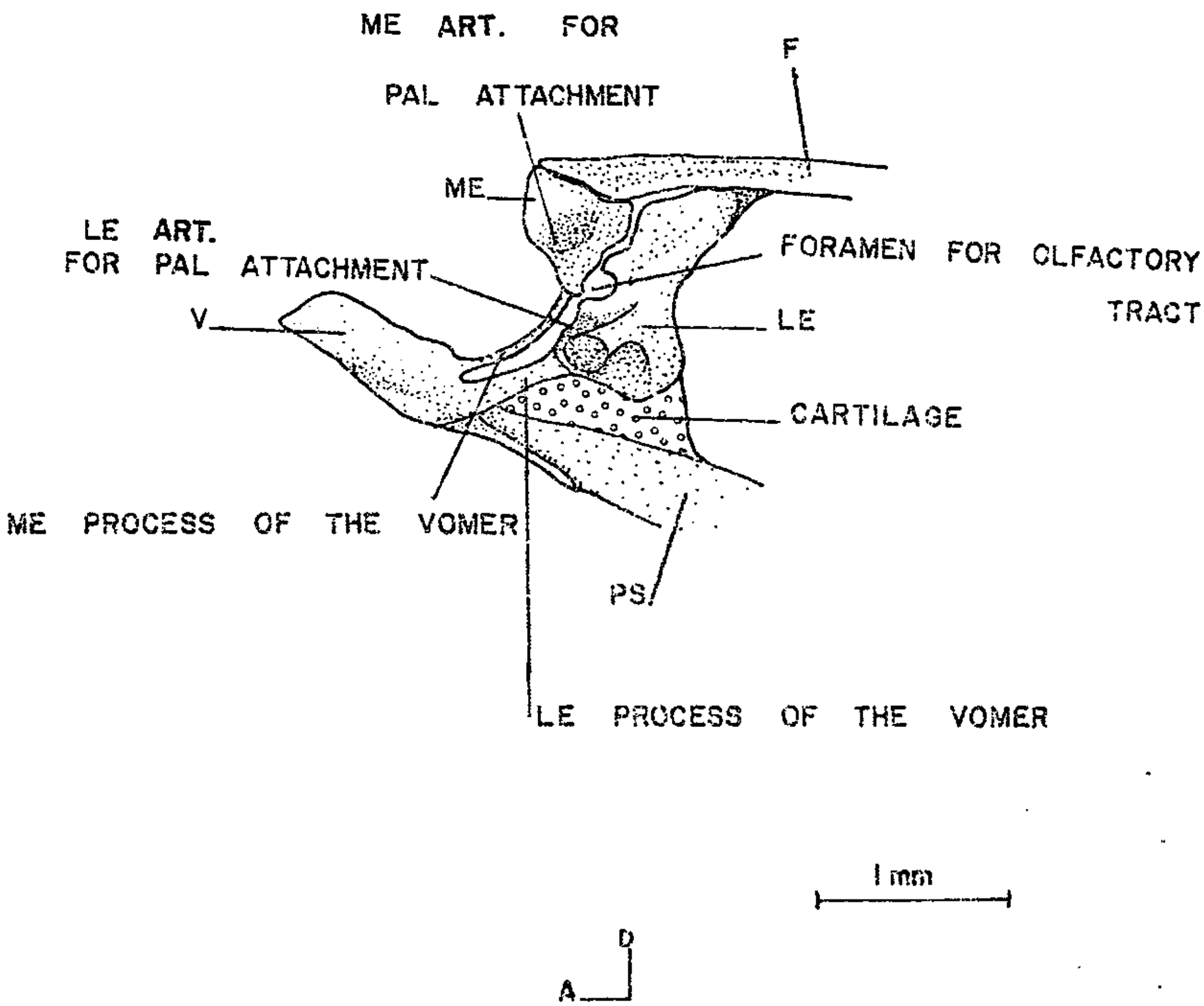
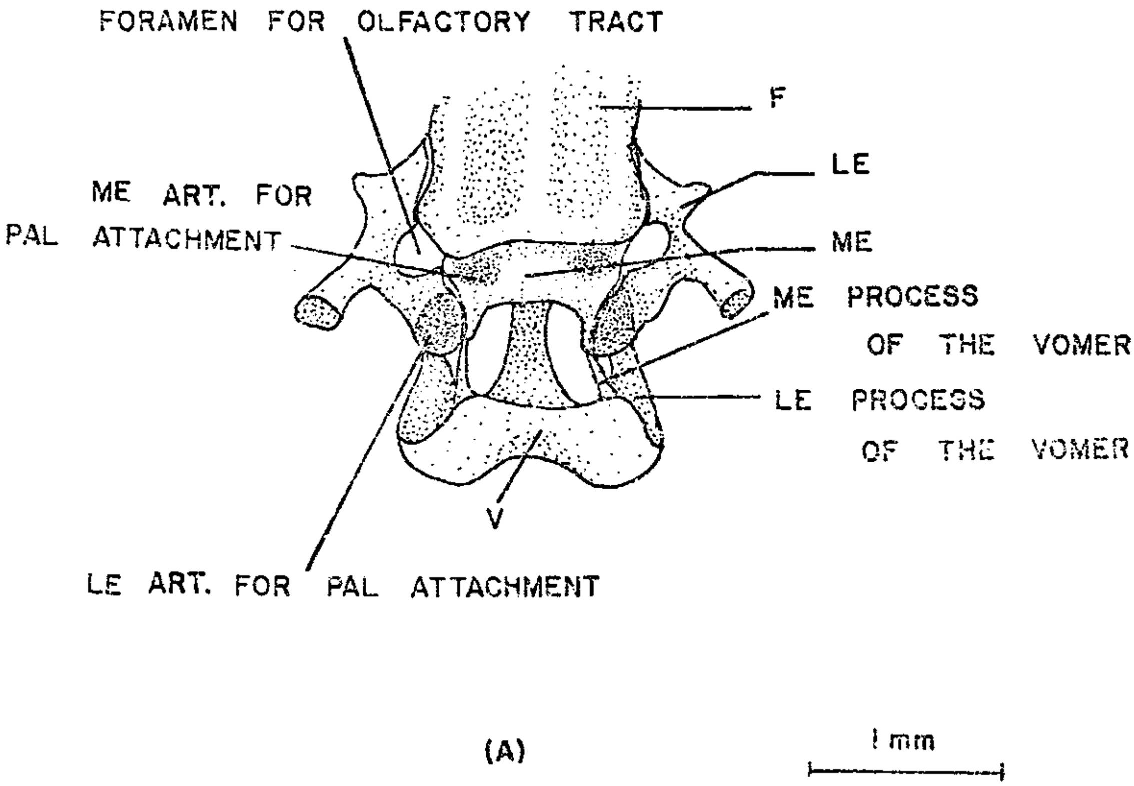

ME ART. FOR
PAL ATTACHMENT
F
ME
LE ART.
FOR PAL ATTACHMENT
FORAMEN FOR OLFACTORY
TRACT
V
LE
CARTILAGE
ME PROCESS OF THE VOMER
PS
LE PROCESS OF THE VOMER
1 mm
D
A

Figure 7. Snout region of *Trypauchenichthys sumatrensis* anterior view.


FORAMEN FOR OLFACTORY TRACT
F
LE
ME ART. FOR
PAL ATTACHMENT
ME
ME PROCESS
OF THE VOMER
LE PROCESS
OF THE VOMER
V
LE ART. FOR PAL ATTACHMENT
1 mm

(A)

Figure 8. Disarticulated cranial bones of *Trypauchenichthys sumatrensis*. A - Vomer. B - Median ethmoid. C - Left lateral ethmoid. D - Left lateral ethmoid.

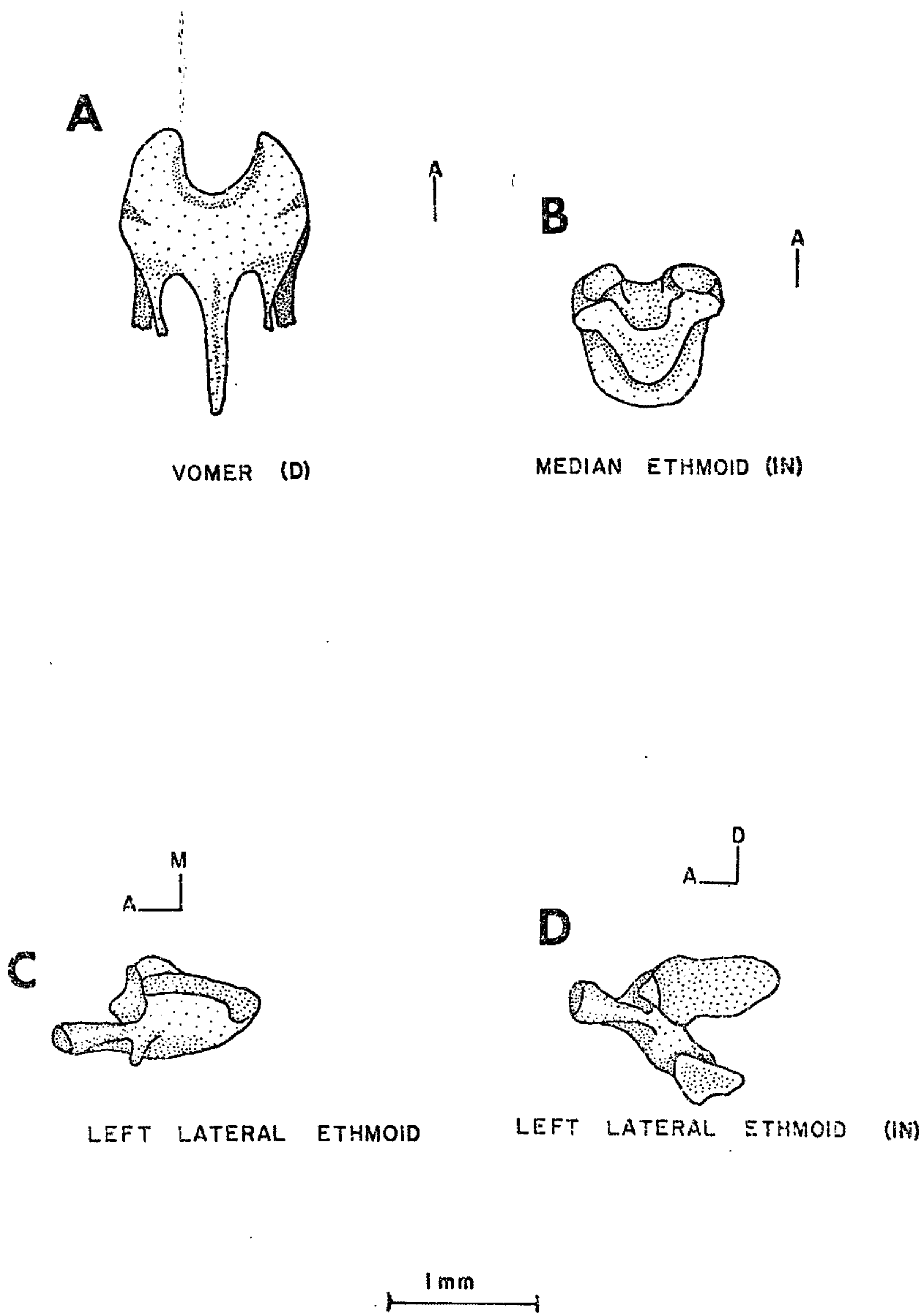
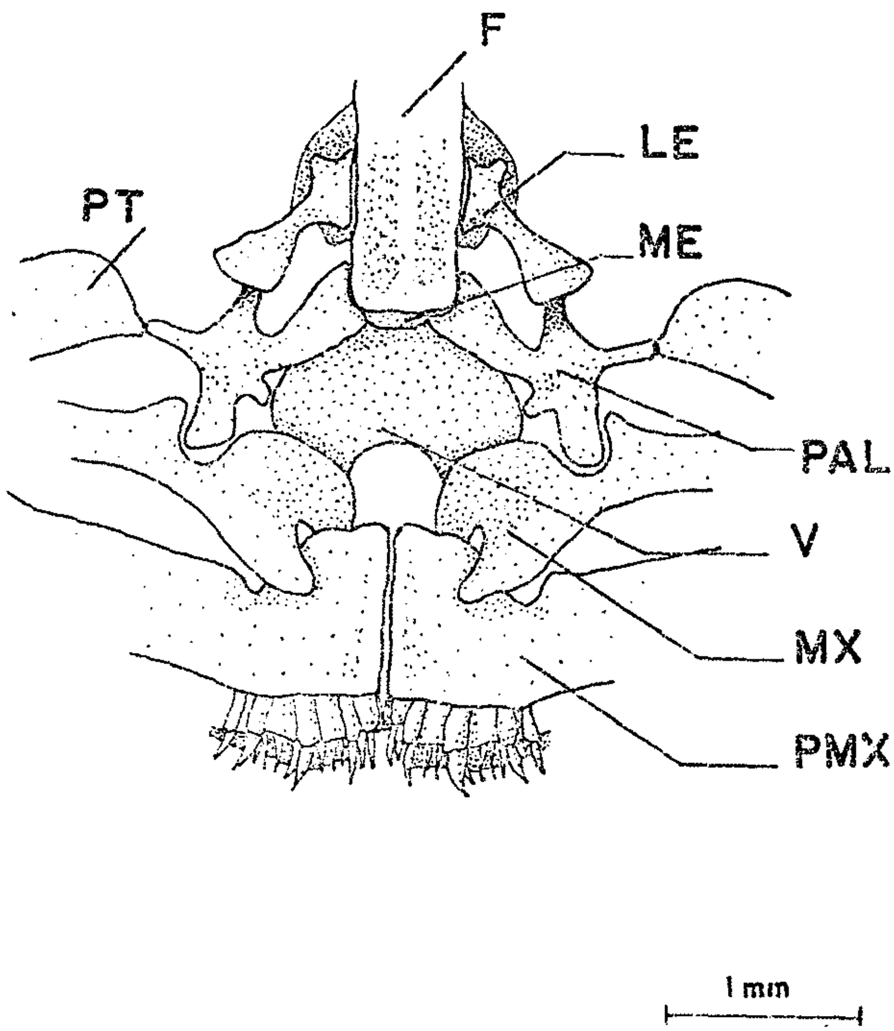

A
A
VOMER (D)
B
A
MEDIAN ETHMOID (IN)
M
A
C
LEFT LATERAL ETHMOID
D
A
D
LEFT LATERAL ETHMOID (IN)
1 mm

Figure 9. Diagrammatic of snout region of *Trypauchenichthys sumatrensis* dorsal view.

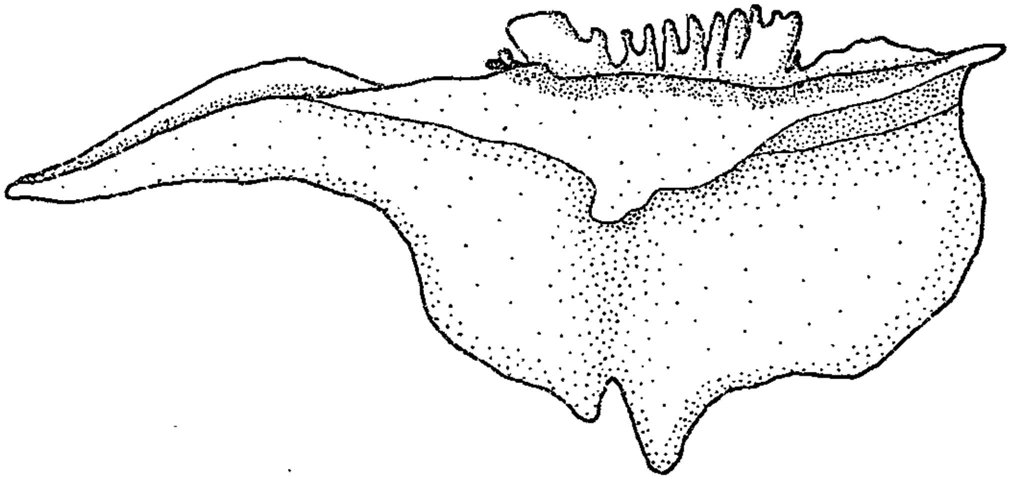


(L)

Figure 10. Disarticulated cranial bones of *Trypauchenichthys sumatrensis*. A - Frontal. B - Supraoccipital.

A

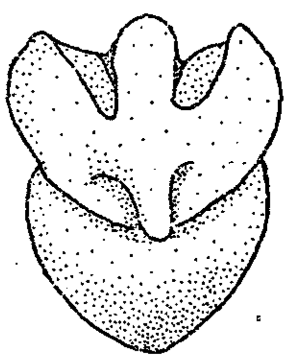
D
A



FRONTAL (EX)

B

D
A



SUPRAOCCIPITAL (EX)

1 mm

Figure 11. Disarticulated cranial bones of *Trypauchenichthys sumatrensis*. A - B Right exoccipital. C - D Basioccipital.

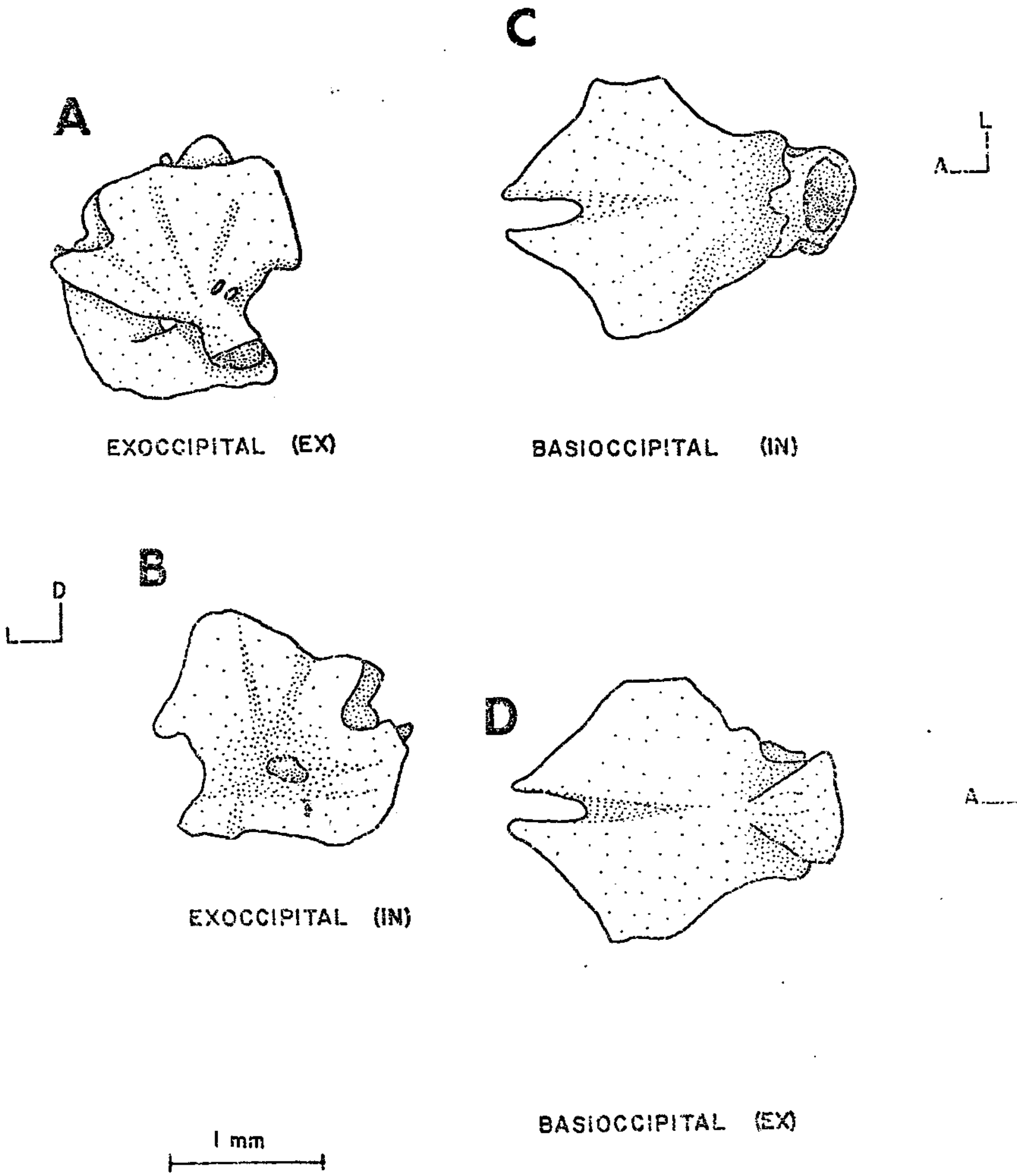

A
EXOCCIPITAL (EX)
B
EXOCCIPITAL (IN)
C
BASIOCCIPITAL (IN)
D
BASIOCCIPITAL (EX)
D
L
L
A
A
1 mm

Figure 12. Disarticulated cranial bones of *Trypauchenichthys sumatrensis*. A - Parasphenoid. B - C Left prootic. D - Left pterosphenoid.

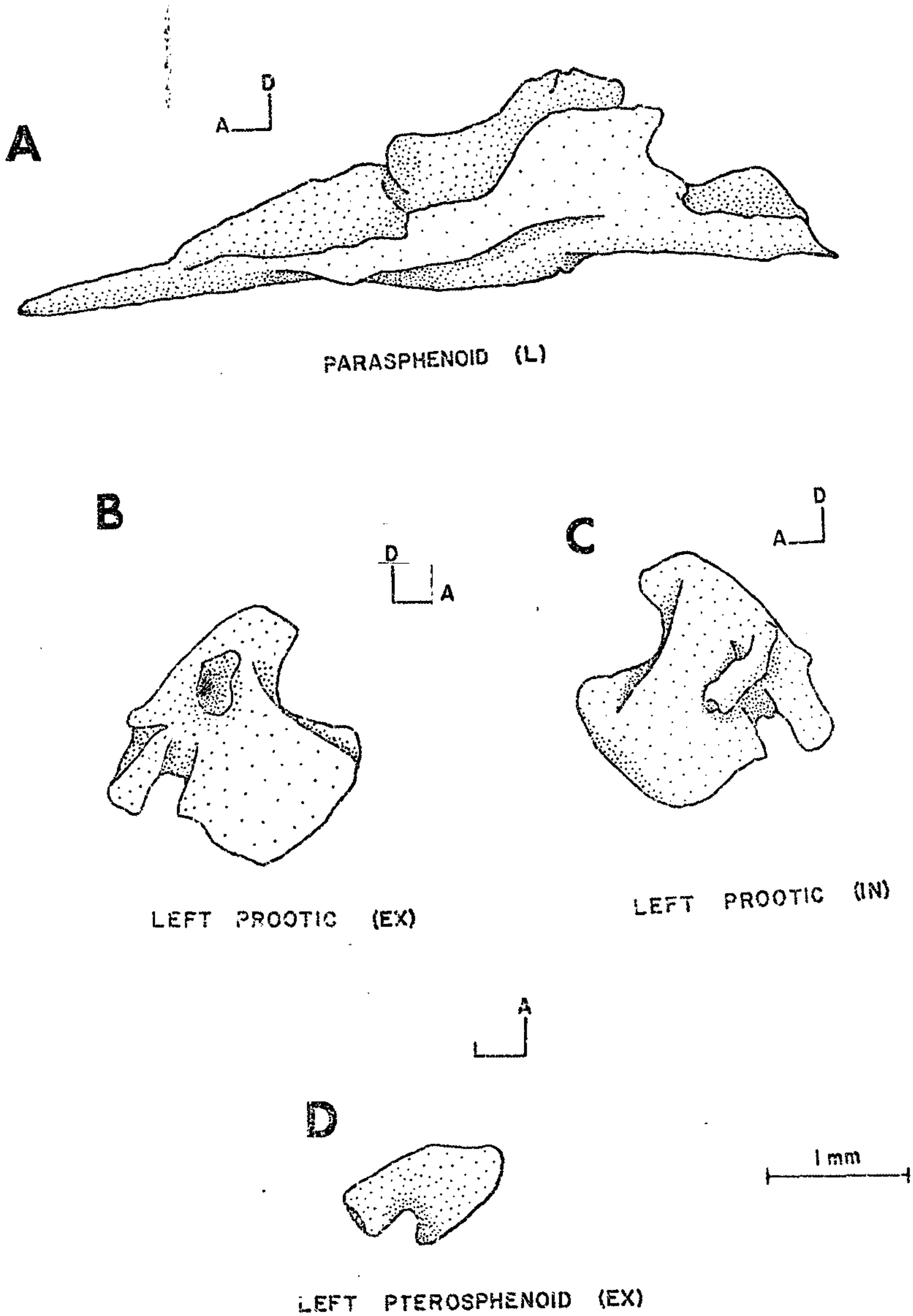

A
D
A
PARASPHENOID (L)
B
D
A
LEFT PROOTIC (EX)
C
D
A
LEFT PROOTIC (IN)
A
L
D
1 mm
LEFT PTEROSPHENOID (EX)

Figure 13. Jaws of *Trypauchenichthys sumatrensis*. A - Left dentary lateral view. B - Left premaxilla lateral view.

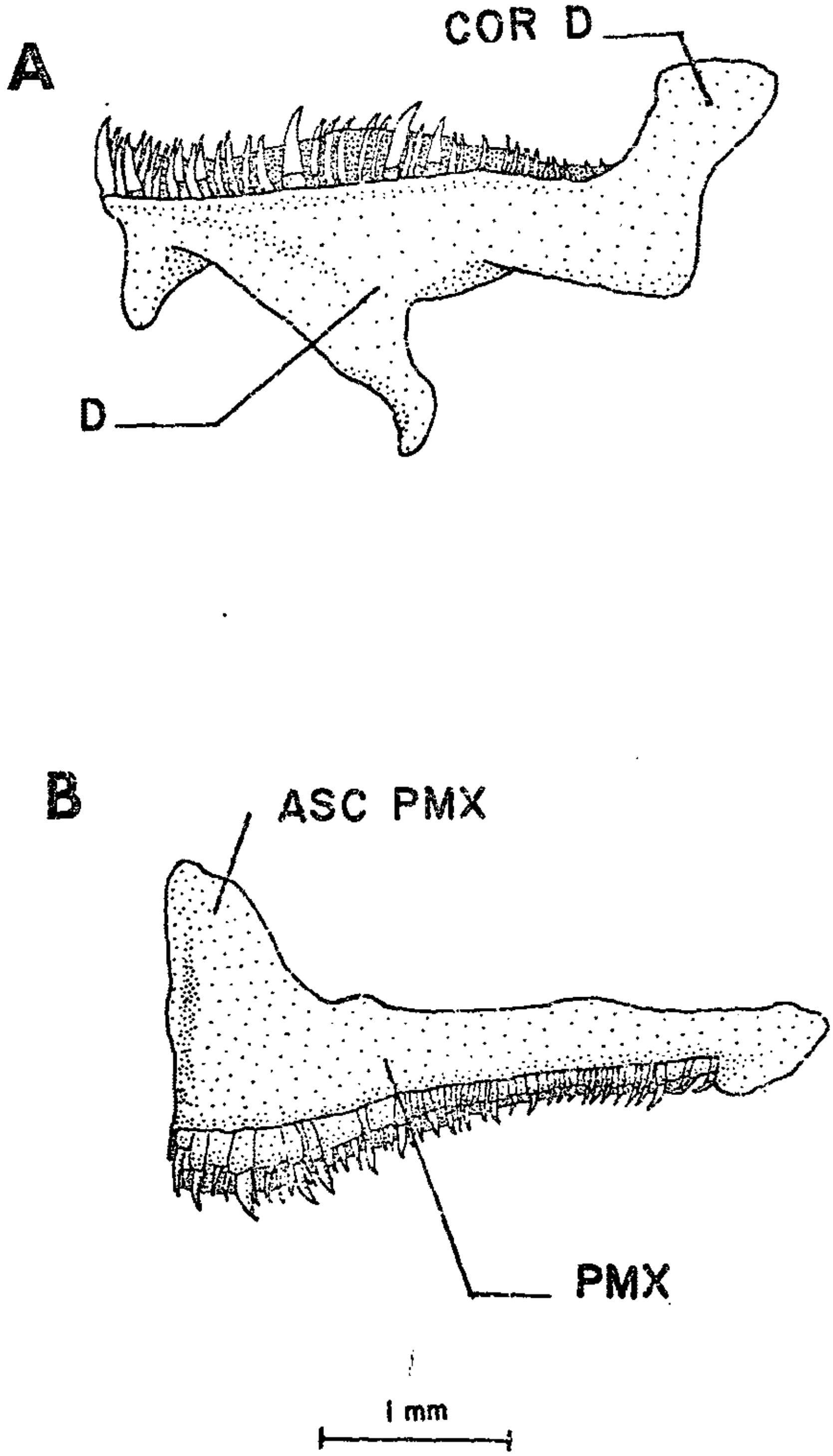

A
COR D
D
B
ASC PMX
PMX
1 mm

Figure 14. Left maxilla of *Trypauchenichthys sumatrensis*. A - Lateral view. B - Medial view.

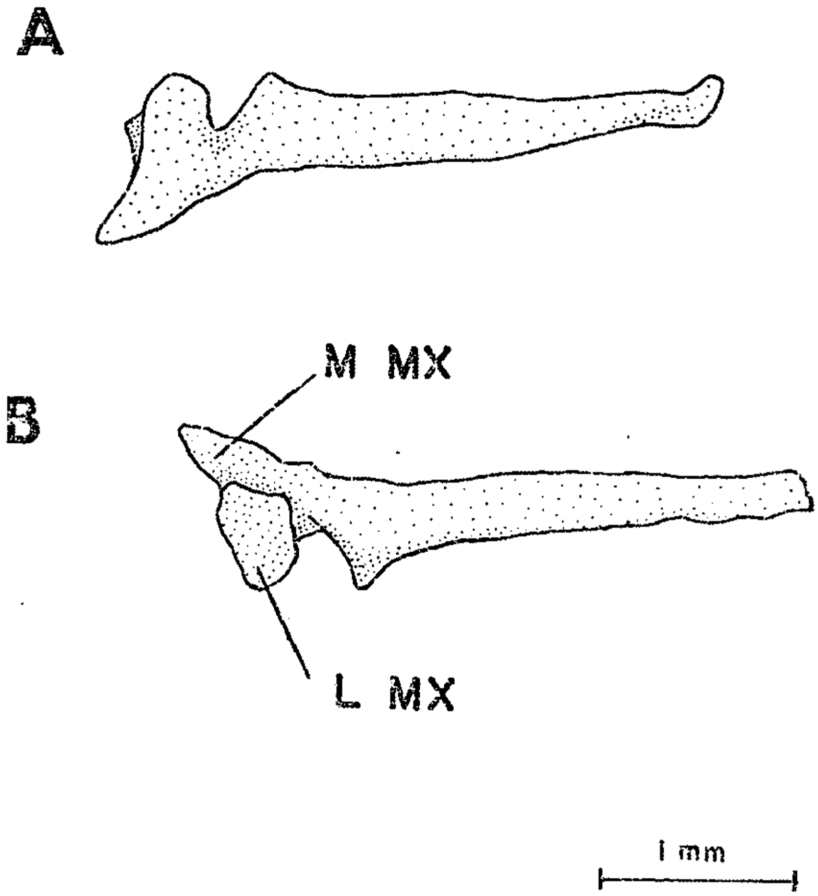

A
M MX
B
L MX
1 mm

Figure 15. Disarticulated bones of *Trypauchenichthys sumatrensis*. A - Palatine. B - Left articular lateral view. C - Medial view of left hyomandibular, interhyal, and preopercle.

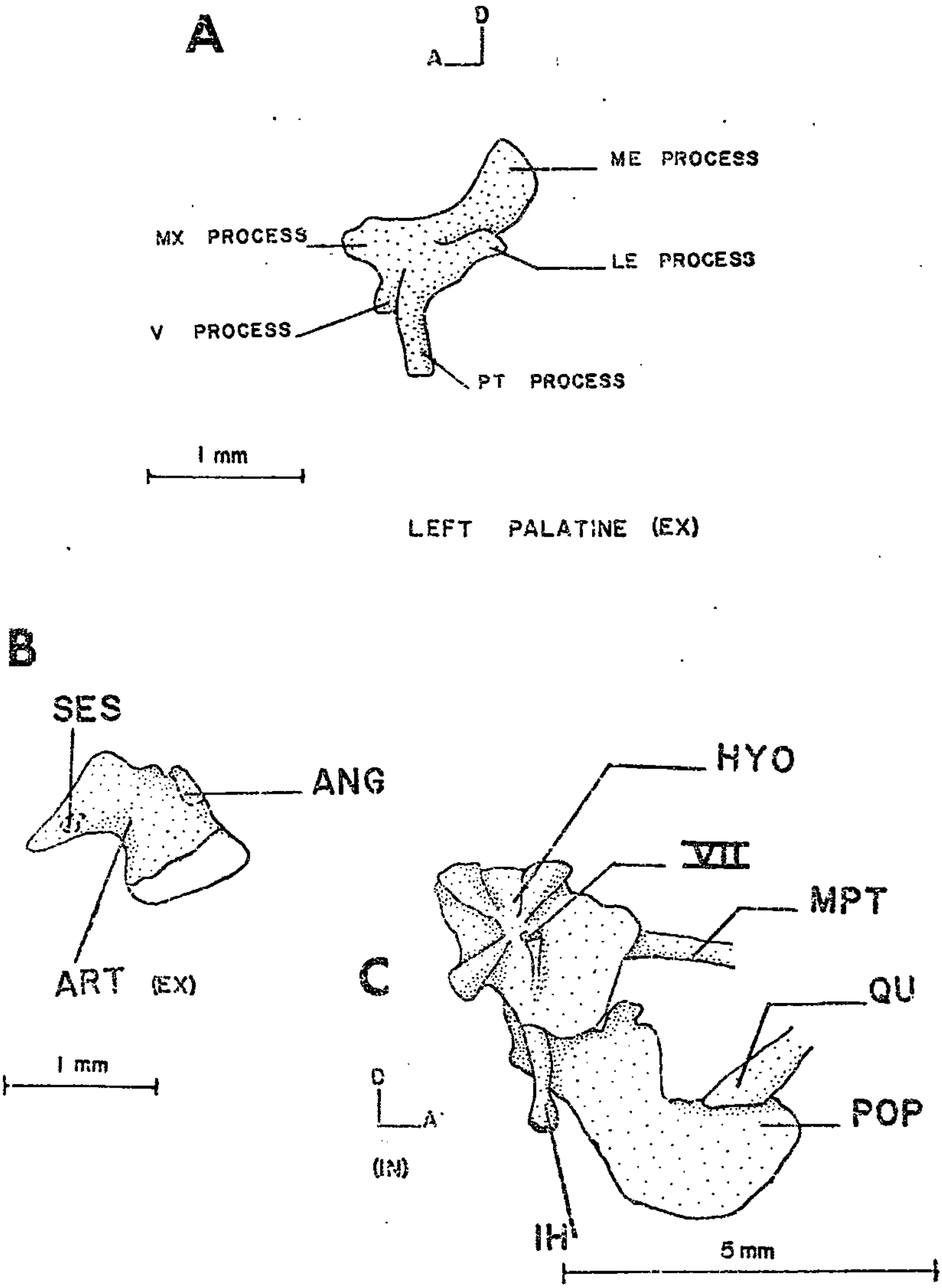

A
D
A
ME PROCESS
MX PROCESS
LE PROCESS
V PROCESS
PT PROCESS
1 mm
LEFT PALATINE (EX)
B
SES
ANG
ART (EX)
1 mm
HYO
VII
MPT
C
QU
D
A
(IN)
POP
IH
5 mm

Figure 16. Articulated suspensorium and opercular bones (left lateral view) of *Trypauchenichthys sumatrensis*.

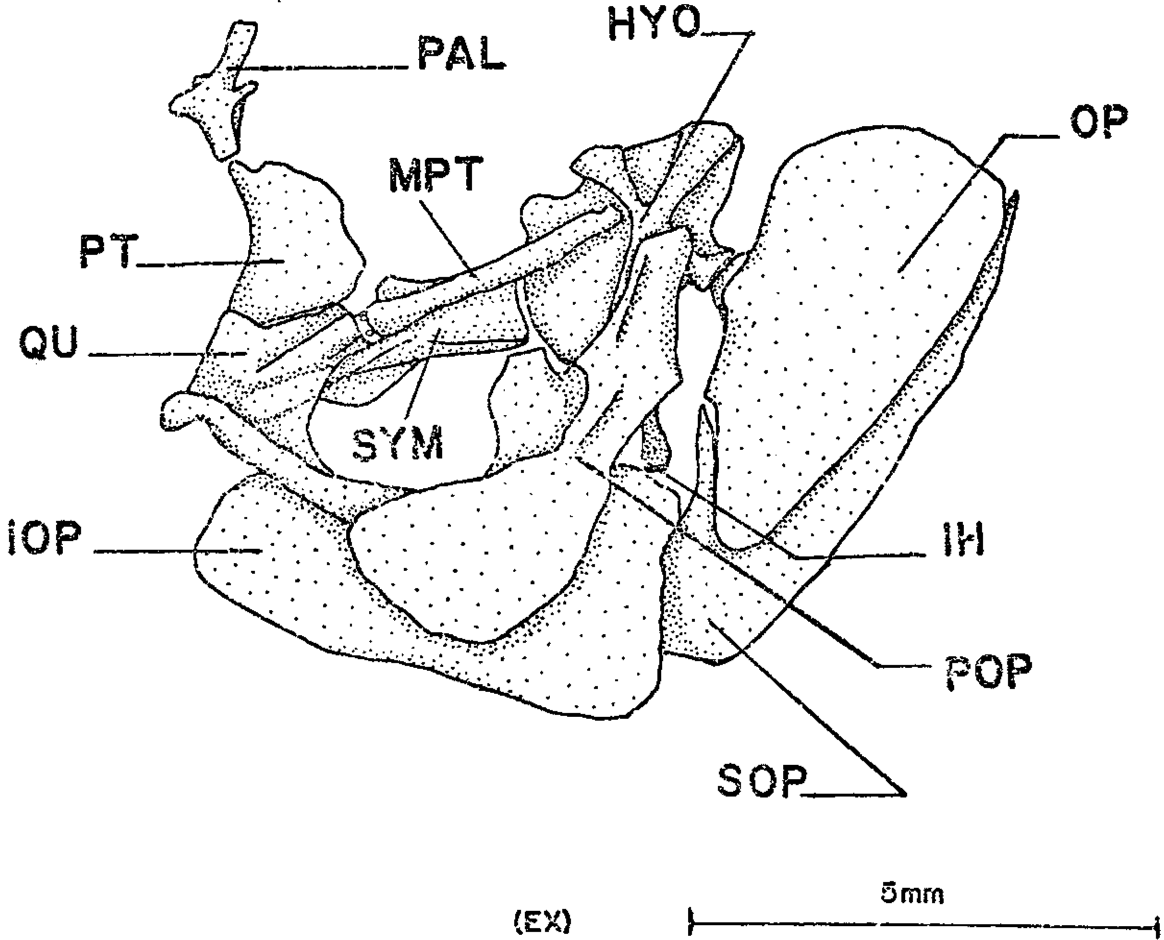
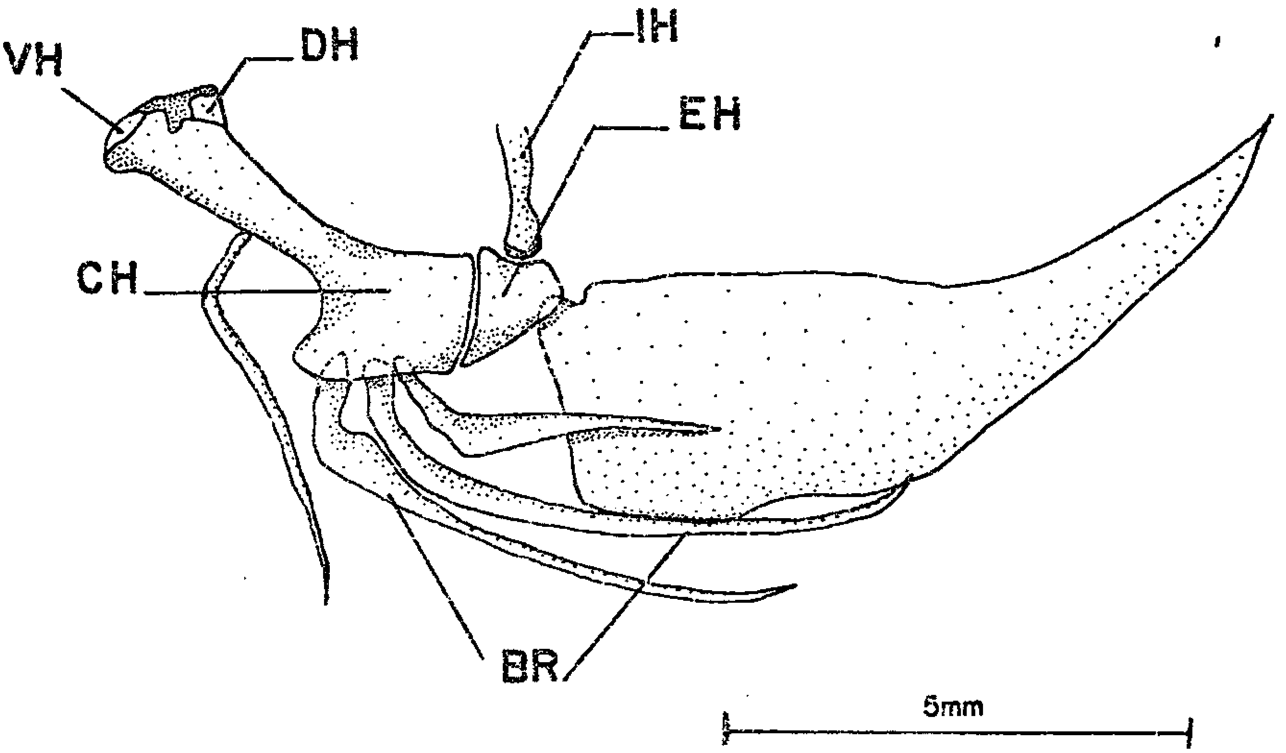

PAL
HYO
OP
MPT
PT
QU
SYM
IOP
IH
POP
SOP
(EX)
5mm

Figure 17. Disarticulated bones of *Trypauchenichthys sumatrensis*. A - Hyal bones (right side, medial view). B - Pelvic girdle (ventral view) and left pelvic spine (lateral view).

A



(IN)

B

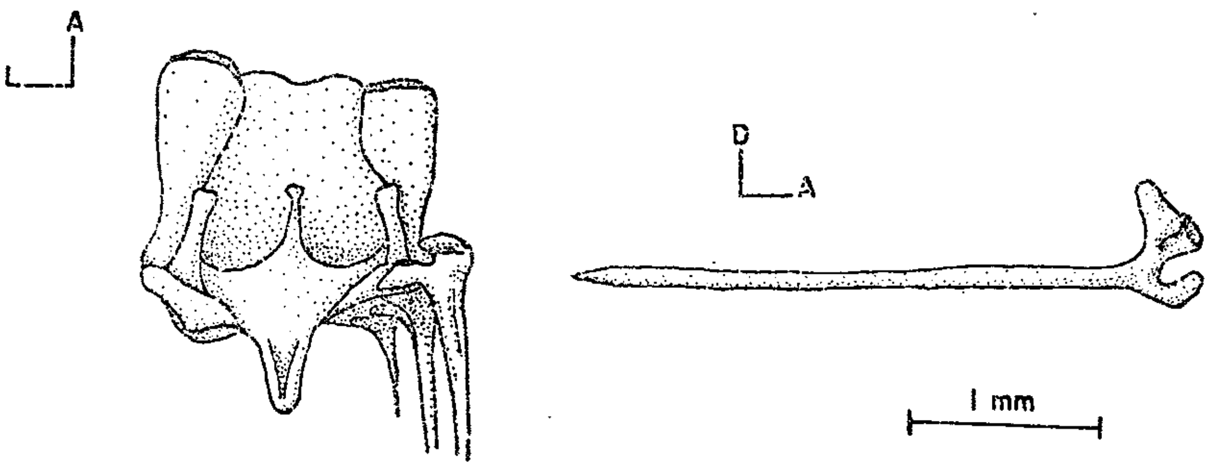
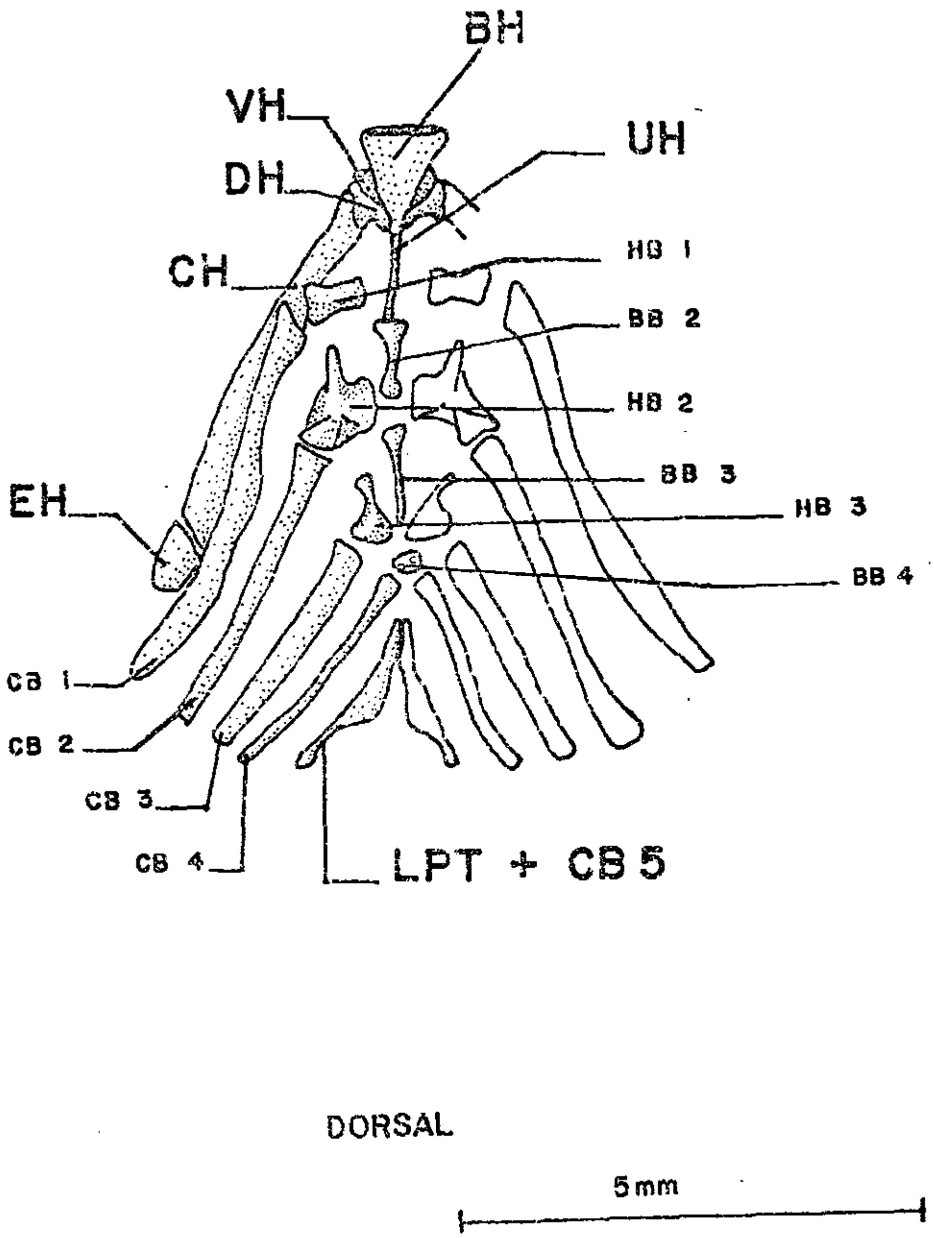


Figure 18. Hyal and lower branchial bones (branchiostegal rays not shown) of *Trypauchenichthys sumatrensis*.


BH
VH
UH
DH
HB 1
CH
BB 2
HB 2
BB 3
EH
HB 3
BB 4
CB 1
CB 2
CB 3
CB 4
LPT + CB 5
5 mm

DORSAL

Figure 19. Upper branchial bones (left side, dorsal view) of *Trypauchenichthys sumatrensis*.

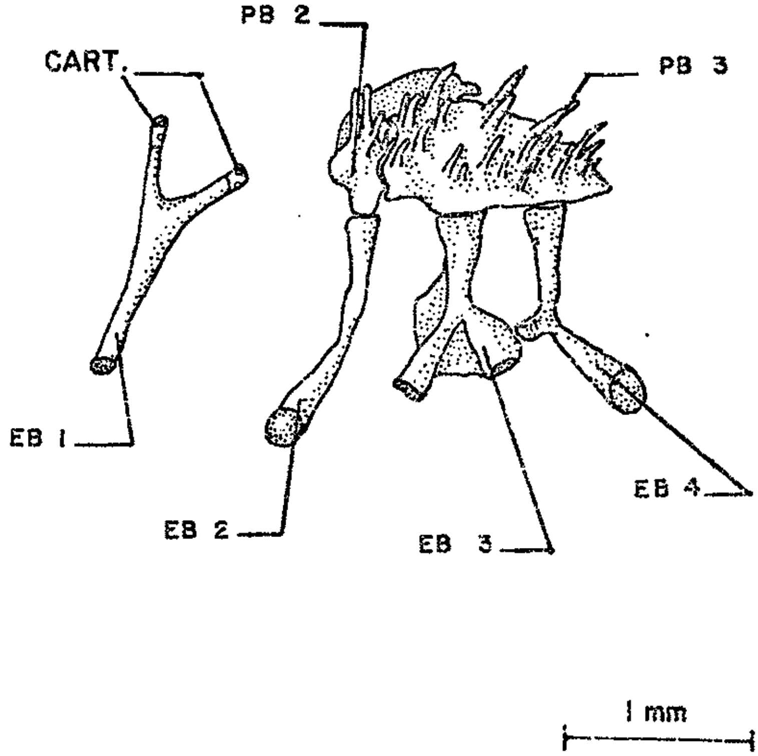
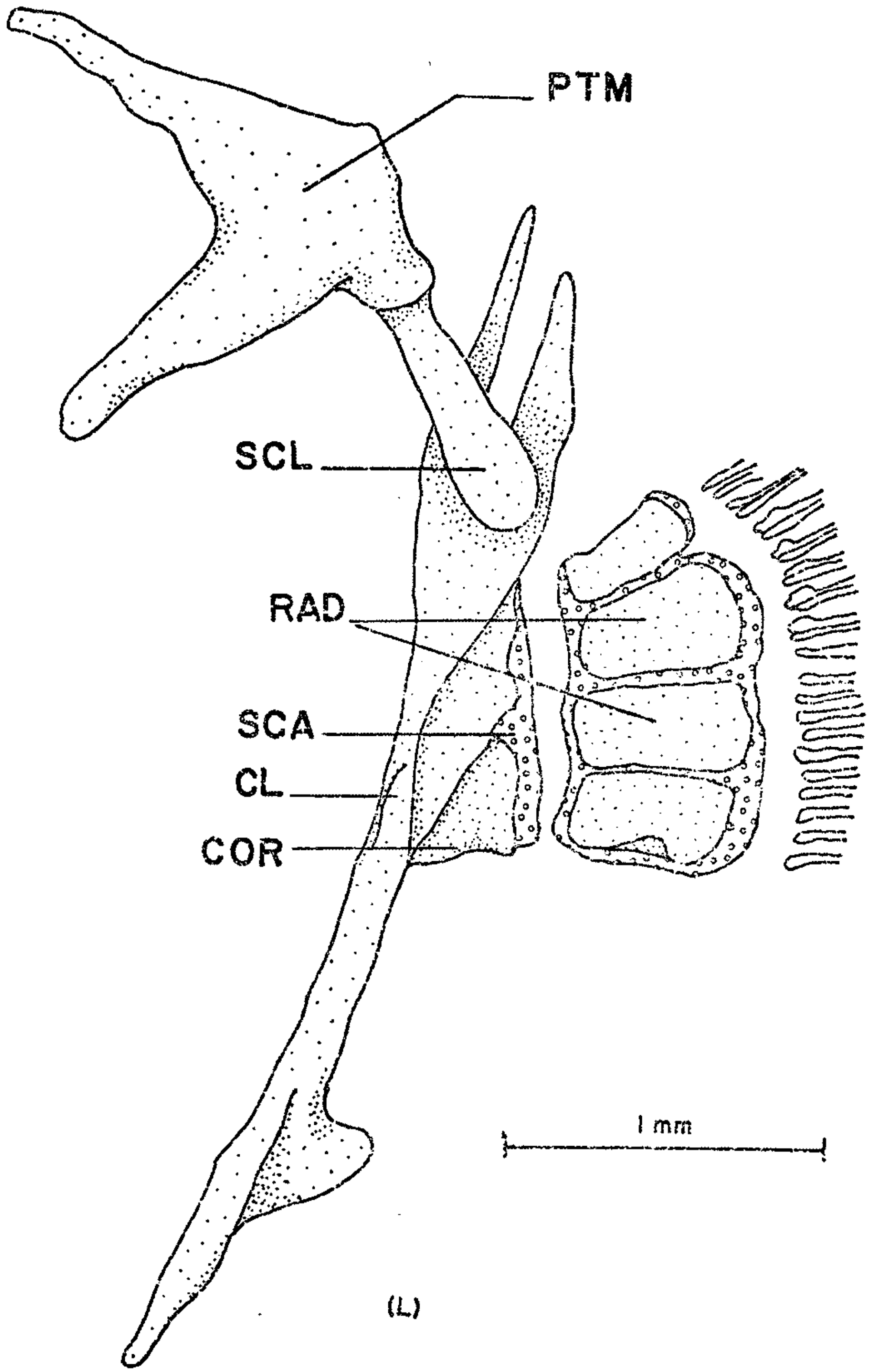

PB 2
CART.
PB 3
EB 1
EB 2
EB 3
EB 4
1 mm

Figure 20. Left pectoral girdle (lateral view) of *Trypauchenichthys sumatrensis*.



(L)

Figure 21. Anterior portion of vertebral column of *Trypauchenichthys sumatrensis*. A - First two vertebrae. B - Vertebrae 3-9.

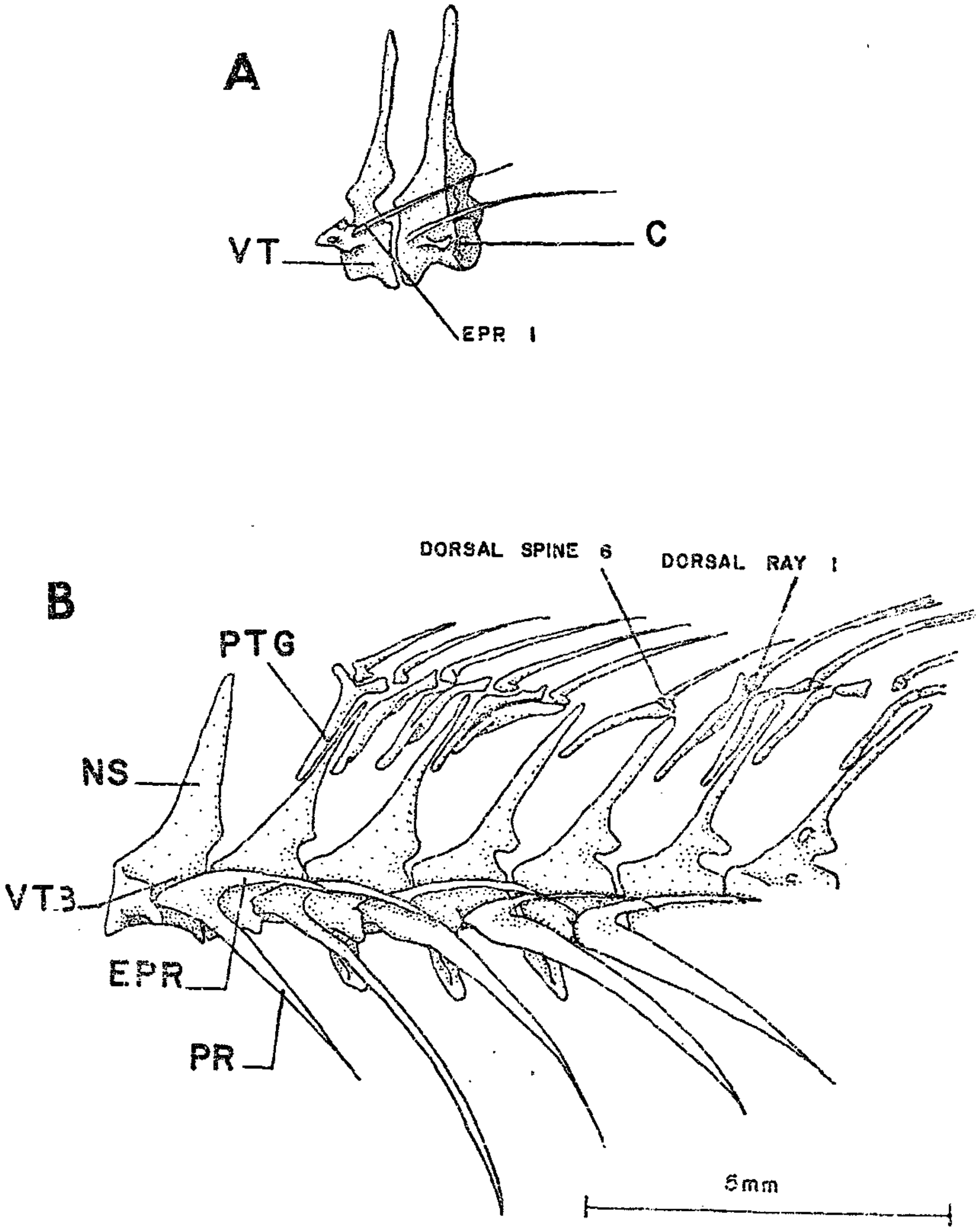

A
VT
C
EPR I
B
DORSAL SPINE 6
DORSAL RAY I
PTG
NS
VT3
EPR
PR
5mm

Figure 22. Posterior portion of the precaudal vertebrae and anterior portion of the caudal vertebrae of *Trypauchenichthys sumatrensis*.

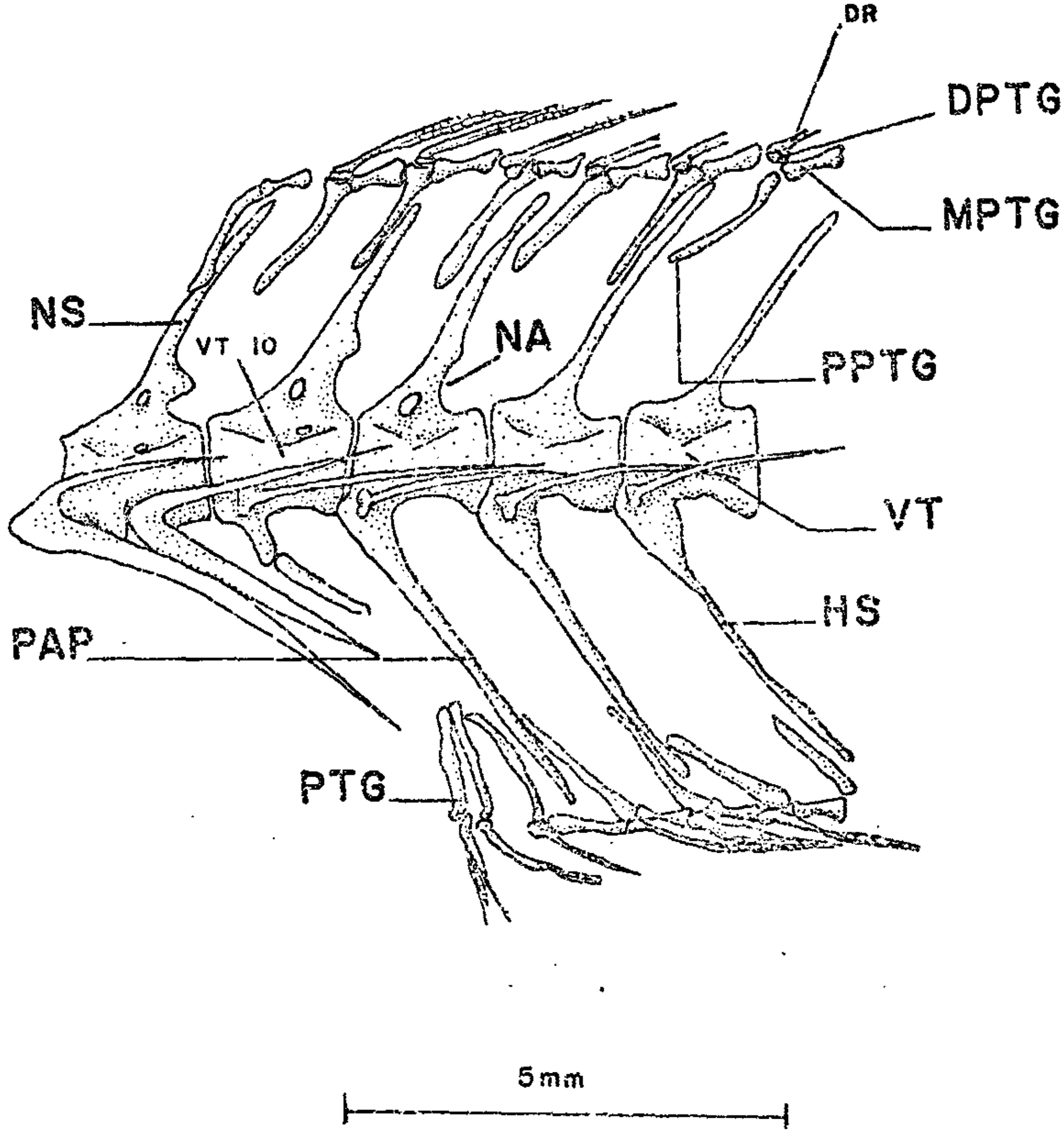
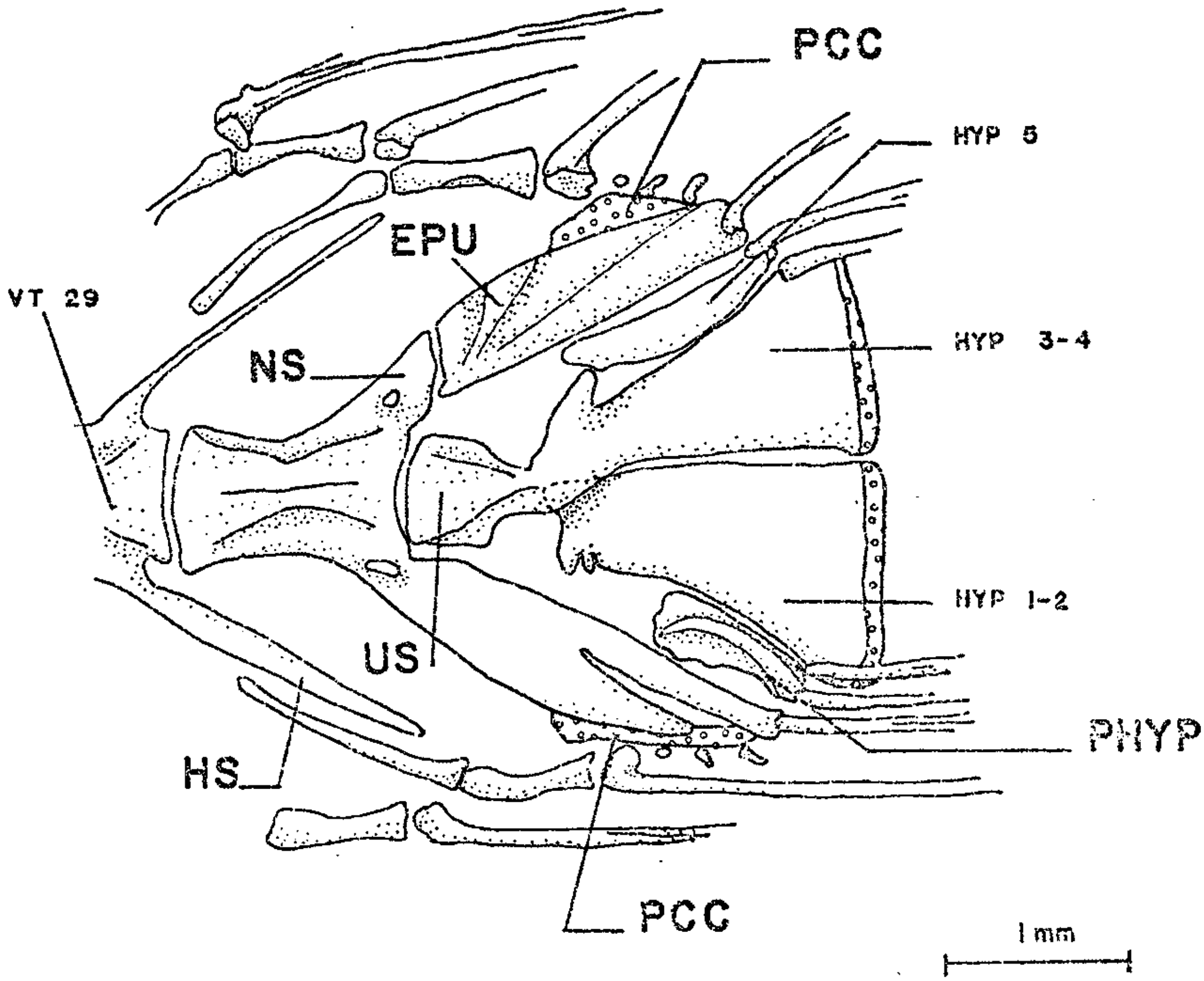

DR
DPTG
MPTG
NS
VT 10
NA
PPTG
VT
HS
PAP
PTG
5 mm

Figure 23. Caudal skeleton of *Trypauchenichthys sumatrensis* (median caudal rays not shown).


PCC
HYP 5
EPU
VT 29
HYP 3-4
NS
US
HYP 1-2
PHYP
HS
PCC
1 mm