UNIVERSITY OF TORONTO

3 1761 00847515 4

UNIV. OF
TORONTO
LIBRARY

2001.
Pisces.

LELAND STANFORD JUNIOR UNIVERSITY PUBLICATIONS
UNIVERSITY SERIES

No. 5

Osteology
of certain
Scombroid Fishes

BY

EDWIN CHAPIN STARKS

Assistant Professor of Zoology

WITH TWO PLATES AND ONE TEXT FIGURE

(Published May 15, 1911)

126887
20/3/13

STANFORD UNIVERSITY, CALIFORNIA

PUBLISHED BY THE UNIVERSITY

1911

1000
1000

CONTENTS.

The Osteology and Relationship of <i>Leiognathus</i> , a genus of Scombroid Fishes	5
The Osteological Characters of the Scombroid Fishes of the Families <i>Gempylidæ</i> , <i>Lepidopidæ</i> and <i>Trichiuridæ</i>	17
The Osteology and Relationships of the Fishes Belonging to the Family <i>Carangidæ</i>	27

Digitized by the Internet Archive
in 2007 with funding from
Microsoft Corporation

THE OSTEOLOGY AND RELATIONSHIP OF *LEIOGNATHUS*, A GENUS OF SCOMBROID FISHES.

BY EDWIN CHAPIN STARKS.

Doctor Boulenger, in his arrangement of fishes in the Cambridge Natural History, has eliminated the family *Leiognathidæ* from among the Scombroïd fishes, where it hitherto has been considered, and has included it in the family *Gerridæ*, a family of more or less evident Percoid affinities.

That Doctor Boulenger had some reason for this decision any one will admit who makes a comparison of the mouth parts of the members of these two families. Comparing then the genus *Gerres* with the genus *Leiognathus*, which are typical representatives of their respective families, we find these parts almost identical. Both have a long mandible, with a concave lower outline, and a small mouth. The ascending limb of the premaxillary is exceedingly long, extending over the top of the head between the eyes and allowing the premaxillaries to be drawn outward or forward to an enormous degree. The posterior tip of the maxillary lies below the preorbital as an ovoid plate. When the premaxillaries are drawn forward the maxillaries are inclined somewhat forward also.

But aside from the mouth parts these genera have little in common. *Gerres* has large scales over the head and body. *Leiognathus* has very fine scales on the body, and the head and breast are naked and covered with silvery skin suggestive of that of the Scombroïd fishes. *Gerres* has a very short anal base; *Leiognathus* a very long one, and the soft rays of both the dorsal and anal fins are arranged each in a step or notch, as in so many of the Scombroïd fishes, indicating a tendency towards a breaking up of the fins into finlets.

The following investigation of the osteology of *Leiognathus* was undertaken (1) to learn its skeletal characters; (2) to compare them with those of *Gerres*; and (3) to ascertain what, if any, its Scombroïd affinities might be.

THE COMPARATIVE OSTEOLOGY OF GERRES AND LEIOGNATHUS.

My material is *Gerres embryx* Jordan and Starks, from Maryland, and *Leiognathus fasciatus* (Lacepede), from Samoa.

The crania in profile and general shape are very similar, but in detail they are not. In *Leiognathus* the supraoccipital extends backwards in a high triangular crest just as it does in the Chætodonts, without extending at all forward over the top of the head. Its upper edge is thick and divided into three longitudinal ridges. On each frontal a high, thick, crest converges backwards to the supraoccipital. In *Gerres* the supraoccipital is simple and extends forward over the frontals. Beneath its anterior end a large conical cavity is formed between the frontals, by a high wing on each frontal curving upward and inward and meeting its opposite fellow at the median line. The long ascending processes of the maxillaries projects into this cavity, while in *Leiognathus* they lie wholly on the upper surface of the cranium.

Both genera have a lateral process projecting back from the middle of the premaxillary, which, however, is common to many forms. This process in *Leiognathus* closes inside of the maxillary, while in *Gerres* it closes outside. The maxillary elements are very similar.

In *Gerres* the suborbital chain of bones is complete, and there is a suborbital shelf present. In *Leiognathus* the suborbital chain is incomplete,* and no suborbital shelf is present. The absence of the suborbital shelf was one of the characters by which Doctor Boulenger defined the family Gerridae (+Leiognathidae). That the character is valueless in this connection is proved by the fact that it is not found in *Gerres cineurus*. In *Gerres brasiliensis* it is present, but not so well developed as in *Gerres embryx*.

In *Gerres* the articulation of the hyoid arch to the suspensory is as usual—the interhyal attached between the lower end of the hyomandibular, and the upper end of the symplectic, which is long and runs along the inner surface of the quadrate in a channel. In *Leiognathus* the articulation is unique so far as known, the interhyal being articu-

*I have long had in mind the question as to whether the suborbital canal was ever present in the adult and the bones undeveloped for its protection. Until now I have always found the bones accompanying the canal; when the canal was absent the bones were. *Leiognathus*, however, proves to have a suborbital canal and the bones not developed around it.

lated to the lower edge of the very short symplectic and the epihyal to the interopercle, as described in greater detail elsewhere in this paper.

Leiognathus has three distinct tooth-bearing superior pharyngeals on each side about equal in size. *Gerres* has two: a very small anterior one, and a very large ovoid one behind it, to which the third and fourth arches are very distinctly attached. There are traces of a suture separating off a small, lunate, posterior portion of this plate, but if this portion represents a third pharyngeal element it is entirely behind the fourth arch and unattached to it. The lower pharyngeals of both genera meet broadly on the median line, but are not at all coalesced.

There is no very important difference between the shoulder girdles of these two genera. In *Gerres* the pelvic girdle is wide as in most of the percoid fishes, but in *Leiognathus* it is deep and compressed, with a wing of bone on each side extending forward so that a deep channel is left between them. This resembles the pelvic girdle of most of the Chætonontoid fishes, and of other deep forms related to the Scombroids.

As might be expected these genera are too closely related to show important differences in the vertebral column. They both have 10 + 14 vertebræ. The parapophyses in *Leiognathus* are larger than in *Gerres*, stand out more prominently, and are unconnected at the base. The last pair are anchylosed, and spread out in a broad trowel-shaped bone about the end of the abdominal cavity. In *Gerres* they are as in most of the Percoid fishes—the last three or four with a bony ridge connecting them in pairs at the bases.

Internally, as externally, the long anal of *Leiognathus* is a noticeable difference. The abdominal cavity is very much shorter, with the first interhæmal and hæmal bones vertical, instead of sloping far backwards as in *Gerres*.

In *Leiognathus* there is a very large baseost at the base of each dorsal and anal ray firmly joined, suturally, to the interspinous bones. In *Gerres* baseosts are present in connection with these rays, but they are small, detached nodules of bone.

On the whole these two forms, aside from the similarity between the mouth parts, have no more in common than most any Percoid fish might have with any Scombroid fish. Hence I propose to recognize the Scombroid family Leiognathidæ and the Percoid family Gerridæ.

RELATIONSHIP TO THE SCOMBROID FISHES.

That *Leiognathus* belongs with the scombroid fishes there can be little doubt. Its external characters and general appearance, which must be considered, point to such a relationship—to the extent, in fact, that it has often been considered as a member of the family Carangidæ. On the other hand it does not resemble in any way the percoid fishes.

It is not, however, a member of the family Carangidæ, nor is it probably very closely related to it. The gill-membranes are connected with the isthmus in *Leiognathus*. In the family Carangidæ they are free from the isthmus. The suborbital chain is incomplete. In the Carangidæ it is complete. The supraoccipital crest does not extend forward. In the Carangidæ it is carried forward by the frontals for the entire length of the cranium. The alisphenoids are in contact. In the Carangidæ they are separate. *Leiognathus* differs further from the members of the Carangidæ in the peculiar attachment of the hyoid arch to the lateral head bones; in the pelvic arch being deep, and in the very protractile premaxillaries.

Where its relationship lies among the scombroid fishes is more difficult to say. It is probably an abbarrent family like so many others in that relationship. The character of its supraoccipital crest, and its deep pelvic girdle may indicate a connection with the scombroid stem near place where the Chaetodontoid fishes branched off.

THE OSTEOLOGY OF LEIOGNATHUS FASCIATUS IN
DETAIL.

SUPERIOR VIEW OF CRANIUM OF LEIOGNATHUS FASCIATUS.

Drawn by C. L. STARKS.

<i>e</i> , ethmoid.	<i>fr</i> , frontal.	<i>p</i> , parietal.	<i>soc</i> , supraoccipital.
<i>eo</i> , exoccipital.	<i>n</i> , nasal.	<i>pf</i> , prefrontal.	<i>v</i> , vomer.
<i>epo</i> , epiotic.	<i>op</i> , opisthotic.	<i>pt</i> , pterygoid.	

On each frontal, beginning at the anterior outer edge just behind the prefrontal, is a high, thick ridge which converges backwards with its fellow of the opposite side, and is continuous with the lateral ridge

of the supraoccipital crest. These and the median supraoccipital ridge are finely sculptured on their upper edges, and in the undissected specimen are externally visible, being covered only with very thin skin. Between the frontal ridges there is a broad median area depressed below the level of the supraorbital region on the outer side of the frontal ridges. From the sphenotic a sharp ridge curves upward to the posterior end of the great frontal ridge, joining it near its union with the lateral ridge of the supraoccipital crest. In the base of the lower end of this ridge is the opening of a sensory tunnel, which curving upward and backward pierces the great frontal ridge, and opens at the posterior end of the frontal near the supraoccipital. This sensory tunnel is in continuation with the suborbital and pterotic tunnels, and also with the frontal tunnel, which runs forward traversing longitudinally the great frontal ridge and thence the nasal.

The supraoccipital extends back in a high triangular crest without either extending forward over the frontals, or being in continuation with a median frontal ridge. Following its entire upper contour on each side is a lateral ridge, which is in continuation with the high ridge on each frontal as described above. Posteriorly the supraoccipital extends down over the exoccipital suture, but it does not reach to the foramen magnum.

The exoccipitals meet both above and below the foramen magnum, and their vertebral articular fascets are nearly in contact above the basioccipital. Each bears three foramina more or less in a horizontal line. The middle one, the vagus foramen, has two smaller foramina close beside it, and the anterior one, the glossopharyngus foramen, is only partially contained by the exoccipital, being between that bone and the prootic. The posterior one, the foramen of the occipital nerve, is situated on the ridge that runs forward from the exoccipital condyle to the pterotic crest.

The whole lower posterior part of the basioccipital is occupied by a very large opening to the myodome, filling the width of the bone and leaving its side walls thin. From the upper posterior edge of the basioccipital is a sharp ridge running downward and forward to its lower edge just in front of the posterior opening to the myodome. Between this and the basioccipital condyle are some pits ending blindly, but resembling neural foramina.

The parasphenoid bears a thin median keel below, behind which is a saddle-shaped notch where on each side the first toothless pharyngeal lies. Just back of this is a swollen knob for the support of the other superior pharyngeals, and still farther back, extending under the knob,

is a deep conical cavity with its apex pointed forward, just as in the genus *Gnathanodon* and in several members of the family Scombridae, only the myodome does not open into its side, as it does in the Scombridae. The parasphenoid extends a little behind the front of the posterior opening to the myodome in a little sliver of bone on each side, but it does not reach nearly to the basioccipital condyle. A broad wing is developed upwards along the prootic on each side of the myodome and is strengthened by a lateral ridge continuous with a sharp thin ridge on the prootic and the outstanding wing of the sphenotic. As the prootics and the lower edges of the basioccipital end abruptly against the parasphenoid, without curving inward at all toward each other, the parasphenoid forms the entire lower floor of the myodome.

Through the lateral wing of the prootic is a rather long tunnel—the trigemino-facialis recess, running from the middle of the preorbital surface of the bone forward, and opening on the orbital surface. A foramen opens into this recess at about its middle on the postorbital surface just below the articular cup of the hyomandibular.

The alisphenoids meet and divide the anterior opening of the brain case into two parts—a lower round part, and an upper, much larger, triangular part.

Bordering the posterior half of the lower opening is the basisphenoid. It is connected with the prootic roof of the myodome for its full width without an opening between. It sends down a long process to the parasphenoid.

The sphenotic stands outward in a very prominent lateral wing behind the eye, and is continuous with the frontal supraorbital border. To its outer edge is attached one of the suborbital sensory tube bones, which reaches upward to the frontal.

The opisthotic is almost wholly on the inferior surface of the cranium, though a portion of its thickened posterior end is visible from above. It covers the pterotic-exoccipital suture, and no part of it is interposed between the pterotic and exoccipital. The broad lower limb of the posttemporal is firmly attached to it without the intervention of a ligament.

The parietals are widely separated by both the supraoccipital and the posterior points of the frontal which project backwards. They are situated just above and anterior to the epiotics. Each is in outline an irregularly round bone, and is traversed by a sharp wing running from just behind its middle upward to where the frontal joins the supraoccipital ridge.

The epiotic is round in outline and elevated at its middle where the posttemporal broadly and firmly articulates with it. It sends back a thin horizontal shelf.

The pterotic bears a wide ridge running obliquely upward from its posterior end to the posterior end of the frontal. It bears a sensory channel which is inclosed as a tube along its lower half, and is a deep open canal along its upper. At its upper end this is in communication upward with the frontal system of sensory tunnels, and downward along the sphenotic with the suborbital system. At its lower end it communicates backward through the supratemporal with the lateral line along the side of the body, and downward with the preopercular system.

The prefrontals are not in contact with each other, though they are separated only by a small area of cartilage—apparently an unossified part of the ethmoid cartilage. Each is pierced by the olfactory foramen. Near the upper end of each are two blunt spines, and the lower end is a facet for the articulation of the palatine. The spines are apparent externally through the skin in the undissected specimen.

The ethmoid lies between the prefrontals and the anterior end of the frontals, separating the latter for a considerable distance. It may be seen from below forming part of the orbital roof. In its anterior part, on the superior surface of the cranium, an area of cartilage extends forward and is continued along the posterior half of the vomer. This in the dried skeleton shrinks and leaves an open channel.

The vomer is toothless and ends below at its anterior end in a double point.

The nasals are slender, crooked bones continuing the sensory tube from the frontals and carrying it forward.

The suborbitals are represented by a preorbital plate and by some thin, delicate bones behind the eye, but the chain is incomplete below the eye. A long slender one extends up the side of the sphenotic, carrying the sensory tube up to the frontal, where it communicates with the pterotic sensory tube and with the frontal tube.

The supratemporal is an inverted T-shaped, tube-bone, its horizontal branch continuing the lateral line to the pterotic sensory tube, its vertical branch running upward to the top of the head at the side of the supraoccipital just under the skin. Thence it runs backward along the side of the supraoccipital spine nearly to the interneurals, resembling the auxiliary branch of the lateral line common to many flounders.

The hyomandibular is a long, rather simple bone, with a process behind for the articulation of the opercle, and without a process to the

metapterygoid. Its lower end is at a considerable distance from the symplectic.

The palatine is firmly articulated to the lower edge of the prefrontal, and bears a process which hooks over the maxillary.

The symplectic is a short, small, triangular sliver of bone occupying a notch in the posterior angle of the quadrate. On its lower edge not far from its posterior end is a cup-shaped cavity for the reception of the interhyal.

A well developed angular is present and forms the lower posterior angle of the articular. The articular and dentary are loosely attached to each other so that they are slightly independently movable in the undissected specimen. The tooth-bearing portion of the dentary does not reach nearly back to the middle of the upper edge of the bone, which in most forms is completely toothed. The gape of the mouth is restricted to this portion, while the posterior portion is covered by the end of the premaxillary upon which it hinges. Hence the lower jaw attached at its posterior end as usual, and the premaxillary attached to it in front of its middle, the fish can only open its mouth by projecting the long premaxillary processes forward from their sheath. In most fishes the maxillary elements if attached at all to the lower jaw are attached so far back, or so loosely, that the opening of the mouth only effects the posterior end of them at the most. There are many examples of intermediate conditions between those described above. The mouth of *Capros* and of many fishes of the family Chætodontidæ approaches rather closely the condition of *Leiognathus*.

The maxillary is a complex-shaped bone, shaped roughly like the figure 3. It meets its fellow above the premaxillary process, and nearly meets it below, thus forming a sheath in which the process moves.

A small, round nodule of bone represents the interhyal. It is rather firmly bound down to the epihyal by tissue. It fits into the cup-shaped cavity in the lower edge of the symplectic remote from the hyomandibular, instead of between the hyomandibular and the symplectic as is the usual arrangement. But the chief articulation of the hyoid arch to the lateral head bones is through the interopercle. This element is thickened along its upper edge, and about midway in its length is a prominent facet, partly sunk below the surrounding surface of the surrounding bone and partly raised above it. To this the posterior end of the epihyal is firmly articulated by a specialized articular facet. The hypohyals are paired on each side. A glossohyal and urohyal are present, the latter with wings standing out horizontally from its lower edge.

There are three tooth-bearing superior pharyngeals on each side.

The inferior pharyngeals are broadly in contact but are not co-ossified. Just in front of them the ceratobranchial of the fourth arch becomes compressed and as thin as paper. The hypobranchial of the last arch is missing. Two basibranchials are ossified.

The clavicle extends far below and anterior to the lower end of the hypocoracoid, as it does in members of the family Scombridæ. Its lower end is broad and rounded. At the middle of its length a thin, vertical plate extends inward, nearly meeting its fellow of the opposite side, and forming a partition behind the branchial cavity. At the outer edge of the clavicle are two triangular projecting points, which show prominently just under the gill cover of the undissected specimen. A process is developed backward from the upper edge of the clavicle for the suspension of the postclavicle.

The hypocoracoid is small, and arches away from the clavicle to rejoin the latter at its lower end, inclosing a space between as is usual.

The hypercoracoid is pierced at its middle by a large, round foramen, but this element sets so far behind the clavicle that the clavicle appears to bound the foramen at its anterior edge when viewed from the outer surface of the shoulder girdle.

The actinosts increase in size downward, and have a small hole between each pair. The upper edge of the pectoral works directly on the edge of the hypercoracoid. Two of the actinosts are on the hypercoracoid and two on the hypocoracoid.

The postclavicle is in two parts—the lower part lance-head-shaped and a little wider than usual.

The post-temporal is rather widely forked, and joined to the cranium without the intervention of ligaments on either fork. The supraclavicle is present below it.

The pelvic girdle is attached closely between the clavicles. From the base of each ventral spine a long spine projects forward just beneath the skin of the breast, and is stiffened above by a wide web of bone between it and the main part of the girdle, thus inclosing between them a deep cavity at the front of the girdle. Posteriorly above the ventral fins each part of the girdle sends back a stout spine which is suturally united with its fellow into a single spine.

At the base of each anal and dorsal ray is an exceedingly large baseost. Each of these is firmly united by suture to two interspinous rays, so that each of the latter bears two halves of a baseost. These project outward between the rays making the steps or notches into which the rays fit that are referred to at the beginning of this paper.

The baseosts are not evident at the bases of the anal and dorsal spines—probably becoming co-ossified with the interspinous bones. An auxiliary interneural is in front of the first spine-bearing interneural.

There are ten abdominal and fourteen caudal vertebræ, including the hypural.

Anteriorly the neural processes are wide—nearly as wide as the length of their vertebral centra, and each is channeled on its anterior edge to receive the edge of the next preceding neural process. Posteriorly they become more slender and wider apart. They nearly coincide in number with the spine-bearing interneurals, but they are only half as numerous as the ray-bearing ones, as are also the hæmal processes as compared with the interhæmal rays.

The first developed parapophyses occur on the fourth vertebra, though a rudimentary pair is present on the third. They gradually become longer posteriorly to the last pair, which are expanded into a broad, trowel-shaped shield united to each other at the median line and inclosing the end of the abdominal cavity. The parapophyses are not connected by a transverse bridge across the base of each pair.

Inferior and superior zygapophyses are well developed. The interspinous bones of two vertebræ anterior to the hypural assist in supporting the caudal.

The first two vertebræ have epipleurals only. Anteriorly the epipleurals are attached to the bases of the ribs, but posteriorly they creep up to the vertebral centra. They are present behind the abdominal cavity for a considerable distance.

THE OSTEOLOGICAL CHARACTERS OF THE SCOMBROID FISHES OF THE FAMILIES GEMPYLIDÆ, LEPIDOPIDÆ AND TRICHIURIDÆ.

BY EDWIN CHAPIN STARKS.

The descent of the family Trichiuridæ from the Gempylidæ through the Lepidopidæ was long ago pointed out, and the following results of an osteological comparison between these families only go to strengthen the evidence in favor of this relationship, though the descent is not in a direct line, if we can take *Promethichthys* as a typical representative of the family Gempylidæ.

Promethichthys is more closely related to *Scomber* than to any other existing genus of the family Scombridæ, or at least *Scomber* has retained more ancestral characters of *Promethichthys* than any other member of its family has. These two genera are alike in the character of the cranial crests; in having the opisthotic at the lower surface of the cranium not separating the exoccipital from the pterotic; the suborbital ring complete and bearing a sensory tube; and the caudal peduncle without a lateral keel.

That *Lepidopus* and *Trichiurus* did not come, however, directly from *Promethichthys*, but from some form that has begun to develop in the direction of *Scomberomorus*, is shown by the opisthotic interposed between the exoccipital and the pterotic, and the incomplete suborbital ring and sensory tube. This ancestor may have been *Gempylus*, a form I have been unable to obtain, but showing a development towards the elongate forms of *Lepidopus* and *Trichiurus*.

In view of the extremely close osteological resemblances between the families Lepidopidæ and Trichiuridæ it is with much hesitation that the former family is recognized here. The former family differs from the latter chiefly in the possession of a caudal fin, but when it is considered that this fin, in *Lepidopus*, though well developed, is not very strongly supported, and being at the end of a long, weak, ribbon-shaped body, is probably of little assistance, its loss does not appear of great importance.

The three families here considered differ but little from the family Scombridæ. The eye has no bony sclerotic case, there are no separate bony baseosts, and the caudal rays are not deeply divided at the base to receive the hypural plate.

These three families have the following characters in common: prefrontals meeting at the median line, with the ethmoid appearing nowhere between them posteriorly; alisphenoids separated from each other; supraoccipital extending over the epiotic suture, but not separating epiotics as viewed from within the cranium; myodome and basisphenoid present; the latter with a descending process; eye without a bony sclerotic case; ascending processes of premaxillaries not developed; supplementary maxillary present; teeth in alveoli; coracoid suture ending at middle of third actinost from top; head of hyomandibular divided into two parts; symplectic joined to metapterygoid by a dentate suture; three pairs of tooth-bearing pharyngeals present; the anterior basibranchial remote from the first hypobranchial; anterior ribs and epipleurals attached to vertebral centra; caudal rays, when present, not deeply divided.

The principal characters that differentiate these families is shown in the following synopsis:

GEMPYLIDAE (*Promethichthys*)

The pterotic and temporal crests coterminous against an oblique ridge from the supraoccipital; myodome opening posteriorly through a rather broad foramen; opisthotic on lower surface of cranium not separating the exoccipital from the pterotic; suborbital ring complete and with a sensory tube; pelvic bones attached between clavicles; no parapophyses present, but hæmal arches developed behind middle of abdominal portion of vertebral column; no sharp ridge along the side of vertebræ; ribs anteriorly in pits on centra, posteriorly at tips of abdominal hæmal spines with their bases in contact as in the family Scombridæ; body incased in two series of intermuscular rays, the upper series composed of epipleurals.

LEPIDOPIDAE (*Lepidopus*)

The temporal crest ending as in *Promethichthys*, but the pterotic crest ending against middle of temporal crest; myodome opening posteriorly through a very small pore; opisthotic partly on superior surface of cranium, and separating exoccipital from pterotic for a con-

siderable distance; suborbital ring not complete, and without a sensory tube; pelvic bones represented by a pair of long, simple rays lying free just beneath the skin remote from the shoulder girdle; no abdominal hæmal arches present; small, slender parapophyses present on last two vertebræ; a sharp keel running along side of vertebræ for nearly whole length of vertebral column; body not incased in rays of bone, and only four or five epipleurals present anteriorly.

TRICHIURIDAE (*Trichiurus*)

Skeleton differing from *Lepidopus* in having no pelvic bones (not represented in all Lepidopidæ); in having the tail taper to a point which is without hypural bones or caudal fin; and in having the weak anal reduced to short, stiff spines.

In the following descriptions the osteology is given in detail.

PROMETHICHTHYS.

A specimen of *P. prometheus* from the Canary Islands, 17 inches in length.

The cranium is elongate and the preorbital portion is somewhat produced. The crests and ridges on the superior surface form a complicated pattern, but in general resembling those of *Scomber*, having an oblique ridge from the supraoccipital against which the temporal and pterotic crests stop. This ridge is forked in front of the temporal crest, and the inner branch runs forward to the ethmoid, while the outer reaches the edge of the cranium above the front of the eye. The myodome opens through a round foramen posteriorly. The occipital region is not produced as in *Scomber*.

The exoccipitals meet broadly over the basioccipital, and have large condyles overhanging the latter. The supraoccipital extending down over the suture between the epiotics and the upper part of the exoccipitals appears from the exterior to separate them, though both the epiotics and exoccipitals meet for their full length within the cranium as in the *Scombridae*.

The supraoccipital crest is but little developed. It is considerably behind the eye and not very far anterior to the occipital condyle. It is not formed at all by the frontals anteriorly, and scarcely rises above the level of the temporal crests. It has no sharp apex directed upward as in *Lepidopus*.

The basisphenoid is present and has a descending process to the parasphenoid. The alisphenoids are widely separated by the anterior opening to the brain cavity. The prefrontal is elongate and meets its fellow of the opposite side at the median line in front of the orbital cavity. It has the usual lateral wing which is pierced by the olfactory nerve and supports the posterior end of the palatine below. In front of the prefrontal a lateral protuberance is formed by the vomer and ethmoid and extends up nearly to the frontal. The vomer is obliquely truncate on each side for the articulation of the maxillary. The opisthotic is on the lower surface of the cranium covering the exoccipital-pterotic suture, and scarcely showing on the superior surface. To its posterior edge the lower limb of the post-temporal is attached.

The nasals are rather wide and are attached to the front of the frontals and ethmoid. They are produced anteriorly in front of the ethmoid over the maxillary. The preorbital is long and carries a sensory tube in continuation with that of the suborbitals. The suborbitals are little more than a chain of small bony tubes, but they form a complete suborbital ring. There is no suborbital shelf, and the eye is not incased in a bony sclerotic cup.

The premaxillary bears only a slight suggestion of an ascending process. The maxillary carries a long, narrow, supplementary maxillary along its upper edge. The anterior inner end of the maxillary has a conspicuous fascet for articulation with the vomer. The teeth on the side of the premaxillary are set in alveoli, but the long lance-like canines, forming a short inner row in front, though developed from cavities are of a different character, as the cavities behind them become filled with "bone of attachment" as the teeth are pushed out.

The head of the hyomandibular is divided into two parts, though a little less completely than in the Scombridæ. The opercular elements are not so smoothly united to each other. The upper part of the symplectic is united to the metapterygoid by a dentate suture as in *Sarda* and *Thunnus*. The palatine is armed with a single row of small sharp teeth, and anteriorly the usual process extends over the maxillary. The articular entirely fills the notch in the dentary; a small angular is present. The teeth at the side of the dentary resemble those of the premaxillary, but one or two teeth at the front are apparently of the character of the inner premaxillary row.

The posttemporal is a slender, widely forked bone. Its upper limb is rather solidly attached to the epiotic, and slightly overlaps the parietal, but it does not impinge on the supraoccipital as in some of

the Scombridæ. Its lower fork is attached to the posterior edge of the opisthotic. A well developed supraclavicle is present. Above the pectoral the clavicle is bent at a considerable angle, allowing the body of the shoulder girdle to extend forward even more horizontally than in the Scombridæ. The hypocoracoid foramen is large and at the center of the bone. The hypocoracoid differs from that of the Scombridæ in reaching downward to the end of the clavicle. The actinosts are a little longer and more slender than in *Scomber*, but arranged the same in relation to the coracoid elements, the third from the top being opposite the coracoid suture. There is no wing from the clavicle above the pectoral fin to support the postclavicle. The superior element of the postclavicle is very short and firmly attached to the clavicle; the inferior element is long, slender and slightly expanded below, the two portions appearing as a single piece.

The pelvic girdle is very long and slender, extending forward to between the clavicles and attached in the way usual to thoracic ventrals.

As in the Scombridæ, there are three basibranchials; the anterior one remote from the hypobranchial of the first arch. Four pairs of superior pharyngeals are present; the first toothless; the second long and narrow and lying beside the third; the third the largest; and the fourth in line behind it, and lying so close that the third and fourth form an almost continuous tooth patch, though they are not so closely connected as in the Scombridæ.

The glossohyal and urohyal are both present; the latter without lateral ridges. A pair of very large hypohyals are present on each side; a long ray of bone from the ceratohyal extends under them to support the anterior branchiostegal ray. Four branchiostegal rays are upon the ceratohyal and three upon the epihyal.

There are 20 abdominal vertebræ and 13 caudal, or a total of 34 with the hypural. There are no parapophyses, but on the 11th vertebra there is a small, round, hæmal arch, formed by connected parapophyses, as in the Scombridæ. It is without a spine, is inclined forward, and is longitudinally flattened. Posteriorly the abdominal hæmal arches gradually develop a spine and incline backward. The ribs are set in sockets anteriorly low on the centra of the vertebræ, and posteriorly are carried at the tips of the hæmal arches, each pair with their bases in contact as in the Scombridæ. Each rib or hæmal arch is placed almost directly at the middle of the vertebra. The neural arches are more posterior, but still at some distance from the ends of the vertebræ.

Two series of long, slender bones lie just beneath the skin and incase the body, one series above and one below the middle of the side. The upper series is composed of the epipleurals, which curve outward to the skin and then upward nearly to the dorsal. The lower series is an extra intermuscular ossification, and is perhaps not present in the young, as is the case with a similar ossification in the genus *Chanos*. The first two vertebræ bear epipleurals only. On the third vertebra and some of the succeeding ones the epipleurals and ribs join the vertebræ together, with their bases connected, but a short distance back the epipleurals lose all connection with either ribs or vertebræ and lie loose in the intermuscular connective tissue. The last two or three vertebræ are as in *Scomber*, not abruptly shortened as in most of the Scombridæ. There is no trace of a lateral caudal keel. The hypural bears a large urostyle.

The upper ends of the interneurals of the spinous dorsal are laterally expanded, and probably represent the anchylosed baseoste. No separate bony baseoste are present in any of the fins. The bases of the caudal rays are not deeply divided, nor are the rays widely divergent as in most of the Scombridæ.

A skiograph of *Epinnula magistralis* from a specimen in the U. S. National Museum shows the number of vertebræ to be 15 + 17 (counting the hypural); the ribs are borne at the tips of the abdominal hæmal spines; the body is not incased in a series of intermuscular rays, as in *Promethichthys*, and the ventral fins are attached to slender pelvic bones which extend between the clavicles.

LEPIDOPUS.

A specimen of *L. caudatus* from the Canary Islands, measuring 3 feet in length.

In this form the supraoccipital crest is far anterior to that of *Promethichthys*. As viewed from the side of the eranium it rises as a stout triangular process far above the rest of the skull, with its sharp apex directed upward. It is over the posterior part of the orbital cavity, or nearly a fourth of the distance from the occipital condyle to the tip of the vomer. The frontals form the anterior part of it. The ridges, which in *Promethichthys* are low, and run from the front of the supraoccipital obliquely to intercept the temporal crest in *Lepidopus*, are high, sharp ridges, starting at the apex of the supraoccipital crest and running more directly forward. Deep between them is a small median ridge representing the front part of the supraoccipital crest.

Instead of the pterotic and temporal crests being coterminous anteriorly, the latter ends against the middle of the former, which continues alone to the ridges from the supraoccipital. The epiotics meet very broadly behind the supraoccipital, but a thin sheet of bone from the supraoccipital extends over the median suture between them and reaches down to the exoccipitals. The sheet of bone is so thin and transparent that it is difficult to see it, and the outline of the epiotics is clearly to be seen through it. The ethmoid is not at all posterior to the front of the vomer. The lateral process of the parasphenoid ends as a free point nearly reaching the alisphenoid. The opisthotic separates the exoccipital from the pterotic to a considerable extent, and the lower limb of the posttemporal is attached to its superior surface a little before its posterior edge. The myodome is nearly closed posteriorly. With these exceptions the cranium is very similar to that of *Promethichthys*.

The suborbital ring is incomplete posteriorly, and there is a suborbital shelf loosely attached to the bones anterior to it. The preorbital is large and traversed by a sensory tube, which is not in continuation with the suborbitals.

The maxillary and teeth are essentially as in *Promethichthys*. The middle portion of the maxillary projects behind in a thin wing, and the supplementary maxillary is not very large.

The head of the hyomandibular is widely divided into two portions. The opercle and subopercle are made up posteriorly of radiating rays of bone, which stand apart like bristles when the tissue connecting them is removed. The symplectic is suturally connected with the metapterygoid, and all of the lateral head bones are almost identical with those of *Promethichthys*.

As the cranium extends backward below the upper limb of the posttemporal farther than in *Promethichthys*, the lower posttemporal limb is not in consequence so long. A tube bearing supratemporal is present.

The portion of the clavicle above the pectoral fin is nearly as long as the portion below, and is turned at a right angle to the latter. The hypocoracoid is thin and much produced backwards. The actinosts are shorter than in *Promethichthys*, but arranged the same in reference to the coracoid elements, and the arrangement of the postclavicle is the same.

The pelvic bones are long, simple rays, lying just beneath the skin, remote from the shoulder girdle. The flattened or scale-like ventral

spines are attached at about the anterior third of the length of the pelvic bones.*

The branchial and hyoid elements are almost identical with those of *Promethichthys*.

There are 41 abdominal vertebrae, and in the specimen at hand 62 caudal, besides a few (probably not exceeding 5) that are missing at the end of the tail.

Lepidopus differs from *Promethichthys* in having no abdominal hæmal arches. The last two abdominal vertebrae bear small, slender parapophyses, but the ribs are still attached to the vertebral centra at the base of them, though they are also attached to the full length of the parapophyses at the side. The abdominal hæmal arches and spines in *Promethichthys* are not differentiated from those of the caudal region, but in *Lepidopus* the change from the small parapophyses of the last abdominal vertebrae to the large hæmal arch and spine of the first caudal vertebra is very abrupt. The ribs are set in very deep pits low on the vertebral centra, and, as in *Promethichthys*, each rib or hæmal spine occupies a position at about the middle of the length of its vertebra. There is a sharp, low, lateral ridge running the length of the vertebral column. Along the caudal region it occupies the middle of the sides of the vertebrae, and is a little elevated at each end of each vertebra. On the abdominal region it is ventral in position, and forms a sharp lower edge, which bears the sockets for the ribs.

The first two vertebrae bear epipleurals only. There are only three other epipleurals attached to the vertebral centra just above the base of the ribs. There are no long intermuscular bones incasing the body, as in *Promethichthys*. The hypural is small, but in no way remarkable; the caudal rays are not deeply divided. The interneurals are T-shaped, with the horizontal limb connecting them, and forming the outline of the back. They are only slightly expanded laterally just beneath the skin. No ossified, separate baseoste are present. The fourth and fifth interneurals bear large bean-shaped swellings near the upper end, each nearly as large as a vertebra.

*The abdominal ventrals might indicate a direct descent from more primitive forms with similar ventrals, did not *Promethichthys* (with thoracic ventrals) so obviously stand between. This condition in *Lepidopus* probably shows an independent degeneration or modification. As the body has become elongate, and the ventrals functionless, the latter have lost their connection with the shoulder girdle and have moved backwards. Since the above was written a paper by Mr. C. Tate Regan (Ann. and Mag. Nat. Hist. (8) Vol. III. 1909) has been received in which he has come to the same conclusion: "This condition may be regarded as secondary and due to the degeneration of the fins."

TRICHIURUS.

A specimen of *T. lepturus* from Jamaica, 32 inches in length; a head and partial skeleton of a slightly smaller skeleton from Virginia, and a head and shoulder girdle of a specimen, about the same size as the first, with the species and locality unknown.

In the first specimen the sutures separating the cranial bones are well marked and the clavicle is normal. In the second specimen the frontals, parietals, epiotics and supraoccipital have become covered with spongy bone substance, thickening them and uniting them into a single piece. The clavicle is normal. In the third specimen the frontals have become ankylosed, but not thickened, and well marked sutures separate the other bones. In this specimen the lower part of the clavicle is very much swollen, so much so that the usual deep channel along its posterior edge is filled in. This bone thickening does not appear to be of the same character as that of the cranial bones of the second specimen, where the thickening appears to be a superficial, soft, cellular deposit. In the clavicle the surface of the swollen portion is the same as that of the unmodified portions, as if it were a regular periosteal deposit.*

The skeleton of *Trichiurus* scarcely differs from that of *Lepidopus*. The front of the skull is nearly devoid of ridges extending forward from the supraoccipital. The supraoccipital extends more broadly over the epiotics than in *Lepidopus*, appearing to widely separate them, though they meet within the cranial cavity.

The suborbital ring is represented by the preorbital and one ossicle behind it, with a third at the posterior margin of the eye unattached to the others. The last is developed inward as a thin wing, so that it is apparently the suborbital shelf, but shifted backward from its position in *Lepidopus*. There is no suborbital sensory tube.

The maxillary elements and lateral face bones are identical with those of *Lepidopus*. The teeth differ only in being larger and occupying deeper pits. The hypocoracoid is not broad and produced backwards abnormally, and the postclavicle is more slender. The shoulder girdle and its attachment is otherwise as in *Lepidopus*. The pelvic

*I have examined a number of specimens in the collections of Stanford University for a similar condition of the clavicle, and find it only in a specimen from China labeled *Trichiurus japonicus*. This condition may be of enough importance to separate its possessors into another genus. It is apparently a condition parallel to that of *Melanogrammus*, which has been separated from *Gadus* by a similarly swollen hypocoracoid. Sufficient material is not at hand to decide whether it is a development with age.

bones are entirely absent. The hyoid and branchial arches differ in no way from those of *Lepidopus*.

There are 39 abnormal vertebræ, and 100 caudal vertebræ may be counted to where the tail tapers to so fine a point as to make counting difficult. The vertebræ are much shorter than in *Lepidopus*, and in consequence the neural and interneural bones are at shorter intervals and with shorter arms between the fin rays. The lateral ridge along the vertebral column is much higher and sharper, the anal is represented by very small sharp spines, there are no swollen interneurals, and the tail tapers to a point without a hypural bone or caudal fin. Otherwise the vertebral column and fin elements are nearly identical with those of *Lepidopus*.

PROMETHICHTHYS PROMETHEUS.

C. L. STARKS, del.

LEPIDOPUS CANDATUS.

C. L. STARKS, del.

EXPLANATION OF PLATES.

e, ethmoid.
eo, exoccipital.
ep, epiotic.

fr, frontal.
n, nasal.
op, opisthotic.

p, parietal.
pf, prefrontal.
pt, pterygoid.

soc, superoccipital.
sp, sphenotic.
u, vomer.

THE OSTEOLOGY AND RELATIONSHIP OF THE FISHES BELONGING TO THE FAMILY CARANGIDÆ.

BY EDWIN CHAPIN STARKS.

SCOMBROID RELATIONSHIP.

The alliance of the family Carangidæ with the Scombridæ only is here considered, though there is little doubt but that it is also closely related with the Percoid fishes. The difficulty in tracing this relationship with the Scombridæ lies as usual in the fact that the divergence of the two families doubtless commenced from a form that resembles neither family very closely as we now know it.

In this consideration the possible importance of one character over another is more than usually puzzling, as, for example, how much weight should be given to the possession or absence of a complete suborbital chain of bones. All of the genera of the family Carangidæ have a complete suborbital system of bones which carries a sensory tube. The only form of the family Scombridæ so equipped is *Scomber*. Consequently, if we consider this character, we must concede (1) that the Carangidæ finds its nearest living relative in the family Scombridæ in *Scomber*, (2) or that the Carangidæ is related through some earlier representative of any other Scombroid before it lost its suborbital bones, (3) or that this series of bones has been regained in the Carangidæ. In the consideration of other characters each of three different Carangoids suggests a different relationship to the family Scombridæ.

The condition of the caudal peduncle vertebræ in *Megalaspis*, braced and strengthened for a strong lateral movement only, of the deeply cleft caudal rays nearly covering the hypural bone, and of the lateral bony keel, is all identical with the condition of these parts in some of the Scombridæ, suggesting, at least, that it, among the Carangidæ, comes closest to some of the keel-tailed forms of the Scombridæ. A resemblance to *Euthynnus* (one of these keel-tailed forms) is further suggested by the greatly enlarged inferior vertebral foramina. The most probable explanation of this similarity is parallel development brought about by similar habits or conditions of life. As *Megalaspis*

has developed into a strong, swift swimmer, the bones of the tail have naturally developed for strength and the caudal rays have clasped the hypural more firmly.

Considering still other characters, another relationship is suggested. In the Scombridæ the first interhæmal is scarcely enlarged and is not closely attached to the hæmal process of the first caudal vertebra. The hæmal process of the first caudal vertebra is in no way differentiated in shape or size from the last hæmal processes (united parapophyses) of the last abdominal vertebra. Consequently when the ribs and interhæmals are not attached it is impossible to distinguish between the abdominal and the caudal vertebrae. In these characters *Naucrates* and *Seriola* most resemble the Scombridæ. The size and development of the first interhæmal and the last one or two pairs of parapophyses united to form hæmal arches, scarcely differentiated from the hæmal arches of the caudal vertebrae, are the same, except that in the Scombridæ there are always a number of abdominal hæmal arches rather than one or two (*Scomber*, which has the fewest in its family, has five or six).

These problems are touched upon not only because they are suggestive of relationship, but also because they show so well the difficulty of selecting characters that have meaning, and the danger of giving to what may be minor characters undue importance. On the whole, however, *Oligoplites* and *Scomberoides* seem to approach the Scombridæ more closely than do other Carangoid forms. Not only is the general appearance, with a large number of more or less disconnected finlets to the anal and dorsal fins, suggestive of the Scombridæ, but the premaxillaries are non-protractile, the vertebrae are slightly increased in number and the epiotics are broadly in contact within the cranium.*

*The character of the union of the epiotics within the cranial cavity has not the value in the Carangidæ that it has in the Scombridæ. In the Carangidæ the character seems to be in a transitional stage, and its stability has been lost in changing from the broadly united epiotics of the Scombridæ to the separated ones in the Percoid fishes. In the Percoid fishes (these need further study for this character; ten forms were examined) the epiotics are either separated by a generous area of cartilage below the supraoccipital, which extends downward at least half way between them, or the supraoccipital almost entirely separates them, as in the examples of the Carangoids where the epiotics are separated to the greatest extent. In two closely related Carangoids the condition of the epiotics may show considerable variation, so not much reliance can be placed upon them. In *Oligoplites* and *Scomberoides*, however, where the epiotics are in close and broad contact and the supraoccipital sends no entering wedge between them, the character no doubt has some value in showing Scombroid affinities.

MUTUAL RELATIONSHIP.

The family Carangidæ is a much more compact group than the Scombridæ. The gaps between the genera are much smaller, and though the osteological characters, like the form of the body, differs much in the extremes of variation, there are no sudden or complete changes. Consequently the genera do not so readily group themselves into subfamilies as do the genera of the Scombridæ. Though the groups here indicated are not very definite, they may show at least relationship.

The subfamily Scombrodinæ contains the genera *Oligoplites* and *Scomberoides*. It may be distinguished by the non-protractile premaxillaries, the presence of many finlets, the broad union of the epiotics within the cranium, the slightly increased number of vertebræ, and the ribs (except the posterior two or three pairs) attached high on the side of the centrum, not even in contact with the parapophyses.

Oligoplites and *Scomberoides* do not resemble each other so closely as might be expected from their close external resemblance. The latter differs from the former in having a supplemental maxillary. In *Scomberoides* the temporal crest reaches far forward to above the prefrontal, while in *Oligoplites* it ends over the posterior part of the eye. In *Scomberoides* the top of the cranium is deeply concave at each side of the supraoccipital crest above the eye, while in *Oligoplites* it is flat. In *Scomberoides* the exoccipital condyles are broadly in contact, while in *Oligoplites* they are separate. *Scomberoides* has a well developed subocular shelf, which in *Oligoplites* is absent.

The Naucratinæ includes *Naucrates*, *Seriola* and *Elagatis* (the vertebral column of the last has not been seen). This group is distinguished by having the first interhæmal unenlarged, the last one or two pairs of parapophyses each united to form a hæmal arch and spine, at the tip of which the ribs are attached with their bases in contact, the first hæmal spine unenlarged and not firmly attached to the first interhæmal, the lateral line not abruptly arched, and the anal not preceded by two free spines. In the other Carangoids the posterior parapophyses are distinct, not united as a single hæmal spine, though a bridge of bone connects their bases.

Decapterus in the condition of the posterior parapophyses approaches this character. It shows an alliance to *Elagatis* in the pos-

session of finlets, and should perhaps be included in this subfamily, or else these two genera might be considered together as a separate subfamily characterized by the possession of finlets.

All of the other forms considered, except *Trachinotus*, are here included under the Caranginae. It is even less satisfactory to try to divide them than in the case of the others, and though *Selene* is not nearly so closely related to *Trachyurops*—for instance—as some forms are to each other that are here arranged in different subfamilies, there is no place to draw a dividing line. There seems no good reason for recognizing the Chloroscombrinae.

The Caranginae may be characterized by the strong first interhæmal process firmly united with the strong first hæmal process and together forming a long curved brace bordering the abdominal cavity behind, as in the flounders. In *Decapterus*, *Trachyurops* and *Trachurus* this character is not so well marked as in the others, and it is a character of all of the Carangidae except the Naucratinae. The Caranginae have the lateral line abruptly arched in front, and usually armed with keeled plates, and there are usually two detached spines in front of the anal.

The Trachinotinae contains only the genus *Trachinotus* and is a well defined subfamily. It is placed at the end of the series, as it has no characters to show from where it may have branched from the other Carangoids.

It is characterized by having the snout region shortened; the maxillary without a supplemental bone; the posttemporal but little forked; the opisthotic separating the exoccipital from the pterotic to a greater extent than in the other genera; the pharyngeals enormously developed, with the parasphenoid expanded to accommodate the superior ones; and with the posterior opening to the myodome reduced to a pore or obsolete.

DIAGNOSIS OF CHARACTERS.

Supraoccipital crest carried forward to ethmoid by the frontals. Supraoccipital variously separating epiotics, or not at all, as viewed from within the cranium.

Exoccipitals meeting above and below, always for their full length above, and broadly below, or in most cases for their full length. Pre-frontals broadly meeting at the median line; each pierced for the passage of the olfactory nerve.

No auditory bulla apparent externally.

Temporal crests well developed, and usually reaching the edge of the cranium above the orbital cavity.

Myodrome large and (except in *Trachinotus*) opening to the exterior posteriorly.

Opisthotic sometimes interposed more or less between the exoccipital and pterotic, but usually scarcely at all, and never to the extent that it is in the Scombridae.

Basisphenoid present and with a process descending to the parasphenoid. Eye with a bony sclerotic case not so well developed as in most of the Scombridae.

Suborbital ring complete and with a sensory tube; a suborbital shelf variously developed or absent.*

Nasals well developed and projecting.

Premaxillaries protractile in all but the Scombroideinae; their ascending processes of varying length from moderately short to very long.

Maxillary with a supplementary element on its upper posterior edge in all but *Oligoplites* and *Trachinotus*.

Preopercle unarmed except in the very young.

Head of hyomandibular, where it joins the cranium, more or less divided into two parts.

Four pairs of superior pharyngeals present (three with teeth).

Three basibranchials, the first in front of the arches and extending under the glossohyal.

Clavicle more nearly vertical than in the Scombridae, extending farther above the pectoral fin, and not so far anteriorly; never projecting much in front of hypocoracoid at its lower end.

Actinosts, 4; moderately short; $2\frac{1}{2}$ or $3\frac{1}{2}$ of them on hypercoracoid.

Postclavicle in two parts.

*The worthlessness of the character of the presence or absence of the suborbital shelf, which has been used in taxonomy, is shown by *Oligoplites* and *Scomberoides*—two genera of undoubted close relationship. In the latter genus the shelf is well developed and in the former it is absent. It may, furthermore, even vary within a genus. In *Trachinotus kennedyi*, from the Pacific Coast of Central America (five specimens examined from 8 to 20 inches in length) there is no suborbital shelf developed. While in *T. rhodopus*, from the Pacific Coast of Central America (five specimens examined from 6 to 12 inches in length), and in *T. glaucus* and *T. carolinus* from Florida (one specimen of each 12 and 18 inches in length) there is a well developed suborbital shelf. It is not coössified with the suborbital chain but connected by tissue. In *T. ovatus* from Formosa, however, (a specimen 30 inches in length) the shelf is large and firmly coössified with the suborbital bone that bears it.

Vertebrae in small numbers; the abdominal always 10; the caudal from 14 to 16 (usually the former).

Parapophyses not developed very far anteriorly; the last two or three pairs with a bridge of bone connecting them; but they do not (except in the *Naucratinae*) unite in pairs, each pair to form a single haemal spine.

Epipleurals anteriorly borne by ribs (only so in one genus of *Scombridae*).

First interhaemal enlarged (except in the *Naucratinae*) and very closely attached to the enlarged first haemal process.

Caudal rays rather deeply divided, usually not so much so as in the *Scombridae*, but more than in the *Percoid* fishes.

Dorsal spines usually stiff and stout; dorsal and anal finlets sometimes present.

Caudal peduncle slender and the caudal rays divergent.

HYPEROSTOSIS.

Many of the forms of this family have some thickened bones. These are here described away from the main descriptions for better comparison. They are usually dense or ivory-like on the surface, but are more or less cellular inside. Apparently they are a development of age rather than of maturity. That entirely different bones may become thickened in different species of the same genus, or between closely related species, is shown in the two species of *Caranx* here described. It appears further from this material that where the bone thickening occurs at all it occurs consistently in the same bones in individuals of the same species. What individual variation may be expected, or what taxonomic value the character may have, we have not enough material at hand to say. As shown, however, by *Selene* and *Citula*, there may be considerable variation in the size of the thickening, or it may not develop at all in species that normally, or sometimes, have it at a certain age or size. There is no proof with this material that in the latter case, where it has not occurred, it might not have developed with time. The problem should be studied in some locality where a large number of *Carangoids* of different ages may be examined.

In *Oligoplites mundus*, 18 inches in length, the frontals above the orbital cavity are so thickened that the supraoccipital crest is nearly obliterated. The frontals in this region are nearly $\frac{1}{2}$ inch in thickness. On the lower end of the clavicle is a swollen area $1\frac{1}{2}$ inches

long and $\frac{1}{2}$ inch thick. In a specimen 9 inches long these parts are normal. In *Scomberoides* 12 inches in length no bone thickening has developed. In crania and shoulder girdles of *Seriola* and *Elagatis*, in specimens 3 or 4 feet in length, the bones are normal (the bodies of these specimens are missing). In *Naucrates*, $9\frac{1}{2}$ inches long; *Trachurus*, 15 inches; *Trachurops*, 10 inches; *Decapterus*, 17 inches; *Megalaspis*, 15 inches, and *Chloroscombrus*, 11 inches, the bones are nowhere swollen, though in larger specimens they may occur.

In *Caranx chrysos*, 14 inches long, the only swollen bone is the upper limb of the posttemporal. The distal two-thirds of this bone is so swollen that it forms a heavy round rod on top of the cranium. In *Caranx hippos*, 29 inches in length, there is a great mass of bone in front of the spinous dorsal, and with some of the dorsal rays attached to it, representing one or several united interneurals; it is $2\frac{5}{8}$ inches long, 1 inch wide by 1 inch deep. Three unmodified interneurals occur between it and the occipital crest. In front of the anal fin on the first interhæmal (doubtless representing several interhæmals) is a large knob of bone $1\frac{1}{2}$ inches long, $1\frac{1}{4}$ inches deep, by 1 inch wide. The pelvic girdle is swollen near the middle of its length to about twice its normal thickness, and the interspinous bones at about the middle of the soft dorsal and anal—especially the latter—are swollen. The posttemporal is not swollen.

In *Gnathanodon*, two specimens 20 and 25 inches in length, the interspinous bones of the soft dorsal and anal, except a few anterior ones, are swollen until they are $\frac{1}{2}$ an inch thick in the larger specimens.

In *Selene* almost the entire supraoccipital crest from the frontals backward, and from just above the body of the cranium, is greatly swollen. *S. vomer* and *S. oerstedii* differ from each other, however. In the former the swelling is gradual from the edges of the crest towards the middle, so that the edges are sharp, while in *S. oerstedii* the swelling is abrupt and reaches its full width near the edges of the crest so that the edges are rounded. In *S. vomer*, $16\frac{1}{2}$ inches long, the swollen portion is 2 inches long, $1\frac{3}{4}$ inches deep and $\frac{9}{16}$ of an inch wide. In *S. oerstedii*, 12 inches long, the swelling is of the same proportions, though smaller. In a specimen of *S. vomer*, 5 inches long, the swelling has not yet started.

Several alcoholic specimens of these species were examined and considerable variation found. In two specimens of *S. vomer*, 11 and 12 inches long, the occipital swelling is scarcely indicated, while in two 8 inches long it is developed to a considerable extent, and in a specimen

6 inches long it is just beginning. In a specimen of *S. oerstedii*, 18 inches long, the swelling is exceedingly large, in two 8 inches long it is well developed, and in one 7 inches long it is not yet evident.

In the skeleton of *S. vomer* the lower parts of the clavicle and hypocoracoid are slightly thickened, and the lower end of the post-clavicle is swollen club-shaped. In *S. oerstedii* some of the interspinous bones are very slightly swollen.

In *Vomer setipinnis*, 13½ inches long, there is no occipital swelling whatever. Fourteen alcoholic specimens of this species and of *V. spixii*, from 6 to 12 inches in length, were examined, and they all agree with the skeleton in this respect. In the skeleton the lower part of the hypocoracoids are very much thickened and some of the interspinous rays slightly so.

In a specimen of *Citula dorsalis*, 11 inches in length, there is an abrupt swelling at the upper angle of the supraoccipital crest, so abrupt as to be almost circular in transverse section; it is ⅜ of an inch long and ¼ of an inch deep. It is not dense and ivory-like on the surface, as is usual in other forms, but more spongy and cellular. Just behind it the first interneural is swollen to a similar knob, though not so wide. For the occipital swelling several alcoholic specimens were examined. In two specimens, 23 and 11 inches in length, the swelling is as described for the skeleton. In one, 11 inches in length, it covers the same area but is not swollen over half as full, and in one, 10 inches in length, there is no trace of any swelling.

In *Alectis ciliaris*, 14 inches long, only some of the interspinous bones are slightly thickened. Four alcoholics, 8 to 10 inches in length, were examined for an occipital crest swelling, but none was found.

In *Trachinotus* this bone thickening is more marked than in any other form. In the young of *T. carolinus*, 7 inches long (with 4 duplicate skulls), the bones are all normal. In the adult of *T. kennedyi*, 24 inches in length, and the skull of an unknown species, the cranium 4 inches in length, the nasals are much swollen. Each is shaped like an inverted comma (‘) or like a chemist’s glass still. The lower ball-like part is in contact with its opposite fellow, and the arm runs upward and outward to attach it to the cranium. In the largest specimen the ball is ½ an inch across. The preorbital is a heavy dense bone ⅜ of an inch thick. The first interneural (or possibly several anchylosed ones) is a large oblong mass of bone slightly overlying the supraoccipital crest, and from its posterior end a ray of bone projects down to the first neural spine. This bone in the large specimen is 2¼ inches long, ½ an inch deep and ⅞ of an inch wide. Between it and the spinous

dorsal there are 2 or 3 supplementary interneurals. It suggests a somewhat similar bone in *Caranx hippos*, but in *Caranx* there is no downward projecting ray of bone, the extra interneurals are in front of it rather than behind it, and no dorsal spines are attached to it. In the large *Trachinotus* the rib of the seventh vertebra is swollen round in section, and is $\frac{3}{4}$ of an inch in diameter. The next preceding one is half as thick, and the next only slightly swollen. The ribs succeeding the seventh are very slender, and not at all swollen. Some of the posterior interspinous rays are somewhat thickened.

The enormously developed pharyngeals, though they are proportionately somewhat larger in the adult than in the young, apparently do not belong to this class of bones; they are large at all ages, while the swollen bones show no indication of increasing size in the young.

OSTEOLOGY.*

Form of Cranium and General Cranial Characters.

The cranium of *Elagatis* is more depressed than any other of these forms, though *Seriola*, *Naucrates* and *Caranx* closely approaches it. In all of these, especially *Seriola* and *Elagatis*, the middle portion of the frontal at each side of the supraoccipital crest is much depressed or sunken far below the level of the anterior and posterior ends. *Megalaspis*, *Trachurus*, *Decapterus* and *Trachurops* follow in about the order named, growing a little deeper in comparison with their width; they all have the region beside the supraoccipital crest somewhat sunken. *Trachinotus*, *Scomberoides* and *Oligoplites* follow in becoming less depressed and in having the frontal region scarcely sunken at the middle. *Chloroscombrus*, *Alectis*, *Citula* and *Gnathanodon* are more compressed than depressed; *Gnathanodon* approaches the shape of *Selene* more nearly in having the upper profile sloping forward and downward toward the vomerine region. And last are *Vomer* and *Selene*, very narrow and deep; the latter triangular in profile, highest at the occiput and sloping steeply to the anterior end.

The myodome is well developed and opens to the exterior at the posterior end through a foramen of varying size, except in *Trachinotus*, where it is reduced to a pore, growing smaller or becoming obsolete in the larger specimens.

There is no auditory swelling or bulla apparent externally.

*See the last end of this paper for a list of species, with their size and locality.

For the accommodation of the more or less divided hyomandibular head there are two depressions on the lower surface of the cranium on each side. The anterior depression is nearly round, and occurs between the preotic and the sphenotic. The posterior one is elliptical and is confined to the pterotic. There is no indication of the depression on the under side of the cranium, which in some genera of the Scombridae excludes the pterotic from the brain cavity.

The supraoccipital crest is always well developed and rises in a thin, high, blade-like crest, extending nearly the whole length of the cranium, and reaching forward in all cases to the ethmoid. The crest is formed anteriorly by the frontals. Above the frontals its base is always expanded and thicker than above the supraoccipital. Posteriorly the crest extends behind the epiotics to above the occipital condyle, where it is usually the highest.

The temporal crest is always thin and high, and is formed by the epiotic, the parietal and the frontal. In nearly all genera it reaches the edge of the cranium a little in front of the middle of the orbital cavity. In *Citula* and *Oligoplites* the crest ends more posteriorly than in any of the others, and in the latter scarcely reaches the cranial edge (see under pterotic crest). In *Trachinotus* the crest does not typically reach the edge at all, but runs nearly straight forward to the front of the frontal, where it ends considerably inward from the edge of the cranium. This, however, is apparently not a stable character, as in some of the young examples the crest on one or both sides is deflected towards the edge and is then not different from the usual arrangement. In *Oligoplites* the crest is produced to a slight spur on the parietal and dips low on the epiotic and frontal. In *Scomberoides* the crest is high throughout, as in the other forms.

The pterotic crest in most of the genera reaches the edge of the cranium just behind the anterior ending of the temporal crest. In *Decapterus*, *Trachurus* and *Trachurus* it ends farther back than in the others, or over the posterior end of the orbital cavity at a considerable distance behind the temporal crest. *Citula* differs from the others in having the pterotic crest united with the temporal at a considerable distance behind the anterior end of the latter. In *Oligoplites* the temporal and pterotic crests come together and sink into the level of the frontal over the posterior edge of the orbital cavity much as they do in *Scomber*. From this union only the slightest indication of a ridge runs laterally to the cranial edge.

Posteriorly the pterotic crest ends in a more or less well developed secondary spine at the base of the backward projecting pterotic spine.

The crest carries a series of sensory tubes, which radiate outward from its base to its edge. A sharp, high, superorbital rim is always distinct, curving downward behind and below the pterotic crest.

CRANIAL ELEMENTS.

The exoccipitals are in contact with each other for their full length along their upper edges, but as the supraoccipital overlies the suture between them they appear on the surface of the cranium to be separated by the latter bone. They are also in contact along their lower edges over the basioccipital, though in the small specimens of *Trachinotus*, and in *Decapterus*, they fail to meet at the mouth of the foramen magnum. In the large specimen of *Trachinotus*, however, they meet broadly in this region (the small and large specimens being of different species, this may be either a variation of species or of age). The articular facets of the exoccipital condyles are not always contiguous above the basioccipital, even when the exoccipitals are in contact just in front of them. In *Trachurus*, *Trachurops*, *Megalaspis*, *Naucrates*, *Oligoplites* and *Decapterus* they are separated. In the others they meet more or less broadly. In the fusiform genera the exoccipital condyles slope over the basioccipital condyle in a normal degree, but in the deep compressed genera the former overhang the latter so much that their slope towards each other forms a right angle. *Decapterus* is peculiar in having the exoccipital condyles at the side and wholly below the level of the upper edge of the basioccipital, while their posterior surface is a little anterior to that of the basioccipital condyle.

The supraoccipital is developed very far forward in the crest, extending in most cases to above the middle of the orbital cavity, but in *Trachinotus* it extends to above the front of the orbital cavity, or nearly the whole length of the frontals. In this genus the length of the supraoccipital equals three-quarters of the length of the entire cranium. Between these two conditions are all intermediate gradations.

As viewed from the outside of the cranium the epiotics appear on each side of the supraoccipital widely separated, but from the inside their condition is various. In *Oligoplites* and *Scomberoides* the epiotics meet for their full length at the median line, and the supraoccipital can not be said to separate them in any degree. In *Caranx* they are joined for about half of their length, while the supraoccipital separates them above. In *Megalaspis* and *Chloroscombrus* they only narrowly meet. In the others a wedge of the supraoccipital extends downward between them, below which an area of cartilage separates them more or less widely.

The opisthotic separates the exoccipital from the pterotic to a varying extent, or not at all, but in no case is it interposed to so great a degree as in most of the family Scombridae. Usually the condition of this bone does not differ from that of the Percoid fishes; i. e., the opisthotic is chiefly on the lower surface of the skull covering the exoccipital-pterotic suture, so that superficially, as viewed from below, the exoccipital seems to be widely separated from the pterotic. As viewed from above a very small portion of the opisthotic shows just behind the exoccipital-pterotic suture. Often there is a shallow notch at the end of this suture in which the opisthotic appears, but to so small an extent that the opisthotic can scarcely be said to separate the exoccipital from the pterotic in any degree. The notch as viewed from above is a little deeper in *Oligoplites*, *Scomberoides*, *Alectis*, *Citula*, *Gnathanodon* and *Megalaspis* than in the other genera, and in *Trachinotus* it is very much deeper, separating to a considerable extent the exoccipital from the pterotic, approaching nearer the condition of the Scombridae than any of the others do.

In *Oligoplites* and *Scomberoides* the lower posttemporal limb is attached to the upper surface of the opisthotic, as it is in most of the members of the family Scomberidae. In the others it varies from this condition to that of having the lower limb attached more or less to the posterior edge, as in the Percoids.*

In *Gnathanodon* the anterior part of the pterotic incloses a very large foramen, at least two-thirds as wide as the pterotic crest. This is developed to a smaller degree in *Decapterus* and *Trachurus*; in all of the others it is entirely absent.

The basisphenoid is present and has a well developed process descending to the parasphenoid, where it is rather broadly attached. There is always a foramen just behind it, in front of the prootic suture, and opening into the myodome.

The alisphenoids are in all cases widely separated by the anterior opening to the brain case. A pair of wings or ridges on the lower surface of the frontals are continuous with the alisphenoid edges. They converge forward except in *Trachinotus*, where they run straight and nearly parallel to the prefrontals.

The parietals are always well developed and form the middle portion of the temporal crest. They are always widely separated by the supraoccipital.

*The distinction between posterior upper surface and posterior edge is not great, and as it is somewhat variable, its importance is of questionable value. *Scomber* is nearer to the Percoids in this respect than it is to the other genera of its family, or to most of the Carangoids.

Though the supraoccipital widely covers the greater part of the suture between the frontals, they meet below it for their full length. They form the anterior part of the supraoccipital crest, carrying it to the ethmoid. In this portion of the crest, especially when the crest is thin, there is often no trace of a suture between the frontals. The suture is, however, always evident on the lower surface of the frontals within the orbital cavity, and in a fresh or well macerated specimen the frontals may be separated through the crest.

No portion of the ethmoid shows in the orbital cavity between the prefrontals except in *Chloroscombrus*, where a very small portion of it shows in this region at the upper part of the prefrontal suture.

In *Seriola* the ethmoid is very broad, and for convenience may be described as consisting of two portions. The superior portion is a broad plate, concave in front, and directly from under it medially a blunt keel on the inferior portion projects downward and forward. *Megalaspis*, *Elagatis*, *Oligoplites*, *Scomberoides* and *Naucrates* are essentially the same, but in the last three the inferior portion is sharper in front and descends more abruptly, not projecting much forward. In *Gnathanodon*, *Citula*, *Trachurops*, *Chloroscombrus* and *Caranx*, the superior portion is concave in front, but very narrow (only slightly so in *Caranx*), and just below it is a cup-shaped depression replacing the keel, which is only developed at the lower end near the vomer remote from the superior portion. *Decapterus* is somewhat between these two conditions; the superior portion is very narrow, with only an indication of a concave front, and the keel of the lower portion, though not in intimate relation with the superior portion, is not separated from it by a depression. In *Trachinotus* and *Alectis* the superior portion is produced, moderately narrow, convex in front, and with a keel about as in *Decapterus*. *Trachurus*, *Selene* and *Vomer* are of the same type as the last, but with the superior portion scarcely, or not at all, widened. These conditions, though marked in the extremes, merge more or less with each other.

The prefrontals meet broadly behind the ethmoid in front of the orbital cavity. They are pierced by the olfactory nerve. Usually they form a broad outstanding mass on each side, angulated below and having an articular surface on their lower edge for the palatine, but in *Selene* they are gently rounded in outline, and ascend nearly straight to the frontals without an angle. On the anterior surface of each prefrontal at the side of the ethmoid, and often assisted by the latter, a cavity is formed in many examples. In *Elagatis* the cavity is particularly shallow, but very wide and long. The frontal reaches far over it,

forming a roof, and the ethmoid forms a septum between it and its opposite fellow, though behind the ethmoid there is a communicating passage, which in the fresh fish was probably filled with cartilage. The olfactory foramen enters this chamber at its outer edge. *Seriola* and *Naucrates* have only a trace of this chamber. It is particularly well developed in *Gnathanodon*, but is lower on the prefrontal, and the frontal forms no part of its roof, though the ethmoid forms a large part of it. It is in this form much deeper than long, and extends downward to the parasphenoid. The olfactory foramen enters the posterior end of it. It is similar to *Gnathanodon*, though scarcely so large, in *Trachurus*, *Trachurops* and *Decapterus*; in *Megalaspis* it is considerably smaller. It is moderately developed in *Citula* and *Alectis*, but the foramen is so far to its outer edge that it can be scarcely said to enter it. In *Chloroscombrus*, *Vomer* and *Selene* it is not well developed, and in *Trachynotus*, *Caranx*, *Oligoplites* and *Scomberoides* it is not present at all.

The vomer bears a keel on its upper surface, which is a continuation of the ethmoid keel. At each side of the keel rests the ascending premaxillary process.

The parasphenoid is sharply keeled under the orbital cavity. At the mouth of the myodome it sends a lateral wing up along the edge of the prootic, but it is confined to that bone, never reaching to the alisphenoid or sphenotic. *Trachynotus* differs from the other genera in having the parasphenoid expanded to two or three times its ordinary width to form a broad, flat table, against which the greatly enlarged superior pharyngeals lie. This expansion is reinforced above by the prootic, which is developed outward to the edges of the parasphenoid, or a little beyond. *Gnathanodon* differs from the others in having a protuberance on the parasphenoid under the prootics, which contains a conical cavity with its apex pointing straight forward. This is doubtless the homolog of a somewhat similar cavity in the Tunninae division of the Scombridae, into which the posterior myodome foramen enters. In *Gnathanodon*, however, it is farther forward, remote from the foramen.

Other cranial elements not mentioned do not depart to any notable extent from the majority of spiny-rayed fishes.

The Lateral Head Bones.

The lateral bones of the head do not differ materially from those of the family Scombridae. The bones of the suspensorium set closely together, and there are usually no openings between them.

The opercular bones do not in general form such broad, smooth areas as in the Scombridæ. There are no preopercular serrations except in the very young, and there is never an open sensory canal along the preopercular ridge. When there is any indication of a sensory system in the bone in this region it is in the form of very fine tubes. *Trachurus* is somewhat of an exception to this in having much larger tubes than in any of the other genera.

The head of the hyomandibular, where it articulates with the cranium, is more or less divided into two parts. In *Gnathanodon* the parts are contiguous, or with only a slight notch between them. In *Elagatis* they are remote from each other. Between these two degrees of separation there are all intermediate conditions, though they are usually at least slightly separated. The hyomandibular is channeled behind to receive the preopercle, and sends back a process to support the opercle. In *Oligoplites* the upper end of the hyomandibular bears on its outer surface a large wing of bone, pointing forward as in *Caranx hippos* (see under suborbitals), but there is no stay from the suborbital ring attached to it. In *Scomberoides* this process is reduced to a small, inconspicuous point.

There is never any opening between the hyomandibular and metapterygoid that frequently appears in Percoid fishes except in *Gnathanodon*, and to a slight extent *Trachurus*. The condition in the former genus is identical with that of *Roccus*. The metapterygoid throws out a broad wing, which extends backward to near the preopercular ridge, leaving a wide, open space behind it. In *Trachurus* the wing is feebly developed, and it fits so closely against the hyomandibular that the open space is scarcely apparent. No trace of it is apparent in any of the others.

The mesopterygoid forms a broad supporting shelf for the orbit.

The symplectic extends for a considerable distance behind the quadrate in a channel.

Usually the pterygoid turns at a right angle and reaches forward towards the prefrontal, as it does in the majority of fishes. The anterior end of the pterygoid, and often a small part of the posterior end of the palatine is attached to the prefrontal. Often a small tubercle of bone is developed on the pterygoid just behind this attachment. But as the cranium becomes flexed downward and the face bones drawn forward, as in some of the deep, compressed forms, the pterygoid is directed nearly straight upward and finally even somewhat backward, while the tubercle of bone becomes a long spur or process extending

behind the prefrontal. *Gnathandon* and *Chloroscombrus* show a marked inclination towards this condition. The pterygoid is developed nearly straight upward, and the process behind the prefrontal is long. In *Alectis* and *Citula* the pterygoid is bent farther back, and the process is longer, while in *Vomer* and *Selene* it is bent very decidedly back, the process is still longer, and serves as the only attachment of the pterygoid to the prefrontal.

The palatine is attached more or less firmly, and with or without a differentiated articular surface, to the front of the prefrontal. The anterior end bears a strong process, which hooks over the maxillary.

The angular is well developed. In *Oligoplites* and *Vomer* the articular completely fills the V-shaped space between the backward extending arms of the dentary. In *Scomberoides* a small space is unfilled above. In *Naucrates* and *Elagatis* a considerable space is unfilled, and in the others the upper arm of the dentary and the upper edge of the articular are only in contact at a small place anteriorly.

In *Oligoplites* the dentary is peculiar in having a free wing of bone on the inside, running forward nearly to the symphysis. This wing is present in nearly all other bony fishes, but it curves downward and becomes absorbed near the middle of the mandible. In *Scomberoides* this free wing does not run far forward, but from below its lower edge a second wing is developed, which folds downward and runs back to the posterior end of the lower limb of the dentary, keeping considerably above the lower edge of the dentary for its full length.

In *Oligoplites* and *Scomberoides* the maxillary and premaxillary elements are long and slender, and rather closely attached to each other. The premaxillary sends no sharp spur behind the maxillary, though a long inner fold of bone clasps the latter rather closely. A supplementary maxillary is not present in *Oligoplites*, but in *Scomberoides* it is developed, though rather small as compared with those of the other Carangoids. In *Trachinotus* the maxillary elements are short and loosely attached to each other; the maxillary spur behind the premaxillary is little developed; and the supplementary maxillary is absent. In all of the other forms the maxillary elements are very wide, particularly the posterior end of the maxillary; rather loosely attached to each other, especially in those forms with long premaxillary processes; they bear upon their upper edges very large supplementary maxillaries, and from the middle of the premaxillary a large triangular spur is sent behind the maxillary.

The ascending processes of the premaxillaries are very short and triangular in *Oligoplites*, *Scomberoides*, *Elagatis* and *Naucrates*. In

Decapterus, *Megalaspis*, *Caranx*, *Trachurus*, *Trachurops* and *Chloroscombrus* they are longer, while in the rest, *Gnathanodon*, *Alectis*, *Citula*, *Vomer* and *Selene*, they are very long.

The nasals are attached to the frontals and ethmoid and project forward. They are never nonprojecting and attached for their full length to the frontal and ethmoid, as in some genera of the family Scombridae. They are close together or wide apart, according to whether the ethmoid is wide or narrow, so their variation in this respect is indicated by the description of the ethmoid. In *Trachurus*, which has the thinnest ethmoid, the nasals are almost in contact at their bases.

The suborbital chain of bones is always complete and carries a sensory tube. In *Caranx hippos* a wide process is sent from the last suborbital that is on the lower level of the eye (apparently the third suborbital) upward and backward across the cheek to the upper end of the hyomandibular, where it is attached to a broad, thin wing of bone, which bends forward to receive it from just in front of the upper end of the preopercle. The upper suborbitals send back a wide, thin plate, which partly covers this stay. In *Caranx chrysos* the stay is only a little developed. It ends in a free point, and there is no process developed from the hyomandibular to meet it. In *Oligoplites* the lower and posterior suborbitals are spread out into thin laminae, which, running backwards, covers a large part of the cheek. The lower edge of this is developed from the lower level of the eye, and extends downward and backward along the maxillary nearly to the ridge of the quadrate, which is a continuation of the preopercular ridge. There is no indication of a stay in any of the other forms.*

The suborbital shelf is in various conditions (see footnote under diagnosis of characters). In some forms it is well developed, in others it is slightly indicated or absent. In *Oligoplites* and some species of *Trachynotus* it is absent. In *Vomer* it is only slightly indicated, and between this condition and a well developed shelf there are all gradations.

The eye has a bony sclerotic case, never so complete or never so dense and thick as in the Scombridae, and often no better developed than in many Percoid fishes.

*The condition of the suborbital bones in *Caranx* and *Oligoplites* suggests the suborbital stay of the mail-cheek fishes. Though in one genus it extends upward across the cheek and in the other downward it springs in each of them from the last suborbital on the lower level of the eye just as it does in the mail-cheek fishes. In this connection it of course signifies nothing, being doubtless a case of parallel development.

The Branchial and Hyoid Arches.

There are three tooth-bearing superior pharyngeals on each side of the last three arches, and a styliform naked one on the first arch in all of the forms here considered. The first toothed pharyngeal is elongate and lies in front and along the outer edge of the second. The second is always the largest; the third is directly behind it and rather closely joined to it, so that they together form an elliptical plate. The teeth on both the superior and inferior pharyngeals of *Elagatis*, *Oligoplites* and *Naucrates* are fine and sharp. In the others some, or nearly all, of the teeth are blunt molar teeth, particularly on the second toothed superior pharyngeal and along the middle of the inferior pharyngeal.

The inferior pharyngeals lie close together along their inner edges for the greater part of their length and widely diverge posteriorly. In *Elagatis*, *Naucrates*, *Scomberoides* and *Oligoplites* they are less closely attached than in the others.

Trachinotus is an exception to all of the foregoing pharyngeal characters. In this genus the pharyngeals are developed to a remarkable size. In the largest skeleton (*T. kennedyi*, 24 inches long) the first toothed pharyngeal is so reduced as to be practically functionless; it is $\frac{1}{4}$ of an inch wide and half as long. The second is greatly enlarged, being $\frac{15}{8}$ inches long by half as wide, and $\frac{3}{4}$ of an inch thick. The third is $\frac{7}{16}$ of an inch wide by $\frac{3}{16}$ of an inch long. Each inferior pharyngeal is 2 inches long by half as wide and $\frac{3}{4}$ of an inch thick. The first superior pharyngeal lies at the outer side of the second, considerably behind its front end, while the third is at the posterior end of the second and does not enter into its outline as in the other forms. The inferior pharyngeals and the second toothed pharyngeals of opposite sides meet at the median line and are closely joined to each other, each pair forming an equilaterally triangular plate, so closely joined as to form an almost unbroken surface from side to side. In the superior pharyngeals the triangular shape is less evident, as the outer angles are broadly rounded. The inferior plate is shallowly concave, and the superior correspondingly convex. Except at the anterior end the plates are covered with a smooth pavement, as if the bone, or close-set teeth, had been ground down to a common level. The anterior parts are deeply pitted.

In the young the tooth plates are scarcely so thick correspondingly, and they are pitted all over the grinding surfaces. These bones are apparently not of the same character as the bones that thicken or swell

with age. They are large in all ages, and the base of the skull is expanded to accommodate them.

Three basibranchials are present in all genera, the first in front of the hypobranchials of the first arch and hooking under the glossohyal, as in the family Scombridae. The hypobranchials of the fourth arch are missing, as they almost universally are in bony fishes.

There is nothing remarkable about the hyoid arch. All of the usual elements are present: a glossohyal and urohyal, two hypohyals on each side and a cerato, epi and interhyal. The urohyal bears a longitudinal wing of bone along its lower edge on each side, and the ceratohyal is pierced by a large foramen near its upper edge.

The Shoulder and Pelvic Girdles.

The shoulder girdle shows scarcely any departure from the typical acanthopteroïd arrangement. The pectoral is not placed so near the level of the top of the clavicle as in the Scombridae, and the clavicle does not slope so far forward below it, being more nearly vertical. *Elagatis*, *Seriola*, *Naucrates*, *Oligoplites* and *Scomberoides* approach the condition of the Scombridae in this respect more nearly than the others do, though not very nearly. The clavicle ends above in a point, over which the supraclavicle articulates. Below the point and just above the actinosts a broad, rounded wing is sent back for the support of the postclavicle.

The postclavicle is in two parts, an upper wide, thin bone and a lower long, narrow bone, sometimes long and slender like a typical fish rib.

A large foramen is entirely contained by the hypercoracoid, but either the clavicle or the hypocoracoid may send a lamina of bone to its border on the outer surface of the girdle.

The suture between the hypo and hypercoracoids usually ends between the third and fourth actinosts from the top, but it may vary from the middle of the third to the middle of the fourth, so that $2\frac{1}{2}$ to $3\frac{1}{2}$ of the 4 actinosts are supported by the hypercoracoid.

The hyocoracoid arches away from the clavicle and nearly, or quite, meets it again at its lower end. The clavicle never projects far beyond the lower end of the hypocoracoid as in many of the Scombridae.

A large supraclavicle is always present. The posttemporal is widely forked except in *Trachinotus*. The upper fork broadly overlies the epiotic, and is a little more firmly attached than is usual. It often

extends to, or very slightly encroaches upon, the supraoccipital or the parietal. The lower limb of the posttemporal is attached directly to the opisthotic without the intervention of a ligament. In *Trachinotus* the posttemporal is scarcely forked at all. Its lower end is very wide and its lower fork is exceedingly thick and heavy, being but little produced beyond the general outline of the bone. It forms an unusually broad union with the opisthotic.

The pelvic girdle is in no way notable. Each side rises along its inner edge at the median line to form a low ridge, while at the outer edge each side turns downward and is divided into two longitudinal wings, with often a more or less evident third wing between. At the posterior union of the sides a spine-like process is sent forward below from the base of the ventrals, and above a forked process is sent backward over the base of the ventrals.

The Vertebral Column, Ribs, and Fin Elements.

The number of the abdominal vertebræ in all of the forms here considered is 10. The number of the caudal vertebræ is 14 in all but *Naucrates* and *Caranx chrysos*, which have 15 (though *Caranx hippos* has 14), and in *Oligoplites* and *Scomberoides*, which have 16.

The parapophyses are not developed very far forward. From three to five are usually present, though one or two undeveloped ones may be present in front of these in some forms (they appear so gradually it is difficult to be exact as to the number of developed ones). The last two or three (in *Alectis* one) of them are connected with their opposite fellows by a bridge of bone, leaving a hæmal canal above, and their points projecting separately below. The first hæmal process is differentiated from the last connected parapophyses by being single pointed and much longer and stronger, so that the vertebral column is sharply divided into an abdominal and caudal portion, aside from the indication of this division by the attachment of ribs and anal fin.

Seriola and *Naucrates* are exceptions to these rules. These forms approach the Scombridæ in having the posterior pair of parapophyses united into a single spine, with the ribs at its tip, and the first hæmal process not abruptly enlarged or otherwise differentiated from it. *Decapterus* approaches this condition in having the last pair of parapophyses united into a rounded arch, but with scarcely a spine developed, the ribs not in contact, and the first hæmal process considerably enlarged.

The zygopophyses are usually very large and resemble those of the Scombridæ. On the upper surface of the front of each vertebra a flat

process at each side of the neural canal extends upward and forward, while just below it and separated from it by a notch is a small spine or spur directed forward. On the posterior end of each vertebra a similar spur is directed backward and fits into the notch of the succeeding vertebra. At each end of the lower surface of each vertebra is an inferior zygopophysis; the anterior one projecting over the posterior one of the next preceding vertebra. These are larger in *Megalaspis* than in the others.

In *Megalaspis* the neural and hæmal spines of the tail region become flattened and lie flat each against the surface of the next succeeding vertebra, restricting its movement to a lateral one. From the upper and lower surface of each caudal peduncle vertebra a sharp longitudinal wing is developed laterally, and from the side of each of the 5 or 6 vertebræ preceding the third in front of the caudal a flat spine is produced, forming a broken caudal keel. The caudal fin rays are very deeply cleft at the base, and so broadly clasp the hypural bone as to nearly hide it from sight. *Caranx* approaches this condition, and to a less degree *Trachurops*, *Trachurus* and *Decapterus*. In *Megalaspis* the inferior vertebral foramina are greatly enlarged. These attain their greatest size in the bases of the last parapophyses, where the largest is equal in diameter to the least width of the vertebral centrum just above it. *Caranx*, *Chloroscombrus* and *Gnathanodon* show this condition to a less degree; *Citula*, *Alectis* and *Vomer* have the inferior foramina more or less developed in the bases of the hæmal arches and parapophyses, while in *Decapterus*, *Trachurops*, *Trachurus* and *Selene* the foramina are confined to the hæmal arches.

With the exception of *Seriola* and *Naucrates* and to a much less degree *Trachurops*, *Trachurus* and *Decapterus* the first interhæmal is very large and strong, and is very solidly attached to the equally strong first hæmal process. Often this stay is further reinforced behind by other interhæmal bones, which incline forward against it.

The interspinous rays of the dorsal spines about coincide in number with the neural processes, but those of the dorsal and anal rays are two or three to one of the neural and hæmal processes.

The first two vertebræ bear epipleurals only. The other anterior epipleurals are always on the ribs. The anterior ribs are attached directly to the vertebral centra, sometimes, as in *Trachurops*, *Caranx* and *Decapterus*, in deep pits, whose edges are raised above the body of the centra. *Scomberoides* and *Oligoplites* are peculiar in having the ribs attached high on the centra, remote from the parapophyses, except the posterior two pairs, which drop down to the tips of the parapophyses.

MATERIAL.

This paper is based upon the following genera and species:

Oligoplites.

A specimen of *O. mundus*, 18 inches in length, and a cranium of the same species of a specimen 9 inches in length; both from Panama.

Scomberoides.

A specimen of *S. toloparah*, 12 inches in length, from the Philippine Islands.

Elagatis.

A head and shoulder-girdle of a specimen of *E. bipinnulatus*, 31 inches in length, from the Galapagos Islands.

Naucrates.

A specimen of *N. ductor*, 9½ inches in length, from Japan.

Seriola.

A cranium and shoulder-girdle of *S. dorsalis*, of a specimen 3 or 4 feet in length, from San Diego; the cranium 5½ inches long; the vertebral characters described from an alcoholic specimen of *S. zonata*, opened along the vertebral column.

Decapterus.

A specimen of *D. punctatus*, 17 inches in length, from Florida.

Trachurops.

A specimen of *T. crumenophthalmus*, 10 inches in length, from Cuba.

Trachurus.

A specimen of *T. mediterraneus*, 15 inches in length, from the Canary Islands.

Caranx.

A specimen of *C. chrysos*, 14 inches in length, from Cuba, and one of *C. hippos*, 29 inches in length, from the Pacific Coast of Mexico.

Megalaspis.

A specimen of *M. cordyla*, 15 inches in length, from Formosa.

Gnathanodon.

Two specimens of *G. speciosus*, 20 and 25 inches in length, from the Pacific Coast of Central America.

Citula.

A specimen of *C. dorsalis*, 11 inches in length, from Panama.

Alectis.

A specimen of *A. ciliaris*, 14 inches in length, from Cuba.

Chloroscombrus.

A specimen of *C. chrysurus*, 11 inches in length, from Florida.

Vomer.

A specimen of *V. setipinnis*, 13½ inches in length, from Panama.

Selene.

A specimen of *S. vomer*, 16½ inches in length, from Mazatlan, Mexico; one of the same species 5 inches in length, from Maryland, and a specimen of *S. oerstedii*, 12 inches in length, from Panama.

Trachinotus.

A specimen of *T. kennedyi*, 24 inches in length, from Panama; one of *T. carolinus* (with 4 duplicate crania), 7 inches in length, from Maryland, and a head with the locality and species unknown, the cranium 4 inches in length.

Zool.

126887

Pisces.

S

Author Starks, Edwin Chapin

Title Osteology of certain Scombroid fishes.

UNIVERSITY OF TORONTO
LIBRARY

Do not
remove
the card
from this
Pocket.

Acme Library Card Pocket
Under Pat. "Ref. Index File."
Made by LIBRARY BUREAU