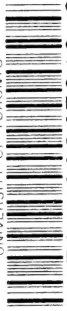


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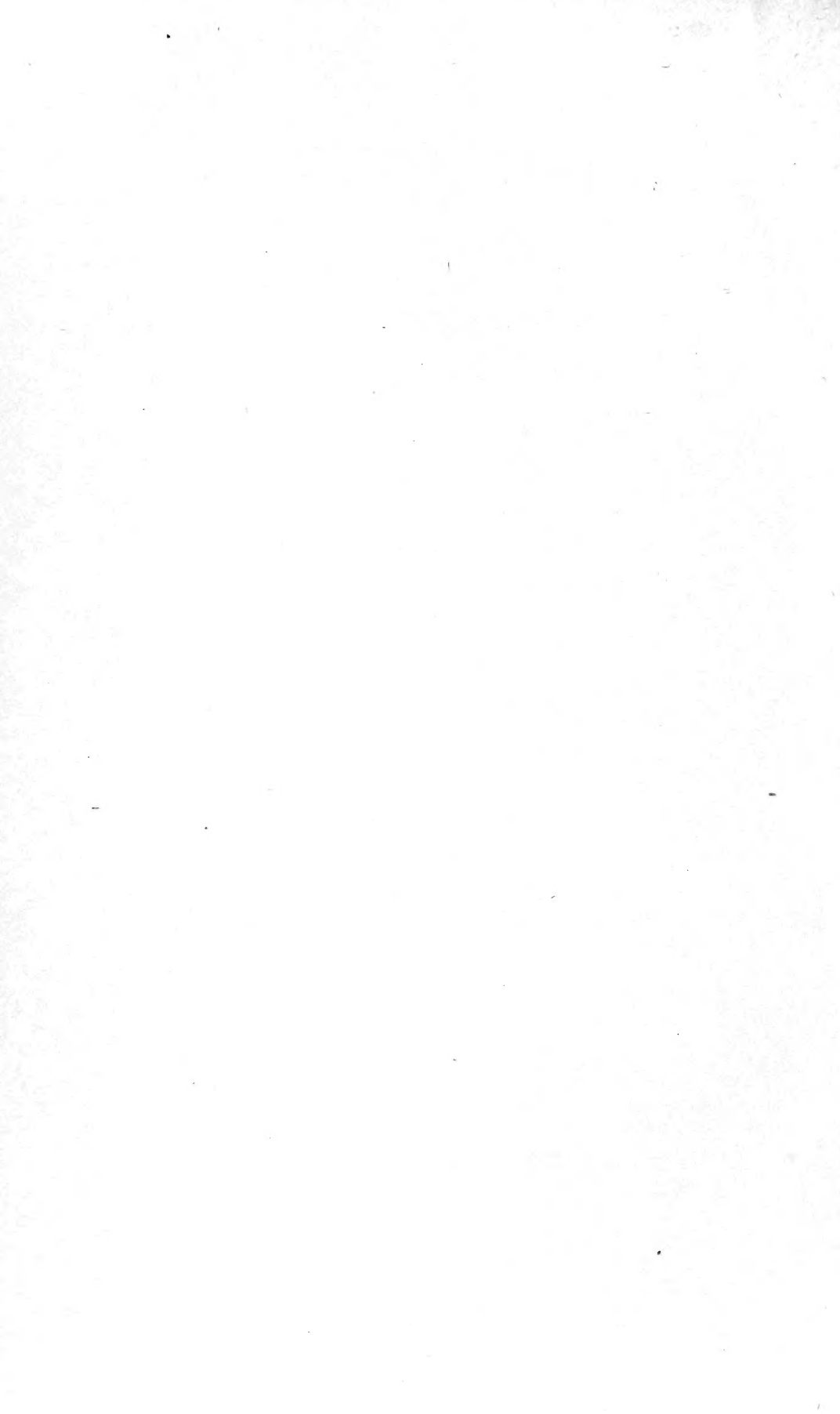


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# The Sesamoid Articular

A Bone in the Mandible of Fishes

BY

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WITH FIFTEEN TEXT FIGURES

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# THE SESAMOID ARTICULAR: A BONE IN THE MANDIBLE OF FISHES

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## INTRODUCTION

The sesamoid articular is a small bone on the inner surface of the articular of fishes giving attachment to a stout tendon from the adductor mandibulae muscles.

This investigation was undertaken to ascertain in what groups of fishes it might occur; what its variation and condition might be in different groups; and to give the early history of the literature, which recent authors seem to be ignorant of.

Originally it was intended to work on the homologies of the adductor mandibulae muscles in order better to establish the identity of the sesamoid articular and its tendon; but after considerable work (done mostly at the Zoological Station at Naples in January and February of 1915), it appeared that the muscles are so variable in size, position, and relationship to each other that the sesamoid articular and its tendon were more valuable in identifying the muscle than the reverse.

A few of the drawings and brief descriptions of the muscles are here presented, and show their diversity of form and position. Many other fishes were worked on, but to report on all of them does not appear to be of advantage to the present inquiry.

The first notice of the sesamoid articular occurs in Cuvier and Valenciennes's *Histoire Naturelle des Poissons*. Cuvier found it in the perch, and published such a picture of it that there can be no question as

to its identity. He called it the Operculaire (number 37 of his picture), homologizing it with a bone in the jaw of reptiles that he called by the same name, supposing the reptile bone homologous with the true opercle bone of fishes, though in the fish he also uses this name (number 28) for the bone commonly so called.

In 1846 Owen, in his Lectures on Comparative Anatomy and Physiology of the Vertebrates, published a picture of the mandible of the Sudis, *Arapiama gigas*, with the following remarks: "The great Sudis and the Polypterus have the splint-like plate along the inner surface of the ramus, answering to that which Camper and Cuvier have unfortunately called 'operculaire' in the mandible of reptiles, but to which I have given the name of 'splenial' to prevent the confusion from the synonymy with the true opercular bone of fishes." Later in his Comparative Anatomy Owen included *Amiatus* with the other two forms, and adds: the splenial "supports teeth and develops a coronoid process."

It thus appears that Owen's splenial is the bone that usually bears that name in the Ganoids. It need scarcely be added that no homology exists between the splenial, which is clearly a dental cement bone, and the sesamoid articular (Cuvier's operculaire).

Günther, in his Introduction to the Study of Fishes (p. 91), makes a similar mistake when he refers to the os operculare as a synonym of the splenial as follows. "The splenial or os operculare, which is situated on the inside of the articulary."

Ridewood (Linn. Soc. Jour., XXIX, p. 267), in writing of the mandible of the Sudis, says: "Although the bony lamina that bears the teeth occupies the position of the splenial bone, it is not a distinct plate of bone as might be concluded from the remark of Owen." There can be little question but that Owen referred to this inseparable toothed plate, rather than to a sesamoid articular. Dr. Ridewood reports the sesamoid articular not present.

Owen, in a table of synonyms that he published in his Lectures, includes the name subvomerale of Geoffroy St. Hilaire. I fail to find the term in the paper Owen cites (Ann. des. Sci. Nat., III, 1824), and therefore can not be sure whether it is the homolog of the sesamoid articular or of the splenial; but if of the former it is an earlier account of the bone than the one given by Cuvier.

Agassiz also uses the term operculaire for the splenial of *Polypterus* and *Lepisosteus* (Poissons Fossiles, vol. 2, part 2, pp. 20 and 42, pl. B and C, 1843), but in the Sudis (*Piscium Brasiliensium*, pl. B, 1829) he applies operculaire to an entirely different bone, that Owen in the same



form called the surangular—confusing it with the surangular of Ganoids—and that Ridewood says, is “merely the endosteal articular displaced.”

Erdl, in his work on *Gymnarchus*, labeled the sesamoid articular, in both German and Latin, the kronenforsatz des Unterkiefers, pars coronoidea mandibulae. He thus, doubtless, as Cope did later, considered it the homolog of the coronoid of reptiles.

Bridge in 1877 described the bone in *Amiatus* that I have herein homologized as the sesamoid articular. He termed it simply ossicle C, but since that time every anatomist who has worked on *Amiatus* has referred to it as “ossicle C of Bridge.”

The last author to write of this bone was Ridewood (Proc. Zool. Soc. Lond., 1904, p. 72), whom I follow in the use of the term ‘sesamoid articular’ as the best suggested for it. It is the Anglicized form of Vetter’s Sesamoidverknöcherung. He gives a history of the literature of the bone since the time of Cope, which I need not here repeat. Among the papers touched upon he gives undeserved prominence to a hastily prepared foot-note published by me in 1899 (Proc. U. S. Nat. Mus., XXII), in which I listed various unrelated forms that possessed a sesamoid articular. My material was such prepared skeletons as happened to be at hand, and the note was published purely with the object of showing the worthlessness of the bone in taxonomy as used by Cope. As my discussion was based on Cope’s paper I followed him in the use of the term ‘coronoid bone’ without thought of homology.

Most of the examples I reported upon were adult; and because the bone happened to be missing in a young individual of *Mugil*, the question was brought up as to whether it was not the ossified end of the tendon, that is always attached to it, developed with age. This seemed more probable at that time, as I was investigating the skeleton of *Dallia* in which the posttemporal ligament ossifies rather late in life. In the young *Mugil* referred to the bone was doubtless lost in preparing the skeleton, for I find it well developed in much smaller individuals than those reported upon.

It has seemed most convenient for the needs of this paper to follow no scheme of grouping. The captions are not at all coordinate in value, nor are they consistent in terminology. For instance, the small orders of Ganoids together with the lung fishes are under one caption. “The eels” includes two orders; “the clupeoid fishes” is of superfamily rank; and the spiny-rayed fishes are grouped under such comprehensive captions as “the blennies” or “the mailed-cheeked fishes,” or even under family names.

Where the term 'endosteal' or 'ectosteal part of the articular' is used it does not mean that these elements are necessarily separate. Nearly always the anterior end of the endosteal part remains distinct from the ectosteal part, though no trace of suture may remain. The endosteal part forms the surface for the articulation of the quadrate, and usually projects forward in a process, which I have herein referred to as the endosteal process. The process abruptly becomes Meckel's cartilage (or more correctly Meckel's cartilage abruptly ossifies to form the endosteal process). Often the anterior part of the endosteal process is of the same size and shape as Meckel's cartilage, and the line of demarcation between the two is difficult to appreciate, by sight alone, until the latter begins to dry. The ectosteal part of the articular, usually herein called the ectosteal plate, lies outward from the endosteal part and forms the greater part of the bone. It is the continuation of the part articulating with the dentary, sheltering Meckel's cartilage on the outer surface.

I may here point out the danger of reporting on the absence of the sesamoid articular in material that the investigator has not prepared for himself, for it is often so loosely attached to the other elements of the mandible, and so firmly to the tendon, that in cleaning the bones it is easily removed with the latter. For instance, I found it in all of the Clupeoid forms that I examined, though in several of them it has been reported absent.

It was the original intention to investigate the development of the bone; but from lack of good material it appears better to publish the paper in its present form, reserving the development for the indefinite future when, it is hoped, material shall have accumulated to illustrate the various phases of it.

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### SYNONYMY

- Operculaire Cuvier (C. & V. Hist. Nat. Pois., 1827).  
 Kronenforsatz des Unterkiefers, pars coronoidea mandibulae Erdl  
 (Abhand. Bayer Akad. Wiss., V—I, 1847).  
 Ossicle C. Bridge (Jour. Anat. Phys., XI, part 4, 1877).  
 Sesamoidverknöcherung Vetter (Jena Zeitschr., XII, 1878).  
 Coronoid Cope (Proc. Am. Phil. Soc., XVII, 1878).  
 Addentary Gill (Proc. U. S. Nat. Mus., XVIII, 1895).  
 Sesamoid articular Ridewood (Proc. Zool. Soc. Lond., 1909).

## THE ADDUCTOR MANDIBULAE MUSCLES

### *Scorpaena scrofa*.

This short description and drawing is presented only to include a common type. Dr. Allis, in his *Cranial Anatomy of the Mail-Cheeked Fishes* (Zoologica Stuttgart, H, 57, 1909), has given a very complete, and much better description.

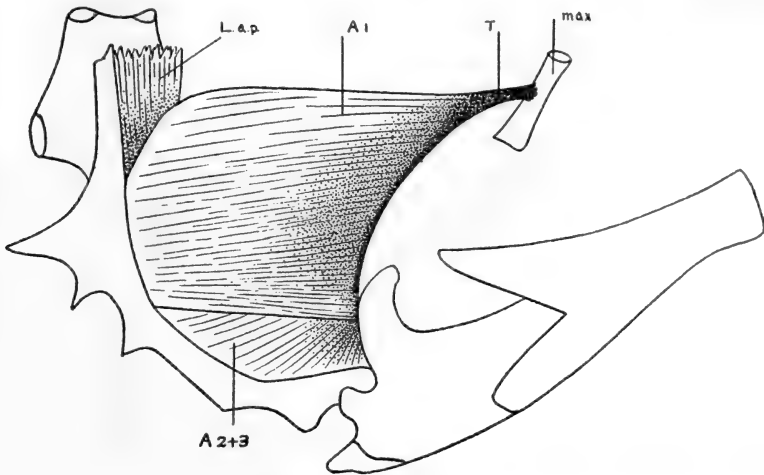


Fig. 1.—SCORPAENA SCROFA

*A 1-2-3*, muscles of Vetter; *Lap*, levator arcus palatini; *max*, maxillary; *T*, tendon.

The superior part of the adductor mandibulae consists of two parts: (1) A dorsal muscle originating on the preopercle and running forward to a broad tendinous band along its entire front, which at its upper end forms a tendon to the maxillary, and at its lower end joins the tendons of the ventral muscle to the mandible. (2) A ventral muscle originating on the preopercle (and on other bones anterior to it), and covered on its upper part by the dorsal muscle. Anteriorly it is inserted on three tendons running to the mandible; the middle one of which is the sesamoid articular tendon. This muscle represents *A-2+3* of Vetter.\* According to

\*Vetter. *Janaische Zeitschr.*, XII, 1878.

Dr. Allis that part of it that posteriorly runs internal to the levator arcus palatini may represent A-3 and the part external to it A-2.

### Dentex vulgaris.

The superior part of the adductor mandibulae muscle consists of two parts: (1) A dorsal muscle which at first sight appears to be made up of two muscles—an outer and an inner one. The outer part is strongly attached to the maxillary at one end by a short stout tendon, and to the preopercular ridge at the other end by a longer, but scarcely less stout, tendon. Above the preopercular tendon projects the inner part. It originates on the preopercle and runs downward and forward obliquely behind the outer part, and is attached anteriorly to the lower edge of the outer part, and to a thick sheet of tendon that covers the greater part

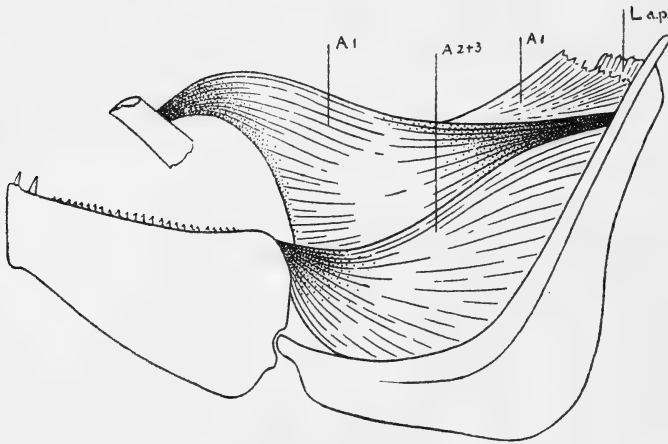


Fig. 2.—DENTEX VULGARIS

A 1-2-3, muscles of Vetter; *Lap*, levator arcus palatini.

of the inner surface of all of the muscles. The lower edges of the inner and the outer parts are continuous, so that when the two are spread out it is apparent that they are a single muscle folded upon itself. It represents A-1 of Vetter.

(2) A ventral muscle, which is larger than the dorsal muscle, originates on the preopercular ridge and the surface of the anterior adjoining bones. The thick sheet of tendon, that covers much of the inner part of this and the dorsal muscle, shallowly invades this muscle at about its middle, and along the plane of this invasion the muscle may be rather

easily separated. The inner part thus separated may represent A-3 of Vetter, and the outer part A-2.

The upper part of the sheet of tendon is free from the muscle and at its anterior end helps to form the maxillary tendon. Continuous with this sheet of tendon is the tendinous covering of the inferior part of the adductor mandibulae, or the part confined to the mandible (A- $\omega$  of Vetter), which posteriorly sends back a bundle of fibers to the middle of the quadrate. Dissecting this tendinous covering away a stout sesamoid articular tendon is found, which comes from the lower part of the sheet of tendon, or the part covering the ventral muscle (A-2+3). Attached to the articular below the sesamoid articular and below Meckel's cartilage is a less compact bundle of tendinous fibers from the same source. Crossing these two, and attached still lower on the articular, is another bundle of fibers coming more directly from the upper part of the sheet of tendon, or the part covering the dorsal muscle (A-1).

The levator arcus palatini muscle is very small, and no part of the adductor mandibulae runs behind it.

#### Tylosurus acus.

The superior portion of the adductor mandibulae is in two parts: (1) An external part that is ventral to the internal muscle, instead of dorsal to it as in *Scorpaena*. It originates on the preopercle and covers a considerable portion of the levator arcus palatini and of the internal

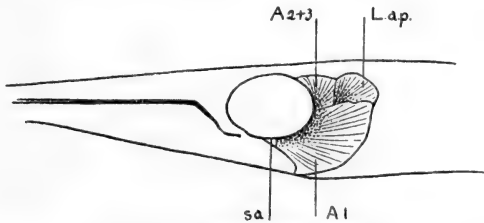


Fig. 3.—TYLOSURUS ACUS

A 1-2-3, muscles of Vetter; Lap, levator arcus palatini; sa, sesamoid articular.

muscle. Its tendinous surface fibers on its lower part converge and are joined directly to the sesamoid articular, while those of the upper part are attached to the tendon which descends from the dorsal internal muscle and borders its anterior edge. (2) The portion referred to above as the dorsal internal muscle has its origin on the anterior edge of the hyomandibular and the surface of the metapterygoid. Posteriorly

it is covered by the levator arcus palatini. It sends down a stout tendon bordering the posterior orbital margin, and the anterior edge of the ventral muscle as described, and joins the sesamoid articular. As neither of these muscles sends a tendon to the maxillary, and as each contributes to the sesamoid articular, the homologies of the two parts are not very clear. From their relation with the levator arcus palatini the outer ventral muscle would seem to represent A-1 of Vetter, and the dorsal inner muscle A-2 (+3?).

### Mugil cephalus.

The superior part of the adductor mandibulae muscle consists of three parts: (1) A lower outer muscle which originates on the preopercular ridge and is connected by a stout tendon to the maxillary (A-1 of Vetter). (2) A muscle situated above and partly under the first originates higher on the preopercular ridge, and lies outside of the levator arcus palatini muscle (A-2 of Vetter). (3) The third is almost wholly

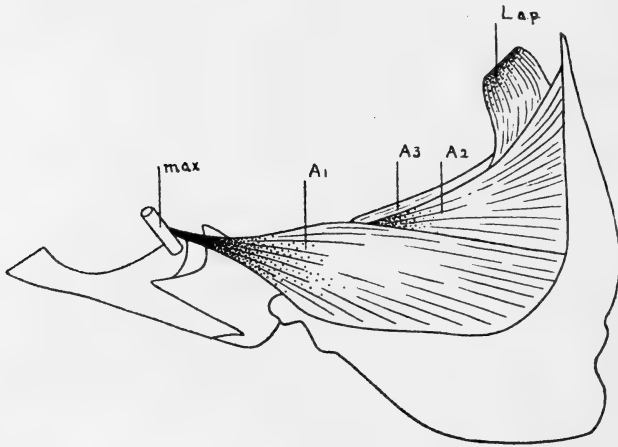


Fig. 4.—MUGIL CEPHALUS

A 1-2-3, muscles of Vetter; *Lap*, levator arcus palatini; *max*, maxillary.

covered by the second, its posterior end lying under the levator arcus palatini, and originating on the surface of the metapterygoid. The second and third unite anteriorly in a stout sesamoid articular tendon. The inferior, or mandibular part of the muscle (A- $\omega$  of Vetter), which is almost confined to the mandible, consists of two parts. The upper part gives off a broad band of tendon which connects it with the front of the quadrate, and it also sends a few fibers to join the sesamoid articular

tendon. The lower part is longer and inward from the first. It runs back to just in front of where the interhyal joins the face bones.

**Leiognathus fasciatus.**

This form is unique in having two equally stout tendons to the sesamoid articular. A large muscle (A-1 of Vetter) springs from the preopercle and covers the cheek. Its fibers converge to a point anteriorly from which a stout tendon runs upward and forward to the maxillary, and another downward and backward to the posterior end of the sesamoid articular. A long muscle (A-3 of Vetter) springing from under the levator arcus palatini gives rise to a second tendon, which, crossing the first tendon, reaches the sesamoid articular near its middle.

## THE SESAMOID ARTICULAR

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### THE GANOIDS AND LUNG-FISHES.

#### *Acipenser transmontanus*, *A. mikadoi*.

In this genus I find only two bones: the very large dentary, forming the greater part of the mandible, and a small splint of bone lying on the inner surface of Meckel's cartilage. (In large specimens a mento-meckelian bone is developed in the anterior part of Meckel's cartilage and forms a third element.) From its position the small inner splint might either represent the sesamoid articular or the splenial. The tendon, however, of the adductor mandibulae (or at least the muscle that functions as such) is attached to the upper edge of the cartilage between this inner bone and the dentary, and though some outer fibers of the tendon are attached to the edges of both bones, the main attachment would suggest that no sesamoid articular were present and that the inner bone represents the splenial. It is the bone called the coronoid by W. K. Parker in his *Structure and Development of the Skull in Sturgeons* (Phil. Trans., 1882, p. 173, pl. 18). In my specimens it is much larger than is shown in Dr. Parker's plate, and is everywhere isolated from the dentary by cartilage.

#### *Lepisosteus platostomus*, *L. osseus*.

Among the eight elements that make up the mandible of *Lepisosteus* (two of which are presplenials) I find none that I can homologize with the sesamoid articular, unless it be an inner shelf of the splenial in the coronoid region. This is not in the typical region for the sesamoid articular, being remote from Meckel's cartilage, and the only ground for considering the possibility of this homology is that a stout adductor tendon is attached to it. A tendinous band also gives muscle attachment to the edge of the supra-angular. I have examined several specimens of various sizes down to 3½ inches in length, but find no indication of this inner splenial process as a separate element.



**Amiatus calva.**

Just above the posterior part of Meckel's cartilage are two small bones in the typical position of the sesamoid articular. They were first noticed by Bridge (Jour. Anat. Phys., vol. XI, 1877), who designated them on his drawing of the mandible of *Amiatus* as "c" and "b" and so referred to them without giving them names. To ossicle *c* is attached a tendon from muscles that are probably homologous with parts of the adductor mandibulae muscles in more highly specialized teleosts.\* Dr. Ridewood (Proc. Zool. Soc. Lond., 1904, p. 56) has failed to find these two ossicles as separate bones and has homologized them with the endo-articular. In two adult specimens I have at hand, however, these two bones are very evident. Ossicle *c* is the sesamoid articular, and ossicle *b* only represents the endoarticular.

**Polypterus bichir.**

In *Polypterus* I find no separate sesamoid articular, but on the inner surface of the articular, just above Meckel's cartilage, in the typical place for the sesamoid articular is a projecting shelf of bone to which a stout adductor tendon is strongly attached. My only specimen is one 18 inches in length. In the young I should confidently expect to find this process as a separate sesamoid articular.

**Ceratodus forsteri.**

Of the lung-fishes I have only *Ceratodus* in which I find no sesamoid articular. A big bundle of tendons gives muscle attachment to both the ectoarticular and splenial just behind the mandibular tooth in the coronoid region. In the other lung-fishes there is no bone in published descriptions or figures that could be homologized with the sesamoid articular.

**THE CLUPEOID FISHES.**

Dr. Ridewood, "On the Cranial Osteology of the Fishes of the Families Elopidae and Albulidae" (Proc. Zool. Soc. Lond., 1904), reports the sesamoid articular present in *Elops saurus* and in *Albula vulpes*, not present in *Pterothrissus gissu* (*Bathythrissa dorsalis*), and in *Megalops cyprinoides* he does not mention it, but he states that except for proportions it resembles *Elops*.

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\*For a discussion of these see Allis, Cranial Muscles and Nerves of *Amia calva*. (Jour. Morph., XII, 1897, pp. 554, 580 and 752.)

In his paper "On the Cranial Osteology of the Fishes of the Families Mormyridae, Notopteridae, and Hyodontidae" (Jour. Linn. Soc., vol. XXIX), he reports a sesamoid articular present in *Notopterus kahirat* and *Hiodon alosoides*.

In his paper "On the Cranial Osteology of the Clupeoid Fishes" (Proc. Zool. Soc. Lond., 1904) he finds a sesamoid present in *Chirocentrus dorab*, *Alosa finta*, and *Chanos chanos*, but fails to find any in *Clupea harengus*, *Dussumieria acuta*, *Engraulus encrasicolus*, or *Coilia nasus*. In *Dorosoma erebi* he mentions neither its presence nor absence.

In his paper "On the Cranial Osteology of the Fishes of the Families Osteoglossidae, Pantodontidae, and Phractolaemidae" (Jour. Linn. Soc., vol. XXIX) he reports a sesamoid articular present in *Osteoglossum leichardti*, and *Heterotis niloticus*, but absent in *Arapaima gigas*. In *Pantodon buchholzi*, and in *Phractolaemus ansorgii*, he does not mention a sesamoid articular, but his material was in the form of prepared skulls and its absence might only mean that it was lost in preparing.

In his paper "On the Skull of *Gonorhynchus greyi*" (Ann. Mag. Nat. Hist., 1905) he reports a sesamoid articular present in *Gonorhynchus greyi*.

#### **Elops saurus.**

The rather small sesamoid articular is attached to the ectosteal part of the articular far in front of the endosteal part, and is somewhat covered with Meckel's cartilage. A deep cavity, open in front, is partitioned off in the ectosteal part just behind the sesamoid articular by a thin plate of bone. This is shown in Dr. Ridewood's picture (Proc. Zool. Soc. Lond., 1904, vol. II, p. 40).

#### **Albula vulpes.**

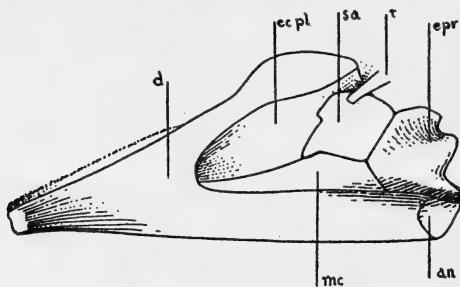


Fig. 5.—ALBULA VULPES

*an*, angular; *d*, dentary; *ecpl*, ectosteal plate; *epr*, endosteal process; *mc*, Meckel's cartilage; *sa*, sesamoid articular; *t*, tendon.

The sesamoid articular is a very large, thick bone closely attached to the front of the endosteal part of the articular, with its outer surface against the ectosteal part. Its surface is almost as great as that of the endosteal part, and has the appearance of being in as close relationship with Meckel's cartilage. Its structure, its union with Meckel's cartilage, and its concave lower edge, from which the cartilage issues, are all strikingly like the endosteal part.

#### ***Dorosoma cepedianum.***

Dr. Ridewood reported on *Dorosoma erebi*, and did not mention a sesamoid articular or show one in his picture. This species has a well developed one in front of the cup-shaped process of the endosteal part of the articular, and partly covered by Meckel's cartilage.

#### ***Dussumieria elopsoides.***

Dr. Ridewood reports the sesamoid missing in *Dussumieria acuta*, but in this species there is a small one situated against the articular and partly covered by Meckel's cartilage.

#### ***Clupea pallasii.***

Dr. Ridewood reports the sesamoid articular missing in *Clupea harangulus*. In this closely related species it is present, situated against the articular just in front of the endosteal process, and covered by the base of Meckel's cartilage.

#### ***Opisthonema oglinum.***

The sesamoid articular is moderately large, and is situated on the upper part of Meckel's cartilage and the endosteal process.

#### ***Coilia nasus.***

In this form Dr. Ridewood failed to find a sesamoid articular. A small one is present, however, in the deep notch that is formed directly in front of the articulating surface of the quadrate, and covered by Meckel's cartilage. The line of demarcation between the endosteal and ectosteal parts of the articular is not evident.

**Pterengraulis atherinoides.**

Though much larger and of more dense bone, the sesamoid articular is essentially as in *Coilia nasus*.

**Engraulis encrasicolus.**

In this species the sesamoid articular is large and essentially as in *Pterengraulis* and *Coilia*, being as large as in the former. Dr. Ridewood reports it missing, it having doubtless been lost in preparing the specimen, for it is easily pulled away and remains attached to its tendon.

**Pterothrissus gissu (Bathyrhissa dorsalis).**

Dr. Ridewood reports the sesamoid articular unossified in this form. It is, however, very well developed, and is placed saddle-like over Meckel's cartilage remote from the endosteal process. It, like *Engraulis*, has this bone so loosely attached that it is liable to be removed with its tendon.

**THE SALMONOID FISHES.****Salmo irideus.**

A small sesamoid articular is loosely attached against the ectosteal part of the articular remote from the endosteal part, and is partly covered by the slender Meckel's cartilage.

**Osmerus dentex.**

In this the sesamoid articular is essentially as in *Salmo*.

**Thymallus signifer.**

The sesamoid articular is moderately large, and on the upper edge of Meckel's cartilage remote from the endosteal part of the articular.

**Argyrosomus hoyi.**

In this form the sesamoid articular is rather large, situated on the upper surface of Meckel's cartilage, and in contact with both the endosteal and ectosteal parts of the articular.

**THE SYNODONTIDÆ.****Synodus lucioceps.**

In this the sesamoid articular is large. It is attached to the endosteal part of the articular at the inner side and posterior end, and arches over Meckel's cartilage to the ectosteal part of the articular.

### THE EELS.

In all the examples examined the dentary forms a sheath about the articular, hiding Meckel's cartilage completely from view, and covering the anterior part of the sesamoid articular. The sesamoid articular tendon is well developed.

#### ***Symbranchus marmoratus.***

A moderately large sesamoid articular is situated on the articular above the endosteal process and base of Meckel's cartilage. The tendon from the sesamoid articular is a flat band somewhat connected with a similar band attached more posteriorly on the articular. A great mass of tendinous tissue gives muscle attachment to the upper, posterior process of the dentary.

#### ***Anguilla chrysypa.***

The sesamoid articular is situated on the endosteal process of the articular, and is covered anteriorly by the inner plate of the dentary, under which it extends forward over Meckel's cartilage.

#### ***Synaphobranchus pinnatus.***

The sesamoid articular is an exceedingly slender splint of bone covering Meckel's cartilage on its upper and inner surface, directly in front of where the cartilage issues from the endosteal process of the articular, and extending forward into the dentary sheath.

#### ***Leptocephalus conger.***

In this form the articular is anteriorly divided. The lower division is entirely outside of the dentary, running along its outer lower edge, while the upper division is sheathed by the dentary. A very large sesamoid articular is on the endosteal part of the upper fork and forms with it the cavity from which Meckel's cartilage issues, and which is usually confined to the endosteal process, though here the sesamoid articular forms the greater part of it. The sheath of the dentary fits tightly about the articular and the sesamoid articular, leaving only a minute hole into the dentary sheath above the sesamoid articular.

#### ***Muraenesox coniceps.***

The sesamoid articular is on the endosteal process of the articular,

and extends into the cavity of the dentary sheath along the top of Meckel's cartilage. The dentary sheath is wide open behind, unlike that of *Leptocephalus conger*.

**Ophichthus triserialis, Ophisurus serpens, Lycodontis castaneus.**

In these forms the sesamoid articular and its relationship to the surrounding elements differ in no important way from that of *Muraenesox*.

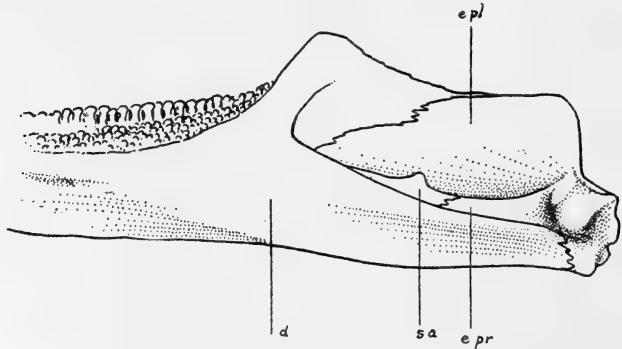


Fig. 6.—LYCODONTIS CASTANEUS

*d*, dentary; *epl*, ectosteal plate; *epr*, endosteal process; *sa*, sesamoid articular.

**THE HETEROGNATHOUS FISHES.**

**Hoplias microlepis.**

The sesamoid articular is a thick, irregular bone on top of Meckel's cartilage, and attached against the articular just anterior to the endosteal process of that bone. The tendon is slender.

**Curimatus isognathus.**

In this the sesamoid articular is placed as in *Hoplias*, but the bone is thinner and flatter and fits more broadly on the articular.

**Hydrocynus cuvieri.**

The sesamoid is a flat bone with a tubercle for the attachment of the tendon. It lies closely against the ectosteal part of the articular on top of Meckel's cartilage and the endosteal process.

## THE EVENTOGNATHOUS FISHES.

*Deltistes luxatus*, here described, but *Ictiobus bubalus*, *Chasmistes brevirostris*, *Myxostoma aureolum* differ only as noted.

Meckel's cartilage appears as a short, deep, thin, somewhat quadrangular plate, situated rather high on the mandible. Posteriorly it abruptly ends against the endosteal process of the articular. Anteriorly it ends in a similar way against a portion of the dentary, which may represent the mento-meckelian ossicle of some of the Ganoids here incorporated with the rest of the dentary.

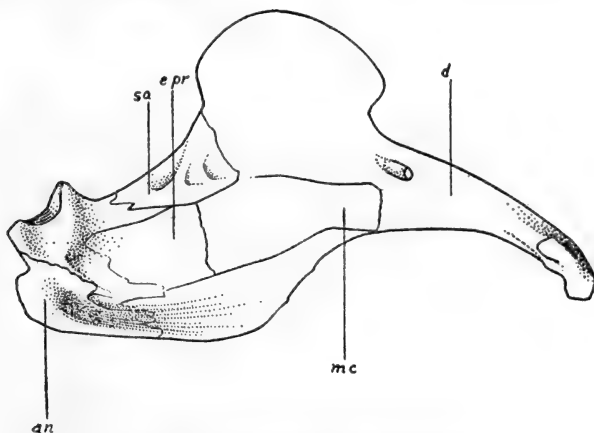


Fig. 7.—CHASMISTES BREVIROSTRIS

*an*, angular; *d*, dentary; *epr*, endosteal process; *mc*, Meckel's cartilage; *sa*, sesamoid articular.

The sesamoid articular is a very large flat plate, somewhat triangular in shape, its upper edge nearly even with the upper edge of the mandible, and its lower about equally overlying Meckel's cartilage and the endosteal process of the articular. It lies broadly, and is connected rather firmly, against the articular, and its anterior end overlaps the dentary. This is unique to my knowledge, for in other forms it is confined to the articular, though in the eels the dentary overlies it. In *Chasmistes* the condition is the same, but in the other two forms the sesamoid articular does not reach to the dentary. Considerable variation was found in this character (all specimens were of rather large size), and as it is of secondary development it is of little importance. The tendon is large and flat, and is attached to the middle of the upper edge of the sesamoid articular.

*Cyprinus carpio*, *Leuciscus bicolor*, *Semotilus atromaculatus*, *Ptychocheilus oregonensis*, *Orthodon microlepidotus*, *Pogonichthys macrolepidotus*.

The sesamoid articular is more slender than in *Deltistes* et. al., more closely associated with Meckel's cartilage, which is much more slender, and it is lower in position, being remote from the upper margin of the

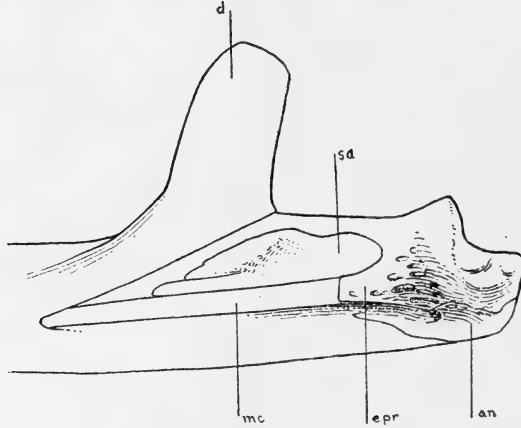


Fig. 8.—LEUCISCUS BICOLOR

*an*, angular; *d*, dentary; *epr*, endosteal process; *mc*, Meckel's cartilage; *sa*, sesamoid articular.

articular. It is a large flat bone lying closely against the articular, and articulated along its lower edge with the endosteal process and with Meckel's cartilage, being concave to fit over them. There is a prominent tubercle of bone above its middle to which a stout tendon is attached.

#### *Misgurnus anguillicaudus*.

In this form I fail to find a separate sesamoid articular, though a tendon is attached to the middle of the articular about in the typical place for one. The inner part of the articular is broken up into a lace-like plate which seems to be an integral part of it.

### THE SILUROIDS.

#### *Silurus glanis*.

The sesamoid articular is smaller than in the other siluroids examined. It is situated on the upper inner edge of Meckel's cartilage, and a small



process from it joins the inner surface of the ectosteal plate of the articular, but does not articulate with the endosteal process. The tendon is large.

#### **Amiurus catus.**

A very large sesamoid articular is present. It is fitted saddle-like around the upper part of Meckel's cartilage. Its inner edge is articulated by a dentate suture with the inner edge of the endosteal process of the articular which covers the posterior part of Meckel's cartilage. Its outer surface lies flat against the inner surface of the ectosteal plate. It thus forms the roof of a cavity for Meckel's cartilage, the inner side wall of which is formed by the endosteal part of the articular.

#### **Platystomatichthys sturio.**

The sesamoid articular overlies the upper edge of Meckel's cartilage, and is articulated with the endosteal process but does not extend to the ectosteal plate of the articular. The tendon is attached to the extreme posterior upper corner of it.

#### **Brachyplatystoma vaillanti.**

Meckel's cartilage turns upward to the point of the coronoid process. A large sesamoid articular overlies the cartilage at a point where it turns up from the typical horizontal portion. It is articulated with the endosteal process of the articular, and arching over the cartilage attaches itself to the inner face of the ectosteal plate. Posteriorly, a little above its middle, is a blunt tubercle of bone to which the tendon is attached.

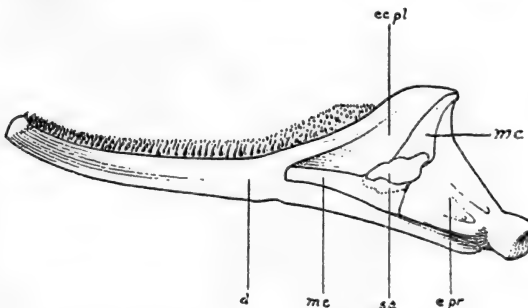


Fig. 9.—BRACHYPLATYSTOMA VAILLANTI

*d*, dentary; *ecpl*, ectosteal plate; *epr*, endosteal process; *mc*, Meckel's cartilage; *sa*, sesamoid articular.

**Trachycorystes galeatus.**

The sesamoid articular extends over the top of Meckel's cartilage, connecting the endosteal process and the ectosteal plate. The tendon is very large and stout.

**Ictalurus furcatus.**

In this the sesamoid articular is as in *Brachyplatystoma*, but much smaller and more slender.

**Selenaspis dowii, Sciadeichthys troscheli.**

In these the sesamoid articular is essentially as in *Amiurus*.

**THE GYMNOTID FISHES.****Electrophorus electricus.**

The sesamoid is here long and rod-like, and is situated against the ectosteal part of the articular in front of the endosteal part. It lies on and slightly arches over Meckel's cartilage. A large tubercle on its posterior end gives attachment to a very stout tendon.

**Gymnotus carapo.**

The sesamoid articular is a very large flat bone situated above the base of Meckel's cartilage and the endosteal process. It projects broadly over the inner surface of the latter and is strongly articulated to it. To a prominent tubercle on its posterior end a large tendon is attached.

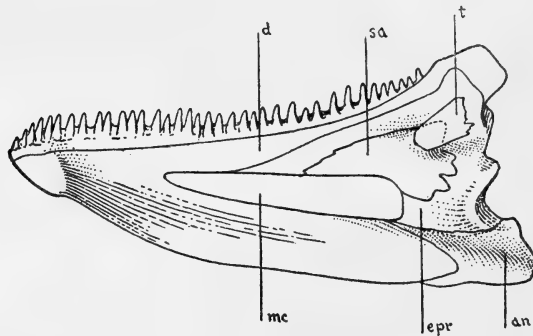


Fig. 10.—GYMNOTUS CARAPO

*an*, angular; *d*, dentary; *epr*, endosteal process; *mc*, Meckel's cartilage; *sa*, sesamoid articular; *t*, tendon.

**THE SCYPHOPHORI.****Gymnarchus niloticus.**

Dr. Ridewood presents a good plate of the mandible of this form (Linn. Soc. Jour., XXIX, pl. 23) in which the sesamoid articular is shown to be nearly as large as the endosteal articular, with which it is connected by a deeply dentate suture. It lies against the ectosteal part of the articular.

In the above paper a sesamoid articular is reported to be present in *Mormyrops deliciosus*, but not present in *Pterocephalus bane*.

**THE HAPLOMI AND XENOMI.****Umbra lima, Dallia pectoralis.**

These two are similar in having the sesamoid articular very large, attached far forward on the ectosteal plate with which it is broadly connected, concave on its lower surface to fit over Meckel's cartilage, and far remote from the endosteal part of the articular, which is little larger than is necessary to form the condyle for the quadrate.

**Esox reticulatus.**

The sesamoid articular is much smaller than in *Umbra*, and not placed so far forward on the ectosteal plate of the articular, nor so broadly connected. Otherwise it and the condition of the small endosteal part of the articular are similar.

**Fundulus similis.**

The large sesamoid articular lies about equally over the top of the endosteal process and Meckel's cartilage, with its outer surface against the ectosteal plate. The endosteal part of the articular, unlike that of *Esox*, is ossified well forward.

**THE SYNENTOGNATHI****Tylosurus marinus, T. acus.**

The sesamoid articular is an exceedingly large, flat bone, suturally attached to the ectosteal plate of the articular, and at its lower edge to

the endosteal process, extending forward over the posterior end of Meckel's cartilage. Upward and backward it projects above the articular in a process that shows to a considerable extent when viewing the mandible from the outer surface. To it the muscle is closely attached by tendinous tissue, as herein described under adductor muscles. It is of such a size and position that it is little wonder Cope called it the coronoid, though it is considerably behind the coronoid bone of reptiles, or the coronoid cartilage of *Amiatus*. The anterior upper angle of the articular of *Tylosurus*, which is just behind the dentary, is in the coronoid region.

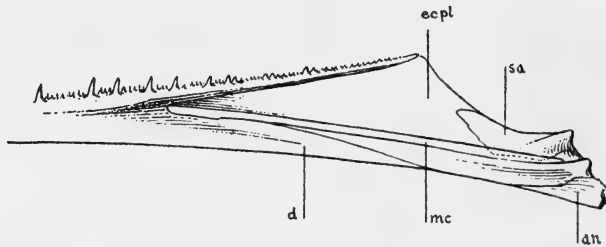


Fig. II.—*TYLOSURUS ACUS*

*an*, angular; *d*, dentary; *ecpl*, ectosteal plate; *mc*, Meckel's cartilage; *sa*, sesamoid articular.

#### **Exocœtus californicus.**

The sesamoid articular is here as it is in *Tylosurus*, except that it scarcely extends above the articular to be visible from the outside.

#### **Chirodorus atherinoides, Hemiramphus richardi.**

These forms have the sesamoid articular essentially alike and almost identical with that of *Tylosurus*.

### **THE HEMIBRANCHIATE FISHES.**

#### **Gasterosteus cataphractus.**

In this form the sesamoid articular is a nodule of bone on the upper part of Meckel's cartilage attached against the ectosteal plate of the articular far from the coronoid region, or the upper margin of the mandible. It is smaller than in the other Hemibranchiate fishes.

**Macrorhamphosus sagifue.**

At the upper edge of the broad Meckel's cartilage is a rather wide, disk-like sesamoid articular placed flat against the ectosteal plate, considerably above the endosteal part of the articular, and directly below the ascending process of the dentary. It extends upwards more than usual, thus approaching the condition of the Synentognathous fishes.

**Fistularia petimba.**

The dentary and articular are very complex in shape. Each of them has three forks, which more or less interlock. The middle fork of the dentary (by far the largest) fits between the middle and lower forks of the articular in a deep notch that extends back nearly to the condyle of the quadrate, thus almost dividing the articular into two parts. Directly above this division in the articular are the endosteal process of the articular and Meckel's cartilage. The upper forks of both elements arch upward, leaving an open space, above which they nearly meet. It is to the posterior edge of this upper fork of the articular, to a small process of bone, that the adductor tendon is attached. The process is remote from Meckel's cartilage, and is probably not the homolog of the sesamoid articular. In the smallest specimen available (5 inches long) no suture was apparent to indicate a separate element in this region.

**Aulostoma valentini.**

The elements of the mandible differ from those of *Fistularia* only in unimportant details. The upper fork of the dentary is scarcely developed, and that of the articular does not arch over an open space, but the posterior part of it bears a process (larger than in *Fistularia*) to which the adductor tendon is attached.

**Aulorhynchus flavidus, Aulichthys japonicus.**

The sesamoid articular is a very large plate, lying flat against the ectosteal part of the articular, and extending up from Meckel's cartilage, which it only barely touches, towards the coronoid region. To its upper end is attached a strong tendon, and to the coronoid process is attached a smaller, more fibrous one.

**THE SALMOPERCÆ.*****Percopsis guttatus.***

The sesamoid articular is very loosely attached to the upper surface of Meckel's cartilage, slightly in contact with the endosteal process of the articular, but scarcely with the ectosteal part.

***Aphredoderus sayanus.***

The sesamoid articular is situated against the ectosteal plate of the articular, above and outward from the endosteal process, and nearly covered from sight by Meckel's cartilage.

**THE PERCESOCES.*****Atherinopsis californiensis***

In this the sesamoid articular is very long. In a mandible 22 mm. in length it is one-third of this length. It is closely attached to the ectosteal plate of the articular, and still more closely to the top of the endosteal process. It overlies the top of Meckel's cartilage, and projects to a considerable extent between it and the articular. The adductor tendon attached to it is large.

***Menidia notata.***

The sesamoid articular is short and deep, attached to the upper and inner surface of Meckel's cartilage and the endosteal process of the articular, and to the ectosteal plate above them.

***Sphyræna argentea.***

The sesamoid articular is a small sliver of bone attached to the ectosteal plate of the articular in front of the endosteal process. It is nearly covered by Meckel's cartilage.

***Mugil cephalus.***

The sesamoid articular is here a rather large, thick disk of bone attached to the ectosteal plate and to the top of the endosteal process of the articular. It extends considerably above Meckel's cartilage, and is covered but slightly by it.

## THE RHEGNOPTERI.

*Polydactylus approximans.*

In this form the endosteal process stands away from the ectosteal plate (inward from it), and a flat bridge of bone projects upward from it to near the edge of the ectosteal plate just in front of the condyle for the quadrate. The cavity behind it (outward from it) is doubtless the homolog of the chamber in the mandible of *Elops* in the same region, where it is completely separated as a chamber rather than simply bridged across. As the partition in *Elops* unquestionably belongs to the ectosteal part of the articular, it probably does here, though it is so completely ankylosed with the endosteal process that its boundary is obscure. The sesamoid articular is situated in the space between the endosteal process and the ectosteal plate. Its middle is opposite the end of the process, and it is equally in contact with the process and Meckel's cartilage, which entirely hide it as the mandible is viewed from the side.

## THE BERYCOID FISHES.

*Beryx splendens*, *Hoplostethus japonicus*, *Monocentris japonicus*,  
*Polymixia japonica.*

In these forms the sesamoid articular is against the ectosteal plate on the outer side, and the endosteal process and Meckel's cartilage on the inner. Viewed from the side, the process and cartilage hide it from view. In *Hoplostethus* it is rather flat and disk-like. In *Beryx* it is a thick, elongate splint of bone with a tubercle at its middle for the attachment of the tendon. In *Polymixia* and *Monocentris* it is very small but thick. In *Monocentris* it is very loosely attached.

*Holocentrus ascencionis*, *Myripristis occidentalis.*

These two forms are similar in the condition of the sesamoid articular. It is of moderate size, situated against the ectosteal plate just in front of the endosteal process, and on its lower edge folding over the top of Meckel's cartilage.

## THE SCOMBRIDÆ.

*Scomber japonicus*, *Scomberomorus sierra*, *Sarda chilensis*, *Gymnosarda palamis*, *Acanthocybium solandri.*

In all of these the sesamoid articular is rather small, situated on

Meckel's cartilage and against the ectosteal plate of the articular. In *Scomber* it is on the upper surface of the cartilage. In *Scomberomorus* it is somewhat between the cartilage and the articular. In *Sarda*, *Gymnosarda* and *Acanthocybium* it likewise is between but more above the cartilage. In all but *Acanthocybium* it is in contact with the end of the endosteal process, but in none of them is it on the upper surface of the process.

### THE CARANGIDÆ.

***Selene œrstedii*, *Naucrates ductor*, *Lichia glauca*, *Alectis ciliaris*,  
*Citula dorsalis*, *Chloroscombrus chrysurus*, *Caranx pisquetus*,  
*Megalaspis cordyla*.**

The sesamoid articular is covered more or less completely by the endosteal process and Meckel's cartilage as viewed from the side, lying with its outer surface against the ectosteal plate.

***Trachurops crumenophthalmus*, *Nematistius pectoralis*, *Elegatis bipinulatus*,  
*Decapterus punctatus*, *Trachurus mediterraneus*.**

The sesamoid articular is as in *Selene* et. al. but more anteriorly placed, and very slightly if at all in contact with the endosteal process. In *Trachurus* it is thinner and more broadly connected with the ectosteal plate than in the others.

***Vomer setipinnis*, *Scomberoides toloparah*, *Gnathanodon speciosus*.**

In these the sesamoid articular is more on top of the endosteal process and Meckel's cartilage than behind them. In *Vomer* it is much less broadly connected with the ectosteal plate than in the other two.

### OTHER SCOMBROID FISHES.

***Leiognathus fasciatus*.**

The lower part of the articular is folded inward as well as abruptly thickened, thus forming a wide longitudinal shelf. The endosteal process is obscure. The sesamoid articular is a wide, thin plate (5 mm. long in a mandible 27 mm. long), closely attached horizontally to the longitudinal shelf. Meckel's cartilage is a very thin rod which disappears under the sesamoid articular. To the upper, flat surface of the sesamoid articular two equally stout tendons are attached: one a little behind its middle,



and one to its posterior end. Opposite the base of each tendon there is a rather deep depression in the articular, which show on the outer surface of the mandible as very thin spots where the bone is easily broken through. I have found no other example where two tendons join the sesamoid articular. The relationship of the tendons is herein described in the section devoted to adductor muscles.

**Promethichthys prometheus, Lepidopus caudatus, Trichiurus lepturus.**

The sesamoid articular is similar to that in the fishes of the family Scombridæ, rather small, more or less between the ectosteal plate and Meckel's cartilage, and just at the anterior end of the endosteal plate, with which it is in contact except in *Lepidopus*.

**Pomatomus saltatrix, Palometa triacanthus, Peprilus paru.**

The sesamoid articular is on the upper surface of Meckel's cartilage and the endosteal process, and on its outer surface it is against the ectosteal plate. In *Rachycentron* it is rather large and only slightly in contact with the endosteal process.

**THE PERCOID FISHES.**

**Lobotes pacificus, Pomoxys sparoides, Priacanthus catalufa, Apogon maculatus, Sciaena stellifera, Nebris occidentalis, Mentacirrhus alburus, Polycirrhus dumerili.**

In these the sesamoid articular is moderate in size or small, and is situated against the ectosteal plate with the endosteal process and Meckel's cartilage overlying it and hiding it from view more or less as it is viewed from the side.

**Dentex vulgaris, Sargus rondeletii, Archosargus probatocephalus, Pagrus vulgaris, Diplodus argyrops, Pagrellus erythrynus, Lutianus aya, Girella nigricans, Oblata melanura.**

The sesamoid articular is very much as in *Lobotes* et. al., but is on top of the endosteal process and Meckel's cartilage, and very little, if at all, hidden behind them. In *Archosargus* and *Pagrus* it is much more over the endosteal process than over Meckel's cartilage. In *Diplodus* this condition is reversed. In the others it is about equally over both.

**Micropterus salmoides, Labrax lupus, Serranus atrarius, Roccus lineatus, Cynoscion maculatus.**

In these the sesamoid articular is as in *Lobotes* et. al., but more anterior in position and not in contact with the endosteal process.

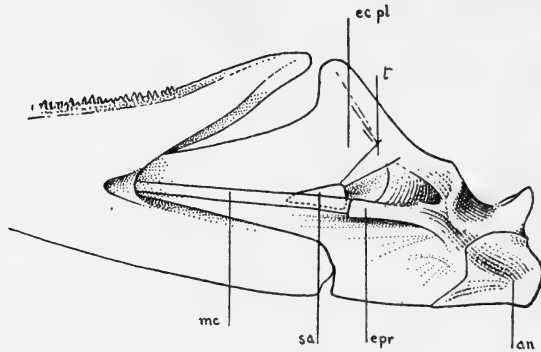


Fig. 12.—LABRAX LUPUS

*an*, angular; *ecpl*, ectosteal plate; *epr*, endosteal process; *mc*, Meckel's cartilage; *sa*, sesamoid articular; *t*, tendon.

**Orthopristis chrysopterus.**

In this the sesamoid articular is very large. It is closely attached to the ectosteal plate, with about a sixth of its length resting on the endosteal process and the rest on Meckel's cartilage. It is long and tapers to a point anteriorly, while on the top of its posterior part is a very large tubercle of bone for the attachment of the adductor tendon.

**THE PHARYNGOGNATHI.**

**Tautoga onitis, Crenilabrus pavo.**

The sesamoid articular is on top of Meckel's cartilage, attached against the ectosteal plate and slightly attached to the endosteal process.

**Harpe rufa.**

There are two adductor tendons originating on the same muscle that are similar in size and structure as in *Leiognathus*, but only the upper one joins the sesamoid articular. The other is attached to the articular ventral to the endosteal process. When stripped of their muscle

they appear at the upper end as a single flat band, but they are easily separated. The sesamoid articular is as in *Tautoga*, though more broadly attached to the endosteal process.

#### **Sparisoma flavescens.**

The sesamoid articular is rather flat and disk-like. It is firmly attached against the ectosteal plate and the upper side of the endosteal process and Meckel's cartilage.

### **THE SQUAMIPINNES.**

**Chaetodipterus faber, Chaetodon bimaculatus, Holocanthus tricolor, Platax teira.**

The sesamoid articular is closely attached against the ectosteal plate and about half hidden by the overlying endosteal process. In *Chaetodipterus* it is only slightly in contact with Meckel's cartilage; in the others it is broadly in contact. In *Chaetodon* it is more above the process and cartilage.

#### **Drepane punctata.**

In this the endosteal process is obscure. The sesamoid articular is small and disk-like, and is closely attached against the ectosteal plate, where it is hidden behind Meckel's cartilage.

#### **Zanclus canescens.**

The sesamoid articular is attached against the ectosteal plate only very slightly in contact with Meckel's cartilage and remote from the endosteal process.

#### **Teuthis bahamus.**

The articular is very short and its endosteal process reaches to its anterior end, leaving but little space for Meckel's cartilage. Almost directly at the anterior end of the articular, on the upper surface of the endosteal process and the base of Meckel's cartilage, is a rather large sesamoid articular.

#### **Xesurus punctatus.**

In this the endosteal process does not occupy so great a part of the articular as in *Teuthis*, and the sesamoid articular is confined to the upper surface of Meckel's cartilage and the endosteal part of the articular.

## THE AMPHACANTHI.

*Siganus fuscescens*

The sesamoid articular is broad and flat; its flat side is firmly attached against the ectosteal plate, and its lower edge rests on the endosteal process and Meckel's cartilage. The tendon is attached near its center.

## THE PLECTOGNATHI.

*Balistes vetula*.

The sesamoid articular is a thick nodule of bone on the upper surface of the endosteal process (whose limits are obscure) and Meckel's cartilage.

*Spheroides annulatus*.

In this form the sesamoid articular more evidently originates within the tendon than in any other example I have encountered. Near the mandible end of the tendon an area of it is ossified, forming a shaft of bone about four times as long as broad. The tendon is attached to the region of the endosteal process, which is obscure, at some distance behind Meckel's cartilage. Between the mandible and the ossified portion of the tendon (sesamoid articular) is a considerable area of unossified tendon. A large part of the inner surface of the dentary as well as the upper angle (coronoid region) of the articular and dentary, is covered by a great mass of tendon from the adductor muscles. The tendon that forms the sesamoid articular ossification is below this mass of tendon and comparatively small.

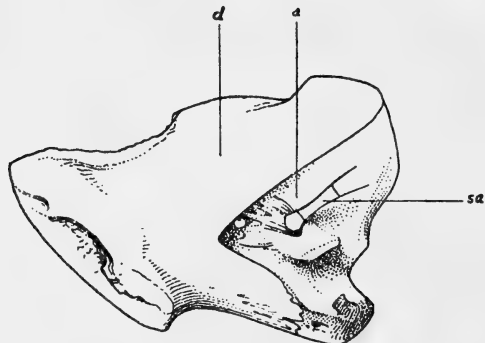


Fig. 13.—SPHEROIDES ANNULATUS  
a, articular; d, dentary; sa, sesamoid articular.

**Ovoides setosus.**

This differs from *Spheroides* only in having the sesamoid articular attached more directly to the mandible without the intervention of much tendinous tissue, and in the bone being enlarged and spreading out at the end of the tendon.

**Chilomycterus schoepfi.**

The endosteal process is obscure. The sesamoid articular is rather large, and is attached closely against the articular just above Meckel's cartilage, which covers its lower edge.

**Lactophrys tricornis.**

The sesamoid articular is situated on the surface of the endosteal process, and on Meckel's cartilage to a very small extent.

**THE MAIL-CHEEKED FISHES.**

*Scorpaena senorae*, *Scorpaena scrofa*, *Scorpaena ustulata*, *Scorpaena plumieri*, *Sebastes marinus*, *Sebastolobus alaskanus*, *Sebastes flavidus*, *Prionotus evolans*, *Prionotus horrens*, *Trigla corax*.

The sesamoid articular is situated against the ectosteal plate just in front of the endosteal process, and more or less completely hidden by Meckel's cartilage. In *Scorpaena scrofa* it is rather large and runs forward in a splint of bone. In *Trigla* it is moderate in size, and in the others it is small.

**Zaniolepis latipinnis, Ophiodon elongatus, Liparis agassizii.**

These differ from *Scorpaena* et. al. in having the sesamoid articular covered by the endosteal process as well as by Meckel's cartilage. In *Liparis* it is only slightly behind the process.

*Hexagrammos decagrammus*, *Scorpaenichthys marmoratus*, *Myoxocephalus octodecemspinosus*, *Podothecus acipenserinus*.

The sesamoid articular is more on top of the endosteal process and Meckel's cartilage than covered by them. It is closely connected with the ectosteal plate.

**Hemilepidotus jordani.**

The sesamoid articular is on top of Meckel's cartilage against the ectosteal plate and remote from the endosteal process.

**THE GOBIES.****Dormitator latifrons.**

The sesamoid articular is large and disk-shaped, with its flat side attached firmly to the ectosteal plate, its posterior lower edge to the endosteal process, and its lower edge extending downwards over Meckel's cartilage to a considerable extent. The tendon is attached near its middle.

**Philypnus dormitator.**

The sesamoid articular is a rather small triangular bone, situated on top of Meckel's cartilage well in front of the endosteal process, and slightly against the ectosteal plate.

**THE DISCOCEPHALI.****Echenis naucrates.**

The endosteal process is obscure. The sesamoid articular is a large, flat bone of rather complex outline, attached against the articular just above and slightly covered by Meckel's cartilage.

**THE TRICHODONTIDÆ.****Trichodon trichodon.**

The sesamoid articular lies just in front of the endosteal process between Meckel's cartilage and the ectosteal plate.

**THE LATILIDÆ.****Lopholatilus chamoeleonticeps.**

The sesamoid articular is a rather large, thick bone wedged between the ectosteal plate and the endosteal process.

**THE BATHYMASTERIDÆ.****Bathymaster signatus.**

The sesamoid articular is here essentially as in *Trichodon*.

**THE URANOSCOPIDÆ AND TRACHINIDÆ.****Uranoscopus scaber, Trachinus radiatus.**

The large sesamoid articular is broadly attached against the ectosteal plate with its lower surface resting on the endosteal process and Meckel's cartilage.

**THE BLENNIOID FISHES.****Lumpenus anguillaris, Cebedichthys violaceus, Ziphidion mucosum.**

The sesamoid articular is large and attached closely to the ectosteal plate, resting at its lower edge on Meckel's cartilage, and sometimes on the endosteal process; in *Lumpenus* it rests equally on the cartilage and process; in *Cebedichthys* it is only slightly in contact with the process; in *Ziphidion* it is remote from the process.

**Heterostichus rostratus.**

In this the sesamoid articular is small and against the ectosteal plate remote from the endosteal process, while Meckel's cartilage covers its inner surface.

**Anarrichthys ocellatus.**

This has the sesamoid articular situated as in *Lumpenus*, but it is much larger, roughly elliptical in outline, and very thick, with its thickness extending to its edges.

**THE ZOARCIDÆ.****Lycodopsis pacificus, Lycodes brevipes.**

The sesamoid articular is long and rather thick. It is wedged in between the ectosteal plate and Meckel's cartilage, extending up, however, considerably above the latter. Its posterior end extends a little behind the anterior end of the endosteal process.

## THE ANACANTHINI.

*Melanogrammus aeglinus*, *Brosme brosme*.

The sesamoid articular is large and is attached against the ectosteal plate just at the end of the endosteal process. It extends downward somewhat behind Meckel's cartilage, but its bulk is above the cartilage and arches over its upper surface.

*Microgadus tomcod*.

The condition of the sesamoid articular is most surprising, for it is apparent that part of it at least is endosteal in origin, ossifying directly from Meckel's cartilage. For a short distance in front of the endosteal process Meckel's cartilage is as usual, then it is abruptly ossified in a rod of bone in front of which, as it runs toward the dentary, it is again cartilaginous. The posterior outer part of the ossification is enlarged against the ectosteal plate, and to this enlargement the stout adductor tendon is attached. It appears evident that the enlarged outer portion is the usual sesamoid articular, and that Meckel's cartilage in ossifying has become ankylosed with it. The part anterior to the enlarged portion is a white, poorly organized, granular bone, but at the enlargement it is clear and dense. Several specimens between 8 and 10 inches in length were examined, and considerable variation found in the length of the ossified portion of Meckel's cartilage.

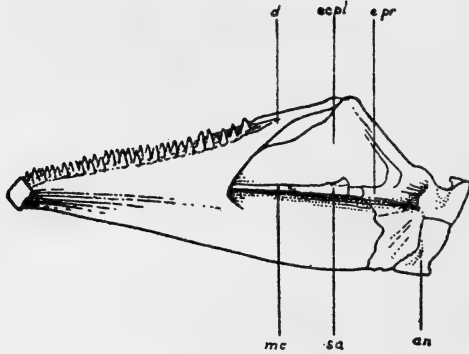


Fig. 14.—MICROGADUS TOMCOD

*an*, angular; *d*, dentary; *ecpl*, ectosteal plate; *epr*, endosteal process; *mc*, Meckel's cartilage; *sa*, sesamoid articular.



**Gadus callarias, Pollachius brandti.**

A small part of Meckel's cartilage is replaced by the sesamoid articular and the cartilage is unossified before and behind it. The outer part of the ossification spreads out in a broad plate of bone over the ectosteal plate, where it is firmly attached. This outer part resembles the sesamoid articular as found in many forms. A stout tendon is attached to a rather wide base formed by both the part replacing cartilage and the part against the ectosteal plate. The endosteal process is ossified on the surface only, for a considerable space at its anterior end leaving cartilage within.

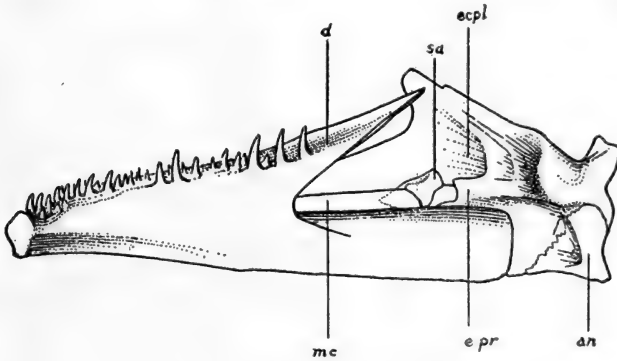


Fig. 15.—GADUS CALLARIAS

*an*, angular; *d*, dentary; *ecpl*, ectosteal plate; *epr*, endosteal process; *mc*, Meckel's cartilage; *sa*, sesamoid articular.

**THE HETEROSOMATA.**

*Psettichthys melanostictus*, *Eopsetta jordani*, *Parophrys vetulus*,  
*Citharichthys sordidus*.

The sesamoid articular is against the ectosteal plate directly in front of the endosteal process, and covered more or less by Meckel's cartilage. In *Parophrys* it is larger than in the others and more disk-like.

**Usinosita japonica.**

The endosteal process is scarcely developed, and the endosteal part of the articular consists of little more than enough bone to form the concavity for the articulation of the condyle of the quadrate. Articulated to this bone directly in front of the concavity is a large sesamoid articular which rests broadly on Meckel's cartilage.

**THE PEDICULATI.*****Antennarius* sp.**

The small sesamoid articular rests against the ectosteal plate directly in front of the endosteal process, and is nearly covered from sight by Meckel's cartilage.

***Ogcocephalus radiatus*.**

The sesamoid articular is broad and disk-like, and is attached tightly against the ectosteal plate and the upper surface of the endosteal process, while anteriorly it rests on the surface of Meckel's cartilage.

## SUMMARY

Specimens from nearly every important group of fishes have been examined and are herein reported upon. The sesamoid articular was found in every group that is more highly specialized than the primitive Clupeoid fishes as well as in one of the Ganoids, *Amiatus*, though here its identity may be open to some doubt.

The sesamoid articular is variable in size and somewhat in position, though it is always in relationship with Meckel's cartilage—usually in very close association with it. Typically, as in the perch-like fishes, it is rather small and more or less covered by Meckel's cartilage. Sometimes, as in *Albula*, it is as large as the endosteal process; or, as in some of the Synentognathous fishes, it is so large that it projects above its surrounding elements, so that it is visible from the outer surface. Sometimes it is loosely attached to the mandible and is easily pulled away with its tendon. Sometimes it is attached to the mandible by a dentate suture and is disarticulated with difficulty. Usually it is more or less broadly attached to the ectosteal plate of the articular, but sometimes only narrowly attached, and occasionally scarcely, or not at all, in contact. Sometimes it lies saddle-like over the top of Meckel's cartilage, remote from any bone. It is variable in its connection with the endosteal process, but as the attachment may depend upon the extent of the ossification of Meckel's cartilage to form the process, this is without significance. In at least one case (*Leiognathus*) two equally stout, dense tendons join the sesamoid articular at a considerable distance from each other.

The sesamoid articular is doubtless, as its name implies, a sesamoid bone. This is especially well shown in *Spheroides annulatus*, where the adductor tendon has obviously ossified for a short space, leaving an interval of tendon between the ossified portion and the mandible. Intermediate between this condition and the more typical condition is the sesamoid articular of *Ovoides*, a close relative of *Spheroides*, where the interval of cartilage between the tendon bone and the mandible has disappeared and the former has spread out to some degree on the mandible.

On the other hand *Microgadus* and *Gadus* appear to have the bone partly endosteal in origin, or at least a bone endosteal in origin has become ankylosed with it. In *Gadus*, however, it is not altogether clear

that the sesamoid articular in replacing a section of Meckel's cartilage is necessarily the ossified cartilage. The sesamoid articular may have surrounded Meckel's cartilage, and developing from without inward may thus have replaced it. The beginning of such a process is suggested by *Melanogrammus*, and other forms, where the sesamoid articular arches over the upper surface of Meckel's cartilage. Such, however, does not account for the condition in *Microgadus* (*M. tomcod*), where the cartilage is ossified in a rod in front of the sesamoid articular.

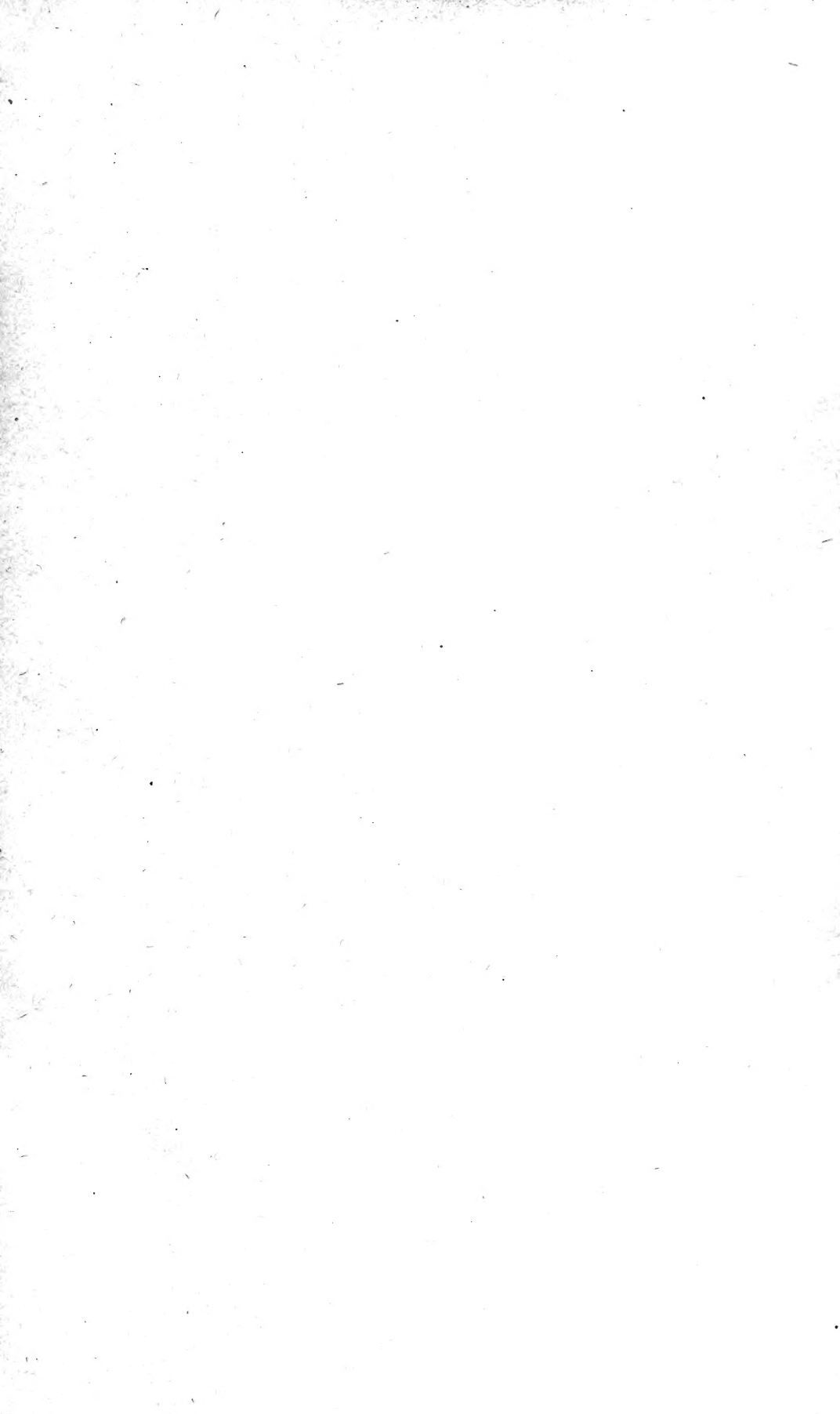
The fact that ossification has taken place in Meckel's cartilage suggests an apropos observation of Dr. Ridewood's (Proc. Zool. Soc. Lond., 1904, p. 56) in regard to bones that are both ectosteal and endosteal in origin, whether the two sorts are ankylosed or distinct from each other. "The endosteal ossification has been set up in sympathy with the ossification taking place in the dermal tissues. The process of ossification is infectious, if one may employ such a term in this connection."

It is significant that in every case the sesamoid articular is in close relationship with Meckel's cartilage (or with the endosteal process, which is ontologically the same). Even in cases where it has developed upwards towards the coronoid region it still retains its connection with the primitive cartilage.

Moreover, in some cases, as *Albula*, it is strikingly like the endosteal part of the articular, and appears (at least superficially) to bear the same relationship with Meckel's cartilage—the cartilage apparently issuing from it as it does from the endosteal process.

Other tendons than that to the sesamoid articular join the mandible at various places, sometimes originating on the same muscle and same place as does that to the sesamoid articular; but they are nearly always less compactly organized, though often they are larger. There is never a second sesamoid articular developed for these other tendons, though they may appear to be more important in doing the greater share of the work.

The sesamoid articular is of no use in taxonomy of groups larger than species, as it often differs within the genus. To pronounce upon its value in differentiating species, or upon its individual variation, would necessitate much more work within narrower limits than has been here undertaken.





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