The following papers were read:—

1. The Caudal Fin of the Teleostomi.
   
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   [Received February 4, 1910.]

   (Plates XLVII.—L† and Text-figure 57.)

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   1. Introduction.

   While the study of the paired fins of fishes, and also the dorsal and anal among the median unpaired fins, has been prosecuted in great detail, a systematic, detailed investigation of the caudal fin seems to have received much less attention. Some authors have dealt somewhat extensively with the subject, yet these have only treated of a comparatively few species; it was thought advisable, therefore, that such an important organ as the caudal fin of fishes should receive a broad treatment, and to carry out this purpose, several scores of different species have been subjected to a detailed examination of the skeletal parts of the fin. The number treated of includes species from as many widely different families as it has been possible to obtain, so that almost every form of tail likely to occur should be made known. It is impossible to include every type examined in the present paper, but the subject will be completed at as early a date as possible.

   The Teleostei will receive the fullest treatment, but some reference will be made to other groups for the sake of presenting a more complete account of the piscine tail-fin. It has been impossible, as yet, to investigate the tail of the Dipnoi, but it is hoped that this group also will be dealt with in due course.

   Material for the work has been obtained from various sources, the largest quantity having been obtained at Naples during my occupation of the British Association table at the Zoological Station in that town, during the six months ended May, 1908. Other valuable material has been supplied to me by a number of friends. I should like to mention here that the whole investigation is due to the suggestion of the late Professor Bridge, F.R.S., under whose superintendence the work was carried out; it was a pleasure and fortune to have so able a critic and kindly adviser as my late revered teacher. I wish also to express my best thanks to the British Association for appointing me to occupy their table

* Communicated by Dr. P. Chalmers Mitchell, M.A., F.R.S.
† For explanation of the Plates see p. 625.
Caudal fins of Teleostomi.
CAUDAL FINS OF TELEOSTOMI.
CAUDAL FINS OF TELEOSTOMI.
at the Naples Zoological Station. The many friends who have supplied me with material and suggestions also have my best thanks. For the identification of most of the species I am greatly indebted to Dr. Lo Bianco of the Naples Zoological Station. Lastly, I am deeply grateful to the Birmingham Natural History and Philosophical Society and others, for grants without which the work could scarcely have been done.

The dissections have been carried out as carefully as possible under the microscope, and it was found necessary in most cases to render the specimen transparent by some clearing agent such as turpentine or xylol, in order to see exactly how the vertebral column ended, and to clear up any other doubtful points.

In reviewing the literature on the subject of caudal fins, the very numerous casual references must be omitted for the present. Perhaps the earliest definite work relating to fishes' tails is that of Agassiz in 1833, in which the author recognized two types of caudal fin, the heterocercal and homocercal; the former term still retains its original meaning, but the latter was only used to indicate an externally symmetrical fin as distinguished from the asymmetrical heterocercal form. In a geological contribution by McCoy in 1848, the term "diphyceral" first appeared to designate the truly symmetrical caudal fin; it is interesting to note that Cope in 1871 coined the term "iscoceral" to mean the same thing, in ignorance, as that author states, of McCoy's paper. Stannius, in a text-book on the Vertebrae, published in 1854, gives considerable attention to the tail-fin; he refers to a very large number of Teleosts, but with questionable accuracy. The most interesting feature of his remarks concerns his belief, which seems to be true, that the supports of the fin-rays are formed of arches and radials fused; Belone is quoted in support of this view.

But it was in 1859 that Huxley first gave a correct description and interpretation of the homocercal tail; he exposed the false symmetry of form in Gasterosteus, and traced its development. It is unfortunate that the promised account of the development of the eel's tail never appeared, for the slight reference made to this form is of doubtful accuracy, due, no doubt, to only a superficial examination. Very soon followed (in 1860) an excellent essay on caudal fins among Ganoids and some Teleosts by Kölliker, accompanied by valuable figures which have been reproduced almost universally since. Lotz followed in 1864 with a paper containing little new work.

A revival was given to the subject in 1878 by Alex. Agassiz in a short paper on the development of the tail of the flounder; his remarks had the effect of raising the important question of the true morphology of the homocercal caudal fin. In 1882, E. T. Newton read a paper on "Fishes' Tails" before the Quekett Microscopical Club; this consisted of a general review of past work, together with a description of the tail of the sprat; the paper included an incorrect figure of the caudal fin of the cod.
The most comprehensive work of all, however, was published by Ryder in 1886; on the whole, it contained very useful information, but his figure of the tail of the young eel is wrong with respect to the neural arches. Ryder's suggestions on the origin of heterocercy are interesting and probably correct, though somewhat novel. Ryder's evolutionary series of the forms of the caudal fin has come to be acknowledged as the order of appearance of the different types in time. The next work of importance dealing with caudal fins of fishes was written in 1895 by Dollo in discussing the phylogeny of the Dipnoi; basing his conclusions on geological evidences, he gives the term gephyrocercy an extraordinarily wide application; this arises from the idea, strongly upheld by Dollo, that the present caudal fin in many Teleosts is really a posterior anal fin, brought into its present position by complete atrophy of the real caudal. Dollo's is the last of important references regarding the tail-fin.

Boulenger, in 1901, in dealing with the fishes of the Congo, gave a good summary of work done. In 1907, Gregory, in his work on the classification of Teleostomous fishes, makes continual references to the caudal fin; but it is difficult to reconcile many of his statements: for instance, the caudal fin of Mastacembelus is referred to as gephyrocercal, while in fact internally it is quite a generalized homocercal type. As an appendix to the work, there was given an elaborate scheme of the evolution of the caudal fin, which includes several new terms, considered by some as unnecessary.

2. Terminology.

In order to avoid any ambiguity, I have thought it necessary to modify the meaning of several terms; some have been widened and others have been more restricted as regards their denotation. The reasons for such modifications are given in their respective paragraphs:

1. *Caudal*.—This term is used in the generally accepted sense denoting the more or less elongated cone-like termination of the vertebral column, appearing as a prolongation of the last centrum. It represents the fusion of several centra.

2. *Hypaxial*.—This adjective refers to any structure morphologically ventral to the chordal axis.

3. *Epaxial*.—This adjective refers to any structure morphologically dorsal to the chordal axis.

4. *Hypural*.—Any hypaxial element having a direct connection with the chordal axis, and bearing one or more fin-rays distally, will be called a hypural or hypural bone. Previously, this term has been used rather loosely and in such a way as to leave one in doubt as to its limitation; the limitation given above, concerning its direct connection with the chordal axis—i.e. as a general rule, with centra—as will be seen later, both widens and narrows the meaning of the term.
5. Eparal.—This term may be regarded as applying to the dorsal homologue of the ventral hypural, i.e. any epaxial element, having direct continuity with the chordal axis, and bearing one or more fin-rays at its distal end, will be called an epural or epural bone. It is only after the most careful consideration that I have decided to change the definition of this term. It was established by Huxley in 1859, and appears to have been used by him to indicate those isolated ray-bearing bones situated immediately dorsal to the urostyle in Gasterosteus. The change suggested is based solely on my conclusions respecting the real morphological value of the several fin-ray supports, and, reluctant as I am to make any changes in established nomenclature, I believe the reader will agree that the subject will be much simplified by the change.

6. Radial.—The term radial is used in its usual sense as synonymous with "interspinous bone" and "somactid" of some writers; it implies a more or less dagger-like bone, primarily having no direct continuity with the vertebral column, and supporting distally one or more fin-rays.

7. Last vertebral segment.—This term will refer to the last centrum plus urostyle, if such exists. The last centrum is never perfect, and is often no more than a cone, the apex of which is directed posteriorly.


This section will be descriptive of a selection of caudal fins, and the order in which they are dealt with corresponds essentially with the classification given by Sedgwick in his 'Text-Book of Zoology.' Owing to lack of time and material, the series is not as complete as one would wish; for example, only the Siluride among the Ostariophysii receive attention, and the Symbranchii are completely omitted. Except for these sub-orders, however, the types are fairly representative of the others, at least of the Teleostei. Almost every example taken presents interesting features, but owing to the impossibility of including, in the present paper, figures of all the species treated, only the barest description of many forms can be attempted at present.

Acipenser sturio. (Chondrostei, Acipenseridae.) (Plate XLVII, fig. 2.)

The Sturgeon presents a definitely heterocercal tail; the end of the caudal axis from the root of the tail-fin is directed upwards, and the ventral lobe is enlarged, producing a very unsymmetrical fin. No centra are formed from the notochordal sheath. The ventral lobe of the fin is supported by a very regular series of hypurals; the name hypural has been applied here, since these structures strictly comply with the definition. They are of particular interest, because, in the anterior part of the fin, where they are most strongly developed, they exhibit a definite segmentation: the largest show four successive segments (h.a., p., m., and d.,
in the figure); proceeding backwards, as they become smaller, three segments are shown, then two, and finally only one can be traced. This segmentation is due, I believe, to the formation of the hypural by the coalescence of radial with haemal arch; anteriorly, the three segments, the proximal (p.), medium (m.), and distal (d.), of the radials are present, the distal still remaining free; from before, backwards, the fusion becomes more perfect and finally all trace of it is lost. This composite nature is a feature which substantiates the claim of these hypaxial supports to the title hypural. The dermatrichia constituting the ventral lobe considerably overlap their endoskeletal supports. Dorsally, the arches (n.a.) and radials (d.c.r.) remain distinct throughout the fin and are less regular than the hypaxial elements. The dorsal radials are almost hidden from view by the forking proximal ends (removed in the figure) of the stout fulcra which fringe the margin of the dorsal lobe. The whole of the elements at the extremity of the tail are hidden by the dermatrichia.

Polyodon spatula. (Chondrostei, Polyodontidae.) (Plate XLVII. fig. 3.)

Externally the tail of Polyodon is very deceptive; its symmetry of form is most marked, and it resembles in outline the deeply cleft tail of some Teleosts. It is well-known, however, that on dissection it proves to be an excessively heterocercal type, the caudal axis being directed upwards and extending to the extremity of the dorsal lobe. No centra are formed. Almost throughout the tail-fin the neural arches (p.a.) are single elements, and are somewhat irregular in size, particularly towards the extremity of the axis. Resting upon these arches are the radials (d.c.r.); the first four or five are slender in build, but almost throughout the fin they resemble the neural arches themselves. They, too, are very irregular both in disposition and size, and here and there they show signs of having been more numerous formerly. The various elements at the extremity of the axis are difficult to distinguish, owing to their small size and tendency to fusion; the same difficulty is experienced ventrally in this region. The radials are the immediate supports of the fulcra (/). Turning to the ventral elements, a very regular series presents itself, in striking contrast to the dorsal side: there is a regular series of hypurals, very large at the root of the fin where the large dermatrichia of the ventral lobe are supported. As in Acipenser, very many of these hypurals show distinct segmentation, thus giving evidence of being composed of four successive elements, the distal of which, in the case of the first seven supports, is distinct and separate. The interpretation seems to be that each hypural is composed of haemal arch and radial fused, the tri-segmental nature of the latter being retained in several cases. Naturally the best examples of this are given by the anterior hypurals, where the supporting elements are larger. The tri-segmental arrangement gradually gives way to a bi- and finally a uni-segmental
structure in passing from before, backwards. The caudal fin of *Polyodon*, then, is obviously heterocercal, but of a more specialized type than *Acipenser*, on account of its nearer approach to the homocercal type.

**Amia calva.** (Holostei.) (Plate XLVII, fig. 4.)

The caudal fin of *Amia* is externally symmetrical, or at any rate the discrepancy in symmetry is very slight indeed, and negligible. But dissection reveals a very unsymmetrical internal structure; at the root of the fin the vertebral column takes a sudden turn upwards, at a considerable angle. The centra are well formed and retained throughout the length of the axis, and consequently no urostyle is present. Nearly the whole of the dermotrichia are supported by hypurals, a feature which it shares with the majority of Teleostean fishes; these hypurals are slightly expanded or somewhat club-shaped at their distal ends, and each bears a single fin-ray. The last three hypurals belong to the last centrum, but each of the other centra possesses but one hypural. The final dorsal element (fig. 4, n.a.) is strikingly large, and continues beyond the vertebral axis for some distance between the fin-rays. Kolliker remarks that it is cartilaginous and contains the spinal cord: he regards it as an incorporation of vertebrae and neural arches. In the specimens I have examined, the same structure proved to be bony, and grooved along the dorsal edge to conduct the spinal cord; it appears to correspond to a bone, frequently found among the Teleostei, which I have regarded as a persistent neural arch, retained, even when its adjacent homologues are suppressed, as a protection for the delicate termination of the spinal cord. According to Kolliker, there are three dorsal caudal radials (d.c.r.) remaining as supports for the insignificant fin-rays which constitute the epaxial contribution to the caudal fin; but these dorsal radials are very poorly developed. Most authorities agree that the caudal fin of *Amia* is scarcely correctly described by being called heterocercal, and therefore it is generally referred to as hemi-heterocercal. So near, however, does the structure approach homocercy that hemi-homocercal would probably be a more suggestive designation: however that may be, the fin may certainly be considered the most specialized type of heterocercal forms.

**General remarks on the Ganoid Caudal Fin.**

It has been thought advisable to omit any detailed references to other Ganoids than the three considered, for the present, since they have not been cleared up to my entire satisfaction and material is lacking. But the Ganoid caudal is characteristically heterocercal; truly protocercal forms are absent, and homocercy is nowhere attained within the group. The three types considered illustrate how the tendency of specialization is to approach the homocercal condition; in *Acipenser*, the typical heterocercal form, so characteristic of the Elasmobranchs, is present; *Polyodon*, by
an increase in the size of the ventral lobe reaches a step towards the externally symmetrical homocercal fin; while Amia proceeds furthest of all in the homocercal direction, requiring but one single feature, the possession of a true urostyle, to attain the homocercal condition.

TELEOSTEI.

MALACOPTERIGII.

MORMYRUS KANNUM. (Mormyridae.)

In general, Mormyrus provides a type of homocercal caudal fin by no means generalized. The last two or three vertebrae are directed slightly upwards. The urostyle is absent or fused completely with a hypural bone; such an advanced homocercal feature as this is not consistent with the position of Mormyrus as one of the least specialized of Teleosts, a position assigned to it according to general characters. In respect to the hypurals, uncommon features are shown: in the first place the last centrum presumably is fused with the last hypural but one, instead of the last as is usual; again, two hypurals are attached to the penultimate vertebra and the anterior of these is exceptionally large. It is important to notice that only two hypural bones are associated with the last vertebral segment—the small number being another feature of the specialized homocercal caudal. The epaxial elements are interesting; the neural arch to the last centrum is strongly developed; it is pierced throughout by the spinal cord which is continued beyond the arch among the dermotrichia. It will be remembered that a similar condition of the last neural arch was found in Amia. The neural arch of the penultimate vertebra is very much reduced, and the antepenultimate vertebra bears an epural bone.

ENGRAULIS EXCRASICCHUS. (Clupeidae.)

The Anchovy provides an illustration of one of the least specialized of homocercal caudal fins. No centra enter into the upturned part of the caudal axis. The notochord is prolonged beyond the long urostyle, but except for the extreme end which extends among the dermotrichia, it is protected by several slender and closely fitting enshewing bones which it is difficult to homologize. Dorsally and ventrally at the end of the notochord is a delicate cartilage, each, it may be, a vestige of once functional neural or hemal arches; such vestiges are referred to by Ryder as opisthural cartilages. The hypaxial endoskeletal supports of the fin-rays are nine in number, seven of which belong to the last vertebral segment. It is a little difficult to decide whether the term hypural is correct for all these supports, as some, at any rate, appear to be ventral caudal radials only; however, it will be better for the present to call all of them hypurals. This fish possesses the largest number of hypurals (viz. seven) to the last
vertebral segment which has been found. The dorsal contribution to the caudal fin is comparatively small. Of the last four vertebrae all but the last bear epural bones and the last appears to have its neural arch greatly reduced. The most posterior of the epaxial fin-rays are supported by two or three poorly developed dorsal caudal radials; the proximal ends of these radials are almost in contact with a triangular cartilage applied to the dorsal side of the notochord near the termination of the urostyle; this cartilage probably represents a vanishing neural arch.

**Clupea pilchardus.** (Clupeidae.) (Plate XLVII. fig. 5.)

The caudal fin of the Pilchard very closely resembles that of the Anchovy. The urostyle (ur.) is long and slender, and the notochord (n.) is produced beyond it, but not beyond the distal ends of the endoskeletal supports. An opisthural cartilage (o.c.) is attached to the end of the notochord, and extends between the dermotrichia. Nine hypural bones are present, seven of which belong to the last vertebral segment, as in *Engraulis*; the hypurals vary considerably in size. Epaxially, the dermotrichia are supported by two epurals (ep.) and three dorsal caudal radials (d.c.r.); the latter are short bones situated between the last epural and the notochord. Proximally the dorsal radials abut a triangular bone (n.a.)—cartilage in *Engraulis*—on the dorsal side of the urostyle; this triangular bone probably represents one or more neural arches of vertebrae now absorbed into the urostyle. The last centrum (l.v.) is provided with a large spatulate neural arch (n.a.) peculiarly constricted at its proximal end.

Comparing the caudal fins of the two Clupeoids here described and also that of the Sprat as detailed by Newton, it will be seen that there is a striking similarity throughout; the figure given in Newton's paper is that of a young *Clupea sprattus*, and the urostyle is seen to be composed of several centra which, no doubt, are also present in *C. pilchardus* and *Engraulis encrasicholus* in the young, but which are obliterated in the adult. All show a lowly specialized homocercal form, approaching very closely the *Amia* type.

**Notopterus borneensis.** (Notopteridae.) (Plate XLVII. fig. 6.)

This fish is provided with a highly specialized caudal fin, and also presents one or two peculiarities. The caudal is continuous with the ventral median fin, but the caudal proper may here be limited to that part composed of dermotrichia which are attached to the endoskeleton by means of a proximal forking, as distinguished from the ball-and-socket nature of the attachment of the anterior fin-rays to the radials. Thus the caudal fin is supported by three hypurals and one epural; hence it is not strictly homocercal as Gregory states. No urostyle can be seen in the dissection, and even clearing fails to give any certain clue as to its exact outline in the substance of the last hypural bone, and what
may be at first considered a urostyle, indicated by a ridge along the dorsal side of the hypural, has a companion ridge directed ventrally; the loss of the urostyle or its fusion with a hypural bone is an advanced character. A large hypural bearing four dermotrichia is attached to the penultimate vertebra, while that of the antepenultimate supports only one. An interesting feature in this caudal fin is the epaxial fin-ray support; this consists of a single epural bone broadly expanded distally, and attached to the penultimate vertebra. Such an expanded epural is quite unusual in caudal fins, and I know of no other instance.

**General remarks on the Malacopterygii.**

The examples chosen illustrate how varied the caudal fin structure may be, even in a single sub-order of Teleosts. Two extreme types are met with: the Clupeoids, by the extension of notochord beyond the bony axis, by the vestiges of once functional arches in the form of opisthural cartilages, and by the large number of hypural bones to the last vertebral segment, provide an example of a lowly specialized form of caudal fin; while *Notopterus*, by the loss of the urostyle and the reduction of the number of hypurals to the last vertebral segment to a single bone, is an example of a highly specialized form.

**Ostariophysi.**

*Clarias sp.?* (Siluridæ.)

Only a single specimen of this fish has been procurable, but the caudal fin appears to be quite normal. The tail-fin is fully differentiated although the dorsal and ventral fins reach nearly to the end of the body. Internally the skeleton is remarkable in presenting a very long urostyle, longer than that of any fish examined, extending posteriorly as far as the distal ends of the hypurals; it does not appear to be actually fused to a hypural. The hypaxial part of the fin is supported by five hypural bones, four of which are associated with the last centrum and urostyle, and also by one ventral caudal radial occupying the space between the first and second hypural bones. The hypural of the penultimate vertebra has the appearance of being formed by the coalescence of a radial and a haemal arch. The epaxial fin-rays are borne by one epural bone belonging to the last vertebra but one, and also by a dorsal caudal radial between the epural and the urostyle. The spinal cord can be traced to the end of the urostyle. The final centrum possesses the vestige of a neural arch, through which the spinal cord passes.

Here then is a generalized type of homocercal caudal fin, for in it are representatives of all possible endoskeletal supports, viz., hypurals, ventral caudal radial, and dorsal caudal radial, and besides, it possesses a well-marked urostyle.
Plotosus sp.? (Siluridae.) (Plate XLVII, fig. 7.)

The caudal fin of Plotosus is very interesting and very simple; it forms part of a continuous median fin and terminates a gradually tapering tail. All the specimens examined were from Torres Straits and were presented to me by the late Professor Bridge. They were all young, but the skeletal elements were quite fully established. Before entering into a description of the fin, it will be instructive to call attention to the remarks made by Mr. Tate Regan before the Zoological Society on April 28th, 1908, concerning the caudal fin of Cnidosalanis megalotomi, also a member of the Plotosine. He writes:—

"The Siluroid fishes of the subfamily Plotosine have been generally defined as having two dorsal fins, a short anterior one and a larger posterior fin continuous with the caudal, similar to the long anal. The so-called second dorsal proves to be a procurrent portion of the caudal fin which has extended forward along the back, and, in the species exhibited, has a base of more than two-thirds the total length of the fish, and is formed of about 130 rays; these are supported directly by the neural spines. In striking contrast to the externally similar anal fin, the rays of which are attached to a series of interhemals." Presumably interhemals are synonymous with radials.

On examining Plotosus, which is a very close relative, I was pleased to find that the same characters were exhibited in both cases, or, I believe, practically the same, for although in Plotosus the rays of this "procurrent caudal" are not actually attached to the neural spines but interdigitate between them, they have no other endoskeletal support, as the anal rays have.

Now, the conclusion to be drawn from the above quotation is that Mr. Regan would define a caudal fin as that part of the median fin system which is directly supported by hemal or neural spines, or in the language adopted in this paper, by hypurals and epurals alone. It must be pointed out, however, that fin-rays of true caudal fins are frequently supported by undoubted radials, in addition to hypurals and epurals, and interdigitating between these supports; throughout the Gadide this is the case, many Acanthopterygii show the same thing, as also does Clarias just considered. But I fully agree with Regan's remark that the so-called second dorsal fin is part of the caudal, but for an entirely different reason. I hope to deal with the definition of the caudal fin at a future time after my observations have been more extended; but for the present, in connection with this discussion I base my agreement with Regan's conclusion on the nature of the fin-rays themselves, and not on their endoskeletal supports. The dermo-trichia of the caudal fin differ from those of the remainder of median fins in the method of attachment to their internal supports; the caudal fin-rays of Teleosts attach themselves by means of a forking at their proximal ends, while those of the dorsal and anal fins are provided with a kind of socket by which they are attached to the distal segment of the radial. So far as
I am aware, this difference is universal among Teleosts, but, as stated above, as yet I do not assert it to be without exception. The matter is called attention to, in order to make it quite clear that fin-rays of a caudal fin may be supported directly by undoubted radials.

Concerning other features of the caudal fin of *Plotosus*, the last dorsal ray is supported by an epural which is attached to the penultimate vertebra, and which shows the union of two elements, a radial and a neural arch. Hypaxially is a large hypural firmly united with the urostyle, and bearing ten dermotrichia. In the specimen figured the penultimate centrum possesses two ventral appendages, a hypural supporting one ray, and a haemal arch. Curiously enough, the next anterior ray is without a support and seems to anticipate a similar state of affairs ventrally as dorsally: such, however, is not the case, for each ray preceding is a typical anal fin-ray supported by a true radial.

Hence the caudal fin of *Plotosus* is a very highly specialized organ, totally different from the preceding type, *Clarias*.

**Syxodontis schall.** (Siluridae.) (Plate XLVII, fig. 8.)

The last six vertebrae form the basis of support for the deeply cleft caudal fin in this fish. The urostyle is lost and the last centrum is firmly fused to the last two broad hypurals, which occupy a terminal position. The hypaxial fin-rays are mainly supported by these two hypurals, but in addition there are five others, one to each of the preceding five vertebrae: these two hypurals afford excellent evidence of the coalescence of radials and haemal arches in their formation. Epaxially are four epurals, one to each of the four vertebrae preceding the last two; these epural bones, like the hypurals, show the duplicate nature well; it will be seen that the neural arch of the penultimate vertebra and its corresponding radial have not fused, but a little forward movement and then the fusion with the neural arch, on the part of the radial, would produce an exactly similar structure to the preceding epurals. This caudal fin provides one of the best illustrations of the fusion of radials with arches in the formation of epurals and hypurals. Needless to say the fin is a highly specialized homocerebral type.

*General remarks on the Siluridae.*

The single family Siluridae, therefore, includes great diversity in the form of the caudal fin structure, from a very generalized to a highly specialized type.

**Apodes.**

**Anguilla vulgaris.** (Muraenidae.)

Having obtained a good series of stages, I have been able to trace the development of the caudal fin in *Anguilla* from the *Leptocephalus* stage to the adult.
1. *Leptocephalus brevirostris.* (Plate XLVIII. fig. 9.)

It is perhaps somewhat unfortunate that in the *Leptocephalus* all essential skeletal structures are already present; in fact, there is very little difference between it and the elver four inches in length. There is very clearly shown a comparatively long urostyle slightly directed upwards; this urostyle is not fused with the hypural bone immediately ventral to it. In my specimen this hypural, the distal end of which extends beyond the urostyle, was already a single cartilage, though in older specimens, a very distinct cleft was frequently to be seen. Three of the four fin-rays attached to this hypural were bifid distally, though I believe the number of distally bifurcated rays is a matter of accident. The penultimate vertebra carries the characteristic U-shaped hypural of the Apodes, representing two pieces fused proximally. The antepenultimate vertebra is a double structure, and carries two haemal processes, the posterior of which bears a fin-ray and shows a definite trace of being formed by the union of a radial and a haemal arch; this has already been drawn attention to by Ryder. The double vertebra mentioned is not, as Ryder seems to suggest, a constant feature, but certainly is very common. Dorsally, no epural bones are present; every ray is supported by a radial. In the only figure of the caudal fin of a young eel I am aware of, namely that of Ryder's, the neural arches are not truly represented; in reality they are rectangular plates, equal in length to the vertebrae to which they are attached; even the last retains its rectangular shape, covering up urostyle and overlapping the last hypural to some extent. The spinal cord can be traced even among the fin-rays beyond the distal end of the last hypural; this fact is evidence of considerable abbreviation.

2. *The Elver.* (4½ ins. or about 12 cm. long.) (Plate XLVIII. fig. 10.)

This stage is next taken as being the last in which the urostyle can be traced; the last hypural has already encroached upon it dorsally, while in specimens five inches long it has vanished, and the last hypural and the last vertebral segment have become a single piece. Neural spines have appeared on all the neural arches except the last two, and a thickening indicative of a spine is seen there also. The spinal cord does not extend among the fin-rays as in the *Leptocephalus*. All other features are much the same as in the *Leptocephalus* stage, though naturally more pronounced.

3. *Common Eel—adult.* (Plate XLVIII. fig. 11.)

After the preceding stage, and sometimes earlier, the last two neural arches often fuse into one. But the main feature to be noted in the adult is the complete absorption of the last vertebral segment, including centrum and urostyle, by the last hypural; all efforts to reveal the urostyle by clearing agents have failed; the union is complete, hence, what appears in the adult to be hypural
only is in reality hypural plus the last vertebral segment. The distal arms of the U-shaped hypural of the penultimate vertebra often tend to fuse and so produce an elliptical bone. There is considerable variation in the number of fin-rays supported by the various terminal elements; the terminal dorsal and ventral radial may or may not support a ray. It is usual for the last two hypurals to support four rays each, but this too is liable to variation. In young animals it is quite accidental whether fin-rays bifurcate or not distally, and it is not safe to conclude, with Ryder, that bifurcated dermatrichia are caudal proper and others dorsal or ventral respectively.

_Conger vulgaris._ (Murenidæ.) (Plate XLVIII. fig. 12.)

In most respects the caudal fin of the Conger is similar to that of _Anguilla_. Only by the aid of clearing agents can the exact outline of the various elements be traced; when thus treated, it is seen that the vertebral column proper ends in a long cone-like vertebra, directed posteriorly in a straight line with the vertebral axis, _i.e._, there is no tendency to upturning, and a urostyle cannot be said to exist. But all this is invisible without the aid of clearing agents, and the last centrum appears to be merely the proximal end of the three hypurals, which in reality are firmly fused with the last centrum. However, any difficulty concerning the ending of the vertebral axis is removed by a reference to the young stages: a young conger of 3½ inches (9:5 cm.) length or less will show a condition of things very like those in _Anguilla_, viz., a urostylar process upwardly directed, and occupying a position along the proximal dorsal edge of the last hypural; in a specimen 4½ inches (or 11·5 cm.) long, this could not be seen in the mere dissection.

Those dermatrichia which may safely be called caudal are supported by four hypural bones: the first of these is attached to the penultimate vertebra, instead of the antepenultimate, as in _Anguilla_, and the remaining three are all fused to the last vertebral segment. In this respect, the Conger differs from the Common Eel in which only one belongs to the last centrum, and the next two (forming the letter U) to the penultimate vertebra; this may represent a further shortening of the vertebral axis in _Conger_. A word should be said here, calling attention to the excellent illustration afforded by these hypurals, particularly the first and second, of their double nature; a line of fusion can be traced across the hypural dividing the latter into two parts, the proximal of which is almost exactly similar to the preceding haemal arches, and the distal part is like a radial.

There are no epural bones. The neural arches closely resemble those of _Anguilla_, but are more simple, the anterior ones possessing a very feeble spine; the last, which is specially long, to protect the end of the spinal cord, possesses a peculiar bony process running in an antero-ventral direction across the last centrum; this is probably a process for the attachment of caudal muscles.
Murena helena. (Murenidae.)

The caudal fin of the Roman Eel is essentially similar to that of the Conger, and attention need only be drawn to the peculiarities presented. The hypural bones are attached to the last centrum. The spur-like process of the last neural arch, mentioned in Conger, is more pronounced and fuses with a posteriorly directed process of the first hypural bone. The posterior neural arches are very simple, having no spine, and the closely aggregated radials of the dorsal fin are in close contact with them. The haemal arches very closely resemble the neural arches: the penultimate vertebra does not bear a hypural bone.

Myrus vulgaris. (Murenidae.) (Plate XLVIII. fig. 13.)

The caudal of this fish is again similar to the preceding types. Only one hypural is attached to the last centrum, which is quite indistinguishable, appearing only as the proximal end of the hypural bone: only one hypural may be said to be attached to the penultimate vertebra, though it is clear that this has been formed by the caesalence of the distal ends of the arms of the U-shaped structure in other genera. The haemal arches of the posterior vertebrae are of a horseshoe shape; this may account for the U-shaped hypural of the penultimate vertebra, which is so general in the family.

General remarks on the Apodes.

There is a striking uniformity in the structure of the caudal fin in this sub-order, due possibly to similar habits. In spite of observations, as early as Huxley's in 1859, to the contrary, writers repeatedly refer to the Eels as possessing diphyceral or protocercal tails. It cannot be too greatly insisted on, that whenever an upturned urostyle is present, either in the adult or the larva, a tail is not protocercal or diphycercal. Externally, of course, the Eels, with their undifferentiated median fin system, do present a primitive protocercal condition, but dissection proves the terminal endoskeletal supports to be very unsymmetrical; the broad hypural bones have no corresponding dorsal homologues. The caudal fin of the Apodes complies in all its essentials with the definition of homocercy, which will be discussed later; it cannot be called anything but an advanced form of homocercal caudal.

While dealing with the Apodes, it is interesting to note the references to the ancestral forms. The fossil Urenchelys from the Chalk beds has a homocercal tail—presumably an externally recognizable homocercal tail—and probably, therefore, much less specialized a form than the advanced form the modern Apodes have been shown to possess. Thus all that has happened is a steady process of specialization, exactly as is to be expected.
HAPLOMI.

Galaxias sp.? (Galaxiidae.)

Only a single specimen was available for examination; this revealed a free urostyle, beyond which the notochord continued for some distance, but did not reach the dermochordia. Seven hypurals are present, five of which are attached to the last vertebral segment; the last three are closely applied to each other and so form a large plate. Dorsally the dermochordia are supported by two epural bones and a dorsal caudal radial, the latter being cartilaginous. Both the epurals and hypurals of the penultimate and antepenultimate vertebrae are very broadly expanded, and show traces of the inclusion of radials in their formation. The last vertebra possesses a small neural arch and the spinal cord can be traced to the end of the notochord. Such a caudal fin must be considered a lowly specialized form of homocercy.

No generalizations can be made on the Haplomi until more species have been examined.

HETEROMII.

Fierasfer acus. (Fierasferidae.)

In this fish the median fins are continuous. At the extreme end of the tail no fin-rays are present in the fin-fold, so that there is a gap between the fin-rays of the dorsal and ventral fins. The vertebral column ends in a perfectly straight line, and, towards the end, consists of alternate segments of centra and notochord, the final element being notochord which comes in contact with the integument. The fin is therefore perfectly symmetrical externally and internally and moreover shows obvious signs of degeneration. Ryder concludes that the whole of the true caudal has been lost, and hence the tail is truly gephyrocercal. It is interesting to note that the developmental stages do not reveal any heterocercal tendencies.

Fierasfer dentatus. (Echidrion dentatus.) (Plate XLVIII, fig. 14.)

The figure of the tail of this species given by Emery is most interesting as presenting a typical gephyrocercal tail. The larva is provided with a long filamentous tail-ending, which is eventually lost in some way, and the adult tail gives the appearance of having had the end bitten off; the vertebral column ends in a vertebra exactly similar to the preceding ones; the dorsal and ventral fin-rays attempt to bridge over the gap caused by the loss of the caudal extremity, but never actually meet. The fin-rays of the dorsal and anal fins are supported by very small cartilages which represent radials, and which are far removed from the axis. I have not yet had an opportunity of examining this caudal fin, and so I reserve any remarks on this remarkable form.
General remarks on the Heteroni.

All fishes belonging to this sub-order, whether fossil or living, appear to be either eel-like or deep-sea forms; from this it is to be expected that the tail-fin when present is similar throughout, i.e., gephyrocercal.

Catostomi.

Gasterosteus aculeatus. (Hemibranchii.)

The caudal fin of this fish was well described by Huxley in 1859. The vertebral column ends in a long urostyle which is fused along the dorsal edge of the last hypural bone. There is a small neural arch to the last centrum, which Huxley figures as being continuous with it, though there is a line of junction separating arch and urostyle. The penultimate vertebra possesses an epural and hypurals; between the epural and the urostyle is a dorsal caudal radial (the "epural" of Huxley).

Centriscus scolopax. (Hemibranchii.)

The urostyle here is suppressed and the "cone" of the last vertebra shows only the slightest suggestion of upturning. Two hypurals are attached and equally well fused to the last centrum. An epural and hypural are attached to the last vertebra but one, and both show well that they are composed of a neural and a haemal arch respectively, together with a radial. A single dorsal caudal radial is situated between the epural and the last hypural.

Thus the caudal fin of Centriscus is highly specialized in contrast with the nearly related form Gasterosteus.

Syngnathus acus. (Lophobranchii.) (Plate XLVIII. fig. 15.)

The caudal fin of the Pipe-fish presents a perfectly symmetrical appearance, but morphologically it is quite unsymmetrical since all the eight dermatichia are supported by hypaxial elements consisting of two expanded hypural bones. Although the young stages show a distinct urostyle, this structure is absent in the adult. There are no complications of any kind and the whole caudal structure is exceedingly simple. The spinal cord can be traced to the distal end of the hypural bone. On account of the presence of a urostyle in the larva and the hypaxial nature of the fin, the tail must be classed as homocercal; moreover, it is a highly specialized form of homocercy.

Siphonostomus roxellani. (Lophobranchii.)

Precisely the same structure is found in this species as in the preceding type, hence it is unnecessary to repeat the description. The similarity is no doubt associated with the similarity in habits of the two fishes.

**Nerophis ophiion.** (Lophobranchii.)

This fish has lost its tail-fin probably on account of the prehensile function of the tail, but other species of *Nerophis*, e. g. *N. aquoreus*, do possess a very small one, which resembles that of *Syngnathus* in miniature.

**Hippocampus brevirostris.** (Lophobranchii.)

The Sea-horse has no caudal fin in the adult, but the larva possesses a urostyle and hypurals, which degenerate, probably owing to the prehensile habits.

**General remarks on the Catosteomi.**

Of the three families of the Catosteomi (Gasterosteidæ, Centriscidæ, and Syngnathidæ) types of which have been examined, the Gasterosteidæ certainly are the least specialized, and the Syngnathidæ the most so, while the Centriscidæ occupy an intermediate position, as regards the structure of the caudal fin. This order corresponds exactly with the general classification based on specialized features as a whole; this bears out what is often seen elsewhere, that the caudal fin may be useful in classifying fishes among smaller divisions, though it may not be depended upon as a broad taxonomic feature.

**Percoideæ.**

**Belone acus.** (Seombresocidæ.)

Only the smallest trace of a urostyle can be seen in the adult. There are six hypural bones in all, four of which correspond to the last vertebral segment; the most anterior of these four possesses a prominent bony process to which muscles are attached. The neural arch to the last vertebra is very large and protects the spinal cord which can be traced to the distal end of it. The epaxial fin-supports are liable to some variation: there are sometimes two, and at other times three dorsal caudal radials; when two are present, it is on account of the third (the most anterior) having fused to the neural arch of the antepenultimate vertebra and so constituting an epural bone: this point in itself is evidence as to the way in which epurals may be formed.

The variation exhibited here is probably what Stannius referred to, in 1854, when he quoted *Belone* as demonstrating the fact that the fin-ray supports may be of a double nature, *i. e.* arches plus radials. *Belone*, therefore, is interesting as being the fish in which this feature, so frequently met with elsewhere, was first seen.

The penultimate vertebra never appears to possess an epural, as the radial and neural arch are always separate.

On the whole the caudal fin of *Belone* attains to a fair standard
of specialization, particularly as regards the suppression of the urostyle; but at the same time the number of hypurals, viz. four, associated with the last vertebra is indicative of a comparatively low type of specialization. The proximal ends of the fin-rays embrace their endoskeletal supports so as to almost exclude them from view.

Ammodytes tobianus. (Ammodytidae.) (Plate XLIX, fig. 16.)

The last vertebra and last hypural are completely fused and thus there is no free urostyle. The hypaxial supports consist of five hypurals, four of which are attached to the last vertebra. The dorsal elements are somewhat complicated: lying between the single dorsal caudal radial and the last vertebra and hypural are four separate bones, through three of which the spinal cord passes; these three possibly represent neural arches, while the fourth may be a dislodged arch, or a spine detached from its arch. It is interesting to notice that fusion of these four bones into a single piece would form a large neural arch exactly as in Belone.

Atherina bayeri. (Atherinidae.)

A small but free urostyle is found here; connected with it and the last centrum are five of the seven hypural bones supporting the hypaxial dermatrichia. A small cartilage, situated between the distal ends of the first two hypurals, shares in the support of the anterior rays of the ventral lobe; this may possibly represent a radial, but it is doubtful. Dorsally the fin-rays are supported by two dorsal caudal radials and one epural bone, the latter attached to the antepenultimate vertebra. The neural arch of the last vertebra is very large and is composed of three bones; it affords protection for the end of the spinal cord. Thus Atherina possesses a fairly generalized caudal fin, lacking only a ventral caudal radial, though even this may possibly be represented by the small cartilage mentioned.

The development of the caudal fin in this fish is interesting as being almost identical, in the earlier stages, with that of the Flounder as figured by Agassiz, and shows very clearly the deep incision between the original and the permanent caudals.

Mugil capito. (Mugilidae.)

The urostyle is lost in the tissue of the last hypural bone; three hypurals in all are attached to the last vertebral segment; three dorsal caudal radials are present, the last of which is applied to the dorsal side of the last hypural. The neural arch to the penultimate vertebra is very much reduced. The anterior fringe of the ventral lobe of the caudal is supported by small cartilages; what these represent it is difficult to determine. The fin therefore may be classed as an advanced type of homocercy.
General remarks on the Percosoces.

This sub-order presents considerable diversity in caudal fin structure; *Atherina*, with its free urostyle and numerous hypurals attached to it, possesses a comparatively lowly specialized caudal, while that of *Mugil* is quite a specialized form. Arranged in ascending order of homocercy, the four genera will appear thus: *Atherina, Ammodiides, Belone, Mugil*, which arrangement does not correspond with that of general classification.

**Anacanthini.**

*Macruridae.*—The fishes in this family possess no caudal fin; they are deep-sea forms and the body ends in a finely tapering tail.

**Molva vulgaris.** (Gadidae.) (Plate XLIX, fig. 17.)

The Ling possesses a simple type of Gadoid tail. No less than thirteen vertebrae contribute towards the support of the caudal fin; all of these vertebrae are provided with hypural bones (*hyr.*) and all, except the last two, with epural bones too; special attention, therefore, need be directed only to parts connected with these last two vertebrae. The final vertebra possesses no urostyle, and is firmly fused with the broad last hypural which occupies a terminal position and bears five derrmotichia. That part of the last hypural which encroaches upon the dorsal side of the last centrum is seen in other Gadidae, e.g. *G. minustus*, to be a secondary extension of this bone, only appearing late in development; in young stages the hypural is totally ventral to the centrum. The hypural bone of the penultimate vertebra is also broadly expanded and bears three fin-rays. Between this hypural and the next anterior one is a ventral caudal radial (*v.c.*), in no way fused with any other skeletal element. Most of the hypural bones show signs of being formed by the coalescence of haemal arch and radial, the line of fusion being specially prominent after clearing agents have been used; the shading in the figure is intended to show this.

Epaxially, it is interesting to note the great reduction of the neural arch of the penultimate vertebra; that of the antepenultimate contributes to the formation of an epural bone. Between this last epural and the dorsal side of the last hypural are two dorsal caudal radials, each bearing a fin-ray; these radials never fuse with the neural arch, but always remain perfectly free. It will thus be seen that the caudal fin of *Molva* is not symmetrical internally and that the hypaxial fin-rays outnumber the epaxial; it is in every way consistent with homocercy, and its terminal skeleton with a very highly specialized type of homocercy.

**Gadiculus argentatus.** (Gadidae.) (Plate XLIX, fig. 18.)

This small Gadoid possesses a more generalized caudal fin than does the preceding type; this is due solely to the presence of a
large number of radials in addition to the epural and hypural bones. Except for the fact that eleven vertebrae form the basis of support for the fin instead of thirteen as in Molva, all remarks made in reference to the latter genus apply equally to Gadiantus. The whole interest in this tail-fin lies in the radials; in addition to the epurals no less than six are present epaxially, and ventrally three are to be seen alternating with hypurals. Moreover, these radials may be either quite free, like ordinary radials, or they may be more or less fused with the neighbouring hypurals or epurals. This affords one of the strongest cases for the theory that hypural bones are formed by the coalescence of radials with haemal arches. In the other median fins two radials are present between successive vertebral arches; thus probably the hypurals and epurals of the caudal have already absorbed one radial and the tendency is to effect a fusion of the second also. There can be no doubt about these radials being true radials and not a second neural or haemal arch, since they never reach the centrum itself and never embrace the spinal cord or haemal vessels at their proximal ends, as they would do if they were arches. The spinal cord can be seen to extend to the distal end of the last hypural bone. This caudal also is therefore a homocercal form.

General remarks on the Gadidæ.

There seems to be a certain amount of misconception among writers concerning the caudal fin of the Gadidæ; one or two quotations will make this clear. J. T. Cunningham, in 'Science Progress,' 1897, says:—"The structure and development of the tail described above (heterocercy) occur in the flat fish, but are entirely wanting in the Gadidæ. In the latter the tail is permanently diphyceral and is composed of dorsal and ventral rays which are equal in number and size, and, in fact, closely resembles the tail of the extinct Cœlacanthidæ. There can be little doubt that even if the Gadidæ cannot be directly derived from the latter family, they are descended from Crossopterygian Gadoids with diphyceral tails and have never passed through a heterocercal condition." And Boulenger, in the Ann. & Mag. Nat. Hist. xii. 1902, writes:—"I have reason to believe that Gadoids must have been derived from such a group as the Berycidæ, through forms of which the Macruridæ with thoracic ventral fins composed of seven to twelve rays are the nearest known examples, and in which the caudal fin has entirely vanished. I regard the isocecal condition of the Gadidæ as the result of the formation of a new caudal fin, the homocercal extremity of the vertebral column having been lost by the direct ancestors of these fishes." The same writer in comparing the caudal fin in the Pleuronectidæ with that of the Gadidæ says: (in the Pleuronectidæ) "the tail, whenever a caudal fin is well developed, belongs to the homocercal type (heterocercal in the embryo) with comparatively few rays (20 or less),"—thus differing from the Gadoids.
Other references might also be quoted, but these will be sufficient to show what misconceptions are held. Dealing with Cunningham's remarks first, a reference to either of the two figures given will show at a glance that the tail is not "permanently diphyceral" and is not "composed of dorsal and ventral rays equal in number." In all, eight different species have been very carefully examined, and any of the following remarks apply equally to all; there are always more hypaxial fin-rays than epaxial; this is due to the fact that a broadly expanded hypural bone is attached to the last centrum. Thus the tail is a highly specialized homocercal form.

This author has apparently never been fortunate enough to secure young forms of Gadida for detailed examination of the caudal fin structure or he would never have said that during the development the heterocercal stage is "entirely wanting."

_Gadus minuta_ of one inch length shows an upwardly directed urostyle along the dorsal edge of the last hypural as clearly as in the flat-fish; this becomes much reduced in the adult and is in fact almost completely lost; and since the extremity of the vertebral axis is almost precisely the same in all adult Gadidae, it is quite reasonable to suppose that the young forms in every case are similar to _G. minuta._ Cunningham's error in this connection led him to suppose that the Gadidae "are descended from Crossopterygian Ganoids with diphyceral tails and have never passed through a heterocercal condition." The latter statement, however, falls through.

Assuming Cunningham to be correct as regards the diphyceral condition, Boulenger comes to the conclusion that the Gadidae are descended from a homocercal form, such as the Berycidae, but that homocercy was entirely lost, and the "isocercal (i.e. the diphyceral) condition ..., is the result of the formation of a new caudal fin." But development proceeds just as in any highly specialized homocercal form, and hence the caudal fin of the Gadidae cannot be considered a new thing.

The caudal fin of this family further conforms to advanced homocercy in the great reduction of the neural arch of the penultimate vertebra; in all previous figures of the Gadoid tail, the last vertebra but one is shown bearing an epural bone; but in all the Gadidae examined, this has proved not to be the case; immediately dorsal to the penultimate vertebra there are always two dorsal caudal radials perfectly free and never fused with any other part of the neighbouring skeleton. Hypaxially, the same vertebra always bears a hypural bone.

Thus the caudal fin of the Gadidae is undeniably a specialized form of homocercy.

**A Canthopterygii.**

A preliminary note will be necessary before entering into details of the types chosen in this sub-order. In many forms in which a free urostyle is present, there is a fin-ray support
which occupies a position exactly in line with the urostyle; a difficulty comes about, therefore, in determining whether this element is hypaxial or epaxial. In shape it closely resembles the dorsal caudal radials, but the spinal cord runs along its dorsal edge; it may therefore be considered a dorsal caudal radial which has moved ventral to the spinal cord; but its present position below the spinal cord makes it possible also that it is a hypural bone, or perhaps a ventral caudal radial. For the present, however, I have decided to call it a hypural in order to simplify description, but the reader may consign it to any of the three suggested classes he may consider desirable.

SERRANUS CABRILLA. (Perciformes, Serranidae.) (Plate XLIX. fig. 19.)

The vertebral column ends in a well-developed and free urostyle (uv.), which is about the length of an ordinary vertebra. Six hypural bones (hy.) of varying size are associated with the last vertebral segment; the most anterior of these possesses a long spur-like process, running parallel with the urostyle, and undoubtedly functioning as an attachment for muscles; the last hypural is in direct line with the axis of the urostyle. Between the distal ends of the hypurals of the second and third last vertebrae is a small cartilage (c.) which shares the support of the smaller anterior ventral caudal fin-rays. Dorsal to the urostyle and extending beyond it, is a slender splint-like bone (n.a.) protecting the delicate end of the spinal cord; this probably represents one or more neural arches of vertebrae now absorbed into the urostyle. Independent of this bone, the last vertebra (l.v.) possesses a neural arch of its own; the neural arch of the penultimate vertebra (p.v.) is much reduced, and the antepenultimate vertebra is provided with an epural bone (ep.). Three dorsal caudal radials (d.c.r.) support the majority of the epaxial fin-rays.

This caudal fin, therefore, is a fairly typical form of a comparatively lowly specialized homocercal type.

CEPOLA RUBESCENS. (Perciformes, Cepolidae.)

This fish possesses a long tapering form of tail. The urostyle is prominent though slender; four hypural bones are attached to the last vertebral segment, the last overlapping the urostyle slightly. All the dermotrichia of the caudal fin are hypaxial, though epaxially there is a bone, not actually supporting a ray, which might be called a radial. Externally the median fin system appears to be a continuous one, but closely examined, there is to be found a very distinct and separate caudal. All the skeletal structures in the terminal end of the tail are very delicate and loose, the neural and haemal arches not being actually fused with the elongated centra. The tail-fin is, however, definitely homocercal.
Cantharus vulgaris. (Perciformes, Sparidae.)

The urostyle is well marked and free, and four hypurals are attached to the last vertebral segment; in all there are six hypurals, the second and third last vertebrae each bearing one. Epaxially, there are three dorsal caudal radials, and one epural which is attached to the antepenultimate vertebra. The neural arch of the penultimate vertebra is reduced. Between the last dorsal radial and the last hypural is a splint-like bone, the proximal end of which rests on the dorsal end of the urostyle; it protects the ending of the spinal cord and is probably a neural arch. The fin, therefore, is homocercal.

Box salpa. (Perciformes, Sparidae.) (Plate XLIX, fig. 20.)

The urostyle is well marked and distinct. Corresponding with the last vertebral segment are three hypurals, two of which are large, and the most anterior is provided with a ridge for the attachment of muscles; there are five hypural bones in all; between the distal ends of the first two is a small cartilage bearing a few of the small anterior hypaxial rays; a very small similar one is present on the anterior side of the first hypural. Epaxially, there are three dorsal caudal radials (d.c.r.), while the antepenultimate vertebra bears an epural bone; this epural is particularly interesting from the fact that in an animal 4 cm. long (fig. 20) it is seen to be two distinct and separate pieces—a neural arch, exactly similar to that of the penultimate vertebra, and a long cartilaginous radial, the proximal end of which is slightly applied to the posterior edge of the neural spine. In the adult, these two elements completely fuse to form an epural. A neural arch is present on the last centrum.

The caudal fin of Box is therefore homocercal, and slightly more specialized than that of Cantharus, on account of the fewer hypurals to the last vertebral segment.

Smaris alcedo. (Perciformes, Mænidae.)

A fairly long and free urostyle is present, on the ventral side of which, together with the last centrum, are four fin-ray supports, three only of which are undoubted hypural bones; the last is somewhat doubtful. Both the penultimate and antepenultimate vertebrae bear hypurals, between the distal ends of which is a large cartilage bearing small fin-rays. Separated from this cartilage only by the distal end of the first hypural are two small cartilages, both of which support the very small anterior epaxial fin-rays; a similar cartilage dorsally performs the same function. Three definite dorsal caudal radials are present and one epural bone; neural arches are borne by each of the last two vertebrae. A splint-like bone is closely fitted between the distal ends of the urostyle and the neural arch of the last centrum; probably it is a neural arch itself, belonging to some vertebra now absorbed into the urostyle. Cartilaginous epiphyses are present on most
of the fin-ray supports, and here and there are additional distal cartilages applied to these epiphyses; they may represent the persistent distal segments of radials.

This caudal fin is a good intermediate form between the lowly and the highly specialized homocercal types.

**Labrus festivus.** (Perciformes, Labridae.) (Plate XLIX, fig. 21.)

No urostyle can be seen in this form, it having completely fused with the last hypural bone; thus the last hypural, urostyle, and last centrum (l.v.) become a single bone. The last centrum bears one other hypural similar in size to the last; the preceding centrum also bears a hypural bone. Between the hypural of the penultimate vertebra and the first of the last centrum is a large bone (v.c.r.), which on account of its not having actually fused with the centrum, is probably better referred to as a ventral caudal radial. Three bony dorsal caudal radials (d.c.r.) are situated between the neural arch of the antepenultimate vertebra and the last hypural bone. In an exactly corresponding position dorsally and ventrally (i.e. on either side of the distal end of the neural spine and hemal spine of the antepenultimate vertebra) are two cartilages (c.) the posterior of which may in some species, e.g. *Labrus turdus*, become quite radial-like. The extremity of the spinal cord is protected along the dorsal side of the last hypural by a secondary bony development (s.).

Though the structure of this caudal fin approaches closely to secondary symmetry as regards general form, it is really not symmetrical owing to the fact that by far the majority of dermotrichia are hypaxial. By the loss of the urostyle and the reduction of the number of hypurals to the last vertebral segment to two, this caudal fin is a considerable advance in homocercy on the preceding type.

**Scomber scomber.** (Scombriformes, Scombridae.) (Plate XLIX, fig. 22)

The tail of the Mackerel is somewhat difficult to interpret at first sight as regards the ending of the vertebral axis; it appears as though a well-marked urostyle were present extending to the length of the broad hypural bones. Examined more closely, doubts will arise as to its true urostylar nature for one or two reasons:—(1) its end is cartilaginous and it bears dermotrichia; (2) its distal end is cut square, a feature no urostyle elsewhere possesses; (3) the end of the spinal cord enters slightly into the tissue of the proximal end of the bone. Another feature worth notice is that clearing agents do not reveal any indications of a normal urostyle fused with any other bone, and moreover, the conical last centrum does not turn upwards as a hook or reduced urostyle as so many other forms show, but ends in a direct straight line. The tail of *Trachinus* is the only other one examined which closely resembles *Scomber* in the termination of
the axis, and clearing agents show, in this type, an oblique line of fusion in the proximal end of this rectangular bone; this suggests that the distal end is hypural, and the proximal, at least partly, is urostyle firmly fused with the hypural. It may be so in *Scomber* too, but the fact that the spinal cord enters the proximal end suggests that a neural arch is also involved. And this seems to be the interpretation, for it cannot be urostyle alone, since it is cut square, tipped with cartilage and bears dermotrichia just as an ordinary hypural does. It seems safe, therefore, to say that the urostyle is greatly reduced and fused entirely with the last hypural—in this case a small one. In all, then, four hypurals are associated with the last vertebral segment; the most anterior being provided with a ridge for the attachment of muscles. Two dorsal caudal radials are present. The penultimate vertebra possesses a reduced neural arch and a well-developed hypural, while the antepenultimate vertebra bears an epural and a hypural bone. All the hypurals are firmly attached proximally; the dermotrichia embrace the terminal endoskeletal supports to their base; thus the fin forms a most efficient organ of locomotion, seen to advantage in the swift swimming Mackerel.

**Zeus faber.** (*Zeorchombi, Zeidæ*) (Plate XLIX, fig. 23.)

In this fish, the John Dory, a fairly typical flat-fish form is met with. The urostyle is lost to view; clearing shows it to be present as a minute hook embedded in the tissue of the last hypural. The three terminal hypurals (hy.) are fused with the last centrum (l.c.) into a single piece, though the outlines of the hypurals still remain visible. The last two complete centra each have a well-developed epural (ep.) and hypural bone, and the former are specially interesting inasmuch as they show clearly that the epural is formed by a fusion of radial with neural spine, apparently by means of a secondary ossification. The last centrum has a small neural arch (n.a.) developed. Of other supports of dermotrichia there are two dorsal caudal radials (d.c.r.) between the last epural and hypural, and also a central caudal radial (c.c.r.) immediately anterior to the large terminal hypural plate. The caudal fin, therefore, is a specialized homocercal type.

**Solea lutea.** (*Zeorchombi, Pleuronectidae.*) (Plate XLIX, fig. 24.)

*Solea lutea* may be taken as possessing a good representative type of Pleuronectid caudal fin. It has a more delicate build, but essentially is very similar to that of *Zeus*. A clearing agent shows the otherwise invisible urostyle to be a mere hook-like upwardly directed termination of the last centrum. The four hypurals of this centrum are firmly united, though less so than in *Zeus*, and occupy a terminal position. The penultimate vertebra has a well-developed epural (ep.) and hypural (hy.) bone; since reference has been made by Cole to the corresponding epural and hypural in the Plaice, it is interesting to compare them in the
two species. In the Liverpool Biological Committee Memoir on
the Plaice, Cole says, on p. 50:—"In the last distinct vertebra
(i.e. the penultimate vertebra) it will be seen that the neural
spine resembles the haemal spine in structure, but that both are
peculiar. Each consists of a partly cartilaginous shaft behind
and a thin laminate portion in front. The posterior shafts so
closely resemble the succeeding epural (i.e. dorsal caudal radial)
and hypural (i.e. ventral caudal radial) bones respectively as to
suggest that an epural above and a hypural below have fused on to
the laminate portions, which latter are undoubtedly similar to and
perhaps represent the neural and haemal spines in front. As,
however, we have no positive evidence of such a fusion, the spines
in question are here described as simple neural and haemal
spines." Though in Solea lutea this point is not so obvious as in
Pleuronectes, there is to be seen a distinct fusion line running
transversely across the proximal part of the epural, so that a
parallelism does occur between the two species. I take it that
Cole reserves committance on the subject on the ground that
actual fusion has not been observed during development; but it
is scarcely to be expected that such a minute feature as the fusion
of a radial with a neural or haemal spine will be recapitulated in
development, so that lack of embryological evidence would not
be fatal to the theory. But we have seen in the case of Box salpa
that such a fusion can be traced in development; had Cole been
acquainted with this as well as numerous other examples re-
sembling that of the Plaice, he doubtless would have considered
these epurals and hypurals more than mere neural and haemal
spines.

To complete the description of the caudal fin of Solea, there
are two dorsal caudal radials (d.c.r.) between the epural and
hypural bones; in the corresponding position ventrally there is
a ventral caudal radial (v.c.r.). The last centrum bears a neural
arch (n.a.) which is not, as may be at first supposed, a urostyle,
since the spinal cord (sp.c.) passes through it, in the fashion of
other neural arches, in its course along the dorsal edge of the
last hypural.

The caudal fin, then, is a homocercal type of an advanced
nature. It may be mentioned that other species of Solea, e.g.
S. monochir and S. impar, differ from S. lutea only in the number
of terminal hypurals and the extent of their collateral fusion.

Gobius paganellus. (Gobiiformes, Gobiidae.) (Plate L.
fig. 25.)

The urostyle (ur.) is greatly reduced, and almost non-existent
and fused with the last hypural bone. There are three hypurals,
the last two, the largest, being fused to the last vertebral seg-
ment. A small trace of neural arch is present on the last
centrum and that of the penultimate is also reduced. Dorsally
there are two caudal radials (d.c.r.) and ventrally one (v.c.r.), the
latter lying between the first and second hypurals. The spinal
cord can be seen to extend along the whole length of the last hypural.

Cartilage enters very considerably into this caudal fin. Both the anterior dorsal and anterior ventral fin-rays are supported by cartilage which is somewhat irregularly disposed, and which extends inwards even to the vertebral axis. It is the irregular nature of these cartilages that has led me to attach no importance to them as homologues of ordinary supporting elements such as radials, but merely to regard them, both here and frequently elsewhere, as convenient secondary developments to support the less important dermotrichia.

I have been fortunate in obtaining a fairly good series of developmental stages of Gobius, and the larve show exceedingly well how a condition in which the urostyle is very much reduced in the adult, is preceded by stages in which this structure is very prominent; and how, by a secondary encroachment of the last hypural bone, the urostyle is incorporated with this hypural.

The caudal fin of Gobius paganellus is a type of considerably advanced homocercy.

Echeneis naucrates. (Discocephali.)

A long well-developed urostyle is present, attached to which, together with the last centrum, are six hypural bones closely fitting together. A well-developed neural arch is closely applied to the dorsal edge of the last vertebral segment; the penultimate vertebra possesses a hypural and an epural, and immediately posterior to the latter are three dorsal caudal radials, slenderly built. This fin must therefore be considered a lowly specialized homocercal caudal.

Scorpaena scrofa. (Scleroparei, Scorpaeniide.) (Plate L, fig. 27.)

The vertebral axis ends in a well-marked and free urostyle. Three undoubted hypural bones are attached to the last vertebral segment, while in a direct line with the axis of the urostyle is a slender ray-bearing bone which may be considered a hypural or a radial. Between this bone and the epural (ep.) attached to the antepenultimate vertebra are three dorsal caudal radials (d.c.r.). The neural arch of the penultimate vertebra is reduced; there is also a slender bone (n.a.) immediately above, and closely approximated to the urostyle, which protects the delicate ending of the spinal cord; it is probably, therefore, a neural arch of some vertebra now absorbed into the urostyle. Both the second and third last vertebrae bear a strong hypural bone. This caudal fin is an excellent example of a form intermediate between a lowly and a highly specialized type.

Trigla lineata. (Scleroparei, Triglidae.) (Plate L, fig. 28.)

The urostyle here is practically non-existent, and traces of it can be seen only after the tail has been treated with a clearing
agent; thus the last vertebral segment and the last hypural become one solid structure. Three more hypurals are attached to the last vertebral segment and one is also attached to the preceding centrum. The whole of the dorsal contribution to the caudal fin is supported by four caudal radials. The neural arch to the penultimate centrum is much reduced. Though classified in the same division of Acanthopterygii as Scorpaena, Trigla provides a striking contrast to this form in the degree of specialization of the caudal fin, being quite a highly specialized type.

**Uranoscopus scaber.** (Jugulares, Trachinidae.)

The urostyle is absent or indistinguishably fused with the last hypural bone. Hypaxially, the last centrum bears three hypural bones, and epaxially a well-developed neural arch. The penultimate vertebra possesses a hypural bone, but its neural arch is greatly reduced; the antepenultimate vertebra bears both a hypural and epural. Between the epural bone and the neural arch of the last centrum are three dorsal caudal radials, while between this same neural arch and the hypural which is fused with the last centrum is a ray-bearing bone which is probably an epaxial element, though situated ventral to the spinal cord, since it is usual for the urostyle to fuse with the last, if any, of the hypural bones. This caudal fin, therefore, attains to a fairly high standard of homocercy.

**Callionymus lyra.** (Jugulares, Callionymidae.) (Plate L, fig. 26.)

The caudal fin of *Callionymus* is a very simple type. No urostyle is present; the last vertebral segment has three hypurals firmly attached to it and to each other, thus forming a single piece, to which dorsally is also fused the neural arch of the last vertebra. The penultimate vertebra bears an epural (ep.) and a hypural, and one dorsal caudal radial (d.c.r.) is present.

**Cristiceps argentatus.** (Jugulares, Blenniidae.) (Plate L, fig. 29.)

The urostyle is present only as a small hook embedded in the tissue of the last hypural bone. Hypaxially, the last vertebral segment possesses two hypurals of about equal size, while dorsally it shows traces of two neural arches, through which the spinal cord passes on its way some distance beyond the end of the axis. The penultimate vertebra possesses an epural and a hypural; posterior to this is a large dorsal caudal radial. Immediately adjoining the distal end of the last hypural, and on its dorsal side, is a small ray-bearing cartilage, and another one on either side of the dorsal radial. Similar cartilages are to be found ventrally in a corresponding position. This caudal fin, therefore, will be regarded as a highly specialized homocercal type.
Ophidium barbatum. (Jugulares, Ophidiidae.) (Plate L, fig. 30.)

All the median fins of this fish are continuous with one another, and the caudal proper may in this particular case be limited to those dermotrichia which are not supported by the typical radial or somactid of the dorsal and anal fins. This confines the caudal rays to those eight or nine supported by a large terminal hypural, often deeply and irregularly cleft, which is firmly coalesced with the last vertebral segment; the urostyle therefore is reduced to the norest vestige. A diminished neural arch is to be seen on the last centrum, and the nerve-cord runs along the whole length of the dorsal edge of the hypural. Thus the caudal fin itself is exceedingly simple in form and very highly specialized. The neural and haemal arches of the penultimate vertebra have a cartilaginous shaft fused to their posterior side; in reality, therefore, they may be considered epural and hypural respectively, but bearing no fin-rays.

General remarks on the Acanthopterygian Caudal Fin.

A sufficient number of types from various divisions of the Acanthopterygii have been dealt with to show how, in a single sub-order of Teleosts, the structure of the tail-fin may vary. Even in the same division of the sub-order, vastly different types are found; for example, in the Perciformes, the genera Serranus, Box, Cantharus, and others have features characteristic of the less specialized homocercal tail, such as a long and free urostyle and a large number of hypural bones attached to the last vertebral segment; on the other hand, the Wrasses (Labridae) have lost these lowly specialized features and attained to the rank of high specialization. The Scleroparei provide a similar contrast, Scorpaena having a much less advanced type than Trigla. It would be difficult to account for such variations between types otherwise so closely related, except on physiological grounds, but it indicates that the tail-fin is not a safe guide, or rather, a wholly satisfactory character, by which fishes can be classified.

In the main, however, advanced homocercy is exhibited among Acanthopterygian caudals, except for the Perciformes; this division possesses the greatest number of less specialized tails (the Labridae are the only family with much exception), but it is, as a division, the least specialized among the Acanthopterygii. From the foregoing descriptions it will be seen that the Jugulares possess the most advanced types of homocercy; of the six genera which have been subjected to examination, viz. Uranoscopus, Trachinus, Lepadogaster, Blennius, Cristiceps, and Ophidium, all possess advanced features in the caudal fin; but the Jugulares are, as a division, among the most specialized of the Acanthopterygii. The Zebrachombi occupy an intermediate position, and all members have very similar tails; they have a greatly reduced urostyle fused with a hypural, and also a large number of hypurals to the
last vertebral segment; thus there is an advanced feature (the former) and a lower feature (the latter) both present in the same caudal—in other words, an intermediate condition in specialization is present, which is consistent with the intermediate position the division occupies among the Acanthopterygii.

It would, therefore, seem that each individual division has its own grades of specialization within itself, and in this minor classification the structure of the tail does correspond with the general structure of the fish in respect to specialized features in general. In the Perciformes, the Serranidae are among the least specialized of the several families, and the Labridae are at the other end of the scale; and it has been pointed out that members of the former family have less specialized tails, by far, than those of the latter; thus caudal features correspond with specialized features in general, within this division. Exactly the same thing occurs among the Scleroparei, where the least specialized members are the Scorpenidae and one of the most specialized the Triglidae; the Scorpenidae have lowly and the Triglidae highly specialized caudal fins.

The Scleroparei are a more specialized division than the Perciformes, and yet Scorpæna, among the former, has a less specialized tail than that of Labrus in the latter division. Thus while the caudal fin may not be depended upon as a feature for classification in a broad sense, it may be useful within the scope of a single division.

**Opisthomi.**

**Mastacembelus** sp. ? (Plate L. fig. 31.)

This fish possesses a continuous undifferentiated median fin; the urostyle is well-marked and free, and equal in length to a vertebra. The limits of the caudal fin proper are probably best fixed here by those dermotrichia supported by hypural bones, of which two are associated with the last vertebral segment, the anterior one being obviously composed of three fused collaterally, and one with the penultimate vertebra. All the remaining fin-rays of the median fin are borne by radials; no epurals are present. A trace remains of the neural arch to the last vertebra. Thus the tail is definitely homocercal; in regard to this, it is strange that authors refer to it as a gephyrocercal tail. The only possible foundation for so naming this type is the apparent symmetry due to the confluent fins; it must, however, be insisted on that gephyrocercy indicates true secondary symmetry, i.e. an abbreviated protocerical condition. It is obvious that such a tail as that of *Mastacembelus* cannot be referred to the same category as that of *Fierasfer*.

**Pediculati.**

**Lophius piscatorius.** (Plate L. fig. 32.)

This fish may be said to illustrate the extremest type of advanced homocercy. Practically only one hypural is present,