A New Type of Luminescence in Fishes, III. The Gland in *Cœlorhynchus cœlorhynchus* Risso.

By

C. F. Hickling, M.A.

With 3 Text-Figures and Plates I–IV.

In 1925 I published a paper (**1**) describing a new type of luminescence in fishes, exhibited by the Macrurid fish *Malacocephalus lævis* Lowe, and a further paper (**2**) described experiments made on the luminescent secretion of this fish. In my first paper, I remarked that the Macrurid *Cœlorhynchus cœlorhynchus* Risso also possesses, "between the pelvic fins, a naked, pigmented patch; resembling that of *M. lævis*, and dissection again reveals a flat, pigmented sac lying in the body-wall adjacent to this pigmented patch." "It gives one the impression of a rudimentary organ, yielding no secretion, but connected with the anus by a pigmented, functionless duct." The present paper describes this gland in *C. cœlorhynchus*.*

Farran (**3**) writes, of *C. cœlorhynchus*, "this species is found in the Mediterranean, and in the Atlantic for about 20° to north and south of the Straits of Gibraltar, occurring along the edge of the continental shelf, and descending for a short distance down its upper slopes." I have recorded it (**4**) from the West Coast of Scotland, and Smitt (**5**) includes it among the fishes of Norway. In my first paper, I stated that I had then only seen five specimens on the Hake grounds south-west of Ireland, but, in 1926, I was able to examine many specimens at sea, and to cut out and fix the glands for further examination ashore. Unfortunately, I did not measure these specimens, which, however, were all comparatively large, certainly not less than 30 cm. in length. They will be referred to, in this paper, as "older specimens." Microscopic examination of these glands showed much variation in structure, and I felt that a proper understanding could be attained only after a comparison with younger specimens. I had to wait until August, 1930, and January, 1931, for this material. In August, 1930, the Ministry of Agriculture and Fisheries' research vessel *George Bligh* took two specimens, 14 and 15 cm. in length, on the "West-

* The work has been done in the writer's spare time, with material collected during voyages on hake research.

ward Ground," in about 180 fathoms, latitude about 49° 50′ N., and in January, 1931, the steam trawler *Tenedos*, aboard which I was engaged in hake research, by courtesy of the owner, Mr. H. E. Rees, took many specimens between 18 and 23 cm. in length, and one of 30 cm.

Some specimens were preserved whole, others were dissected, and the ventral gland, with its associated structures, fixed in Bouin's Fluid. The fixed material was cut into sections and stained by Mr. B. G. Clarke, Chief Laboratory Assistant at the Lowestoft Laboratory, to whom I would here acknowledge my thanks for his care and skill.

The stains used were Iron Hæmotoxylin and Eosin. The material was not easy to cut, owing to the abundance of tough connective tissue, and the sections have not always been perfect.

Finally, I would thank Professor Carl L. Hubbs, of the University of Michigan, for the benefit of his expert advice concerning the Macruridæ. In using his correspondence, I wish to avoid casting any responsibility upon him for my own findings.

A. The Anatomical Relations of the Gland.

Farran (**3**) writes, of *C. cœlorhynchus*, "between the ventral fins is a scaleless, oval depression, black in colour." Smitt (**5**) gives a very fine figure of this fish, and describes "a narrow, oblong, bare spot in the median line of the belly between the ventral fins." In his figure, the scaleless, oval spot, or depression, is placed with its centre decidedly anterior to a line joining the bases of the pelvic fins. This was also the usual position in my larger specimens. In my smaller specimens, the depression tended to lie more directly between the bases of the fins.

There is much bluish-black colouring in the skin in the ventral region of the fish, and the scaleless spot occurs in the midst of this, as a distinct, spindle-shaped depression. The margins of the depression project slightly, and the floor of the depression is itself covered with a comparatively thin skin, thickly strewn with melanophores. The posterior half or two-thirds of the depression bulge slightly.

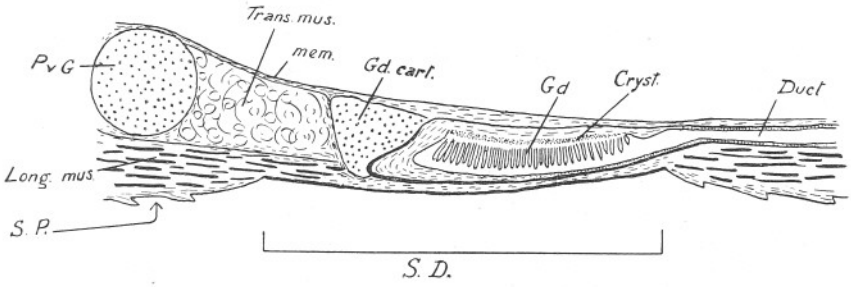
Posteriorly, the depression ends indefinitely, but a well-marked trail of pigment runs backwards from it, between the pelvic fins, to the anus, which is itself surrounded by a slightly swollen area heavily loaded with melanin.

From the dorsal aspect, the body-wall in the region anterior to the anus is seen to be covered by the thin silvery peritoneum, speckled with melanophores, and, when this is stripped off, a gland is revealed, lying in the mid ventral line, appearing as a swelling, well covered with black pigment and silvery guanin, of oval shape, tapering posteriorly into a duct likewise well wrapped in black pigment. Gland and duct are sur-

rounded by the muscles of the body-wall, and are overlaid by a very tough, almost cartilaginous membrane, of stoutly fibrous connective tissue (Text-Fig. 1 : *Mem.*). This membrane runs forward, and is connected to a prominent, curved ridge, which marks the junction of the right and left pelvic bones with the median pelvic cartilage (Text-Fig. 1 : *Pv. g.*). Through this membrane, two small blocks of cartilage may be seen associated with the gland : these cartilages meet in the middle line above the anterior extremity of the gland (Text-Fig. 1 : *Gd. cart.*).

Text-Figure 1 is a drawing of a rough sagittal section of the gland, made with a razor, and viewed through a lens.

The gland (*Gd.*) is a flattened sac overlying the scaleless depression (*S. d.*) ; it is partly filled with a brilliantly white substance, and is surrounded and defined by thick sheaths of black pigment, distinct from the



TEXT-FIG. 1.—Rough sagittal section of the ventral gland and the adjacent structures in a 30-cm. specimen of *C. cœlorhynchus*.

For explanation of the lettering, see text.

black pigment present in the floor of the scaleless depression. Both anterior and posterior to the scaleless depression, the scale-pockets (*S.p.*) are shown.

Posteriorly, the gland tapers away into the duct (Text-Fig. 1 : *Duct*) which runs backward to the anus. Anteriorly, the gland tapers obliquely downwards, to end bluntly, like the toe of a shoe. Text-Figure 1 was made from a specimen of 30 cm. In smaller specimens (for example, of 15 cm., Plate I, Fig. 1) the gland ends roundly, anteriorly, without tapering. This point is dealt with in Section C. In all cases, however, the connective tissue capsule of the gland is strongly bound to the peculiar cartilages (Text-Fig. 1 : *Gd. cart.* ; Plate I, Fig. 1 *et seq.*) mentioned above. Further forward, the section in Figure 1 cuts through the median cartilage of the pelvic girdle (*Pv. g.*) ; between the pelvic girdle and the gland cartilages lie transverse muscles (*Trans. mus.*), and longitudinal muscles lie beneath these (*Long. mus.*).

The gland cartilages are closely associated with the pelvic girdle. In the

first instance, they are bound, and the gland itself with them, to the pelvic girdle, by the overlying membrane of stout connective tissue (Text-Fig. 1 : *Mem.*), but, they are also more directly connected with the posterior processes of the pelvic girdle.

Text-Figure 2 is a reconstruction of the pelvic girdle in *C. cœlorhynchus*. The specimen was of 23 cm., and ossification in the girdle was incomplete.

There is a comparatively large, wedge-shaped median cartilage (*M. c.*) lying in the mid-ventral line, to which the pelvic bones of either side are attached (*P.*). From the posterior region of each pelvic bone, anterior to the point where these expand to form the articulation (*Art.*) of the fin-rays, springs a comparatively stout posterior process (*P. p.*, using the nomenclature of Goodrich, **6**) which inclines in a curve towards the middle

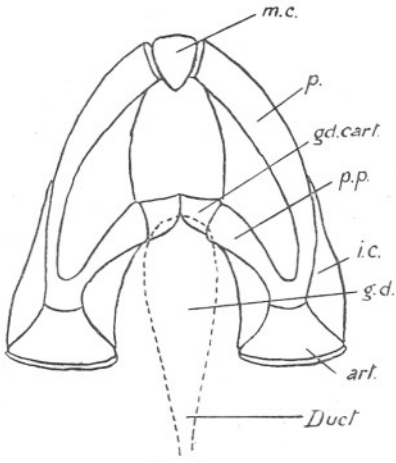


Fig. 2.

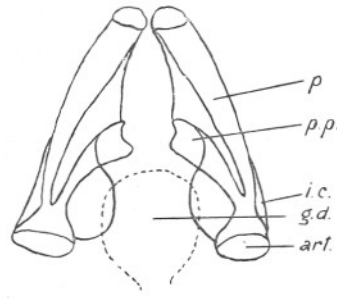


Fig. 3.

Text-Figs. 2 and 3.—Pelvic girdles of *C. cœlorhynchus* of 23 cm. (Fig. 2) and *M. lævis* of 25 cm. (Fig. 3).

line. Each posterior process is bound (but not, apparently, fused) to its corresponding gland-cartilage (*Gd. cart.*). The two gland cartilages curve upwards and towards the middle line, forming a bridge which spans the anterior of the gland. They meet at the middle line, and are bound to each other, and to the connective tissue of the gland, by a strong ligament (Plate II, Fig. 3).

A shallow crest (*I. c.*), which we may call the iliac process, runs dorsally along the pelvic bones of each side, from the angle of the articulation of the fin-rays to a point about half-way along the shaft of the pelvic bone. The posterior process is united, both to the pelvic bones and to the inner (medial) angle of the articulation, by membranes in which ossification was well advanced in the young specimens dissected.

B. The Structure of the Gland in Young Specimens.

Plate I, Figure 1, is a drawing of a sagittal section of the gland and duct in a 15-cm. specimen of *C. cœlorhynchus*. Its general features resemble those of the gland of the 30-cm. specimen in Figure 1. The gland lies in the thickness of the body-wall: above is the body-cavity. The gland is strongly bound with fibrous connective tissue (*C. t.*) which also binds it to the gland cartilage (*Gd. cart.*). In the neighbourhood of the cartilage, the fibres of the connective tissue are very thick, and stain deeply with Iron Hæmotoxylin. Transverse or oblique muscles (*Trans. mus.*) are seen anterior to the gland-cartilage. The scaleless depression can be discerned in the outline of the outer skin of the fish (the lower margin of the section). In this young specimen, the gland overlies the whole of the scaleless depression.

The sheet of stout connective tissue overlying the gland (shown in Text-Fig. 1) is not seen in this section; it has probably become detached, with the peritoneum, during manipulation. The connective tissue in the roof of the gland is thickly impregnated with guanin crystals; these reflect the light strongly, and make this region conspicuous. They constitute the "brilliant white substance" observed in the rough sagittal section of the gland. The walls of the gland also contain a continuous layer of melanophores: these are especially abundant in the floor of the gland (*Mel.*).

From the roof of the gland a system of tubules (*S.t.*) projects downwards; these gradually become confluent into irregular collecting spaces (*C. s.*), which are traversed by trabeculæ of connective tissue with an epithelial lining, and are confluent posteriorly with the duct (*d.*). The tubules are actively secretory; they are lined with a conspicuous epithelium secreting dense masses of minute granules. They seem to resemble, in all respects, those of *M. lævis* (**1**), and the appearance and formation of the secretion is also similar (**2**). A number of small blood-vessels (*B.v.*) are present in the roof of the gland, which branch into very fine vessels passing down into the walls of the tubules.

Plate II, Figures 3, 4, and 5, are drawn from a series of sections cut horizontally through the gland of a 14-cm. specimen of *C. cœlorhynchus*, i.e. parallel to the ventral surface of the fish. Figure 3 is a section just touching the extreme top of the gland, Figure 4 is a section through the upper portion of the gland, and Figure 5 a section near the base of the gland.

The greater part of the space in Figure 3 is occupied by the gland-cartilages (*Gd. cart.*) which almost touch each other at the middle line. They are separated by a few fibres of the stout ligament which binds them together, and to the connective tissue capsule of the gland (*C.t.*). The

fibres of this ligament stain deeply with Iron Hæmotoxylin. The extreme top of the gland is seen posterior to (below in the figure) the gland cartilages. It consists of connective tissue, containing many melanophores (*Mel.*), an area rich in crystals of guanin (*Cryst.*), and numerous much-branched blood vessels (*B. v.*). It is clear that this series of sections is slightly oblique, since the left gland cartilage is cut more longitudinally, the right, more transversely ; this is confirmed by Figure 4, cut at a lower level of the gland, where the left gland cartilage has passed out of the section, while the right, cut more longitudinally as it curves outwards and downwards, is still visible.

In Figure 4, as has just been stated, the right gland cartilage (*G. c*). is seen, attached to the wall of the gland, which contains its usual melanin sheath (*Mel.*) and blood vessels (*B. v.*). The gland itself consists, at this level, almost entirely of the secretory tubules (*S. t.*), here cut transversely. At the anterior end, however, the lumina of these tubules are already running together into collecting spaces (*C. s.*). Longitudinal and transverse muscles surround the gland.

In Plate II, Figure 5, the secretory tubules are no longer present, and the gland consists, at this level, of the collecting spaces (*C.s.*) which are confluent, posteriorly, in the Duct (*D.*). A very complete melanin sheath (*Mel.*) surrounds both gland and duct. There is a constriction at the junction of the gland and duct, and, at first, I suspected some kind of sphincter mechanism : no muscle is apparent, however, and it is probably a fortuitous projection of the wall of the duct.

C. The Structure of the Gland in Older Specimens.

The structure of the gland of *C. cœlorhynchus*, as it is found in small specimens of 14 and 15 cm., may now be compared with that of the gland in larger specimens, whose length, not ascertained, may almost certainly be put at over 30 cm.

In Plate I, Figure 2, is a drawing of a sagittal section through the gland of an older specimen. It is drawn to the same scale as Plate I, Figure 1.

The structure of the gland resembles that of the young fish. The gland cartilage is present, but is out of the field to the right. The gland consists of a connective tissue capsule, bearing melanophores (*Mel.*), and containing secretory tubules (*S. t.*) discharging into collecting spaces (*C. s.*). The tubules are full of secretion.

The striking difference between the larger and the smaller specimens lies in the fact that the gland, in the larger specimen, is about twice the length and depth of that of the smaller, whereas the secreting portion occupies about the same area in both fish. In the larger fish, the connective tissue of the roof has increased greatly in thickness, and the layer

of guanin crystals (*Cryst.*) is separated from the tubular portion of the gland, upon which it abuts in the smaller specimen. The system of collecting spaces occupies a much greater area in the larger fish, and runs far forward, beyond the secretory tubules, as a blind pocket. The melanin sheath is less conspicuous, the pigment is distributed more thinly, almost as if the increase in size of the gland had not been accompanied by an increase in pigmentation.

In Plate III, Figures 6 and 7, are shown, in transverse section, the glands of two older specimens of *C. cœlorhynchus*.

The gland in Figure 6 is, clearly, very similar to that shown in Plate I, Figure 2; there is a well-developed system of secretory tubules (*S. t.*) containing abundant secretion, a well-marked melanophore sheath (*Mel.*), and large collecting spaces (*C. s.*). The tubular portion of the gland, however, is reduced in area as compared with the gland of a smaller fish such as that in Plate I, Figure 1, and appears, in fact, to occupy an even smaller space than that in the gland shown in Plate I, Figure 2, while there is a tendency for the secretory tubules to project obliquely, rather than vertically, towards the collecting spaces.

In Figure 7, the gland has undergone great reduction. The secretory tubules have disappeared, the gland is very much flattened, and contains only collecting spaces (*C. s.*), themselves reduced and flattened. The melanophore sheath is very indistinct (*Mel.*). One of the gland-cartilages (*Gd. cart.*) is visible, bound to the gland by deeply staining fibrous connective tissue.

Three other glands of older specimens were sectioned and examined. In all three there was a relative reduction in the secretory portion of the gland, as compared with a small specimen, and the blind forward prolongation of the collecting spaces, shown in the section in Plate I, Figure 2, is a common feature.

Comparing the structure of the gland in smaller and larger specimens, it appears that, with an increase in the size of the gland, there is no corresponding increase in the amount of the secretory epithelium, and a greater diffusion of the pigmentation of the gland. This points, in my opinion, to disuse and degeneration of the gland as the fish grows larger.

D. The Duct.

It has already been mentioned that the gland narrows posteriorly into a duct, which runs backward to the anus, and is marked by a trail of black pigment. The duct may be seen in Text-Figure 1, in Plate I, Figures 1 and 2, and in Plate II, Figure 5. It is lined with epithelium two or three cells deep, and is, in smaller specimens at least, surrounded with melanophores.

Its length varies with the size of the fish, not only absolutely, as may be expected, but relatively also.

This may be seen in the measurements given below.

Length of Fish.	*Length of Duct.*	$\frac{\textit{Length of Fish.}}{\textit{Length of Duct.}}$
15 cm.	0·5 cm.	30
18 cm.	0·9 cm.	20
19 cm.	0·8 cm.	24
20 cm.	0·8 cm.	25
22 cm.	0·9 cm.	24
22 cm.	0·9 cm.	24
30 cm.	2·0 cm.	15

In the fish of 15 cm., the length of the duct is only one-thirtieth of that of the fish, in one of 20 cm., one-twenty-fifth, and in one of 30 cm., one-fifteenth. This relative lengthening of the duct seems to be associated with a relative forward movement of the pelvic fins, accompanying the growth of the fish.

The duct runs backward to the anus. Its final course there may be traced by examining a series of horizontal longitudinal sections, cut transversely to the rectum, and parallel to the surface of the body in the neighbourhood of the anus.

Drawings are shown, in Plate IV, of sections from such a series in specimens of 21 cm. (Fig. 8), and of 30 cm. (Fig. 9). Both are drawn to the same scale.

In Figure 8, the rectum (*R.*) occupies the centre of the section, lined with its characteristic tall and irregular epithelium. It is surrounded by connective tissue, containing blood vessels (*B. v.*) and melanophores (*Mel.*). The sphincter muscle is not seen in this section. Surrounding the rectum is a system of loose spaces (*P.*) lined with an epithelium closely resembling that of the duct of the ventral gland, but quite distinct from that of the rectum. Surrounding these spaces is a second, and denser ring, of melanophores. Posterior to the anus, there appears, cut in transverse section, the genital duct (*G. d.*), here appearing as a space in the connective tissue, and the kidney duct (*K. d.*) with a well-defined columnar epithelium.

In Figure 9, which is a section cut at a somewhat higher level, in its series, than that shown in Figure 8, the rectum again occupies the centre of the field (*R.*), and the ring of unstriped muscle (*Mus.*) is conspicuous in its wall. Outside this is a dense ring of melanophores (*Mel.*), which surrounds the rectum, and also surrounds a system of spaces (*P.*) lying in the connective tissue surrounding the rectum. Anteriorly (to the right in the figure) the ring of melanophores narrows to a sheath surrounding the

duct of the ventral gland; the latter is shown, cut obliquely, at (*D.*). Posteriorly, the genital duct (*G. d.*) and kidney duct (*K. d.*) are to be seen.

These series of sections show that the duct of the ventral gland widens, at the rectum, into a series of loose spaces, which more or less surround the rectum, and end blindly, dorsally, in irregular pouches. The pouches extend relatively much further up the sides of the rectum in the smaller specimen (21 cm.) than in the larger specimen (30 cm.).

These pouches, with their melanin sheath, are the cause of the " slightly swollen area, heavily pigmented," which may be seen, with the naked eye, surrounding the anus.

E. A Comparison with the Gland and Duct in *M. lævis.*

There can be no doubt but that the ventral glands in *C. cœlorhynchus* and *M. lævis* are homologous. In both, the duct opens to the exterior " about the anus, in such a way as to surround the lower part of the rectum " (**1**). In both, pouches arise from this external opening, which run upwards beside the rectum, and end blindly. In both cases, the secretory part of the gland consists of tubules, which discharge a granular secretion into a system of loose collecting spaces. As pointed out in *M. lævis*, these tubules are best regarded as " an epithelium, which has been thrown into long folds." The tubules and collecting spaces are firmly bound in connective tissue, to form a compact gland, containing a layer of guanin crystals, and insulated from the other tissues of the fish by a screen of melanophores. The gland lies, in both cases, in the thickness of the body-wall, forward of the rectum, and between the pelvic fins.

There are some differences. Firstly, the duct is very short in *M. lævis*, relatively long in *C. cœlorhynchus;* but there is reason to think that this difference becomes less significant in small specimens (Section D). The gland in *C. cœlorhynchus* is notably flatter in shape than that of *M. lævis;* the secretory tubules of *C. cœlorhynchus* project downwards from the roof of the gland, in *M. lævis* they project towards the centre of the gland, mainly from the anterior and lower walls. The gland of *M. lævis* overlies two small scaleless depressions in the skin: one large depression is associated with the gland in *C. cœlorhynchus*. From their respective relations with the gland, the two small depressions in *M. lævis* are probably homologous with the single large depression of *C. cœlorhynchus*. The significance of these depressions might possibly be explained by an embryological study, for which the materials are at present lacking.

These differences are trifling, and might be much less marked in small fish. There are three important differences.

Firstly, the gland in *M. lævis* is furnished with unstriped muscle, which forms a sheet over the top of the gland, " probably closely connected

with the function of compressing the gland to cause emission of the secretion." There is no such muscle even in young specimens of *C. cœlorhynchus*.

Secondly, the gland in *C. cœlorhynchus* is strongly bound, at its anterior end, to two special cartilages, which are connected, in their turn, with the pelvic girdle (Text-Fig. 2). These are present in older specimens of *M. lævis*, but the gland is not closely bound to them, as it is in *C. cœlorhynchus*. The pelvic girdle of a young (25 cm.) specimen of *M. lævis* is shown in Text-Fig. 3. Comparing it with the pelvic girdle of a 23 cm. specimen of *C. cœlorhynchus* it is clear that there are considerable differences. The median cartilage is wanting in *M. lævis*, and the posterior processes, which in *C. cœlorhynchus* are comparatively stout rods, in *M. lævis* are flattened, less definite structures, from which arise sheets of bone, which, arching upwards (dorsally) and towards the middle line, form a shallow cavity in which the gland (of which the outlines are indicated) is contained. In an older specimen of *M. lævis* (43 cm.) the posterior processes are more rod-like, as in *C. cœlorhynchus*, and two very small rounded cartilages are present, which connect the two posterior processes of the pelvic girdle across the middle line. But the luminiferous gland appears to be quite independent of these cartilages.

It seems probable that the " lens-like body " figured and described (**1**) as lying anterior to the gland, in *M. lævis*, is really hyaline connective tissue filling the space between the gland and the enclosing sheets of bone, and in no way " part of an optical apparatus, for casting light from the gland itself," as I doubtfully suggested in my paper on *M. lævis*.

These differences between the relations of the gland and the pelvic girdle are probably associated with a different mode of ejection of the secretion. If ejection is brought about, in *M. lævis*, by the action of the unstriped muscle in the wall of the gland, the sheets of bone, enclosing the anterior portion of the gland, will give the necessary support against which the pressure produced in the gland by the muscle can have effect. In *C. cœlorhynchus*, it seems probable that ejection is accomplished on quite a different plan. The two gland cartilages rise up in an arch, spanning the fore part of the gland, and are united above, at the middle line, by a ligament. This ligament might act as a hinge, so that, if the lower ends of the gland cartilages were pressed towards each other by the posterior processes of the pelvic girdle, to which they are attached, the gland would be squeezed, nutcracker-fashion, and the contained secretion forcibly ejected. Thus ejection could be brought about by the transverse muscles between the two halves of the pelvic girdle, acting on the gland by way of the posterior processes and the gland cartilages.

The third difference is this, that the gland of *M. lævis* remains actively functional, in producing a luminescent secretion, throughout life, whereas,

in *C. cœlorhynchus*, the evidence points to its degeneration with growth. I have not found, among scores of specimens of all sizes, a single *M. lævis* which did not yield abundant brilliantly luminescent secretion on the gentlest pressure applied to the pelvic region. The glands of larger specimens of *C. cœlorhynchus* yield no luminescent secretion, though the gland, newly cut open, may show a very feeble luminescence. In a darkened cabin, I held in one hand a small (20 cm.) specimen of *C. cœlorhynchus*, in the other a 25-cm. specimen of *M. lævis*, and squeezed their ventral glands simultaneously. *M. lævis* instantly yielded a large drop of brilliantly luminescent secretion: *C. cœlorhynchus*, after more vigorous treatment, showed a thin smear, barely visible to the dark-adapted eye.

I have no doubt that the gland on *C. cœlorhynchus* is fully functional in the very small fish, and is probably used in the same way as that of *M. lævis*. But I also have no doubt that, in older specimens, the gland becomes more or less vestigial.

The gland of *M. lævis* is more primitive, or less specialised, than that of *C. cœlorhynchus*, especially in the connection of the gland, in the latter, with the pelvic girdle. If the gland is indeed derived from "a glandular area about the anus, which has become invaginated to form a pouch, and secondarily folded to give an enormous internal area of secretion," the ejecting mechanism in *M. lævis*, consisting of unstriped muscle such as could have been carried in from the rectum, is decidedly more primitive than the association with the pelvic girdle, which we find in *C. cœlorhynchus*, and which must be regarded as a secondary development.

In the adult *Trachyrhynchus trachyrhynchus* Risso, there is no sign of a ventral gland, even in sections of the rectum and its surrounding tissues, and Johnsen (**7**) makes no mention of its presence in young bathypelagic specimens. Had a ventral gland been present, Johnsen could not have failed to mention or investigate it.

F. The Ventral Gland in the Anacanthini.

In my paper on *M. lævis*, I suggested that the gland in *C. cœlorhynchus* was degenerate, and that this might be associated with a stouter armature of scales in the latter species, "which has rendered unnecessary the protective device of a luminous organ." I also suggested that "the organ may be widely spread among Macruridæ, and further work on other species might reveal its presence." The suggestion was ill-informed. The ventral gland is widely spread among the Macruridæ. Gilbert and Hubbs (**8** and **10**) describe its presence in many genera, such as Cœlorhynchus, Abyssicola, Hymenocephalus, Malacocephalus, Ventrifossa, etc. They used it in their classification of these fishes, and suggested that it

might be a phosphorescent organ. Still earlier, Radcliffe (**9**) had suggested that the ventral gland found in *Macrurus lucifer* (= *Ventrifossa lucifer*, Smith and Radcliffe) was phosphorescent.

The macroscopic structure of the ventral gland in the Macruridæ, as described by Gilbert and Hubbs (**8** and **10**), shows great variation. The gland may be sing'e (as I have found it in *M. lævis* and *C. cœlorhynchus*), or double, a second gland being present at the anus. Gilbert and Hubbs (**10**) thus describe the gland in *Cœlorhynchus argentatus*. " The posterior dilatation is bilobed, being divided by the anus. The thick anterior dilatation is roughly triangular in outline . . . it lies within a cavity, and is supported in a strikingly peculiar manner by a cartilaginous rod in close connection with the pelvic girdle. The posterior arm of this bone is a poorly ossified plate, which, by meeting its fellow at the median line, forms a brace directly between the pelvic bases. From the anteromedian angle of each of these posterior limbs, a cylindrical rod of cartilaginous tissue extends forward to the sides of the anterior dilatation, from which it extends dorsad, meeting its fellow in a wide arch, the apex of which is bound to the well-ossified anterior arms of the public (*sic*) bone, where these meet at the middle line." The structure of the gland and cartilages, in their relation to the pelvic girdle, in *C. argentatus* obviously very closely resemble those of *C. cœlorhynchus*. The posterior gland, divided by the anus, described in the former, and in many other species, is plainly to be homologised with the pouches which arise from the duct, about the rectum, in *M. lævis*, and *C. cœlorhynchus*. Hubbs himself, in a letter to me, admits of no doubt that the gland is homologous throughout the group of Macrurids.

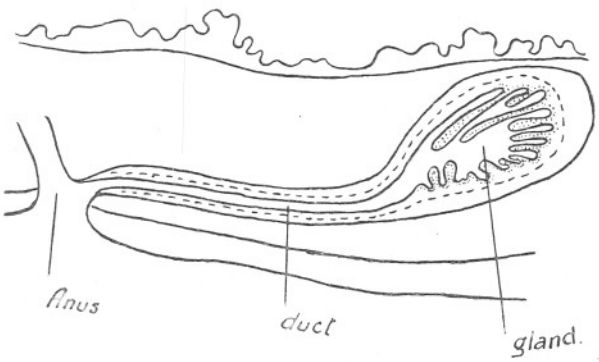
A closely similar gland is present in a genus of the Gadidæ, namely, Physiculus. Franz (**11**) has described briefly the ventral gland in *P. japonicus*. I take the liberty of reproducing his figure below (Text-Fig. 4).

A round, black, scaleless fossa lies in the median line before the anus. " Hierunter eine schöne Drüse im Muskelfleisch eingebettet liegt. Langschnitte . . . zeigten mir ferner, dass der ausfuhrungsgang der Drüse in den After mündet. Die Drüse . . . besteht aus gestrickten, radiär gestellten Drusenschlaüchen, und nicht etwa . . . aus einen gefalteten Drüsenepithel. . . . Das Epithel und überhaupt die Schleimhaut des Ausfuhrungsganges zeigt . . . starke längsfalten." Jordan and Hubbs (**12**) found a similar fossa in three American species of Physiculus, namely, *P. fulvus*, *nematopus*, and *rastelliger*, which makes it probable that a ventral gland is present in these species also.

There can be no doubt that this gland is homologous with that of the Macruridæ : it is present, therefore, in both families of the Anacanthini. As far as I know, it has not been found in any other Gadoids.

Boulenger (**13**) and Regan (**14**) are both of the opinion that the Macruridæ are more primitive than the Gadidæ. I would suggest that the gland arose in the primitive Anacanthini, probably during an invasion of deep water, that it has been retained and elaborated in the Macruridæ, which have persisted in the deeper water, where the gland is presumably of use, but lost in the Gadidæ, with the exception of the genus Physiculus.

Owing to the variation in the structure of the gland among living



TEXT-FIG. 4.—Sagittal section of the ventral gland in *Physiculus japonicus*, after Franz.

Macruridæ, and the fact that it appears to degenerate in some species, it should probably be regarded as essentially a larval or post-larval organ, which may remain functional throughout life in some species. Smitt (**5**) described what is clearly the fossa underlying the ventral gland, in a post-larval Macrurid, but suggested that it might be an adhesive organ.

A comparative study of the structure of the gland in a wide range of Macrurid and Gadoid fishes might throw some light on their mutual relationships.

SUMMARY.

The luminiferous organ of the Macrurid fish *Cœlorhynchus cœlorhynchus* Risso is described in this paper. It consists of a gland, flattened dorso-ventrally, placed in the body-wall, just in front of the pelvic fins. The secretory epithelium is thrown into a series of tubules, projecting downwards from the roof of the gland into a system of collecting spaces : the latter are confluent, posteriorly, with a duct which leads backwards, between the pelvic fins, to the anus. Blind pouches, which run upwards for a short distance beside the rectum, arise from the duct at its external opening at the anus.

The gland itself, which is compactly bound in fibrous connective tissue rich in melanophores, is strongly bound to a pair of cartilages, which rise dorsally to span the anterior end of the gland, are united by a ligament at the middle line, and are connected, lateroventrally, to the posterior processes of the pelvic girdle. It is suggested that contraction of the muscles between the two halves of the pelvic girdle might cause the gland cartilages to squeeze, nutcracker-fashion, the anterior part of the gland, the ligament binding the cartilages together at the middle line acting as a hinge. It is probable that the fish actively expels the luminiferous secretion of the gland by this means.

The gland is apparently functional only in the young fish : it becomes more or less vestigial in larger specimens.

The structure of the gland in *C. cœlorhynchus* is compared with that of the homologous gland in the Macrurid fish *Malacocephalus lævis* Lowe ; the gland of the latter is the more primitive or the less specialised.

Finally, the glands of these fishes are homologised with those in other Macruridæ, and in the Gadoid genus Physiculus. It is suggested that a comparative study of the structure and distribution of these glands might be of help in establishing the relationships of the members of the Anacanthini.

LITERATURE CONSULTED.

1. Hickling, C. F. A new type of Luminescence in Fishes. Journ. Mar. Biol. Assoc., N.S., Vol. XIII, No. 4, 1925.
2. Hickling, C. F. A new type of Luminescence in Fishes, II. *Ibid.*, Vol. XIV, No. 2, 1926.
3. Farran, G. P. Seventh Report on the Fishes of the Irish Atlantic Slope. The Macrurid Fishes. Proc. Roy. Irish Acad., XXXVI, Sec. B, No. 8.
4. Hickling, C. F. The Exploratory Voyages of the *Florence Brierley*. Notes on the Fish recorded. Ann. Mag. Nat. Hist., Series 10, Vol. II, 1928.
5. Smitt, F. A. " Scandinavian Fishes." London, 1892.
6. Goodrich, E. S. On the Pelvic Girdle of Eusthenopteron. Quart. Journ. Micr. Soc., Vol. XLV, No. 178, N.S., Nov. 1901.
7. Johnsen, Sigurd. On some bathypelagic stages of Macrurid fishes. Nyt. Mag. for Naturvidensk, Oslo, B 65, 1927.
8. Gilbert, C. H., and Hubbs, Carl. L. Report on the Japanese Macrurid Fishes, etc. Proc. U.S. Nat. Mus., 51, 1916.
9. Radcliffe, L. Proc. U.S. Nat. Mus., 43, 1912.

10. GILBERT, C. H., AND HUBBS, CARL L. The Macrurid fishes of the Philippine Islands, etc. Bull. U.S. Nat. Mus., 100, Vol. 1, Pt. 7, 1920.

11. FRANZ, V. Abh. bayer Akad. Wiss., II Kl., Supplement 4, 1910.

12. JORDAN, D. S., AND HUBBS, CARL L. Mem. Carnegie Mus., 10, 1925.

13. BOULENGER, G. A. Ann. Mag. Nat. Hist. (7), X, 1902.

14. REGAN, C. T. Ann. Mag. Nat. Hist. (7), XI, 1903.

EXPLANATION OF THE LETTERING USED IN PLATES I–IV.

B. v., Blood vessels. C. s., Collecting space. Cryst., Guanin Crystals. C. t., Connective tissue. D., Duct of gland. Gd. cart., Gland cartilage. G. d., Genital duct. K. d., Kidney duct. L. mus., Longitudinal muscle. Mus., Muscle. Mel., Melanophores. P., Pouches arising from duct of gland. R., Rectum. S. t., Secretory tubules. Trans. Mus., Transverse muscles. The scales accompanying the figures are one millimetre, divided into tenths.

PLATE I.—Sagittal sections through the gland and duct of *C. cœlorhynchus*.

FIG. 1.—In a 15-cm. specimen.

FIG. 2.—In an older specimen.

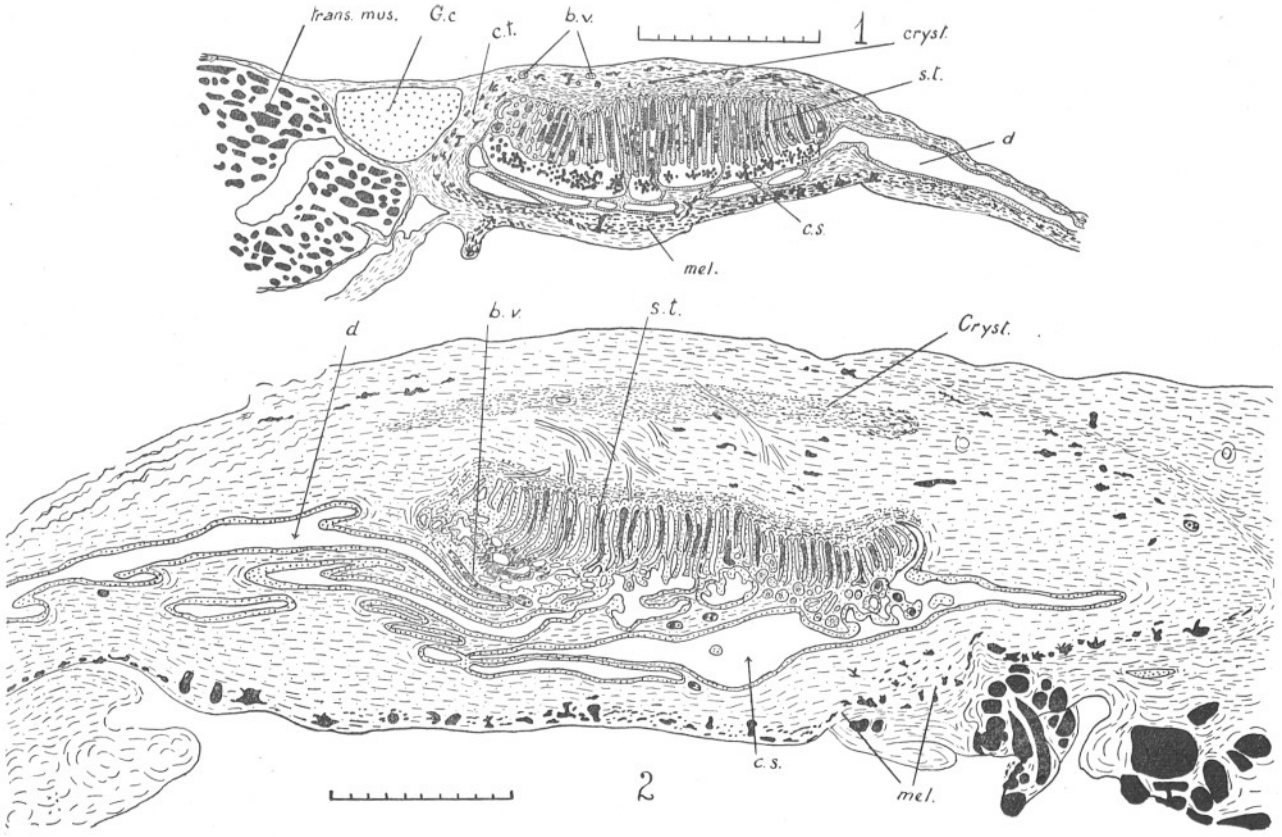


PLATE I.

PLATE II.—Horizontal longitudinal sections through the gland of a 14-cm. specimen of *C. cœlorhynchus*.

FIG. 3.—Through the top of the roof of the gland.

FIG. 4.—Through the tubular portion of the gland.

FIG. 5.—Through the floor of the gland.

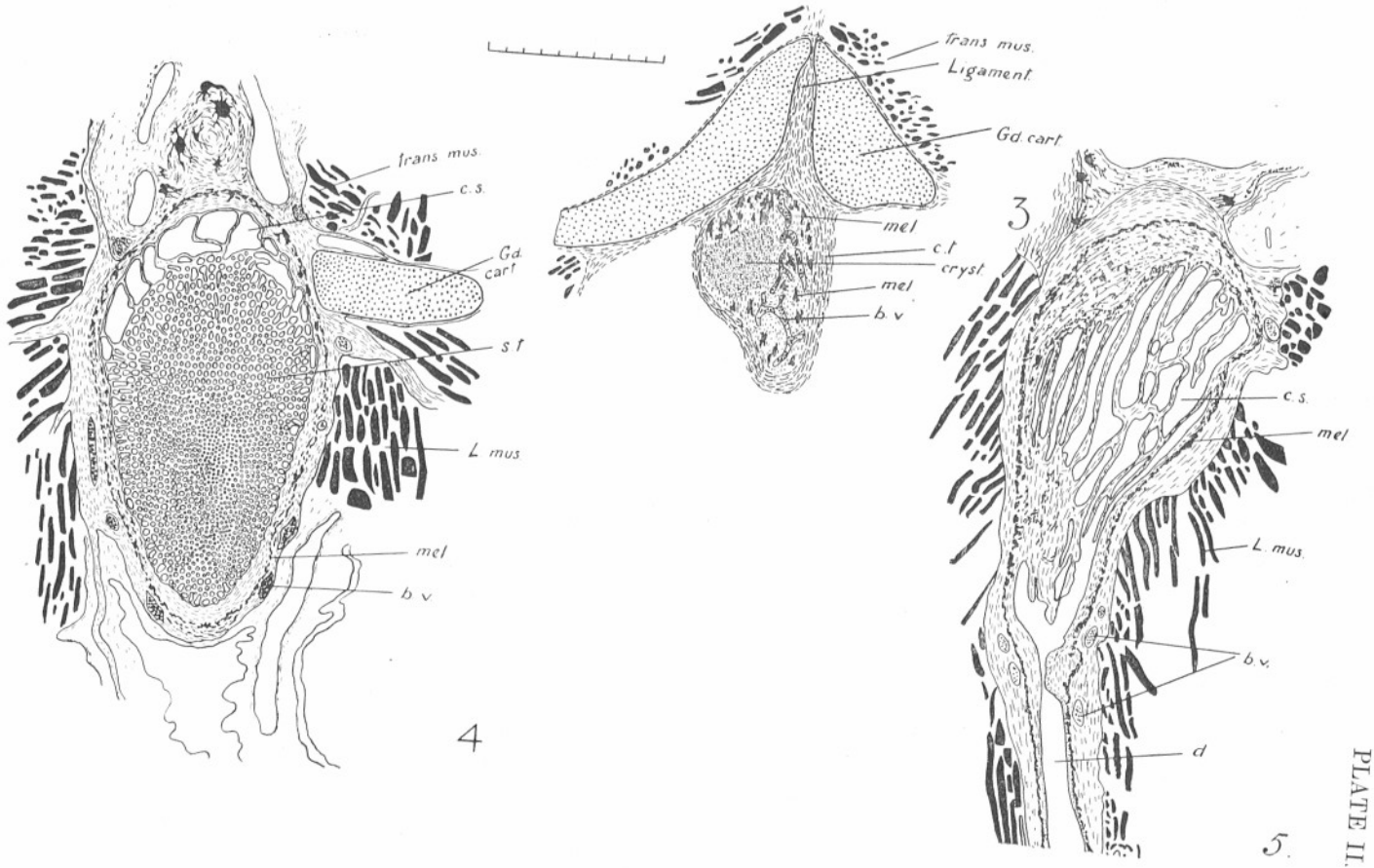

frans mus.
Ligament
Gd cart
mel
c.t
cryst
mel
b.v
3
frans mus.
c.s.
Gd. cart
s.t
L mus
mel
b.v
4
c.s.
mel
L. mus.
b.v.
d
5.

PLATE II.

PLATE III. FIGS. 6 AND 7.—Transverse sections through the gland in two older specimens of *C. cœlorhynchus*.

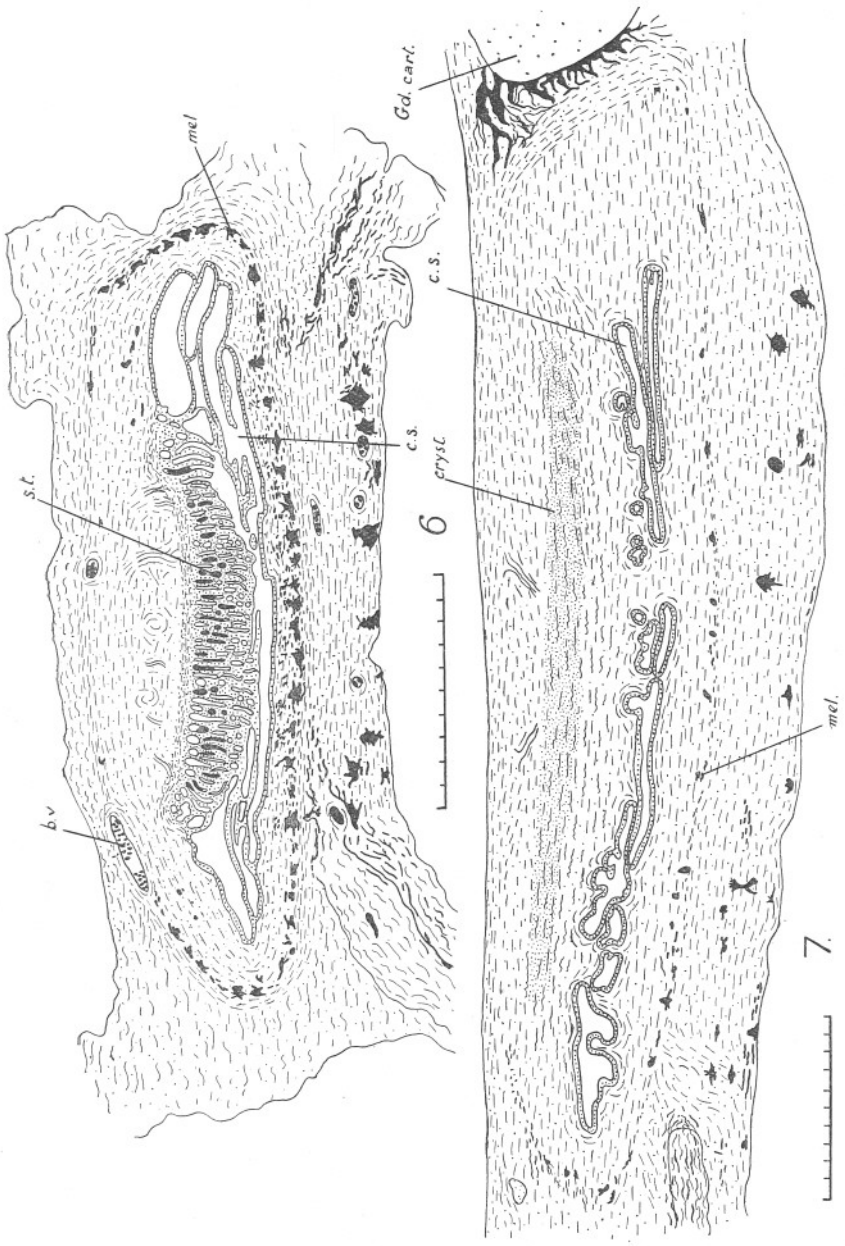
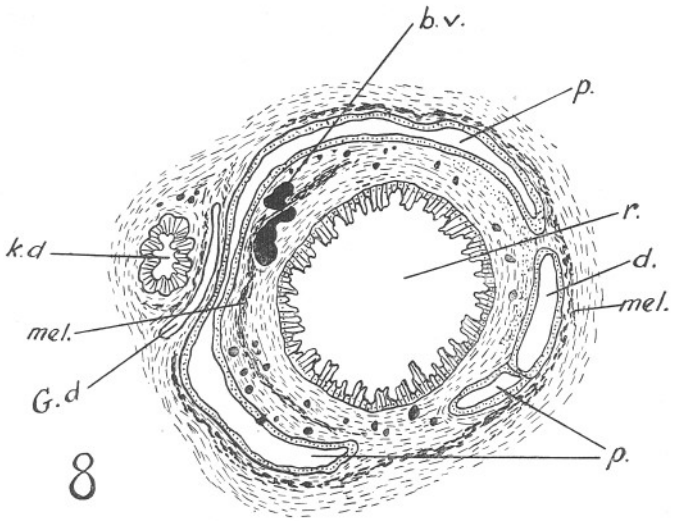

Gd. cart.
mel
c.s.
c.s.
cryst
s.t.
6
b.v
mel.
7.

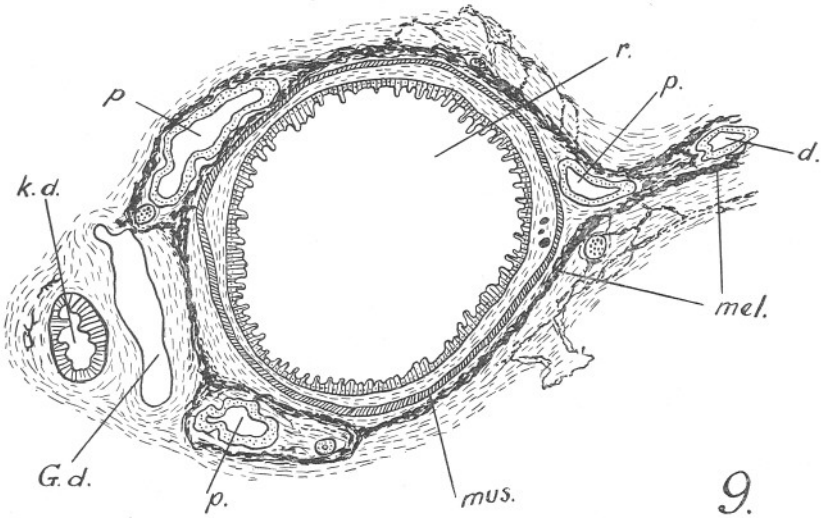
PLATE IV.—Sections transverse to the rectum in two specimens of *C. cœlorhynchus*.

FIG. 8.—In a 21-cm. specimen.

FIG. 9.—In a 30-cm. specimen.



8



9.