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ZOOLOGICA

SCIENTIFIC CONTRIBUTIONS
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# 1.

# On *Sphyrion lumpi* (Krøyer), a Copepod Parasite on the Redfish, *Sebastes marinus* (Linnaeus), with Special Reference to the Host-Parasite Relationships.

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(Plates I-IV; Text-figures 1-3).

## INTRODUCTION.

Many parasites of fishes have little or no appreciable effects on the host tissues. A few, however, are known to be deleterious; either they kill their hosts eventually or result in secondary infections of more virulent types of organisms. More often they weaken the fish so that they become easy victims for their predators. A large number of parasites, especially external forms, render the flesh, in the case of commercially valuable fishes, unmarketable.

Although many species of copepod parasites have been described from fishes, and although the general effects of these organisms on the hosts have been recognized, little is known about the histo-pathology of many such infections. It is the purpose of this paper, therefore, to describe the host-parasite relationships of a copepod infection occurring in the redfish, *Sebastes marinus* (Linnaeus). In recent years (since 1931), this species of fish has become important commercially, millions of pounds being caught annually and prepared for market. The copepod infecting the fish, referred to as *Sphyrion lumpi*, may be found attached to any part of the body, but usually it is buried in the region of the dorsal musculature.

## DESCRIPTION OF THE PARASITE.

The copepod found on the redfish belongs to the family Sphyriidae Wilson, 1919. It was first described by Krøyer (1845) as *Lestes* and later

(1863) as *Lesteria*. It was Bassett-Smith (1899) who gave it the correct name *Sphyrion lumpi* (Krøyer). The parasite has been observed in limited numbers on the lump fish, *Cyclopterus lumpi*, from the Danish coast, by Krøyer (1845, 1863) and Steenstrup (1869); from the British seas by Bassett-Smith (1899), T. and A. Scott (1913) and Leigh-Sharpe (1933). Scott (1905) and Leigh-Sharpe (1933) have also reported the copepod on the wolf fish, *Anarrhichas lupus*. Wilson (1901) recorded *Sphyrion lumpi* from *Nematonurus goodei*, *Haloporhyrus viola* and a salted hake. Again Wilson (1919, 1931) was the first to report it from redfish of the North Atlantic coast of the United States.

The members of the genus *Sphyrion* are easily recognized by the presence of a cephalothorax, the anterior end of which, in females, is expanded transversely to form a process that has been referred to as the sphyra or "hammer" (Plate I, Figs. 1, 2). From the center of the anterior surface of this expanded structure projects the head with its modified appendages. The neck is elongated and smooth while the trunk broadens transversely and in most cases is depressed ventrally. These parasites have no abdomen, but there is a pair of knob-like caudal rami. The copepods are also characterized by the presence of multibranched processes extending from the trunk. The function of these structures is still uncertain. The ovisacs are long and smooth and extend beyond the trunk. In young females, the head appendages are discernible. There are two pairs of maxillae and a pair of maxillipeds which in the more matured parasites become transformed or replaced by simpler processes and in some cases may even be absent.

The male *Sphyrion* is comparatively minute, measuring a little more than 2 mm. in length and 1 mm. in width. The appendages present are the same as those seen in young females. The head is separated from the trunk and there is a small carapace present. The trunk is folded and lacks the arborescent appendage described above.

The present forms of *Sphyrion lumpi* were taken from the body of redfish caught by commercial fishermen off the coast of Maine. They agree in all essential details with the description given by Wilson (1919, 1931), although the measurements of the various parts of the body are slightly different. These are shown in Table I.

TABLE I.

| | Hammer | | Neck | | Trunk | | | Post. Proc | Ovisacs | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Length | Width | Length | Width | Length | Width | Thickness | Length | Length | Width |
| Wilson[1] | 13-16 mm. | 10 | 35-15 | 2.5 | 16-12 | 12 | 6-5 | 8-16 | 20 | 2.5 |
| Nigrelli & Firth | 8-18 | 2-11 | 10-30 | 2-3 | 9-12.5 | 10-15 | 3-8 | 6-20 | 20-46 | 2-3 |

In young females, the body is more or less transparent, a condition which disappears as the copepod becomes more matured and the body structures thicken. During the growth process, the posterior arborescent structure becomes more and more branched. From the measurements given above, it can be readily noticed that there is quite a variation in the size of the different parts of the body. There are other differences not disclosed by these figures (Plate I, Fig. 2). Thus, the terminal parts of the "hammer" are usually swollen in bulb-like form. In some individuals the width of these ends is not much larger than the median parts of the "hammer," while in others they may be considerably enlarged, more or less

[1] Wilson's measurements based on two matured specimens. Our measurements based on 20 specimens showing ovisacs. In these measurements length of hammer is transverse to body axis.

round, slightly bifurcated or even multilobed. In some forms, the long tubular neck may have a comparatively even diameter throughout its entire length, while in others it may be thicker towards the "hammer" or towards the trunk end; sometimes it is long and thin; at other times it is long and thick and often it is short and thick. The trunk may likewise differ. In a few individuals it appears as a transparent structure, so much so that the internal structures are visible to the naked eye. In others, the ventral region of the trunk is more or less depressed, while in still other individuals this ventral depression is lacking, being for the most part slightly raised above the surface much as it is on the dorsal side.

Studies on the internal anatomy of *Sphyrion lumpi* from sectioned material agree with the description given by Wilson (1919). In the matured females the identity of the mouth appendages is entirely lost. The intestine is narrow in the neck region, dilating considerably in the trunk to form a widened rectum. The peculiar processes described by Wilson (1919) for this part of the intestine were also observed in our material. However, besides these processes, the striking feature of the intestine is the presence of a comparatively large number of secretory gland cells found in the epithelium. The large amount of corpuscles and digested blood in the lumen of the intestine shows that these matured parasites feed almost exclusively on the blood of the host.

The ovaries are two in number, more or less tubular, and situated in the anterior region of the trunk, one on each side of the intestine close to the body wall. The tubular cement glands are situated in the posterior half of the trunk, one below each ovary. The oviducts are coiled and surrounded by a thick layer of chitin. Each duct opens directly into the long chitinous ovisacs.

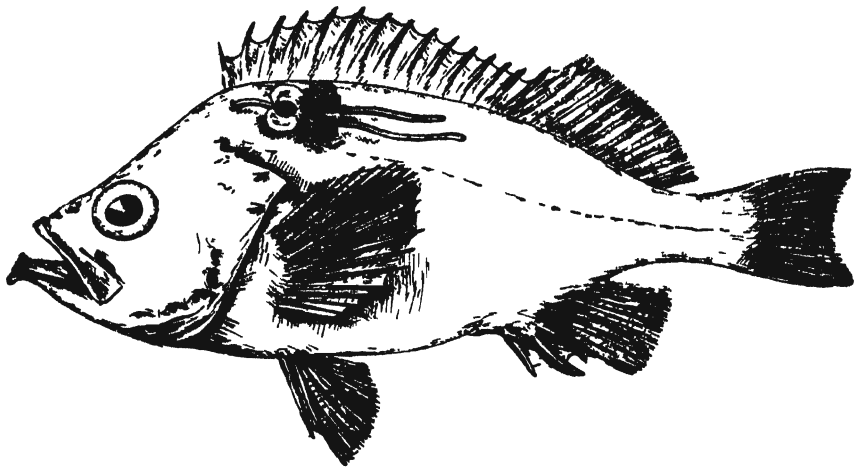
The internal anatomy of the male was not studied.

Although the complete life-history was not followed, due to a lack of living material, from studies of extremely young stages of female *Sphyrion lumpi* and from what we know of the life-cycle of closely related forms, the larvae (copepodid stage?) are the only forms in the cycle that can infect other parts of the body of the fish or other fish. Extremely small forms (2 mm.) found buried beneath the epidermis, beside being highly transparent, show well developed mouth parts, such as maxillae and maxillipeds. It is by means of these structures that the copepod moves about on the body of the host and burrows deeply into the skin and muscle. In such forms the sphyra is not well developed or only slightly so. The neck and trunk are distinct while what will be the arborescent appendage appears as two knob-like outgrowths.

It is of interest to mention here that a large number of redfish examined for *Sphyrion lumpi* were also found infected with a gill species referred to as *Chondracanthopsis nodosus* (see Wilson, 1931).

## Distribution of the Parasite on the Host.

In the majority of the redfish examined, the parasites were found buried deep in the skin and musculature in the region dorsal to the lateral line, usually at the base of the dorsal fin. (Text-fig 1). As in the Lernaeidae (see Wilson, 1919), the parasites attempt to reach the dorsal blood vessel for their nourishment. Occasionally, however, parasites were found attached in the body wall in the region ventral to the lateral line. These invariably had penetrated the body cavity. Several specimens were found attached to the eye, anchoring in the anterior chamber. Quite a number of fish were found with the copepod attached to the bony plates of the pre-operculum and the operculum proper. Here, in the majority of instances, the soft bone was perforated so that the cephalothorax passed



Text-figure 1.

Redfish, *Sebastes marinus*, showing typical infection with the copepod parasite, *Sphyrion lumpi*.

into the branchial cavity and became attached to the gill arches, often destroying parts of the gill filaments. On a few occasions parasites were found pendant from the rim of the anal opening, anchoring between the rectum and the body wall of the host.

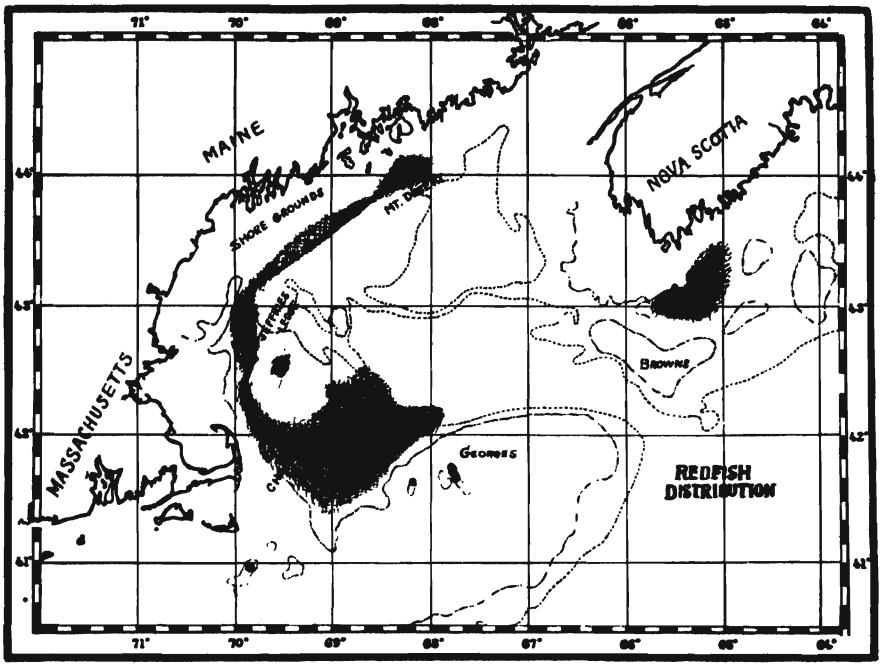
The process involved in this penetration is not exactly known. It is assumed, since the young forms have well developed mouth parts, that they eat their way through the host tissues, for long before they reach any blood vessel there is quite a cavity formed. It is interesting to point out that these copepods have well developed digestive and secretory glands, and it is altogether possible that the secretion given off by these glands may aid the parasite in the penetration.

The number of visible parasites found on each fish may vary somewhat. The largest number of matured parasites recovered from a single fish was 6. Actually, the damage done was considerable, for each copepod would eat and digest away tissue from 1 to 1.5 cm. in depth and about 1 cm. in width, some parasites even penetrating the entire width of the dorsal musculature. However, the parasite population may be greater than that mentioned above, for any fish may harbor many minute copepods underneath the skin. Thus, one fish examined in the laboratory showed three external parasites and two sores. Microscopic examination of the skin revealed as many as twelve immature forms.

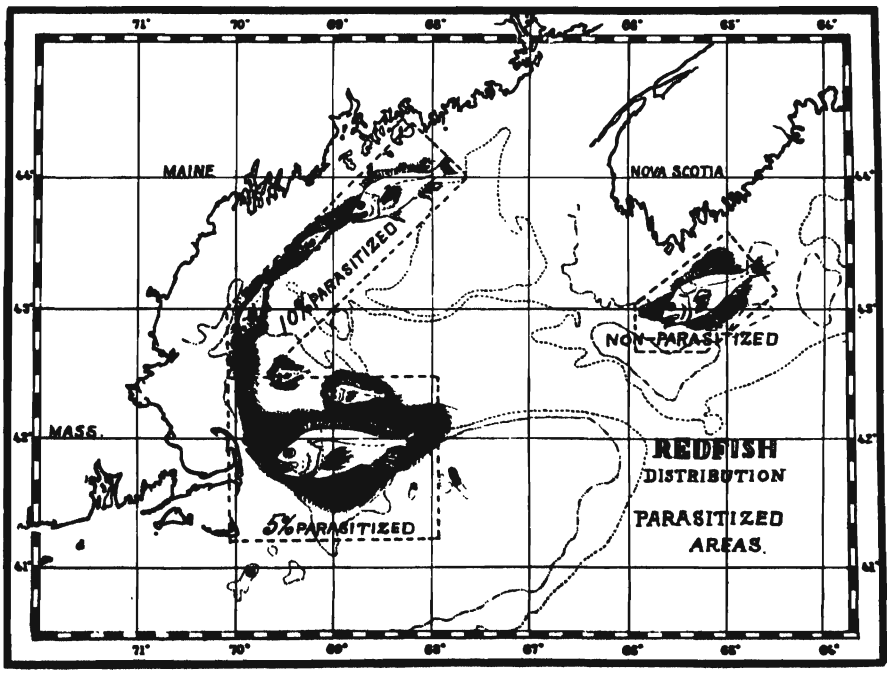
Although the samplings for examination of parasites were taken at random and at various times of the year, there appears to be no definite correlation between temperature (time of year) and the number of visible parasites or the number of infected fish. It has been determined, however, that young parasites are present during the late summer and early fall. It is assumed that these grow and become visible by spring, reaching maturity by summer. It is during the latter periods that the parasites superficially appear to be more numerous.

## Geographical Distribution of Parasitized Redfish.

In the North Atlantic coast of America the normal redfish population is distributed off the coast of Maine, Massachusetts and Nova Scotia. (See




Text-figure 2.
Distribution of the redfish, *Sebastes marinus*.




Text-figure 3.
Distribution of the redfish, *Sebastes marinus*, showing parasitized areas.

Text-figs. 2 & 3).[2] Practically every area in 80 to 150 fathoms on or near the fishing banks supports a redfish population, with the exception of the southern rim and NE peak of George's Bank. About 90% of the commercial catch ranges in size between 24 to 32 cm. from snout to fork of caudal fin in length, and it is among such fish that the copepods were recovered. No redfish under 22-24 cm. were ever seen with parasites, while those under 16-20 mm. do not appear in the catches because most of them pass through the trawl meshes and the balance are culled out at the docks.

Redfish are caught almost exclusively in the daytime, for fishing at night invariably yields only comparatively small catches. Why this should be is as yet not known. It was assumed that the fish might rise off the bottom and therefore not be caught by the deep set trawls of the fishermen, or that they might scatter widely at night and congregate again during the day. The redfish appear to disperse also after spawning, and again in October and November. The spawning period seems to be concentrated between May 15 and July 15, but the season may extend from early May to August. It is probably during these periods and at the times when the fish are concentrated that the majority of infections occur. The incidence of infection should be higher at such times. That this is not demonstrable is not surprising for the reason that the presence of parasites is not recognized until they appear on the body surface or when sores are developed.

One definite item that can be determined, however, is the fact that fishes from the banks off the southern tip of Nova Scotia appear free from the parasite, although the redfish population is nearly as large in this region, comparatively, as it is in the infective areas. Although a seasonal study of the distribution of the infections was made, there was no correlation. It definitely showed that fish from south of Nova Scotia, referred to as Brown's Bank, are free of *Sphyrion lumpi*. Ecologically, this area appears to be characteristically different from the regions where parasitized fish occur, influenced chiefly by cold water currents. In this region the fish are on the average smaller than those found off the coasts of Maine and Massachusetts (Cape Cod). This is supported further by the fact that the growth rate of Brown's Bank haddock is slower and these fish have a different scale pattern. Also, insofar as could be determined, there seems to be no mixing of redfish populations, for if they did, parasites would most certainly show up on fish from Brown's area. The presence of a cold current from the NE is one factor that may possibly divide and separate the Canadian fish from those off our coast.

The fish-parasite relationship is most interesting and is summarized as follows: from 4,971 individual redfish, or 52 samples from the same number of individual trips, examined for the copepod, the average infection for the inshore redfish grounds off Maine and Massachusetts, appears to be roughly 10%, while the average number of parasites per fish is approximately 1½. The fish from the offshore or Channel grounds had an average of roughly 5% infection, with the number of parasites per fish the same as inshore. The redfish population off Nova Scotia was found to be consistently free of the infection. The striking feature of the data collected to date is the gradual reduction in the percentage infection as one leaves the coast of the United States. It must be realized, however, that these percentages refer only to those parasites visible to the naked eye. There is no doubt that the percentage would be greater under laboratory examination at any time, and very probably disproportionately greater in the late summer and fall, when more young are present than at other times. This study covers the first 11 months of 1938 and represents samples of 100 fish per trip in practically all cases.

[2] Other areas, not shown on the map, where redfish are occasionally taken and from which no parasitized fish have been found, include Sable Island, Roseway, Liscombe and Banquero Banks.

The writers wish to thank Mr. Henry M. Bearse of the U. S. Bureau of Fisheries for some of the data presented in the above paragraph, and Mr. B. O. Knake for the drawings. The Bureau of Fisheries is now carrying on research into the further details of the life history of the redfish and relationships between host and parasite.

## Pathological Effects of *Sphyrion lumpi* Infection.

The majority of the parasites protrude from the body through a small opening in the skin of the host. The minute forms are indicated by small, dark, lumpy growths on the skin, the external openings of which are hardly visible. As the parasites increase in size, these openings become larger and larger until, in some cases, the skin and muscle are turned out, forming large flaps. (Plate II, Fig. 4). In such instances, the overlying epidermis and scales are lost.

The striking feature of the histo-pathology of these infections is the tissue response of the host to the parasite. The buried part of the cephalothorax is encapsulated by a well defined wall composed of host connective tissue. (Plate III, Fig. 5; Plate IV, Fig. 8). In older infections, where the healing process is more or less completed, this connective tissue is further developed and entirely surrounds the cephalothorax of the parasite. (Plate II, Fig. 3). The general host response, however, is a typical inflammatory reaction. The muscle bundles become interposed with blood elements and most conspicuous of all, by an extreme dilation of vessels. (Plate III, Fig. 6). In certain regions the tissue is oedematous, showing an exudate of leucocytes, erythrocytes, monocytes and plasma cells in a network of fibrin. (Plate IV, Fig. 7). The cellular elements between the muscle fibers are mostly leucocytes, chiefly small lymphocytes and neutrophiles. Occasionally, however, granulocytes, some distinctly eosinophiles, have been encountered. In certain regions many red blood cells are found free in the host tissue. The activity of the leucocytes is evident by foreign body inclusions in the cytoplasm of these cells.

A similar type of host reaction is present wherever the parasite is attached. Those found around the anal opening cause an intense inflammation of the rectum and surrounding tissues. When the eye becomes the point of attachment, the anterior chamber is the place of anchorage. The cornea is split and stretched, resulting in a distortion of vision. A slight amount of fibrous connective tissue is developed and surrounds the anterior end of the parasite. Here again, a dilation of blood vessels has occurred and numerous leucocytes infiltrate the surrounding tissues.

In two instances, small tumors were found in the region of the dorsal fins. These were more or less round in appearance and about .5 cm. in diameter. Although these fish are red in color, the tumors were black with some red pigmented cells intermingled. Microscopically, however, the melanophores and erythrophores are limited to the surface, while the remainder of the tumor was composed of dense fibrous tissues, infiltrated with all sorts of wandering cells, especially lymphocytes.

The many sores encountered in these redfish are almost invariably the remains of what was previously the anchoring place for the copepods. A few are the sites in which immature parasites are implanted. The larger of these sores consistently contain a slightly viscid exudate. Microscopic examination of this fluid revealed the presence of many algae-like microorganisms, singly or in chains. These were round, ovate, elongated or rod-shaped. The elongated forms measured 18 x 12 $\mu$. All such organisms contained round greenish plastids, many of which were found free in the exudate. Beside these, many flagellates were present which also contained the greenish coccus-like bodies. Whether there is any

relation between the algae-like forms and the flagellates was not determined. Very little bacteria were present in these sores, although the usual host cellular elements were evident. These were leucocytes with ingested particles in the cytoplasm, débris composed of dead cells and partly digested muscle fibers.

## Discussion.

The pathological effects resulting from copepod infestations are not well known. Wilson (1917) reported that the female members of the family Lernaeidae become anchored in the flesh of the host by special organs of attachment. The irritation set up during the burrowing process results in the development of "a tough membrane or skin immediately around them, which adds considerably to the security of prehension. This tough membrane also envelops the free thorax or neck of the parasite and reaches as far as the real skin of the host." In the case of fishes parasitized with *Pennella* these cysts may be found anywhere in the body, including the stomach, intestinal wall, the mesentery, liver and even the heart wall. "When the copepod dies the cyst simply shrivels and hardens still more, and such lumps, nearly as hard as bone, may be cut out of the liver or elsewhere alongside of the living ones!" Wilson further stated that the parasites of the family Lernaeidae and even those of the Sphyriidae (Wilson, 1919) feed upon the blood of their host. He reported (1917), "The simple fact that they burrow through the flesh until their head and mouth are brought into close proximity with some large blood vessel, and sometimes penetrate into the heart itself, leaves us no choice but to conclude that the parasite is making sure of a copious food supply."

From our observations on *Sphyrion lumpi*, however, *the parasites very seldom reach a large vessel, and in no cases did they reach as far as the dorsal aorta.* On the other hand, what does happen in every instance, a strong irritation is set up, both mechanically and by means of secretions given off by the parasite, which result in an inflammatory reaction. There is a considerable dilation of blood vessels in this reaction, so much so that the fine capillaries, usually of microscopic size, become enlarged to such an extent that they are visible to the naked eye in killed and fixed material, and in many cases can be dissected out. Thus, the vessels widen and pour their fluid and cellular contents into the surrounding tissue until it becomes oedematous and infiltrated with leucocytes and scattered erythrocytes. This, in the writers' opinion, is the source of nutriment for these parasites and not any particular blood-vessel as it is supposed. The source of irritation is constant in so long as the parasite keeps growing and moving about. Once the growth process is completed, the parasite becomes an inert object which finally becomes surrounded by repaired host tissue, forming the so-called cysts observed in many cases. It is obvious, however, that in the early stages of growth, the young parasites must feed on muscle and other tissues beside blood.

The allocation of parasitized redfish to a definite area off the coast of Maine and Massachusetts is the striking thing in the present studies. Why this should be we have as yet no definite explanation. That the fish do disperse at certain intervals has been more or less definitely established by investigators in the field. Yet nearby areas and especially those off the coast of Canada have yielded very few parasitized redfish and none in the samples investigated. The fish in the non-infective areas are apparently separated ecologically by a cold current, and on the average are smaller in size than those caught off the coast of Maine. This would indicate possibly that the redfish population in both these areas are distinct and for some reason or other (temperature, current, etc.) the parasites are not present.

SUMMARY.

1. *Sphyrion lumpi* (Krøyer), a parasitic copepod found on the redfish (*Sebastes marinus*) is redescribed.

2. The host-parasite relationships are discussed and the pathological effects of the copepod infestation is described.

3. The geographical distribution of parasitized redfish is indicated.

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## EXPLANATION OF THE PLATES.

### PLATE I.

Fig. 1. Typical female *Sphyrion lumpi*, about 3× natural size showing collapsed ovisacs. All photographs by S. C. Dunton, N. Y. Aquarium.

Fig. 2. Female copepods without ovisacs. Note variability in form and size of cephalothorax. The smaller and younger specimens are transparent. About 2×.

### PLATE II.

Fig. 3. An old female. One ovisac missing. The "hammer" part of the cephalothorax is entirely surrounded with a thick fibrous covering.

Fig. 4. Area just in front of the dorsal fin showing skin and muscle turned out. About 3×.

### PLATE III.

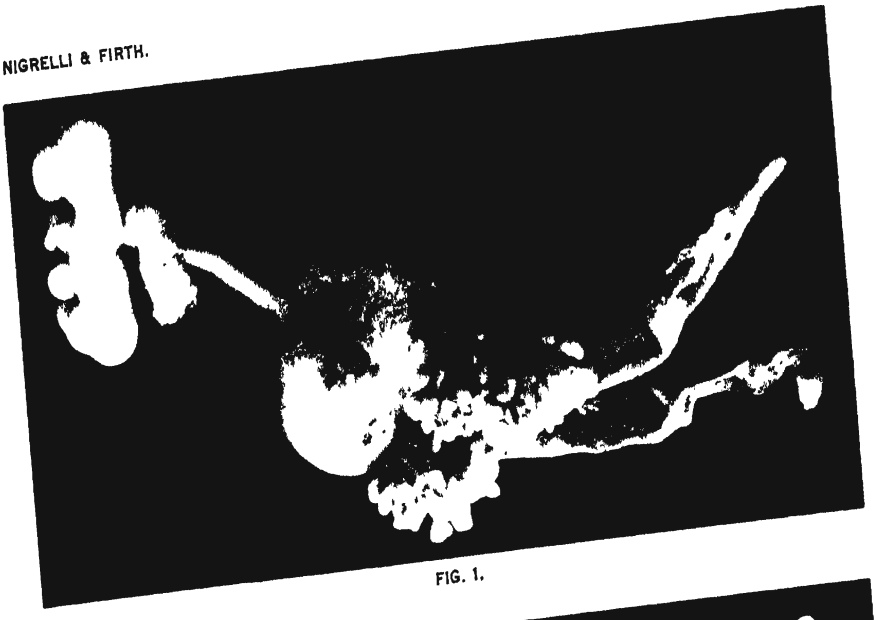
Fig. 5. Extreme low power photomicrograph of section through region of infection, showing encapsulated parasite.

Fig. 6. Low power photomicrograph showing inflammatory reaction to the copepod parasite infection. This reaction is indicated by the extreme dilation of blood vessels.

### PLATE IV.

Fig. 7. High power photomicrograph of one of the dilated vessels and surrounding region filled with an exudate of lymphocytes, monocytes, plasma cells and enythrocytes.

Fig. 8. Photomicrograph of same magnification as in Fig. 7, showing the development of fibrous connective tissue.



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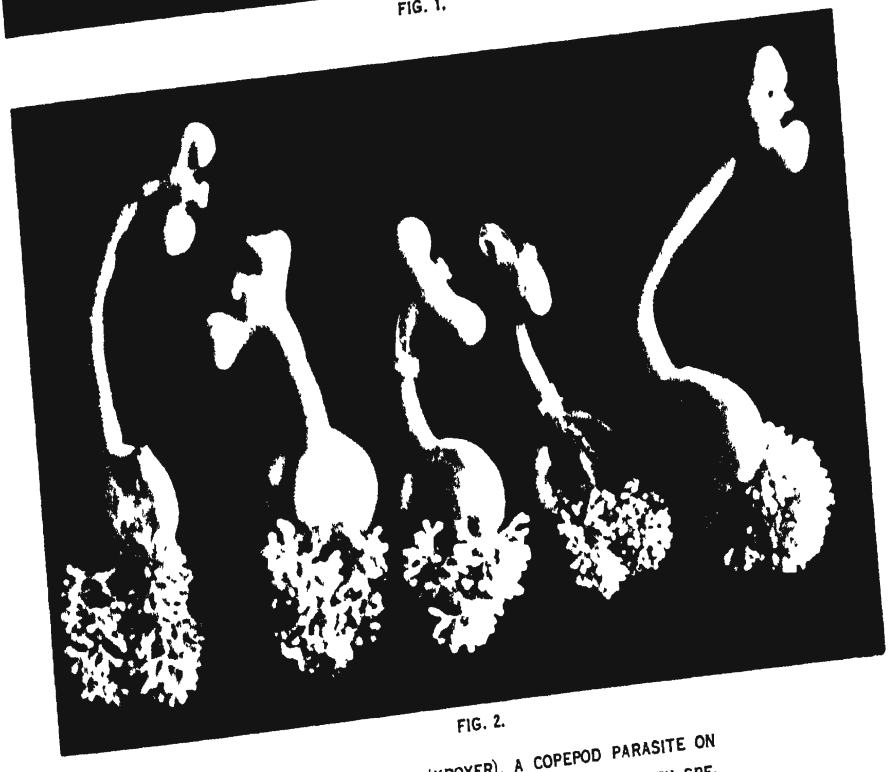


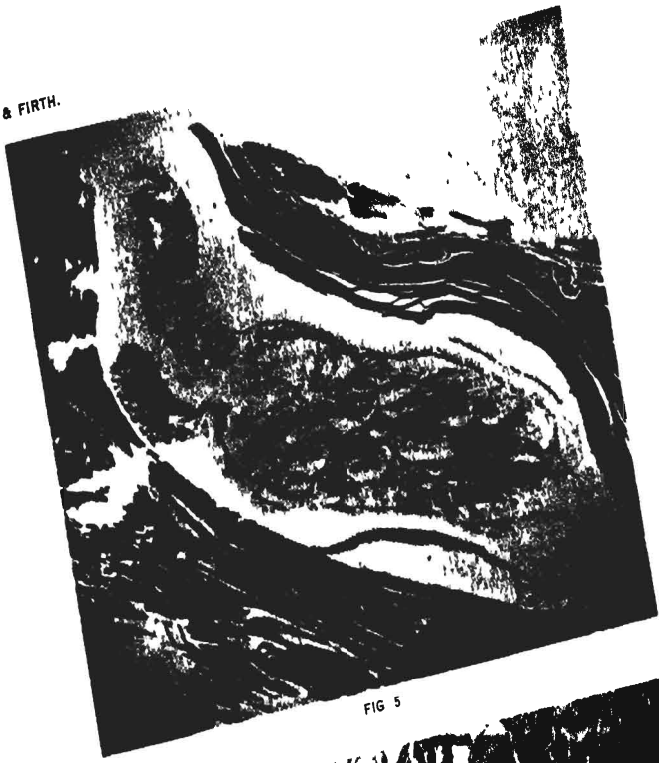
FIG. 2.

ON SPHYRION LUMPI (KROYER), A COPEPOD PARASITE ON THE REDFISH, SEBASTES MARINUS (LINNAEUS), WITH SPECIAL REFERENCE TO THE HOST-PARASITE RELATIONSHIPS.

FIG 3

FIG 4

ON SPHYRION LUMPI (KROYER), A COPEPOD PARASITE ON THE REDFISH, SEBASTES MARINUS (LINNAEUS), WITH SPECIAL REFERENCE TO THE HOST-PARASITE RELATIONSHIPS.



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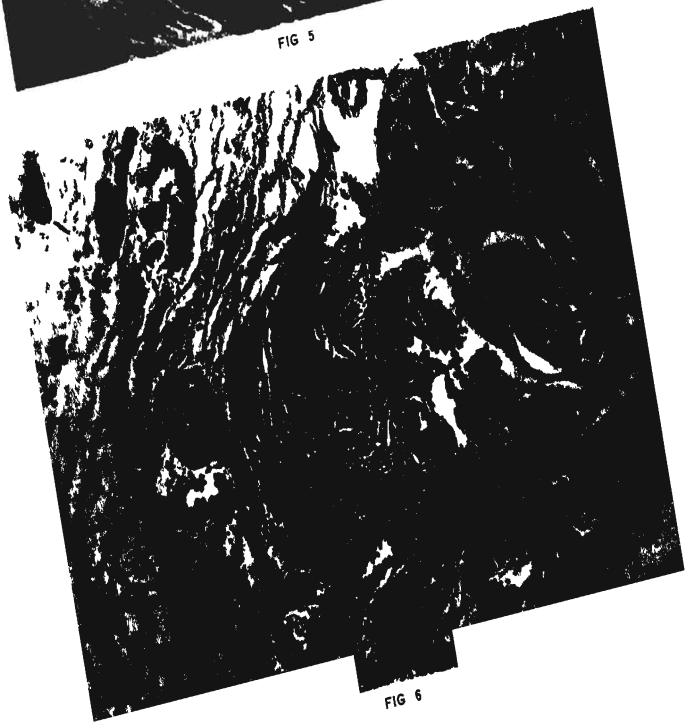


FIG 6

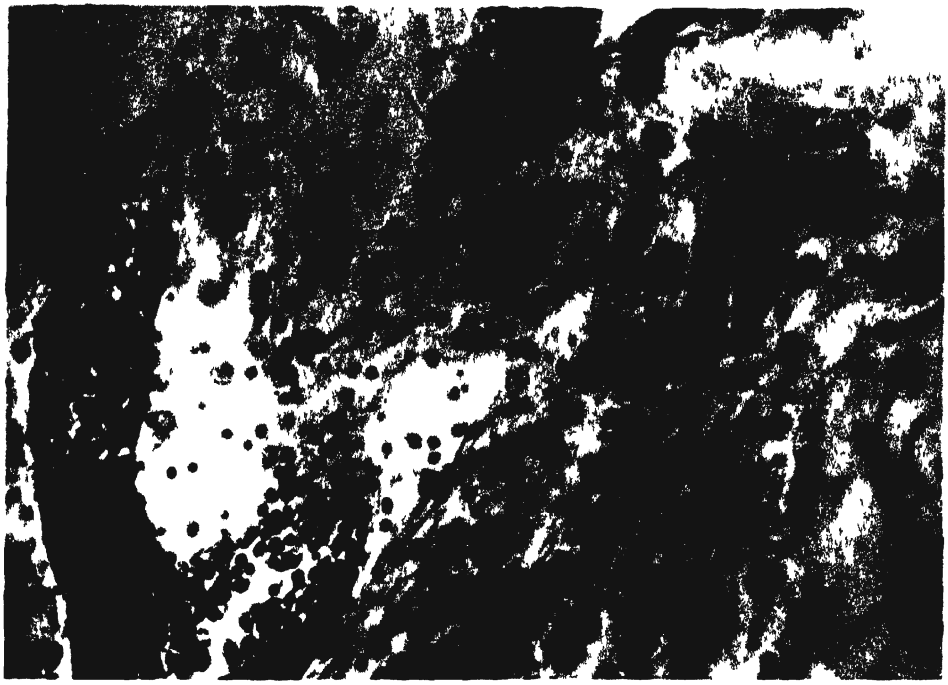


FIG 7

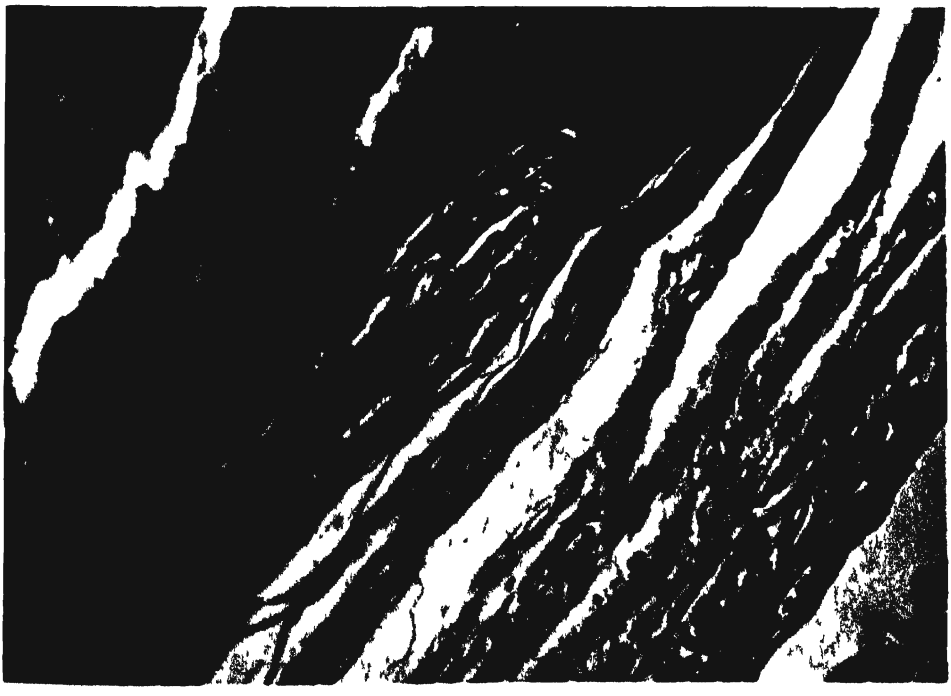


FIG 8

ON SPHYRION LUMPI (KROYER), A COPEPOD PARASITE ON

# 2.

## Notes on the Functions of the Forebrain in Teleosts.

R. G. MEADER

*Section of Neuro-Anatomy, Department of Anatomy, Yale University School of Medicine, and the Bermuda Biological Station for Research, Inc.*

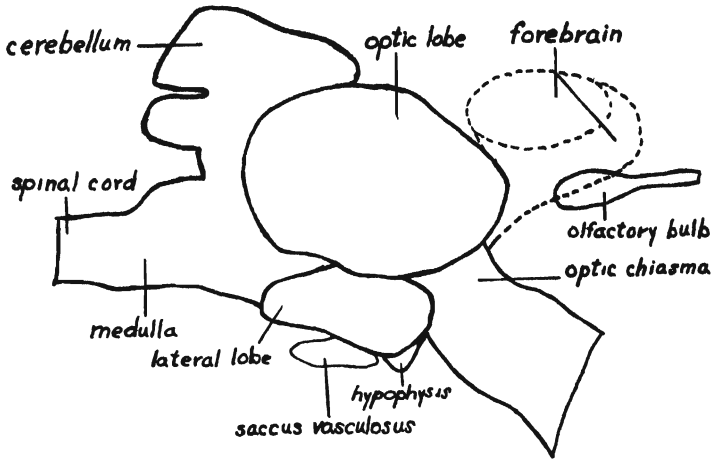
(Text-figures 1 & 2).

It has usually been assumed that the forebrain of fishes is used primarily for olfactory purposes. I wish to submit a report of some observations which, together with others recently published, suggest that the specialized forebrains of some fishes may be of importance for other purposes as well.

In the course of carrying out some experimental studies on the optic system of fishes at the Bermuda Biological Station it occurred to me to make lesions in the forebrains of a few species. The primary object of such lesions was to secure degeneration of fiber tracts arising in the forebrain. Anatomical investigations in one species, *Holocentrus ascensionis* (Osbeck), have revealed an elaborately organized telencephalon intimately connected by large and small bundles of fibers with other parts of the brain. In view of the complexity of this brain and in view of the current interest in the functions of the teleostean forebrain it seems worth while to summarize here the observations recorded in my protocols. The latter include notes on normal control animals, on individuals with one or both eyes enucleated, and on individuals with forebrain lesions.

The specimens of *Holocentrus* used ranged from 8 to 12 cm. in length. These squirrel-fish live very well in aquaria provided with running salt water and they withstand operative interference readily. For all operations they were anaesthetized by immersion in a solution of 1 part chloretone in 4,000 parts of sea water. They were then held in a damp cloth while a segment of the dorsum of the skull was removed to expose the forebrain. One or both hemispheres were extirpated or isolated lesions were produced. When the animals were replaced in sea water, they quickly recovered from the anaesthesia. At first it was thought necessary to close the skull opening with some inert substance but such efforts were abandoned when the substances used failed to adhere and the animals showed no ill effects from the exposure of the brain. At no time was there evident any disturbance which could be attributed to the direct bathing of the brain by the sea water. Granulation tissue growing in from the periphery gradually filled the wound. After 54 to 61 days the fishes were decapitated and the heads were prepared for microscopic study to provide controls of the location and the extent of the lesions and to permit investigations of the degenerated fiber tracts. These preparations have shown that the lesions intended were made. In some cases the total forebrain, with the exception of the sessile olfactory bulbs, was removed. The figures illustrate such a case.

A description (with figures) of the gross appearance of the brain and



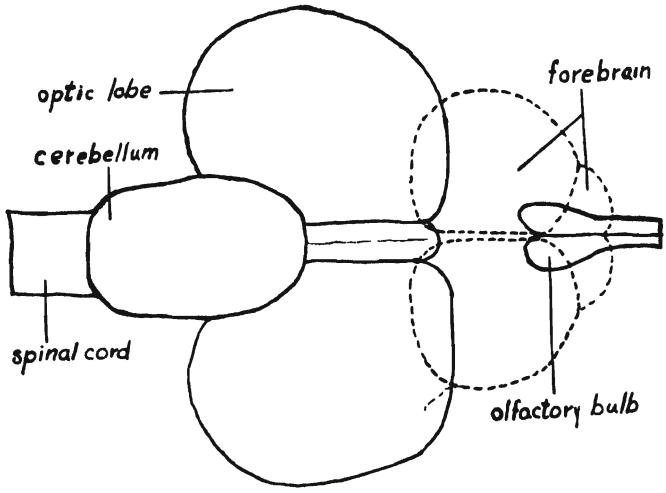

Text-fig. 1.

Outline sketch of a lateral view of the brain of *Holocentrus*. The tissue removed in the most radical operations is indicated by broken lines. ×8.

of the anatomy of the optic system of this fish has previously been presented by the author (1). A short account of the normal behavior of *Holocentrus* was included, emphasizing the importance of vision in the life of this large-eyed, nocturnal teleost. In the aquarium, as in its natural habitat, it prefers the darker corners and recesses where during the daytime it lies more or less quiescent in the shadow of a rock. At dusk and after dark, and in dim light generally, it swims about more freely. For a few days after being placed in an aquarium most individuals remain in concealment and are with difficulty enticed into the open to feed. They notice food only when it is in motion and if anything prevents them from seeing it or securing it before it comes to rest, it will remain untouched. If food is dropped close to the place of concealment, it is usually seized in midwater. There is a notable absence of the investigative nibbling characteristic of so many fishes. In the course of a few days it is possible to induce them to leave their hiding places and come to the surface to take food from forceps or fingers. Inimical visual stimuli generally elicit the sudden erection of the rather large and spiny dorsal fin, a reaction which is usually followed by flight and concealment.

All of this behavior is modified in totally blinded individuals. They are less active and they are indifferent concerning the part of the aquarium they occupy. They tend to find some vertical surface against which they lean as they rest on the bottom. Food is found only with great difficulty even when it is placed close to the mouth or olfactory pit. Blinded fishes are excited by the proximity of food but are unable to localize it accurately enough to obtain it without aid. They react slowly and briefly to an object moving in the water close to the body but their dorsal fins are seldom erected except by direct tactile stimuli.

Individuals blind on one side only illustrate even more strikingly the importance of vision to the squirrel-fish. Their activity is as great as that of intact animals and they respond to visual and tactile stimuli (including movements of objects in the water) presented on the intact side in the same way that normal fishes do. To tactile stimuli presented on the blind side, however, the reaction has a much higher threshold and the flight response is less both quantitatively and in temporal persistence. Such an observation




Text-fig. 2.

Outline sketch of a dorsal view of the brain of *Holocentrus*, showing the area extirpated (in broken lines). ×8.

leads one to suspect that the more lively response obtained from supposedly tactile stimuli presented on the normal side is really due to visual cues. The normal dorsal fin erection and flight response occur even when stimuli presented on the intact side are separated from the body of the fish and from the water by the untouched glass walls of the aquarium.

In no case did partial or complete removal of the forebrain of *Holocentrus* have any apparent effect upon the elements of behavior noted above for the normal control animals. The operated individuals were just as active as the latter, reacted to feeding stimuli in the same way and could be trained to take food from my fingers. They reacted to inimical stimuli with a similar fin and flight response. When normal and operated individuals occupied the same aquarium, their only distinguishing characteristic was the head wound.

It is surprising that *Holocentrus*, provided with such a specialized forebrain, from the anatomical point of view, exhibits so little disturbance of normal behavior when the forebrain is removed. Other investigators (2) have found that decerebration of teleosts is followed by deficits in olfaction, in schooling reactions (3, 4), in breeding behavior (5), and by a rise in the stimulus threshold (6). A restriction to purely reflex types of response has also been noted (6).

It may be that the difference between my observations and those of others can be explained in part by the differences in the habits of the species studied and in part by the adequacy of visual reflexes to carry out the solution of all problems met by the squirrel-fish in uncomplicated aquarium life. Olfaction is relatively unimportant to it but an olfactory deficit would very probably be revealed by more refined methods of testing. Chemical cues alone were not sufficient for finding food, as they are for many other forms, whereas vision unaided by olfaction enabled the fishes to feed normally.

Very little is known of the social behavior of *Holocentrus*. Although it is a relatively individualistic fish, it does "school" on occasion. Mr. Louis Mowbray, Director of the Bermuda Aquarium, has told me that there is a seven-year cycle in the abundance of the squirrel-fishes in Bermuda waters.

At the times of great abundance these fishes swim along the shores in large schools. Under these conditions decerebrate forms might exhibit a deficit not otherwise evident.

Inasmuch as the breeding habits of the squirrel-fishes are also unknown, it is obvious that this aspect of their social behavior cannot well be tested. It is possible that refined methods of investigation, such as those used by Hosch, would reveal some rise in the threshold of stimuli and some change in the patterns of response.

The observations here reported, as well as many others, indicate that the problem of the function of the forebrain in fishes has many complications. There is probably as great a variation in the cerebral physiology of the teleosts as in their cerebral anatomy. No other comparably limited group of vertebrates exhibits so wide a diversity of morphology in its nervous system. In this group, also, are to be found equally wide variations in behavioral habits, which are an expression of neural physiology. The observations made on one form, therefore, cannot safely be generalized to apply to all forms. Careful studies must be made on many different species if we are to arrive at reliable conclusions.

In the meantime, it should not be surprising that different species of fishes studied under different conditions (often those which are decidedly artificial) by different investigators appear to have varying deficits after forebrain extirpation. The work of previous investigators suggests that the forebrain may have many functions which vary in importance in the different fishes. For those species with relatively poor visual or tactile senses the olfactory function may be paramount. For those that normally swim chiefly in groups the forebrain may supply the necessary coordination. For those with other elaborate social behavior characteristics, such as specialized breeding and brooding habits, it may provide the integration of sensory stimuli to produce the customary pattern of reproductive activity; and its massive fiber tract connections with the hypothalmus may possibly influence reproduction through the effect of stimuli on the hypophysis. In many cases it may prove to be true that the forebrain of teleosts, like that of higher vertebrates but to a lesser degree, is an integrative center capable of giving rise to non-stereotyped responses appropriate to the stimuli received. All of these functions, and many others, may be present to varying degrees in all fishes and yet not be evident in an experimental analysis because of inadequate methods of testing or because their expression is masked by more prominent behavioral traits. If, however, one dares to predict physiology from anatomy, then the known anatomical variations in cellular distribution and in the fiber pathways relating the cells indicate a diversity of function of the forebrain in different groups of fishes.

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# 3.

# The Panama Canal as a Passageway for Fishes, with Lists and Remarks on the Fishes and Invertebrates Observed.[1]

SAMUEL F. HILDEBRAND

*United States Bureau of Fisheries.*

(Plates I & II).

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## INTRODUCTION.

Whether the Panama Canal serves as a passageway for fishes, permitting at least some of the species of the opposite oceans to cross the Isthmus, has been a subject of conjecture ever since the Canal was built. It was questioned whether fish could successfully negotiate the locks, and if so whether any of them could endure the journey of about 40 miles through the fresh water between the locks at the opposite ends of the Canal. It is now possible to give limited information on these questions, and on the animal life in the locks in general, as a result of observations and collections made in 1935 and 1937, together with subsequent study.

This work was made possible largely through the financial aid given by Dr. Herbert C. Clark, Director of the Gorgas Memorial Laboratory, to whom the writer is greatly indebted also for numerous other courtesies. He is deeply appreciative also of the extensive help given by Dr. A. O. Foster of the Gorgas Memorial Laboratory, and in fact to the entire staff of that laboratory.

Officers of the Panama Canal, as well as more than a few employees, too,

[1] Published by permission of U. S. Commissioner of Fisheries.

gave valuable aid. Among them are Col. C. S. Ridley, Governor; Col. Glen E. Edgerton, Engineer of Maintenance; Maj. W. D. Styer, Assistant Engineer of Maintenance; R. Z. Kirkpatrick, Chief of Surveys; E. D. Stillwell, Superintendent of Locks; H. M. Thomas and J. C. Myrick, Assistant Superintendents of Locks; Fred Whaler, Carl G. Brown, S. A. Venable, R. A. Cauthors and many others who cannot be named for want of space. Special mention must be made of the extensive aid and many courtesies extended by W. H. W. Komp, medical entomologist, U. S. Public Health Service; and J. B. Shropshire, malariologist, U. S. Army.

The writer is deeply grateful, also, to the several taxonomists, who identified various groups of animals collected. These specialists are named in the text in connection with the discussion of specimens identified by them. To these workers, who gave of their time and energy, the writer especially wishes to extend thanks.

One or more specimens of the species herein named, whether fish or invertebrates, have been or will be deposited in the U. S. National Museum.

Observations and collections were made in Gatun Locks, on the Atlantic side, during the early months of 1935, and in Pedro Miguel and Miraflores Locks, on the Pacific side, during the early part of 1937, when the writer was present to witness the dewatering of one side of each lock. The water is removed, partly by draining and partly by pumping, from the locks at intervals of about three years for the purpose of cleaning and generally overhauling them. Collections were made by others in the sides dewatered during the writer's absence. A particularly fine collection was secured in the east side of Miraflores Locks under the supervision of Dr. A. O. Foster of the Gorgas Memorial Laboratory. Representative specimens, as far as possible, were preserved from among the fishes and invertebrates stranded in the locks as the water was removed. Collections were made also in the fresh waters situated between the locks at the opposite ends of the Canal, as well as at several places on both shores of the Isthmus and some of the outlying islands.[2]

## Remarks Concerning the Canal and Locks.

For the convenience of the reader who has not seen the Panama Canal, it may be stated that the general direction of the Canal is somewhat west of north and east of south, though traffic is designated as "north and south bound."

The Atlantic terminus of the Canal is entered from Limon Bay. A vessel sailing from the Atlantic to the Pacific, that is, southbound, proceeds at sea level as far as Gatun, a distance of 6 or 7 miles from Cristobal, the Atlantic port. There the Gatun Locks are reached. These locks, like those at the other end of the Canal, are double, permitting two-way traffic, the two channels of the locks commonly being designated the east and west side. The Gatun Locks consist of three equal flights whereby a southbound ship is lifted approximately 85 feet, to the level of Gatun Lake, which lies beyond the locks.

Gatun Lake is a large body of fresh water, having an area of about 196 square miles, created by damming the Chagres River. Though the deep water, that is, the course for vessels, is well marked with buoys and beacons in Gatun Lake, a definite channel or canal is not visible for a distance of somewhat more than 20 miles. Thereupon Culebra (or Gillard) Cut, is

[2] The study of the fresh water fishes and data pertaining to the fresh waters has been completed, and a report has been published, entitled, "A New Catalogue of the Fresh-Water Fishes of Panama" (See *Field Mus. Nat. Hist. Pub., Zool. Ser.*, xxii, 1938, pp. 217-359). The results of a study of the data and specimens secured in the locks are set forth herein. Much of the rather large collection of marine species taken along the outside shores of the Isthmus and the islands, however, remains for future study.

reached. This cut, through the continental divide, is about 9 miles long, and leads to Pedro Miguel Locks.

The Pedro Miguel Locks consist of a single flight, whereby a southbound vessel is lowered from the approximately 85-foot level of Gatun Lake to a level of about 53 feet of Miraflores Lake, which lies below these locks.

Miraflores Lake is a small body of fresh or brackish water (sometimes slightly brackish from lockage water when northbound traffic is heavy), scarcely 2 miles long in the direction of the Canal. A southbound vessel reaches the Miraflores Locks after crossing this small lake.

The Miraflores Locks consist of two equal flights whereby a southbound ship is lowered to sea level. The vessel now follows a rather definite channel (canal) to Balboa, the Pacific port of the Canal, a distance of about 4 miles, and then enters Panama Bay.

In passing a northbound ship through the Canal the processes described in the foregoing paragraphs are, of course, merely reversed. As already indicated the locks are double, making it possible to pass two vessels through them simultaneously either in the same or opposite directions.

## The Locks as Physical Barriers.

The locks do not constitute serious physical barriers to fish, as explained at some length by the writer in a paper entitled, "The Tarpon in the Panama Canal" (*Scientific Monthly*, Vol. 44, Mar., 1937, pp. 245-246). Obviously fish may swim into the upper or lower chambers of the locks without meeting any obstruction whatever when the gates at the opposite ends of the locks are open. There they may remain more or less indefinitely, or they may follow the next ship through the locks. In the case of the Gatun Locks, with three flights, they could ascend from the lowest to the middle chamber with a southbound vessel, or descend to this chamber from the uppermost level with a northbound vessel. There they might remain for a time, or complete the transit through the locks with a single ship. It is understood, of course, that when the lock gates are open, as in passing a ship from one chamber to the next one, no physical obstruction remains to prevent the fish from following the vessel.

## Difference in Salinity a Barrier.

The change in salinity from fresh to salt water or *vice versa*, depending upon the direction a fish may be pursuing, in going through Gatun or Miraflores Locks (this does not apply to Pedro Miguel Locks, as they are in fresh water), is a much more formidable barrier, to most fishes, than the locks themselves.

That many marine fish enter the locks and go through a part of the way, at least, is evident from the large number present at each dewatering. Several marine and brackish water species appear to live in the locks indefinite periods of time, and a few probably are permanent residents. It is to be noted, however, that strictly fresh water species seem to avoid the locks, as very few individuals or species were present even in the fresh water of the Pedro Miguel Locks, and in the nearly fresh water of the upper chamber of Gatun Locks. The abundance of fish in the middle and lowest chambers of Gatun Locks and both Chambers of Miraflores Locks suggests that food probably is plentiful and that conditions otherwise are agreeable to a comparatively large number of salt and brackish water species, as shown by the lists appended.

The temperatures and particularly the salinities, as already pointed out, profoundly affect the animal life in different parts of the Canal. The tables

and some of the other data offered were very kindly furnished by R. Z. Kirkpatrick, Chief of Surveys of the Panama Canal. The temperatures, given in Table I, are a summary of records covering the period from 1908 to 1936 inclusive for Balboa and Colon, and from November, 1918, to December, 1936, inclusive for Gatun Lake. The period of time covered by the records of salinity given in Table II, was not furnished.

The "Pacific Entrance (Inner Harbor)" and the "Atlantic Entrance (Inner Harbor)" temperatures, as well as the salinities, were taken respectively at the Balboa and Cristobal Docks.

On the Pacific side a cold water period occurs during the dry season. Concerning this Mr. Kirkpatrick said: "Cold water period is from February to April; it is caused by Antarctic colder water being welled-up over Panama Bay Bottom Shelf during these months." As understood by the writer, the brisk trade winds blowing across the Isthmus from the Atlantic to the Pacific have something to do with the up-welling of cold water in Panama Bay, as they tend to drive the warm surface water off shore.

Outside the inner harbor the water temperatures apparently drop considerably lower, as shown by some records kindly furnished by W. H. W. Komp, U. S. Public Health Service. Mr. Komp took the water temperatures with a pocket thermometer at Amador Beach during the dry seasons of 1934, 1935, 1936 and 1937. Each season, exclusive of 1937, the temperatures ranged downward into the sixties, the lowest occurring in 1934 when the water along the beach, between 4 and 5 o'clock in the afternoon, ranged in temperature from 60.5° to 63° F. from Feb. 11 to 16.

These low temperatures affect fishing profoundly in Panama Bay, as such important game fishes as the sailfish, marlin, and dolphin are missing during this season. On the other hand, the corbina (sea trout or weakfish) seem to become more numerous. The cold water probably causes the fish population to vary to some extent with the season also in Miraflores Locks.

Tides and lockage water have a direct bearing on salinity at both ends of the Canal. Mr. Kirkpatrick stated: "Tidal ranges on the Pacific side vary between an elevation of +11.0 and —10.5 feet, with a mean range of about 12.6 feet. . . . Tidal ranges on the Atlantic side do not exceed 24 inches." He stated furthermore, "Inner harbor salinities and densities are affected, of course, by the down-lockage of fresh water from Miraflores and Gatun Lakes." It is understood, of course, that the chambers of the locks in passing ships through them are filled with water admitted from the lakes above them, which in each instance is fresh (except for the slight brackishness occurring at times in Miraflores Lake). Therefore, if traffic is heavy a large amount of fresh water reaches the sea level ends of the Canal, reducing the percentage of salinity. It is evident, then, that the water in the locks (exclusive of that in Pedro Miguel Locks, which are in fresh water) may vary from about the saline condition of the inner harbor, when the sea level gates are open, to a sort of half and half mixture of the harbor and lake water to almost fresh, as in the upper flight of Gatun Locks.

Salinity records for the locks are not available, except for one day (June 10, 1935), and for Gatun Locks only. According to hydrometer readings furnished by Mr. Kirkpatrick (without making corrections for temperature) the chambers of the upper level were fresh. No appreciable amount of salt was indicated in the east chamber of the intermediate level immediately after the water had been lowered from a 71- to a 43-foot level, and only slight brackishness was evident in the west chamber of the same level after it had been filled from a 43- to a 71-foot level. The two lowest chambers, however, were decidedly brackish, the salinity varying from about 10,000 to 16,000 parts per million. At the Atlantic entrance (outside the locks) the water was about as salty as that shown for the "Atlantic Entrance (inner harbor)" in Table II.

TABLE I.

Monthly water temperatures in degrees Fahrenheit, surface. (See text for periods of time covered).

| Locality | Minimum | Maximum | Average |
|---|---|---|---|
| Balboa Entrance (Inner Harbor) .... | 69.3 | 84.9 | 80.0 |
| Miraflores Lake ..... | 78.0 | 84.0 | 81.0 |
| Gatun Lake ..... | 80.9 | 85.0 | 83.6 |
| Atlantic Entrance (Inner Harbor) .... | 77.6 | 85.3 | 82.1 |

TABLE II.

Salinities, surface.

| Locality | Parts per million |
|---|---|
| Pacific entrance (Inner Harbor) .... | 16,000 to 20,000 |
| Miraflores Lake ..... | 100 to 3,000 |
| Gatun Lake ..... | 5 to 20 |
| Atlantic entrance (Inner Harbor) .... | 18,000 to 20,000 |

It is claimed by employees of the Canal that when the Gatun Locks first were operated dead fish were seen in the locks from time to time, which presumably died from the change in salinity caused by filling the locks with fresh water from Gatun Lake. Dead fish no longer are seen. The employees believe the fish have become "educated" to the necessity of avoiding fresh water.

The extent to which marine fishes have invaded fresh water, nevertheless, is remarkable, as shown by the large number of salt water species listed from fresh or nearly fresh water subsequently. This is true especially of Miraflores Lake where fresh and salt water species seemingly intermingle freely.

## FISHES USING THE CANAL AND LOCKS AS PASSAGEWAYS.

The species that most logically would be expected to pass through the locks and possibly complete the transit from ocean to ocean, are those inhabiting more or less indiscriminately salt, brackish and fresh water. To this group of fishes in Panama belong some of the guavinas (Gobiidae), several species of snook or robalos (Centropomidae), some of the so-called marine mojarras (Gerridae), a few species of rancons or burros (*Pomadasys*), and the tarpon (*Tarpon atlanticus*).

Among the fishes named the tarpon definitely has completed the transit from the Atlantic to the Pacific, as 4 individuals were present in the lower chamber of Miraflores Locks (east side) when dewatered in 1937. When the gates to the lower flight of the locks are open, as they often are, when

vessels are not actually in transit, nothing remains to prevent the fish from swimming into the sea level end of the Canal and out into Panama Bay.

Tarpons, indeed, have been reliably reported from the Pacific sea level terminus of the Canal, though to date this fish does not seem to have been caught in Panama Bay. While tarpons are present in Gatun Lake at all times, there is as yet no evidence that this fish breeds there, as pointed out by the writer (*Scientific Monthly*, Vol. 44, Mar., 1937, p. 242). Therefore, it may be assumed, for the present at least, that the fish came from the Atlantic (or Caribbean Sea); that they use Gatun Locks as a passageway to Gatun Lake whence they pass on through Culebra Cut, and the Pedro Miguel Locks into Miraflores Lake (where they are seen frequently), and then on through the Miraflores Locks.

Among the guavinas, or fresh water gobies, which inhabit principally fresh and brackish water, *Dormitator maculatus* of the Atlantic slope and shores was taken in the lower chamber, that is, at sea level, of Miraflores Locks. *Leptophilypinus fluviatilis*, another species of the Atlantic side, also was taken in Miraflores Locks, though not in the lower chambers. This species was numerous in the Pedro Miguel Locks and one specimen was secured in Miraflores Lake. On the other hand, *Gobiomorus maculatus*, a species of the Pacific side, was secured in Gatun Lake in company with its near relative *Gobiomorus dormitor*, of the Atlantic side. *Gobiomorus maculatus* is very common in Miraflores Lake, though it was not taken in Pedro Miguel Locks. It conceivably could have reached Gatun Lake without passing through the locks, as a few small Pacific slope streams empty into the Canal above Pedro Miguel Locks. Finally, it seems probable that *Eleotris pisonis*, of the Atlantic side, has crossed over to the Pacific, as shown by some specimens taken in the lower chamber of Miraflores Locks, which appear to be hybrids, that is, a cross between *Eleotris pisonis* and *E. picta*. No typical examples of *E. pisonis* were taken, however, on the Pacific side.

Among the snooks or robalos, some of which range from the shores far up fresh water streams, *Centropomus parallelus*, an Atlantic side species, was taken in Miraflores Lake. To reach this lake the fish had to pass through Pedro Miguel Locks. *Centropomus pectinatus*, which occurs on both coasts of Panama, also was taken in Miraflores Lake. Because of its natural distribution this species may have come from either coast. No positive proof has been found, so far as the writer is aware, that any of the snooks breed in fresh water.

Two species of mojarra (Gerridae), namely, *Eucinostomus californiensis*[3] and *Gerres cinereus*, were taken in the locks and the latter also in Miraflores Lake. However, as these species are common to both coasts of Panama it is not known that they have traversed the Isthmus, though they probably pass through the locks freely.

Specimens of rancon or burro (*Pomadasys*) were taken in Gatun Lake, and in Pedro Miguel Locks and Miraflores Lake. These specimens all appear to be one species, but it is not possible at this time to state whether they are *Pomadasys crocro* from the Atlantic or *P. bayanus* from the Pacific, two nominal species which may not be distinct. Though these fish seem to pass through the locks, it has not been determined whether they have crossed the Isthmus. Neither is it known that they breed in fresh water, though they frequent it.

The small anchovy, *Anchovia parva*, present in large numbers in all three chambers of Gatun Locks in 1935, was common in both chambers of Miraflores Locks in 1937. As this species has not been recorded from the Pacific, it seems possible that a migration has taken place, though it was not taken in Gatun Lake, Pedro Miguel Locks nor Miraflores Lake.

The silverside, *Menidia* (*Thyrina*) *chagresi*, though belonging to a

[3] Though I have not been able to date to separate the Atlantic and Pacific coast specimens as to species, other investigators at least have attempted to do so.

family whose members are mostly marine, lives in fresh and brackish water. It was found common in the Chagres Basin during our investigations in 1911 and 1912, before the opening of the Canal. In 1935 it was found in the middle and uppermost chambers in Gatun Locks, and numerous in Gatun Lake. In 1937 several specimens were secured in Pedro Miguel Locks and the lower chamber of Miraflores Locks, presumably a result of a migration from the Atlantic to the Pacific slope through Culebra Cut.

Among the more or less strictly fresh water species the chogorro, *Cichlasoma maculicauda*, an Atlantic slope fish sometimes descending to slightly brackish water, seems to have crossed to the Pacific side, as it was taken in Pedro Miguel Locks, Miraflores Lake and the upper chamber of Miraflores Locks, as well as in the Gatun Locks. Two Atlantic slope species of "sabalo pipon," *Brycon chagrensis* and *B. petrosus*, were taken on the Pacific side, the former in Pedro Miguel Locks and Miraflores Lake, and the latter in the Rio Cocoli, a short distance above Miraflores Lake.

Only one of the numerous species and generally abundant "sardinas," namely *Astyanax fasciatus*, a Pacific slope species, seems definitely to have crossed the divide through Culebra Cut, as it was taken in Gatun Lake. Other species of characins may have crossed through Culebra Cut. However, as several species of this family are common to both slopes, crossing over cannot be determined from specimens.

It was particularly surprising that the abundant "sardina," *Astyanax ruberrimus*, of both slopes, which literally swarms everywhere in Gatun and Miraflores Lakes, did not occur in the locks. Not one specimen even was found in Pedro Miguel Locks, which are in fresh water, though it occurs in abundance above and below them. It was rather surprising also that *Roeboides*, another "sardina," avoids the locks, wherein no specimen was secured. Furthermore, no crossing over nor intermingling of the two easily distinguishable species, *guatemalensis* of the Atlantic slope and *occidentalis* of the Pacific, through Culebra Cut, seems to have taken place, as shown by numerous specimens collected in Gatun and Miraflores Lakes.

The pipefish, *Doryrhamphus* (*Oostethus*) *lineatus*, has been reported as having been caught "in transit through the Panama Canal" by Chickering (*Copeia*, No. 173, 1930, p. 85). However, this fish probably inhabits chiefly fresh and brackish water as shown by many specimens taken during our investigation in 1911 and 1912 (Meek and Hildebrand, *Field Mus. Nat. Hist. Pub., Zool. Ser.*, XV, Pt. I, 1923, p. 262), before the opening of the Canal, when none was secured in salt water. In March, 1935, the writer collected 9 specimens in a few hours seining along the shores of Barro Colorado Island, in Gatun Lake. Four of the specimens are males with abdominal pouches filled with eggs, showing that this fish breeds in the Lake, where it probably is a permanent residence. It was not seen in any of the locks, nor in Miraflores Lake. Therefore, it is not known that it frequents the locks, nor that it has crossed the divide through Culebra Cut.

## Invertebrates Observed and Collected.

It is stated in the foregoing pages that some fishes are so numerous in parts of the locks at each dewatering (see appended lists for the relative abundance of the various species of fishes observed in the chambers of the locks) that they must find conditions agreeable. In this connection a brief account of the condition of each lock, together with remarks on the invertebrates observed, seems desirable. Many of these lower forms of course are eaten by fish.

The collections of invertebrates of necessity are incomplete, as the water drops rapidly in the dewatering process. After the floors of the different chambers become exposed water remains only in the "manholes" in the floors, and in the sumps, at the gates. Some animals are stranded, but

many more of the free swimming forms manage to reach either the bottom holes or the sumps. In any event, collections must be made quickly. As the writer and his helpers were interested chiefly in securing a representative collection of fishes, to which they gave most of their attention, more than a few invertebrates, even of the larger forms, no doubt escaped notice. Therefore, the collections of these lower forms must be considered far from complete.

*Gatun Locks*: The walls and floors of Gatun Locks (east side), when dewatered in 1935, had not accumulated much sediment or rubbish since the previous overhaul in 1932, though sufficient slush was present on the bottom that the collectors were well covered with mud splattered by stranded fish. Neither were the growths on the walls, gates and floors especially luxuriant. The growth in the uppermost and middle chambers consisted mostly of a hydroid, identified by Prof. Charles McLean Fraser as *Cordylophora lacustris* Allman. This hydroid was most abundant in the nearly fresh water of the uppermost chamber, and little in evidence in the much saltier lowest chamber, wherein that growth was largely replaced by oysters and barnacles.

Clusters of mussel-like bivalves, examples of which were identified as *Brachidontes exustus* Linnaeus by Dr. Paul Bartsch, who furnished identification also for the other molluscs mentioned herein, were present in the middle and lowest chambers of Gatun Locks. The gastropod, *Neritina meleagris* Lam., was numerous in the uppermost chamber, less so in the middle one, and was not observed in the lowest chamber.

Small crabs were present in each chamber of Gatun Locks. However, examples were preserved only from the uppermost one. These were identified by Dr. Mary J. Rathbun, who identified the other crabs mentioned herein also, as *Callinectes sapidus acutidens* Rathbun, and who supplied the following note, "A marine species ranging from each coast of Florida to Rio de Janeiro, Brazil." This crab was inhabiting the nearly fresh water in the uppermost chamber of Gatun Locks.

Small shrimps, too, were present in the Gatun Locks. One species, identified as *Macrobrachium acanthurus* (Wiegmann) by Dr. Waldo L. Schmitt, who identified the other shrimps mentioned herein also, was taken only in the lowest chamber, though it may have been present in the others. Dr. Schmitt remarked, "A fresh water species, ranging from Florida to Brazil and Uruguay, and West Coast of Mexico to Ecuador." Juveniles of another species, provisionally identified as *Macrobrachium olfersii* (Wiegmann), were common in the uppermost chamber, and a third species, *Crangon armillatus* (H. Milne-Edwards), was taken in the lowest chamber. Concerning the latter Dr. Schmitt remarked, "A marine species distributed from North Carolina and Bermuda to Brazil; and through the West Indies."

One specimen of *Macrobrachium olfersii* was infested with a bopyrid isopod in the right branchial cavity. This isopod was identified by J. O. Maloney as *Palaegyge meeki* Richardson.

*Pedro Miguel Locks*: The Pedro Miguel Locks, which are in fresh water, though possibly at times very slightly brackish from lockage water from Miraflores Locks, contained mud several inches to a few feet deep (east side). The concrete walls and the iron gates, as high as the permanent water level, were almost entirely covered with a mussel-like bivalve, identified by Dr. Bartsch as *Congeria* (*Mytilopsis*) *sallei* Recluz. On the floors of the locks, where objects for attachment were present, clumps of this bivalve also occurred, and under and around the clumps amphipods, probably of the same species as the one from the upper chamber of Miraflores Locks, identified as *Grandidierella megnae* (Giles) by C. R. Shoemaker, were numerous. Unfortunately the specimens collected were lost. No other molluscs or amphipods were noticed, though they may have been present.

Shrimps were rather common, and no doubt are fed upon by some of the fish that inhabit these locks. Dr. Schmitt identified 4 species, namely,

*Penaeus stylirostris* Stimpson, *Macrobrachium jamaicense* (Herbst), *M. acanthurus* (Wiegmann), and *Palaemonetes* sp. Dr. Schmitt referred to the one first named as a marine species, the next two as well known fresh water shrimps, and the last one as most likely a fresh water form. No crabs were seen in these locks.

*Miraflores Locks*: The fauna of the Miraflores Locks was much more diversified than that of the Pedro Miguel Locks, no doubt because the water ranges from salt to nearly fresh. The upper chamber contained fully as much sediment as the Pedro Miguel Locks, but the lower one contained much less. The walls of the upper chamber were almost as fully over-grown as Pedro Miguel Locks with the same species of bivalve, but in the lower chamber this mollusc was missing, presumably because of the higher salinity. This bivalve occurred also in clusters on the floor of the upper chamber wherever there were objects reaching above the bottom slush to which it could attach itself. Among these clusters were numerous amphipods, presumably all of the species identified as *Grandidierella megnae* (Giles) by Mr. Shoemaker from the single specimen, of many collected, not lost in shipment.

In addition to the abundant bivalve mollusc a scant growth of a hydroid, somewhat doubtfully identified (because of the unsatisfactory condition of the specimens) as *Bimeria gracilia* Clark by Prof. Fraser, was present in the upper chamber. In the lower chamber only a few clumps of the hydroid were seen attached to objects on the floor.

The abundant growths of the bivalve and hydroid mentioned, of the upper chamber, were replaced in large part by barnacles in the lower one. A few other attached forms of which only scattered examples were seen, was the sponge, identified by M. W. de Laubenfels as a cosmopolitan form, *Haliclona permollis* (Bowerbank), and the alcyonarian, *Leptogorgia alba* Duchassaing & Michelotti, as identified by Miss Elisabeth Deichmann, who referred to it as "one of the most common forms in the lava pools off Panama."

In the lower chamber of Miraflores Locks the wooden beams against which the bottoms of the iron gates close were badly infested with teredo, of which no examples were secured. Only one mollusc, the gastropod, *Thais kiosquiformis* Duclos, in addition to the numerous bivalve already mentioned, was taken in the upper chamber. This gastropod was found also in the lower chamber with four others, identified by Dr. Bartsch as *Phyllonotus radix* Gmelin, *Pustularia pustulata* Lamark, *Triumphis distorta* Wood, and *Cymatium* (*Linatella*) *wiegmanni* Anton. Limpids were fairly common in the lower chamber. Examples of two species, *Crepidula aculeata* Gmelin and *C. incurva* Broderip, were preserved. Small squids were common in the sump at the lowest gates of the locks. The examples transmitted to the National Museum were identified as *Loligo* sp.

Crabs and shrimps were in evidence in both chambers of Miraflores Locks and were numerous in the bottom holes after the water had been pumped somewhat below floor level. The crabs in particular were difficult to catch in these holes, as they clung closely to the walls from which they were not readily removed, and generally dived out of reach of a dipnet after some agitation. Because of the difficulty of catching crabs and shrimps, and more particularly because of lack of time, more than a few species surely were missed.

Only two species of crab, identified by Dr. Rathbun as *Panopeus rugosus* A.M.E., and *Callinectes arcuatus* Ordway, were collected in the upper chambers. These two were taken also in the lower chamber with *Panopeus chilensis* M. Edw. & Lucas and *Petrolisthes armatus* (Gibbes). The occurrence of the blue crab, *Callinectes sapidus* Rathbun in fresh water recently was discussed by Gordon Gunter (*Science*, Vol. 87, Jan. 28, 1938, p. 87). It is not surprising, therefore, that other species of the genus also enter brackish and fresh water.

Seven species of shrimp were collected in the upper chambers of Miraflores Locks, which Dr. Schmitt identified as *Penaeus brevirostris* Kingsley, *Macrobrachium jamaicense* (Herbst), *M. acanthurus* (Wiegmann), *Palaemonetes* sp., and two species of snapping shrimp, *Crangon*, unidentifiable as to species because of the "meager and incomplete material." and because of "our too limited knowledge of the west American species."

Four species of shrimp collected in the upper chambers, namely *Macrobrachium acanthurus* (Wiegmann), *Palaemonetes* sp., and the two unidentifiables species of *Crangon*, were taken also in the lower chamber, with the three following species not secured in the upper one: *Penaeus stylirostris* Stimpson, *P. occidentalis* Streets and a third unidentifiable *Crangon*. Besides the shrimps, a stomatopod, *Chloridella aculeata* (Bigelow), was taken.

Dr. Schmitt referred to *Macrobrachium jamaicense* (taken in Pedro Miguel Locks and the upper chamber of Miraflores Locks), and *M. acanthurus* (found in all three levels) as "well known fresh water shrimps," and he regarded it likely that *Palaemonetes* sp. (taken in all three levels) also is a fresh water form. Though these species live chiefly in fresh water they appear to enter brackish water, or even at times salt water. The rest of the shrimps apparently may be regarded as salt and brackish water forms.

## Annotated List of Fishes from the Locks of the Panama Canal.

The nomenclature and sequence of families of the earlier works by Meek & Hildebrand (a. "The Fishes of the Fresh Waters of Panama," *Field Mus. Nat. Hist. Pub., Zool. Ser.*, X, No. 15, 1916, pp. 217-374; b. "The Marine Fishes of Panama," *Field Mus. Nat. Hist. Pub., Zool. Ser.*, XV, No. 215, Pt. I, 1923; No. 226, Pt. II, 1925; and No. 249, Pt. III, 1928, 1045 pages) have been followed as far as it seemed permissible to do so. In order to retain as far as possible this nomenclature and sequence, the rearrangement and splitting of some of the old families (as for example Siluridae, Serranidae, Sciaenidae, and Gobiidae), as well as some of the genera, by some recent writers have not been adopted. This course was followed chiefly for the convenience of those perhaps not entirely familiar with the nomenclature who may wish to check the lists against the descriptions and accounts in the earlier publications.

The large number of marine species present in the locks and their great tolerance for fresh or nearly fresh water are interesting facts shown in these lists.

## GATUN LOCKS.

The level or levels at which the specimens collected in the east side of the locks were taken are shown, without stating that they are from the east side. Those from the west side, collected by workmen, were not kept separate, and therefore are listed simply as from the "west side." In other words, all specimens listed are from the east chambers of the locks unless otherwise stated.

The collections in the east chambers were made by me and helpers from February 20 to 24, 1935. Those from the west side were made by workmen, as already stated, in January, 1935, before my arrival on the Canal Zone.

The marine gobies listed in this paper were kindly identified by Isaac Ginsburg, who is a specialist on that group of fishes.

### Family Myridae. Worm Eels.

***Myrophis punctatus*** Lütken.

Lowest Chamber: 1 specimen, 204 mm. long, picked up in bottom slush.

FAMILY ELOPIDAE.

***Tarpon atlanticus*** (Cuvier & Valenciennes). Tarpon; "Sabalo real."

Uppermost Chamber: A half-dozen or so large ones, all removed by laborers, except one, before the writer could reach them. One female, about 150 cm. long, with small roe, examined.

Middle Chamber: 2 males, ripe or nearly so, 100 and 106.5 cm. long; 6 females, respectively 97, 108, 109, 153, 167 and 199 cm. long, the largest one with well developed gonads, the others entirely undeveloped.

The tarpon, locally known as sabalo real, i.e., king shad, is highly prized as a food fish by the natives and the West Indian negro immigrants. This fish occurs regularly in Gatun Lake and it has passed on to the Pacific locks (see lists). It apparently does not spawn in the fresh waters of the Canal. Therefore, it evidently passes through the locks, which it may use as a feeding ground also. (For a more extended account see "The Tarpon in the Panama Canal," by the author, *Scientific Monthly*, Vol. 44, Mar., 1937, pp. 239-248, 4 figs.). The tarpon has a modified air bladder, which is developed somewhat as a lung, enabling it to breathe air at least in part. This adaptation presumably aids it in tolerating fresh water.

***Elops saurus*** Linnaeus. "Bonyfish"; Big-eyed herring.

Middle Chamber: Hundreds of fish present, probably 1,000 pounds or more; 20 individuals (selected at random) consisted of 7 males, 56.5 to 62 cm. long; and 13 females, 63.5 to 73 cm. long; all with large roe, indicating that spawning time was near at hand.

Lowest Chamber: About one-sixth as many fish as in middle chamber.

West Side: Several, according to workmen; 2 preserved.

The gillraker counts for 18 specimens are 13 and 14, showing that no crossing over had taken place, as the Pacific Coast bonyfish (*Elops affinis*) has 18 to 24 gillrakers on the lower limb of the first arch. There is, in fact, no evidence that this species enters the fresh water of the Canal. It seems probable, therefore, in view of the large number present, that this species uses the locks as a feeding ground. Though the closely related Pacific coast species is not uncommon in Panama Bay, not a single individual was seen in the locks at the Pacific end of the Canal.

This fish was rejected by the natives and negroes as unfit for food, and the large quantity stranded had to be disposed of by burial. This species, nevertheless, is seen in the local markets from time to time.

FAMILY ENGRAULIDAE. ANCHOVIES.

***Anchovia parva*** Meek & Hildebrand. "Sardina."

Numerous in all chambers, many in bottom holes of locks, mostly small, almost transparent; many specimens preserved.

This anchovy was not taken in Gatun Lake, but specimens were secured in Miraflores Locks. This species heretofore was not known from the Pacific.

***Anchovia spinifer*** (Cuvier & Valenciennes). "Sardina."

A single specimen, 88 mm. long, was taken in the locks, shortly after they were refilled, by Felipi Torris, and preserved by Dr. J. R. Martin. It was not seen when the locks were dewatered.

This species, reported from both coasts of Panama, apparently is rare on the Atlantic coast. It was numerous in the locks on the Pacific end of the Canal.

FAMILY BELONIDAE. SALT WATER GARFISH.

***Tylosurus raphidoma*** (Ranzani).

West Side: 1 mutilated specimen 62.5 cm. long.

FAMILY ATHERINIDAE. SILVERSIDES.

***Menidia (Thyrina) chagresi*** Meek & Hildebrand.

Uppermost Chamber: 4 juveniles, 13 to 18 mm. long.

Middle Chamber: 1 specimen 50 mm. long.

This silverside is very common in Gatun Lake. So far as known, it does not enter salt water. Several specimens were taken in the locks at the Pacific end of the Canal, probably the result of a migration through the Canal. These fish were thought to be young tarpons by some of the native tarpon fishermen.

FAMILY MUGILIDAE. MULLETS; "LIZA."

***Mugil brasiliensis*** Agassiz.

Middle Chamber: 5 large fish, ranging in length from 56.5 to 86 cm.; 2 large females, respectively 82.5 and 86 cm. long, contained large roe.

Although this mullet enters brackish water freely in Panama, it is not known to pass through the locks into Gatun Lake.

FAMILY SPHYRAENIDAE. BARRACUDAS.

***Sphyraena*** sp. Barracuda.

None seen in 1935; reliably reported from earlier dewaterings, generally one or two large ones present.

FAMILY CARANGIDAE. CAVALLAS.

***Caranx hippos*** (Linnaeus). "Jack."

Middle Chamber: Many (500 or so) all large; 19 individuals (selected at random) consisted of 11 males, ranging in length from 69 to 88 cm., and 8 females, varying from 67 to 98 cm. in length; all except 4 males with large or developing roe.

Lowest Chamber: About half as many as in middle chamber; 11 individuals (selected at random) consisted of 4 males, 67.5 to 83 cm. long, and 7 females, 76 to 100 cm. long; all of these fish and a dozen or so others, cut open but not measured, contained large or developing roe, showing that spawning time was near at hand.

West Side: 1 specimen 50 cm. long.

This fish quite surely does not pass through the locks into fresh water. It, indeed, was not present in the uppermost chamber, though numerous in the middle one. The locks apparently are a feeding ground for the jack, which is valued locally as a food fish. The largest individual noticed was 100 cm. (40 in.) long, which may be near the maximum size attained. Though it is common also on the Pacific coast of Panama, it was not numerous in the locks at that end of the Canal.

***Selene vomer*** (Linnaeus). Moonfish.

West Side: A single specimen 320 mm. long.

FAMILY CENTROPOMIDAE. ROBALOS; SNOOK.

***Centropomus undecimalis*** (Bloch). Robalo; Snook.

Middle Chamber: 1 specimen 275 mm. long.

Most of the species of the genus ascend brackish and fresh water streams in Panama. However, this species was not taken in fresh water during the recent investigation, nor in earlier (1911 and 1912) investigations.

***Centropomus parallelus*** Poey.

This species was not seen in the locks.. However, three fish, respectively 250, 270 and 300 mm. long, were taken in Gatun Lake near Gamboa. It was reported from Barro Colorado Island by Breder (*Zoologica*, IX, 1933, p. 568). Since there is as yet no evidence that this Atlantic coast fish breeds in fresh water, it apparently may be assumed that the specimens collected had passed through the Gatun Locks. Specimens were secured in Miraflores Lake, indicating a migration through Pedro Miguel Locks.

FAMILY SERRANIDAE. SEA BASSES.

***Promicrops itaiara*** (Lichtenstein). Spotted jewfish.

Middle Chamber: 1 specimen 208 mm. long.

Lowest Chamber: 1 specimen, juvenile, 24 mm. long; identification uncertain because of extreme youth. The jewfish, which is common to both coasts of Panama, occurred also in the Miraflores Locks.

***Rypticus saponaceus*** (Bloch & Schneider). Soapfish.

Lowest Chamber: 3 specimens, respectively 133, 140 and 150 mm. long; picked up from bottom slush. Many more were present.

West side: 6 specimens, 123 to 145 mm. long.

FAMILY LUTIANIDAE. SNAPPERS.

***Lutianus griseus*** (Linnaeus). Gray or mangrove snapper.

Lowest Chamber: 3 specimens, 100 to 110 mm. long, preserved. Examined six others ranging in length from 370 to 540 mm. for spawning condition, all of which were undeveloped. This species was scarcely as numerous as the dog snapper.

West Side: 2 specimens, 150 and 225 mm. long.

***Lutianus jocu*** (Bloch & Schneider). Dog snapper.

Middle Chamber: 3 specimens, 60, 235 and 260 mm. long.

Lowest Chamber: 16 specimens preserved, ranging in length from 34 to 310 mm. Many others were present; examined six ranging from 270 to 335 mm. in length for spawning condition, which were all undeveloped.

West Side: 8 specimens, varying in length from 62 to 300 mm.

***Lutianus apodus*** (Walbaum). Schoolmaster.

Middle Chamber: 2 specimens, respectively 205 and 250 mm. long.

Lowest Chamber: 4 specimens preserved, ranging in length from 245 to 290 mm. Several others were present, but the species was less numerous than the dog snapper.

***Lutianus synagris*** (Linnaeus). Lane snapper.

Lowest Chamber: Only 4 small ones, ranging in length from 106 to 152 mm.

West Side: 1 specimen 105 mm. long.

FAMILY HAEMULIDAE. GRUNTS.

***Pomadasys crocro*** (Cuvier & Valenciennes). Ranco.

Uppermost Chamber: 14 small specimens, 36 to 57 mm. long.

This fish was taken also in Gatun Lake, near Gamboa. In earlier investigations (1911 and 1912) specimens were collected all the way from strictly salt water at Porto Bello to fresh water, above many rapids, in the upper Chagres River. It seems probable that this fish passes through the locks, as no evidence has been secured indicating that it reproduces in fresh water. Specimens of this species, or the closely related *P. bayanus*, were taken in Pedro Miguel Locks and Miraflores Lake.

FAMILY SPARIDAE. PORGIES.

***Archosargus aries*** (Cuvier & Valenciennes). Sheepshead.

West side: 1 specimen 325 mm. long.

This fish is new to the fauna of Panama. The species originally was described from Rio de Janeiro and Maracaibo, and later recorded from Belize, Honduras.

FAMILY GERRIDAE. MARINE MOJARRAS.

***Eucinostomus californiensis*** (Gill).

Uppermost Chamber: 11 juveniles, 24 to 32 mm. long. This species, as here understood, is common to both coasts of Panama. Specimens were taken also in Miraflores Locks and Miraflores Lake, but none at intermediate points. Though it ranges into brackish water streams, it is not known to enter strictly fresh water in Panama.

***Diapterus plumieri*** (Cuvier & Valenciennes).

Uppermost Chamber: 1 individual, quite surely of this species, was seen in a bottom hole but not captured.

Middle Chamber: 3 specimens, respectively, 270, 270 and 315 mm. long preserved. Others were seen.

West Side: 2 specimens, 330 and 340 mm. long.

FAMILY SCIAENDAE. SEA TROUT, CROAKERS, ETC.

***Bairdiella*** sp.

Lowest Chamber: 12 postlarvae, 8 to 10 mm. long, probably belong to this genus.

***Bairdiella ronchus*** (Cuvier & Valenciennes).

Lowest Chamber: 8 specimens, ranging in length from 33 to 95 mm.

FAMILY POMACENTRIDAE.

***Pomacentrus fuscus*** Cuvier & Valenciennes.

Lowest Chamber: 1 specimen 75 mm. long.

FAMILY CICHLIDAE. MOJARRAS DE RIO.

***Cichlasoma maculicauda*** Regan.

Uppermost Chamber: 6 specimens, varying in length from 82 to 210 mm. This Atlantic slope species is not confined to strictly fresh water, as it

frequently was taken in brackish water in Panama during earlier investigations (1911 and 1912). It apparently has crossed the divide through Culebra Cut, as specimens were secured in Pedro Miguel and Miraflores Locks as well as in Miraflores Lake.

FAMILY GOBIIDAE. GOBIES; GUAVINAS.

***Gobiomorus dormitor*** Lacépède.

Uppermost Chamber: 7 specimens, 35 to 75 mm. long.

Lowest Chamber: 1 specimen 73 mm. long.

This fish was not taken in strictly salt water in Panama during the recent investigation nor the earlier ones (1911 and 1912). It most commonly was found in quiet brackish water, though occasionally far upstream. It, also, was secured in Gatun Lake in 1935.

***Eleotris pisonis*** (Gmelin).

Lowest Chamber: 7 specimens, 15 to 75 mm. long, preserved. Others were seen.

This species ranges from brackish to fresh water. It apparently has crossed the divide to the Pacific side locks where it seems to have hybridized with its closely related congener, *picta*. (See Hildebrand, *Field Mus. Nat. Hist. Pub.*, XXII, 1928, pp. 344-347).

***Eleotris isthmensis*** Meek & Hildebrand.

Uppermost Chamber: 12 specimens, 20 to 60 mm. long, preserved. This species was common in the bottom holes after the flight had been drained, but it was difficult to catch.

This fish ranges from salt to fresh water, but it appears to be most numerous in brackish water. No evidence of crossing over was found, though nothing would appear to prevent it.

***Leptophilypnus fluviatilis*** Meek & Hildebrand.

Uppermost Chamber: 28 specimens, 15 to 45 mm. long, preserved. It is very common, like the preceding species, in the bottom "manholes" where many adhering to the walls could be seen.

Middle Chamber: 2 specimens, 49 and 52 mm. long.

Lowest Chamber: 1 specimen 35 mm. long.

Three specimens of this species were taken in Gatun Lake at Barro Colorado Island. It apparently ranges from brackish to fresh water.

This species seems to have crossed the divide to the Pedro Miguel and Miraflores Locks.

***Lophogobius cyprinoides*** (Pallas).

Lowest Chamber: 25 specimens, 30 to 81 mm. long, preserved; many present.

This goby previously was known from Panama from only one specimen, taken at Porto Bello.

***Gobionellus boleosoma*** (Jordan & Gilbert).

Uppermost Chamber: 1 specimen 17 mm. long.

Lowest Chamber: 2 specimens, 27 and 30 mm. long.

***Bathygobius soporator*** (Cuvier & Valenciennes).

Middle Chamber: 1 specimen 38 mm. long.

Lowest Chamber: 7 specimens, 25 to 59 mm. long, preserved; many present.

West Side: 1 specimen 58 mm. long.
This species apparently does not enter fresh water.

***Garmannia hildebrandi*** Ginsburg.
Uppermost Chamber: 26 specimens, 13 to 37 mm. long, type material.
This goby was taken also in the Pedro Miguel Locks.

FAMILY BATRACHOIDIDAE. TOADFISHES.

***Amphichthys cryptocentrus*** (Cuvier & Valenciennes).
Lowest Chamber: 2 specimens, 72 and 75 mm. long.

FAMILY BLENNIIDAE. BLENNIES.

***Hypleurochilus*** sp.
Lowest Chamber: 1 specimen 46 mm. long. This probably is a new species.

***Blennius*** sp.
Lowest Chamber: 4 specimens, 25 to 37 mm. long. This may be a new species.

FAMILY ANTENNARIIDAE. FROGFISHES.

***Antennarius scaber*** (Cuvier).
Lowest Chamber: 1 specimen 45 mm. long.

## PEDRO MIGUEL LOCKS.

All specimens noted in the following list were taken in the east side of the locks, no collection having been made in the west side. The Pedro Miguel Locks are situated in fresh water, as stated elsewhere, and as the fresh water species of the Canal Zone in large part seem to shun the locks, comparatively few species, or even individuals, were present when the east side of these locks was dewatered February 20, 1937. It will be noticed that most of the species recorded are more or less regular inhabitants of brackish water. Several marine forms are included in the list, which in this instance have invaded fresh water.

FAMILY ELOPIDAE.

***Tarpon atlanticus*** (Cuvier & Valenciennes). Tarpon.
This species was not present in the east side of the locks, but Mr. Myrick, the superintendent of the locks, stated that several were stranded in the west side when dewatered in January, 1937. Several tarpons were present in Miraflores Locks. It was seen also in Miraflores Lake.

FAMILY ENGRAULIDAE. ANCHOVIES.

***Anchovia lucida*** (Jordan & Gilbert).
Six specimens, 93 to 106 mm. long.
This species was found in Miraflores Locks also.

***Anchovia spinifer*** (Cuvier & Valenciennes).
Many specimens of this anchovy were taken, ranging upward to 160

mm. in length. It was numerous also in Miraflores Locks. No evidence was secured, indicating that this anchovy, which inhabits both coasts of Panama, invades the fresh water between Gatun and Pedro Miguel Locks.

FAMILY CHARACINIDAE.

***Astyanax fasciatus*** (Cuvier). "Sardina."

This Pacific slope species was taken in Gatun Lake. Though no specimen was seen in Pedro Miguel Locks when dewatered, it may have passed through them to reach Gatun Lake.

***Brycon chagrensis*** (Kner). "Sabalo pipon."

A single specimen of this common Atlantic slope fish, 295 mm. long, was found in Pedro Miguel Locks. Many more were taken in Miraflores Lake, where the species apparently is now well established. To reach Miraflores Lake, the fish originally very probably descended from Gatun Lake and Culebra Cut, through the Pedro Miguel Locks.

***Brycon petrosus*** Meek & Hildebrand. "Sabalo pipon."

Eight small specimens, 49 to 76 mm. long, were taken in the Rio Cocoli, just above Miraflores Lake. This Atlantic slope fish presumably reached the Rio Cocoli from Miraflores Lake by descending from Gatun Lake and Culebra Cut through Pedro Miguel Locks.

FAMILY ATHERINIDAE. SILVERSIDES.

***Menidia (Thyrina) chagresi*** Meek & Hildebrand.

Four specimens, 45 to 70 mm. long, of this Atlantic slope fresh water silverside were secured. It was taken also in Miraflores Locks. This small species, which usually does not exceed a length of about 120 mm., has been mistaken by some Canal Zone residents for young tarpon.

FAMILY MUGILIDAE. MULLETS.

***Chaenomugil proboscideus*** (Günther).

A single small specimen 37 mm. long.

***Mugil curema*** Cuvier & Valenciennes.

Three small specimens, 41 42 and 44 mm. long. This species was taken also in Miraflores Locks and Miraflores Lake. It occurs on both coasts of Panama. No evidence indicating that it has invaded the fresh water between Pedro Miguel and Gatun Locks was secured.

FAMILY CENTROPOMIDAE. ROBALOS; SNOOK.

***Centropomus parallelus*** Poey.

Although this Atlantic coast fish was not taken in Pedro Miguel Locks, it was secured in Miraflores Lake, where it seems to be common. To reach this lake it apparently had to pass through Pedro Miguel Locks.

***Centropomus robalito*** Jordan & Gilbert.

Four specimens 80 to 125 mm. long. Many more were seen and taken in Miraflores Lake, though none was seen in Miraflores Locks, through which they presumably had to pass to reach Miraflores Lake and Pedro Miguel Locks.

**Centropomus aramatus** Gill.

Three specimens, 220, 223 and 240 mm. long. It was not seen in Miraflores Locks through which it presumably had to pass to reach the upper locks.

FAMILY LUTIANIDAE. SNAPPERS.

**Lutianus novemfasciatus** Gill.

One specimen 335 mm. long was preserved. It is quite certain that others were present, but disappeared by the "route of the fish-hungry." It also occurred in Miraflores Locks.

This snapper evidently has great tolerance for fresh water, but to date it is not known to have advanced into the fresh water of the Canal beyond the Pedro Miguel Locks.

**Lutianus colorado** Jordan & Gilbert.

Three specimens, 330, 430 and 580 mm. in length, were preserved, and others were seen. It was secured also in Miraflores Locks and Miraflores Lake.

FAMILY HAEMULIDAE. GRUNTS.

**Pomadasys bayanus** Jordan & Evermann.

Two small specimens, 27 and 50 mm. long. Two considerably larger specimens, 250 and 310 mm. long, were taken in Miraflores Lake. It was not seen in Miraflores Locks.

This fish probably is not distinct from *P. crocro* of the Atlantic, which was secured in Gatun Locks and Gatun Lake.

FAMILY SCIAENIDAE. CROAKERS, SEA TROUT, ETC.

**Cynoscion albus** (Günther). "Yellow corbina."

Three specimens, 153, 225 and 305 mm. long. This species was taken also in the Miraflores Locks.

FAMILY CICHLIDAE. MOJARRAS DE RIO.

**Cichlasoma maculicauda** Regan. "Chogorro."

Three specimens, 260, 293 and 300 mm. long. This Atlantic slope fish seems well established and common in Miraflores Lake where numerous individuals were taken, ranging upward to 320 mm. in length. It was taken also in Miraflores Locks and Gatun Locks and Gatun Lake.

FAMILY GOBIIDAE. GOBIES; GUAVINAS.

**Gobiomorus maculatus** (Günther). "Guavina."

This Pacific slope fish was found in Gatun Lake, where 2 specimens, 127 and 210 mm. long, were taken not far below Madden Dam. Though no specimens were secured in Pedro Miguel Locks the species presumably reached Gatun Lake by passing through these locks. This fish is common in Miraflores Lake, below Pedro Miguel Locks.

**Eleotris picta** Kner & Steindachner. "Guavina."

Twelve specimens, 35 to 480 mm. long, preserved. This species was numerous in the locks, where specimens up to 495 mm. in length were

measured. It is common in Miraflores Lake, and it was found also in Miraflores Locks.

No evidence indicating that this fish has passed through Culebra Cut to Gatun Lake was obtained. However, signs of the hybridization of this species and its closely related Atlantic slope congener, *pisonus*, was found. This apparent crossbreeding is discussed in another paper (*Field Mus. Nat. Hist. Pub., Zool. Ser.*, XXII, 1928, pp. 344 to 347).

***Leptophilypnus fluviatilis*** Meek & Hildebrand.

This Atlantic slope species was numerous in the "manholes" in the floor of the locks, where it seemed so much at home that it may be a permanent resident. Here it clings, very goby-like, to the walls of the holes. Thirty-five specimens 20 to 33 mm. long were preserved. This fish was taken also in Miraflores Locks and Miraflores Lake.

***Garmannia hildebrandi*** Ginsburg.

This species was obtained also in the uppermost chamber of Gatun Locks. Four specimens, 19 to 35 mm. long, were secured in the Pedro Miguel Locks, type material.

***Garmannia homochroma*** Ginsburg.

Ten specimens, 12 to 33 mm. long were preserved, type material.

FAMILY SOLEIDAE. SOLES.

***Achirus fluviatilis*** Meek & Hildebrand.

This species was fairly common in the "manholes" in the floor of the locks, where it was rather difficult to catch. Five specimens, 19 to 34 mm. long, were preserved. It was taken also in the Miraflores Locks.

## MIRAFLORES LOCKS.

Collections were made by the writer and assistants in the two chambers of the west side of the Miraflores Locks, when dewatered from March 24 to 29, 1937, and in the east side by Dr. A. O. Foster of the Gorgas Memorial Laboratory, Panama City, on April 28 and 29, 1937. The specimens secured in the upper and lower chambers of the west side were all kept separate and most of those from the east side similarly were labeled as to the level in which they were taken. When the level is known it is given in the following list.

FAMILY CARCHARHINIDAE. GRAY SHARKS.

***Carcharhinus*** sp.

Lower Chamber, East Side: 1 specimen, a partial skin, about 950 mm. long; a young male. Dr. Foster reported that 3 other sharks, similar to the one preserved, were present. To date the writer has not succeeded in identifying the specimen.

FAMILY SILURIDAE. CATFISH (MARINE).

***Sciadeichthys troschelii*** (Gill).

Upper Chamber, West Side: 3 specimens, 440, 470 and 490 mm. long, were preserved. Many others, supposedly of this species, were seen.

Many males of this and other species carried eggs and young in the mouth, which sometimes were dropped when the fish became distressed as

the water receded. In places in both chambers (west side) the floor of the locks was fairly covered with eggs and young catfish with large yolksacs. A male of this species examined in the laboratory retained a single young, 70 mm. long, with a large yolksac, in his mouth. One might judge that this young could easily have reached a length of 100 mm. (4 inches) on the large amount of yolk remaining. It would seem probable, then, that the young of this species are retained and cared for in the mouth of the male parent until they reach the comparatively large size of around 100 mm.

***Galeichthys seemanni*** (Günther).

Lower Chamber, West Side: 1 specimen, 360 mm. long, was preserved. According to my field notes this species was very common. However, as this and the next mentioned closely related species were not distinguished in the field, it seems probable that both were present in some abundance.

***Galeichthys jordani*** (Eigenmann & Eigenmann).

East Side: 1 specimen, 375 mm. long, was preserved.

This species is closely related to the preceding one from which it is distinguished with difficulty. This species and the foregoing ones very probably were present in the east side, though no specimens were preserved.

***Galeichthys dasycephalus*** (Günther).

Upper Chamber, West Side: 4 specimens, each about 65 mm. long, retaining a large yolksac, evidently dropped by the parent, were preserved.

Lower Chamber, West Side: 1 adult female 353 mm. long; 1 young 80 mm. long with yolk fully absorbed; 4 young removed from mouth of male parent, respectively 52, 54, 55 and 56 mm. long. These young retained a very large yolksac, measuring about 17 mm. in diameter.

According to my field notes this species was very numerous in the locks. It no doubt was present also in the east chambers, though no specimens were preserved.

***Arius multiradiatus*** Günther.

Upper Chamber, West Side: 1 specimen 250 mm. long.

Lower Chamber, West Side: 1 specimen, a male 287 mm. long, with eggs 6 mm. in diameter in the mouth.

FAMILY MURAENESOCIDAE. EELS.

***Neoconger vermiformis*** Gilbert.

This eel was common in the bottom silt of all four chambers. Thirty-six specimens, ranging in length from 42 to 152 mm., were preserved. Many more could have been taken. Specimens under about 75 mm. in length are glassy; the larger ones are pinkish. This eel previously had not been taken in shallow water at Panama.

***Hoplunnis*** sp.

Lower Chamber, West Side: 1 specimen 272 mm. long. I have not yet been able to identify this eel, and in fact am not certain that it belongs to the genus *Hoplunnis*. Upon further study it may prove to be new.

FAMILY MYRIDAE. WORM EELS.

***Myrophis vafer*** Jordan & Gilbert.

Lower Chamber, West Side: 1 specimen 68 mm. long.

FAMILY ELOPIDAE.

***Tarpon atlanticus*** (Cuvier & Valenciennes). Tarpon; "Sabalo real."

Upper Chamber, West Side: 1 female, with undeveloped gonads, 131.25 cm. (52.5 inches) long, became stranded. There was none present in the lower chamber of the west side.

Upper Chamber, East Side: 6 tarpons, ranging in length from 118 cm. (47 inches) to 162.5 cm. (65 inches), present at this level. A female, 141 cm. (56½ inches) long, contained well developed roe.

Lower Chamber, East Side: Four individuals, 2 males and 2 females, were present, ranging from 122.5 cm. (49 inches) to 150 cm. (60 inches) in length. The smallest one, a female, weighed 32 pounds, and the largest one, a male, weighed 57 pounds.

No tarpon were present in the east side of the Pedro Miguel Locks when dewatered in 1937, though reported from the west side, as stated in the preceding list. This species was seen in Miraflores Lake and it has been reliably reported from the sea level end of the Canal below Miraflores Locks. The tarpon, an Atlantic species, then, has completed the transit through the Canal.

FAMILY CLUPEIDAE. HERRINGS.

***Sardinella stolifera*** (Jordan & Gilbert).

Upper Chamber, West Side: This species was very numerous; 15 specimens, ranging from 95 to 130 mm. in length, were preserved.

Lower Chamber, West Side: This small herring was somewhat less numerous at this level than in the higher one. Eleven specimens, ranging from 51 to 132 mm. in length, were retained for the collection.

It was taken also in Miraflores Lake. It is a rather conspicuous fish because of its very bright, broad, silvery, lateral band.

***Ilisha fürthii*** (Steindachner).

Upper Chamber, West Side: A single specimen 150 mm. long.

***Odontognathus*** sp.

Lower Chamber, West Side: 1 specimen 77 mm. long.

Lower Chamber, East Side: 3 specimens, 52, 53 and 62 mm. long.

Because of the immaturity of the specimens it has not been possible to identify them with any degree of certainty even as to the genus.

FAMILY ENGRAULIDAE. ANCHOVIES.

***Anchovia balboae*** (Jordan & Seale).

Lower Chamber, West Side: 4 specimens, each close to 90 mm. in length.

This is the species listed as *A. brevirostris* in our earlier work (1923, p. 198). The name, *brevirostris*, however, is regarded as preoccupied by a Brazilian species of this genus.

***Anchovia naso*** (Gilbert & Pierson).

Lower Chamber, West Side: 3 specimens, 60, 62 and 63 mm. long.

Lower Chamber, East Side: 1 specimen 52 mm. long.

This species was not numerous in the locks.

***Anchovia parva*** Meek & Hildebrand.

Lower Chamber, West Side: 15 specimens, 43 to 65 mm. long.

Upper Chamber, East Side: 62 specimens, 35 to 62 mm. long.

Lower Chamber, East Side: 12 specimens, 33 to 50 mm. long.

This small anchovy heretofore was recorded only from the Atlantic coast of Panama and Trinidad. The specimens have been carefully compared with specimens from the Atlantic coast of Panama (the type locality), without detecting any differences. This species was numerous in the Gatun Locks, even in the uppermost chamber. It was not taken, however, in Gatun Lake, the Pedro Miguel Locks, nor in Miraflores Lake. Therefore, evidence indicating that it has crossed the Isthmus through the Canal is lacking. Its presence in abundance in the uppermost flight of the Gatun Locks, nevertheless, shows that it has great tolerance for fresh water, and the possibility that it has crossed definitely exists.

***Anchovia ischana*** (Jordan & Gilbert).

This anchovy was numerous in all four chambers of the locks. Many specimens, 47 to 93 mm. in length, were preserved.

The great abundance of this species, as well as other anchovies, probably attracts some of the larger fish to the locks.

***Anchovia lucida*** (Jordan & Gilbert).

Upper Chamber, West Side: 1 specimen 85 mm. long.

Lower Chamber, West Side: 18 specimens, 80 to 97 mm. long.

Lower Chamber, East Side: 1 specimen 92 mm. long.

This species was found also in the Pedro Miguel Locks, showing that it can endure fresh water.

***Anchovia curta*** (Jordan & Gilbert).

Although this anchovy was not taken in the locks it seems to belong to this list as 10 specimens, 22 to 54 mm. in length, were taken in Miraflores Lake above the locks. To reach this lake it presumably had to pass through Miraflores Locks.

Its tolerance for fresh water suggests that this anchovy could traverse the Isthmus, but to date no evidence indicating that it has done so has been found.

***Anchovia spinifer*** (Cuvier & Valenciennes).

This species was very numerous in every chamber of the locks. Many specimens, ranging from 33 to 165 mm. in length, were preserved.

It was common also in Pedro Miguel Locks, and a single specimen was secured in Gatun Locks, though not at intermediate points.

As this anchovy was recorded from both coasts of tropical America before the completion of the Canal, it would be impossible to determine whether crossing over has taken place from the study of specimens. Its tolerance for fresh water apparently would enable it to complete the transit.

Its great abundance in the locks was surprising because it was not secured on either coast of Panama during our earlier extensive collecting.

Many of the larger specimens were very conspicuous because of their bright orange color, though others were plain silvery.

The great abundance of this fish in the locks very probably helps to attract many large predatory species.

***Anchovia panamensis*** (Steindachner).

Upper Chamber, West Side: 4 specimens, 58 to 72 mm. long.

Lower Chamber, West Side: 1 specimen 88 mm. long.

Two specimens, 46 and 55 mm. long, were taken in Miraflores Lake. It was not seen in the Pedro Miguel Locks.

***Anchovia rastralis*** (Gilbert & Pierson).

Upper Chamber, West Side: 5 specimens, 53 to 55 mm. long.

Lower Chamber, West Side: Many present; 40 specimens, 57 to 105 mm. long, were preserved.

Lower Chamber, East Side: A single specimen 63 mm. long.

***Lycengraulis poeyi*** (Kner & Steindachner).

Upper Chamber, West Side: 3 specimens, 140, 160 and 185 mm. long.

***Cetengraulis mysticetus*** (Günther).

Upper Chamber, West Side: 1 specimen 53 mm. long.

Lower Chamber, West Side: Numerous; 41 specimens, 53 to 90 mm. long, were preserved.

FAMILY POECILIIDAE. TOP MINNOWS.

***Poeciliopsis elongatus*** (Günther).

Upper Chamber, West Side: 11 specimens, 19 to 38 mm. long.

Lower Chamber, West Side: 54 specimens, 26 to 47 mm. long.

Upper Chamber, East Side: 2 specimens, 56 and 60 mm. long.

This brackish water minnow was numerous in both chambers of the west side, where many either were stranded or occupied the "manholes" in the floor of the locks.

FAMILY HEMIRHAMPHIDAE. HALFBEAKS.

***Hyporhamphus snyderi*** Meek & Hildebrand.

Lower Chamber, East Side: 2 specimens, 143 and 175 mm. long.

FAMILY ATHERINIDAE. SILVERSIDES.

***Menidia (Thyrina) chagresi*** Meek & Hildebrand.

Lower Chamber, West Side: 3 specimens, 25, 27 and 88 mm. long.

This Atlantic slope fish, confined to fresh and brackish water, was taken also in the Pedro Miguel Locks.

***Kirtlandia gilberti*** (Jordan & Bollman).

Lower Chamber, East Side: 2 specimens, 38 and 117 mm. long.

East side: 3 specimens, 36, 48 and 120 mm. long.

FAMILY MUGILIDAE. MULLETS.

***Mugil curema*** Cuvier & Valenciennes.

Lower Chamber, West Side: 9 juveniles of one school, 46 to 56 mm. long, and 14 of another school, 24 to 33 mm. long, were preserved.

Upper Chamber, East Side: 3 specimens, 30, 38 and 45 mm. long.

East side: 1 adult 235 mm. long.

Juveniles were taken, also, in Miraflores Lake and Pedro Miguel Locks.

FAMILY POLYNAEMIDAE. THREADFINS.

***Polynemus approximans*** Lay & Bennett.

Lower Chamber, East Side: 1 juvenile 29 mm. long.

East Side: 2 adults, 195 and 205 mm. long.

FAMILY CARANGIDAE. CREVALLE, JACKS, POMPANOS, ETC.

***Caranx hippos*** (Linnaeus). "Jack."

Upper Chamber, West Side: 1 specimen 135 mm. long.

Lower Chamber, West Side: 8 specimens, 105 to 125 mm. long.

East Side: 1 large individual 610 mm. long.

This species as here understood occurs on both coasts of Panama. Though some writers have attempted to separate the specimens from the opposite coasts, giving the name *C. caninus* to the Pacific coast one, I am not convinced that the supposed differences are well founded.

The scarcity of this species in the Miraflores Locks contrasts sharply with its abundance in the Gatun Locks. It is not known to invade strictly fresh water.

***Caranx marginatus*** (Gill).

Upper Chamber, West Side: A single specimen 140 mm. long.

***Oligoplites mundus*** Jordan & Starks. Leather jack.

East Side: 1 specimen 365 mm. long.

***Oligoplites saurus*** (Bloch & Schneider). Leather jack.

Lower Chamber, West Side: 3 specimens, 29, 38 and 62 mm. long.

East Side: 2 specimens, 190 and 205 mm. long.

This species, which is common to both coasts of Panama, was not seen in the Gatun Locks, and is not known to enter fresh water.

***Trachinotus kennedyi*** Steindachner. Pompano.

East Side: 1 large individual 645 mm. long.

***Chloroscombrus orqueta*** Jordan & Gilbert.

Lower Chamber, West Side: 1 specimen, a juvenile 54 mm. long.

East Side: 8 specimens; one juvenile 40 mm. long, and 7 adults 185 to 205 mm. long.

***Selene brevoortii*** (Gill). Moonfish.

Lower Chamber, East Side: 1 juvenile 70 mm. long, and an adult 265 mm. long.

***Vomer declivifrons*** Meek & Hildebrand. Moonfish; horsefish.

Lowest Chamber, West Side: 1 specimen 335 mm. long.

East Side: 1 individual 250 mm. long.

FAMILY APOGONIDAE. CARDINAL-FISHES.

***Apogon dovii*** Günther.

Lower Chamber, West Side: 1 specimen 100 mm. long.

FAMILY CENTROPOMIDAE. ROBALOS; SNOOK.

***Centropomus pectinatus*** Poey.

This species, which is known from both coasts of tropical America, was not seen in Miraflores Locks. However, 2 specimens, 95 and 330 mm. long, were taken in Miraflores Lake. The fish presumably had to pass through the Miraflores Locks to reach this lake. It was not taken in the Gatun Locks.

***Centropomus unionensis*** Bocourt.

Upper Chamber, West Side: 3 specimens, 110, 160 and 200 mm. long.

Lower Chamber, West Side: 2 specimens, 115 and 170 mm. long.

***Centropomus nigrescens*** Günther.

Lower Chamber, West Side: 1 individual about 450 mm. long, quite certainly of this species, was laid aside, but disappeared by the "route of the fish-hungry."

In addition 2 small specimens, 55 and 95 mm. long, were taken in Miraflores Lake, presumably having passed through Miraflores Locks to reach that lake.

FAMILY SERRANIDAE. SEA BASSES, GROUPERS, JEWFISH, ETC.

***Epinephelus labriformis*** (Jenyns). Grouper.

Upper Chamber, West Side: 5 specimens, 38 to 180 mm. long.

***Promicrops itaiara*** (Lichtenstein). Jewfish.

Upper Chamber, West Side: 1 specimen about a foot long was seen, but disappeared, having been taken by someone who was hungry for fish.

Lower Chamber, East Side: 1 individual 975 mm. (39 inches) long, weighing 47 pounds, was present. Only the head and tail were preserved.

***Rypticus saponaceus bicolor*** (Valenciennes). Soapfish.

Lower Chamber, West Side: 19 specimens, 61 to 155 mm. long, were preserved. Many more were present in the sumps and bottom slush.

East Side: 2 specimens, 86 and 121 mm. long.

The identification is by Dr. L. P. Schultz of the U. S. National Museum, who regards the Pacific Coast specimens as only subspecifically distinct from the Atlantic ones. The two nominal species listed in our earlier work (1925, pp. 481 and 482), *R. xanti* Gill and *R. nigripinnis* Gill, are regarded as synonyms of the above name.

FAMILY LUTIANIDAE. SNAPPERS.

***Lutianus novemfasciatus*** Gill.

Lower Chamber, West Side: 1 specimen, 395 mm. long, was preserved. Only a few others were seen.

This species was taken also in the Pedro Miguel Locks.

***Lutianus colorado*** Jordan & Gilbert.

Lower Chamber, West Side: 1 specimen, 410 mm. long, was measured and critically examined. Many more were present, mostly quite large. Probably about 50 pounds of this species and *L. argentiventris* were removed from this flight by Canal employees.

East Side: 1 specimen, 150 mm. long, was preserved. According to Dr. Foster this fish was numerous in the east side of the locks.

Although this snapper was not taken in the upper chamber (west side) of the locks, specimens were secured in Pedro Miguel Locks and Miraflores Lake, where it appears to be common. Though this snapper tolerates virtually fresh water, it is not known to have advanced beyond the Pedro Miguel Locks.

***Lutianus argentiventris*** (Peters).

Upper Chamber, West Side: 2 specimens, 65 and 353 mm. long, were preserved. Several others were seen.

Lower Chamber, West Side: 13 specimens, 90 to 230 mm. long, were preserved. Many present. Probably about 50 pounds of this species and of *L. colorado* were removed from this flight by Canal employees.

East Side: 3 specimens, 90, 160 and 270 mm. long, were preserved. It was common in the east side of the locks, according to Dr. Foster.

FAMILY HAEMULIDAE. GRUNTS.

***Orthopristis chalceus*** (Günther).

East Side: 5 specimens, 170 to 225 mm. long.

***Pomadasys leuciscus*** (Günther).

East Side: 2 specimens, 370 and 385 mm. long.

This is *Brachydeuterus nitidus* of Jordan & Evermann (*Bull. U. S. Nat. Mus.* XLVII, 1898, p. 1326) and others, which merges with *P. leuciscus* according to our earlier studies (1925, p. 451).

***Anisotremus pacifici*** (Günther).

Upper Chamber, West Side: 3 specimens, 200, 280 and 320 mm. long, were preserved. Many more were present. Ten were dissected and were found to be 8 females and 2 males, all nearly ripe.

Lower Chamber, West Side: 1 specimen, 315 mm. long, was preserved. This species was nearly as numerous in this flight as in the upper one. Six specimens were examined for spawning condition; only 2 had large roe.

***Anisotremus dovii*** (Günther).

Lower Chamber, West Side: A single small specimen, 55 mm. long, was doubtfully identified as this species.

East Side: 1 specimen 200 mm. long.

FAMILY GERRIDAE. MOJARRA (MARINE).

***Eucinostomus californiensis*** (Gill).

Upper Chamber, West Side: 2 specimens, 42 and 60 mm. long.

Lower Chamber, West Side: 13 specimens, 47 to 82 mm. long.

East Side: Two specimens, 62 and 78 mm. long.

One specimen, 145 mm. long, was taken in Miraflores Lake. To reach this lake the fish presumably had to pass through Miraflores Locks.

***Gerres cinereus*** (Walbaum).

Upper Chamber, West Side: 3 specimens, 56, 59 and 68 mm. long.

Lower Chamber, West Side: 1 specimen 55 mm. long.

One large specimen, 370, mm. long, was taken in Miraflores Lake, presumably having passed through the locks to reach this lake.

This species inhabits both coasts of tropical America. Although it evidently has much tolerance for fresh water it does not seem to have advanced in the Canal beyond Miraflores Lake on the Pacific side. It was not seen in Gatun Locks.

***Diapterus peruvianus*** (Cuvier & Valenciennes).

Lower Chamber, West Side: 15 specimens, 23 to 110 mm. long (mostly juveniles).

Lower Chamber, East Side: 6 specimens, 70 to 145 mm. long.

Eight specimens of this species, ranging in length from 50 to 285 mm., were taken in Miraflores Lake. It is probable that the fish passed through Miraflores Locks to reach this lake.

***Diapterus axillaris*** (Günther).

Upper Chamber, West Side: A single specimen, 247 mm. long, seems to belong to this species, which previously was not reported from Panama.

FAMILY KYPHOSIDAE. RUDDER-FISHES.

***Kyphosus elegans*** (Peters).

East Side: 1 specimen 410 mm. long.

FAMILY SCIAENIDAE. CROAKERS, SEA TROUT, DRUMS, ETC.

***Micropogon altipinnis*** Günther.

Upper Chamber, West Side: 3 specimens, 72, 103 and 180 mm. long.

Lower Chamber, West Side: 13 specimens, 52 to 152 mm. long; and 69 juveniles, 12 to 40 mm. long, which probably also belong to this species.

East Side: 2 specimens, 135 and 182 mm. long.

The young of this species seem to be common in Miraflores Lake where 18 specimens, 40 to 125 mm. long, were taken.

***Stellifer oscitans*** (Jordan & Gilbert).

Lower Chamber, West Side: 1 specimen 103 mm. long.

***Stellifer illecebrosus*** Gilbert.

Lower Chamber, West Side: 4 small specimens, 67 to 80 mm. long; and 3 juveniles, 22, 33 and 35 mm. long, which may belong to this species.

***Bairdiella ensifera*** (Jordan & Gilbert).

Upper Chamber, West Side: 2 specimens, 78 and 130 mm. long.

Lower Chamber, West Side: 3 specimens, 85, 120 and 150 mm. long.

***Ophioscion typicus*** Gill.

Upper Chamber, West Side: 3 specimens, 175, 180 and 185 mm. long.

Lower Chamber, West Side: 1 specimen 168 mm. long.

East Side: 2 specimens, 183 and 200 mm. long.

***Ophioscion scierus*** (Jordan & Gilbert).

Lower Chamber, West Side: 1 small specimen, 89 mm. long, doubtfully identified as this species.

***Cynoscion albus*** (Günther). "Yellow corbina."

Upper Chamber, West Side: 5 specimens, 235 to 265 mm. long.

Lower Chamber, West Side: 2 specimens, 240 and 310 mm. long, were preserved. Some fairly large ones, measuring up to 30 inches in length, were present.

Although no specimens were preserved, this species was numerous in the east side of the locks, according to Dr. Foster.

Small individuals were taken also in Pedro Miguel Locks, showing that this species has much tolerance for fresh water.

The "yellow corbina" is a highly prized foodfish in Panama. A length of about 40 inches and a weight of 25 pounds are not unusual. It is sought extensively by sportsmen.

***Larimus effulgens*** Gilbert.

East Side: 1 specimen 280 mm. long.

FAMILY EPHIPPIDAE. SPADE-FISHES.

***Chaetodepterus zonatus*** (Girard).

East Side: 3 specimens, 220, 220, and 235 mm. in length.

FAMILY CICHLIDAE. MOJARRAS DE RIO.

***Cichlasoma maculicauda*** Regan.

Upper Chamber, West Side: 3 specimens, 32, 70 and 85 mm. long.

This Atlantic slope fish was taken also in Miraflores Lake and in Pedro Miguel Locks.

FAMILY TETRAODONTIDAE. PUFFERS.

***Sphoeroides annulatus*** (Jenyns).

Lower Chamber, West Side: 1 specimen 225 mm. long.

East Side: 1 specimen 195 mm. long.

***Sphoeroides fürthii*** (Steindachner).

Lower Chamber, West Side: 1 juvenile 28 mm. long.

***Guentheridia formosa*** (Günther).

East Side: 1 specimen 225 mm. long.

FAMILY GOBIIDAE. GOBIES; GUAVINAS.

Small gobies, principally naked ones, were very common in both chambers of the west side in the slush, where an inch or two of water remained on the floor after pumping had ceased. Although the different species were not recognized in the field, their relative abundance is believed to be shown more or less by the number of specimens collected of each species.

***Dormitator maculatus*** (Bloch).

Lower Chamber, East Side: 15 small specimens, 20 to 85 mm. long, seem to be of this Atlantic slope species.

***Dormitator latifrons*** (Richardson).

This species was not seen in the locks when they were dewatered, but later, after the locks had been refilled (Sept. 30, 1937), Mr. C. B. Lear took several fine specimens which were in spawning condition.

***Eleotris picta*** Kner & Steindachner.

Upper Chamber, West Side: 5 specimens, 43 to 80 mm. long.

Lower Chamber, East Side: 2 specimens, 20 and 245 mm. long.

This fish is common in Miraflores Lake, and it was numerous in Pedro Miguel Locks. Some evidence of cross breeding with its near relative, *pisonus*, of the Atlantic slope was found (see under this species in the list for Pedro Miguel Locks).

***Leptophilypinus fluviatilis*** Meek & Hildebrand.

Upper Chamber, West Side: 16 specimens, 28 to 48 mm. long, were captured. Others were seen in the "manholes" in the floor of this flight. It was not found in the lower chamber.

This Atlantic slope fish was taken also in Pedro Miguel Locks and in the Gatun Locks.

***Erotelis clarki*** (Hildebrand).

Lower Chamber, West Side: 5 specimens, 77 to 150 mm. long, including the type of this species.

Upper Chamber, East Side: 2 specimens, 70 and 115 mm. long.

East Side (level unknown): 4 specimens, 80 to 150 mm. long.

This species recently described by me (*Field Mus. Nat. Hist. Pub., Zool. Ser.*, XXII, 1938, p. 352) has not been taken elsewhere.

***Bathygobius soporator*** (Cuvier & Valenciennes).

Lower Chamber, West Side: 4 specimens, 69 to 86 mm. long. Others were present, but the species was not numerous.

Upper Chamber, West Side: 2 specimens, each 84 mm. long.

***Enypinas aceras*** Ginsburg.

Lower Chamber, West Side: 8 specimens, 24 to 46 mm. long, type material.

***Enypinas seminudus*** (Günther).

Upper Chamber, West Side: 6 specimens, 23 to 45 mm. long.

Lower Chamber, West Side: 95 specimens, 16 to 51 mm. long.

Upper Chamber, East Side: 12 specimens, 36 to 57 mm. long.

Lower Chamber, East Side: 6 specimens, 36 to 53 mm. long.

***Gobionellus liolepis*** (Meek & Hildebrand).

Upper Chamber, East Side: 1 specimen 31 mm. long.

***Gobionellus manglicola*** (Jordan & Starks).

Upper Chamber, West Side: 6 specimens, 27 to 32 mm. long.

Lower Chamber, West Side: 28 specimens, 18 to 32 mm. long.

Upper Chamber, East Side: 16 specimens, 21 to 40 mm. long.

***Gobionellus sagittula*** (Günther).

Lower Chamber, West Side: 1 specimen 38 mm. long.

***Garmania paradoxa*** (Günther).

Lower Chamber, West Side: 33 specimens, 19 to 35 mm. long.

Lower Chamber, East Side: 2 specimens, 25 to 35 mm. long.

***Gobioides peruanus*** (Steindachner).

Lower Chamber, West Side: 1 specimen 248 mm. long. This goby was seined on deep mud in the sump next to the "seagates" of the locks. It was thought to be a snake by my helper, who warned me to keep hands off. A new record for Panama.

***Gobiosoma nudum*** (Meek & Hildebrand).

Lower Chamber, West Side: 1 specimen 27 mm. long.

***Microgobius tabogensis*** Meek & Hildebrand.

Upper Chamber, West Side: 1 specimen 30 mm. long.

Lower Chamber, West Side: 28 specimens, 22 to 50 mm. long.

***Microgobius emblematicus*** (Jordan & Gilbert).

Lower Chamber, West Side: 1 specimen 44 mm. long.

***Parrella spilopteryx*** Ginsburg.

Upper Chamber, East Side: 1 specimen, 74 mm. long, the type.

***Parrella fusca*** Ginsburg.

Lower Chamber, West Side: 1 specimen, 42 mm. long, the type.

FAMILY BATRACHOIDAE. TOADFISHES.

***Batrachoides pacifici*** (Günther).

Lower Chamber, West Side: 5 specimens, 32 to 290 mm. long.

***Porichthys greenei*** Gilbert & Starks.

Lower Chamber, West Side: 2 specimens, each 87 mm. long.

***Porichthys margaritatus*** (Richardson).

East Side: 1 specimen 177 mm. long.

This species previously was not taken in shallow water in the vicinity of the Canal Zone. The determination is by Dr. L. P. Schultz.

***Thalassophryne reticulata*** Günther.

Lower Chamber, West Side: Saw one badly decomposed specimen, about 150 mm. long, floating in a sump a few days after the main body of water had been removed. The specimen certainly was of this genus, though there is doubt as to whether it was *reticulata* or *dowii*.

FAMILY BLENNIIDAE. BLENNIES.

***Hypsoblennius*** sp.

Lower Chamber, West Side: 17 specimens, 16 to 70 mm. long.

The specimens are near *H. lignus*, but differ in minor structures, requiring further study.

FAMILY SOLEIDAE. SOLES.

Small soles were fairly common in the bottom "manholes," but were rather difficult to catch.

***Achirus fimbriatus*** (Günther).

Upper Chamber, West Side: 17 specimens, 15 to 40 mm. long.
Lower Chamber, West Side: 5 specimens, 24 to 50 mm. long.
Lower Chamber, East Side: 2 specimens, 35 to 40 mm. long.

***Achirus fluviatilis*** Meek & Hildebrand.

Lower Chamber, West Side: 1 specimen 50 mm. long.

This sole was taken also in the Pedro Miguel Locks.

***Achirus klunzingeri*** (Steindachner).

Upper Chamber, West Side: 1 specimen 71 mm. long.
Lower Chamber, West Side: 3 specimens, 58, 62 and 63 mm. long.
Upper Chamber, East Side: 2 specimens, 70 and 95 mm. long.

***Symphurus elongatus*** (Günther). Tongue fish.

Upper Chamber, West Side: 14 specimens, 20 to 64 mm. long.
Lower Chamber, West Side: 28 specimens, 17 to 80 mm. long.
Upper Chamber, East Side: 2 specimens, 43 and 65 mm. long.
Lower Chamber, East Side: 3 specimens, 51, 58 and 75 mm. long.

## EXPLANATION OF THE PLATES

### PLATE I.

Fig. 1. Gatun Locks, Panama Canal, looking toward Gatun Lake, showing vessels in transit. Courtesy Panama Canal.

Fig. 2. Scene in base of dewatered Gatun Locks, showing stranded fish, consisting mostly of "jacks," *Caranx hippos.*

### PLATE II.

Fig. 3. Wall of upper chamber of dewatered lock, showing growth of bivalve mollusc, *Congria* (*Mytilopsis*) *sallei;* also the "skiff" operated by a crane, lowering collectors into the lock.

Fig. 4. Lifting collecting seine after a haul in the sump of Pedro Miguel Locks.

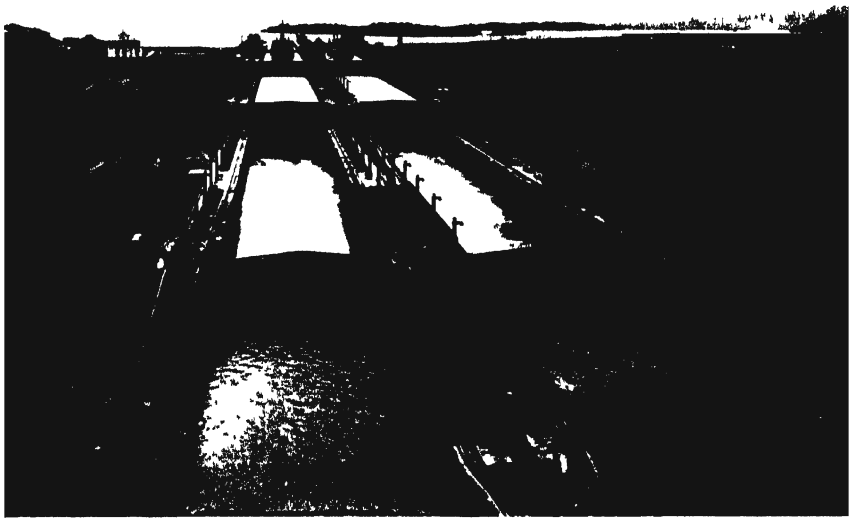

FIG. 1.

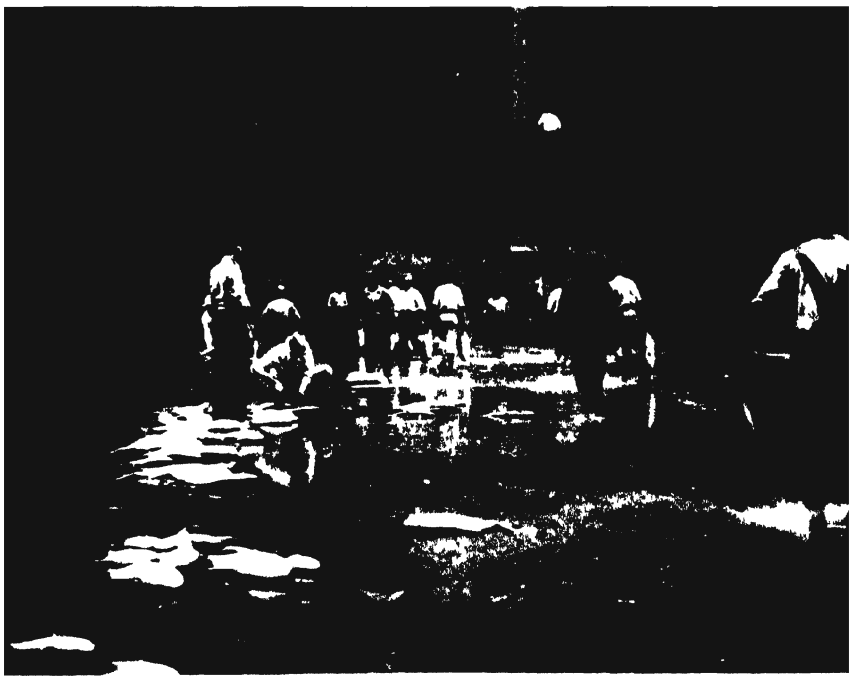

FIG. 2.

THE PANAMA CANAL AS A PASSAGEWAY FOR FISHES, WITH LISTS AND REMARKS ON THE FISHES AND INVERTEBRATES OBSERVED.

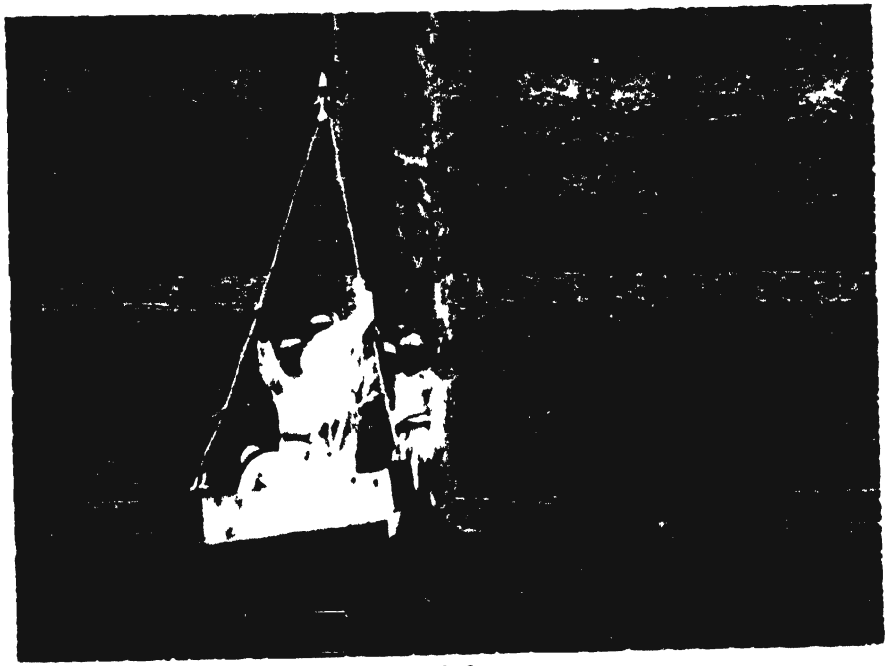

FIG 3

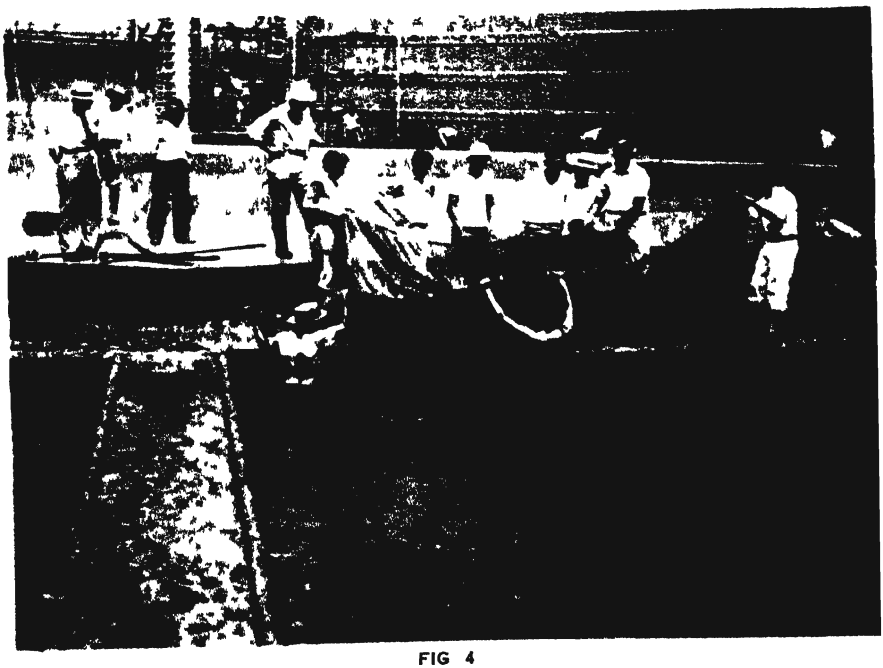

FIG 4

THE PANAMA CANAL AS A PASSAGEWAY FOR FISHES, WITH LISTS AND REMARKS ON THE FISHES AND INVERTEBRATES OBSERVED

# 4.

# The Cytology of the Pituitary Gland of Two Varieties of Goldfish (*Carassius auratus* L.), with Some Reference to Variable Factors in the Gland Which May Possibly Be Related to the Different Morphological Types.

IRVING LEVENSTEIN[1]

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(Plate I).

In recent years the pituitary gland, as compared to other glands of internal secretion, has received a greater amount of concentrated attention and experimental study. However, most of this work has centered around the pituitary of the mammal and only a few investigators have attempted to give any sustained attention to that structure in lower forms. This seems rather unfortunate for the greater part of the confusion, regarding the pituitary, concerns itself with its supposed manifold hormonal activities and inter-relationships. In the higher forms, for example, such functions as corpus luteum formation, uterine growth, lactation and proportional growth in general, have all been shown to be related to the pituitary gland. In lower forms most of these physiological activities are absent. This alone should result in a comparative simplification of the functional activity of the gland. Therefore, it is reasonable to believe that a study of the pituitary gland in the lower forms may lead more readily to a better understanding of the function of the gland. However, before the function of any gland may be adequately studied, it is always valuable to have as complete a knowledge of its microscopic structure as possible. This, of course, becomes especially true if any attempt is made to correlate its function with its structure. In addition, there is still a great need for a cytological study of the pituitary in these lower forms by the use of modern techniques (Charipper, 1937).

The morphology and microscopic anatomy of the pituitary gland of only a few species of Cyclostomes, Pisces and Amphibia have been worked out with varying degrees of completeness. This work has been covered for the most part by Tilney (1911), Stendell (1914) and Bock (1928). More recently, Bell (1938) has reviewed the previous work on the pituitary of the lower vertebrates and has added a morphological description of the pituitary gland of the common goldfish (*Carassius auratus*). None of these workers has attempted a complete cytological description of the cells forming the gland in the species which they considered.

[1] Accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, New York University.

Aside from the work on amphibian metamorphosis, there has been very little, if any, investigation of the relationship of the pituitary in lower forms to deviations from the normal body structure known to occur in such animals. Cushing (1932, a, b) and his co-workers have described cellular changes in the anterior lobe occurring in acromegalic individuals and those suffering from "Basophilia." Keith (1922), Crew (1923) and Stockard (1936) have also related body abnormalities to changes in the endocrine glands. These workers believe that these structural abnormalities are carried on from generation to generation.

The present work has two objectives: (1) to describe the histology and cytology of the pituitary of two varieties of goldfish, and (2) to investigate whether or not easily apparent differences in body structure occur along with variations in the pituitary.

I wish to acknowledge gratefully the interest and helpful suggestions of Dr. Harry A. Charipper under whose guidance this work was carried out. I wish also to thank Dr. C. M. Breder, Jr., of the New York Aquarium for his invaluable assistance and co-operation.

## Materials and Methods.

The pituitary glands of two varieties of goldfish (*Carassius auratus* L.) were examined both histologically and cytologically. They were removed from animals, both male and female, purchased at local supply houses during the months from October to March. The varieties of goldfish studied were the "common" and the "telescope moor." The former has an elongate body, a scaleless head, yellow to gold pigmentation and two sets of paired fins, the ventral and pectoral, as well as three single fins including the tail. The "telescope moor" has a short blunt body which is rounded and egg-shaped and possesses a black pigmentation. All the ventral fins are paired and its tail is divided to its base. In this variety the eyes are set into stalks which project from the sides of the head.

To follow cytological procedures, it was found best to remove the pituitary gland from the animal before placing it into the fixing solutions. In order to obtain the gland, the animal first was quieted in an ice water bath. The head then was severed from the body, the ventral surface of the brain case exposed and the portion of bone below the gland carefully cut away. The exposed gland was removed easily and placed into the fixing solution.

The majority of the pituitary glands were fixed, either by the method of Champy or by Nassonov's modification of the method of Kolatchev. In addition, a few of the glands were fixed according to the Mann-Kopsch method as described by Gatenby. Pituitary glands were also treated according to the Champy-Kull method in order to demonstrate mitochondria.

After fixation and impregnation, all the glands were dehydrated and cleared in dioxan. Dioxan was advantageous in keeping the brittle osmicated tissue from fragmenting. Sections were cut in hard paraffin (60° C.) at two, three and four micra at low temperatures. Glands were sectioned serially in frontal, sagittal and horizontal planes, and stained by either the Masson method or the Dawson modification of the Heidenhain azan procedure.

It is important to note that throughout the work the pituitary glands of the two varieties of goldfish being studied were fixed in sets and run through all the procedures side by side thereby assuring the validity of cytological comparison. Further, the glands were removed from animals of approximately the same weight.

## Observations and Description.

The pituitary gland of the goldfish (*Carassius auratus*) lies below the brain and is connected with it by a short heavy stalk. A tough membrane separates the ventral surface of the brain from the pituitary gland. The infundibular stalk leaves the brain case, along with the optic nerves, through a foramen in the parasphenoid bone. After emerging from the foramen, the stalk continues posteriorly as the pars nervosa and forms a center about which the rest of the gland is arranged. Part of the pituitary gland also extends anteriorly and, as the gland is applied closely to the ventral surface of the brain case, it acts to close the large optic-pituitary foramen. These morphological relationships confirm the findings of Bell (1938).

The pituitary glands of two varieties of goldfish, the common and the moor, were examined cytologically. No easily apparent differences were found in cell types, cell structures or Golgi configurations. Therefore, the following description of the gland may be applied to the pituitary of either the common or black moor varieties.

The pituitary gland is divided, as Bell (1938) has shown, into four easily distinguishable areas. The infundibular stalk enters the gland and is continuous with the pars nervosa which ramifies throughout all parts of the gland. The blood supply of the gland is intimately connected with these ramifications (Plate I, Fig. 9). Blood capillaries are only present between the fibers of the nervosa tissue. The cells found among the pars nervosa fibers are few in number.

### *Pars intermedia.*

The entire posterior end of the goldfish pituitary gland consists of a compact intermediate lobe. The pars nervosa ends here, after having passed through the übergangsteil or transitional lobe, as a heavy clump of fibers which spread out in all directions. The cells of the pars intermedia are arranged along the invading pars nervosa and are large, measuring from ten to fifteen micra in diameter. The cells composing the entire free surface of the intermediate lobe contain many osmiophilic granules while in the interior of the lobe and along the attached border there is a mixture of granular and non-granular cells (Plate I, Fig. 1). These are oriented along the strands of invading nervous tissue. Only granular cells, however, are found in the spaces between the strands of nervosa tissue. The non-granular cells are vesicular, elongate, and contain large nuclei which are clear after Champy fixation. The granular cells are larger and contain nuclei which, after the same fixation, stain a solid red with acid fuchsin. Even after ordinary fixation, the nuclei of the two types of cells can be distinguished by a difference in intensity of staining. They both contain fine strands of nuclear material in a clear nucleoplasm. These nuclei are round or oval after most types of fixation, but take on many bizarre shapes and stain deeply red after exposure to an osmo-sublimate solution.

The cytoplasm of the intermedia cells does not stain in a similar manner following the use of different fixing solutions. After Bouin fixation, a blue granulation is present, while following osmic acid fixing solutions the cytoplasm stains light blue or not at all.

After exposing the intermediate lobe cells to osmic acid fumes, a Golgi apparatus appears in these cells (Plate I, Fig. 2). It is of the same type and occupies the same position in both the granular and non-granular cells. The osmiophilic substance forms a circular cap which is applied closely to the nucleus and never extends over more than one-half of its surface. On cross section it is usually granular although in some cells several strandlike

layers may be found. Sometimes, tiny vesicles are seen between the strands. After the same length of exposure to osmic acid the granular cells have a much blacker and more extensive Golgi apparatus than the non-granular cells. There is no apparent orientation of the Golgi material in relationship to the position of the cell. In one cell the network may be found applied to the nucleus on the side nearest the invading nervosa tissue while the next cell may have its Golgi network on the opposite side of the nucleus.

After the use of the Champy-Kull technique and staining with acid fuchsin, the mitochondria, which are in the cytoplasm on one side of the nucleus, appear as fine granules. In some cells the granules spread out to fill up more than one-half of the cell cytoplasm.

*Pars anterior.*

Each of the cells along the outer surface of the anterior lobe contains a small nucleus, placed at one end of a clear cytoplasm. These cells are from six to ten micra in diameter and are grouped closely together (Plate I, Fig. 8). Their nuclei, after Champy fixation, are clear, while after non-osmic acid fixing solutions they contain a great many chromatin strands and granules. Nucleoli which stain heavily are present at one edge or in the center of the nuclei. The cytoplasm surrounding the nuclei is filled with a flocculated non-stainable material. A few osmiophilic granules are found near the nuclei and a Golgi apparatus is present. This Golgi figure is small, granular, and applied closely to the surface of the nucleus (Plate I, Fig. 3). It covers an area about one-fourth that of the nucleus, and is situated on the side which contains the most cytoplasm. No radiating strands or granules leave the loosely collected central portion of the apparatus to pass into the surrounding cytoplasm. The osmiophilic granules, even after prolonged exposure to osmic acid fumes, do not become greatly blackened. There is no orientation of the Golgi material in respect to the pars nervosa which spreads throughout the lobe.

In addition to the cells which have been described above, there are others which are smaller in size and fewer in number. These cells contain small nuclei which stain similarly to those found in the non-granular cells. The cytoplasm of these cells stains a reddish brown. It contains two types of granules, one of which stains with acid fuchsin and the other which becomes blackened after exposure to osmic acid. These granules fill the entire cell and completely surround the nucleus. A Golgi network is next to the nucleus and is of the same size and extent as that found in the non-granular cell. However, the apparatus is strand-like and contains an increased amount of osmiophilic material which results in more intense blackening. Along the anterior surface of the lobe these cells are few in number and lie between the non-granular cells while in the deeper parts of the lobe large groups are found. They are most numerous at the border between the anterior and transitional lobe.

A third variety of cell is present in the anterior lobe. It is as large as the non-granular cell and has a cytoplasm which contains a few granules. The nucleus is similar to that present in the other types of cells found in this lobe, and is at the edge of the cell. In some of these cells the cytoplasm, immediately surrounding the nucleus, is clear while that at the outer rim is highly granular. In others, the clear area of cytoplasm has increased and only a few granules remain. Cells are present which show different degrees of granulation, ranging from a completely granulated cytoplasm to one containing no granules at all. Thus, these cells may be intermediate cell stages between the clear cells found along the periphery of the lobe and the highly granular cells found in the interior of the lobe. These cells are found mainly

at a point midway between the inner and outer edges of the anterior lobe, where the lobe extends deeply into the transitional lobe.

The Golgi apparatus in this third variety of cell is similar to that found in both the granular and agranular cells. It is not as strand-like and heavily staining as the one in the granular cells but is less granular and stains more deeply than does the apparatus in the non-granular cells. The appearance of Golgi apparatus and the changes in granulation from a granular to a non-granular cell seem to indicate a morphological relationship between all the cells described.

Occasionally a basophile is found among the acidophiles of the anterior lobe. This cell resembles in form and structure the basophilic cells which are present in the transitional lobe. It is larger than the acidophiles, has a smaller nucleus and a cytoplasm which may be highly granular or have a homogeneous structure. The blue-staining granules, when present, are very large and few in number, and are found in a background of more finely granulated material which take a light blue stain. The basophiles generally appear singly, although a group of four or five is seen occasionally. In each cell a heavy strand Golgi network radiates from the nucleus. It is not as small or compact as that present in the acidophiles.

*Transitional lobe.*

A general survey of the transitional lobe of the goldfish pituitary gland is somewhat confusing in that there does not appear to be any definite architectural pattern, such as a nesting or cordlike arrangement, present anywhere in this region of the gland (Plate I, Fig. 4). The fibers of the nervosa ramify, apparently at random, passing as readily between groups of basophilic staining cells as between acidophilic staining cells. Occasionally, bands of nervosa fibers completely surround a group of cells, tending to separate them from their neighbors. The cells in such groups do not appear oriented in any definite way with respect to the investing fibers. It seems that either chromophobes, acidophiles, or basophiles may be opposed to the nervosa tissue.

Histological examination of carefully prepared sections of the gland, in which the transitional area has been treated according to the method of Severinghaus, discloses many different cellular entities. These different cell types can be distinguished, one from the other, by their variation in size, granular or agranular cytoplasmic nature, and chromophilic reactions. The following three major types of cells are found in this portion of the pituitary:

(A) The granular basophilic cells which are characterized by the presence of many large, spheroidal deep blue staining cytoplasmic bodies set in a gray matrix, and crowding on to a large vesicular nucleus.

(B) The granular acidophilic cells which are somewhat smaller than the preceding type and diagnostically contain a fine eosinophilic granulation set in a light clear cytoplasm and surrounding a large vesicular nucleus.

(C) The chromophobic cells which are smaller than any of the other cell types and contain large clear vesicular nuclei set in a scant, non-staining, agranular cytoplasm.

It is interesting to note that both the granular basophilic cell type and the granular acidophilic cell type may be found in an agranular form. Accompanying the degranulation of these types, the nucleus undergoes a change from the large clear vesicular karyosome to a compact almost pycnotic one.

A careful study of the transitional region, in frontal and sagittal serial sections, discloses a rather characteristic distribution of the various cell

types in relation to one another. The acidophiles and basophiles are present throughout the lobe as aggregates, among which may be found a few chromophobes (Plate I, Fig. 4). The acidophiles vary in number in different parts of the lobe. They are relatively more numerous in a mid-sagittal section than in a section near the periphery. The basophiles are found in greater numbers along the dorsal border of the lobe, posterior to the overlying pars anterior, and also appear to be more compactly grouped at the antero-ventral border, posterior to the stalk as it leaves the body of the gland. In addition, a large group of basophiles border the transitional lobe in the area of its contact with the pars intermedia. The chromophobes are the least numerous of the cell types found in the transitional lobe. These cells occur scattered in groups of two and three, throughout the lobe, among both the basophiles and acidophiles. Small groups of chromophobes are present along the nervosa tissue which extends between the transitional and intermediate lobes. Much larger groups are to be found associated with the nervosa tissue passing through the substance of the transitional lobe. In fact, in frontal section, the chromophobes are seen to surround completely the larger branches of the nervosa tissue.

A close study of the individuality of these various cell types under conditions of special techniques presents some interesting configurations of the Golgi material and mitochondrial substance. Both Golgi nets and granular mitochondria are demonstrable in all the cell types to be found in the transitional lobe. The Golgi material, however, presents various differences in configuration which are characteristic of the different cell types. In the acidophiles this osmiophilic substance is compact and closely applied, in the form of a cap, to the side of the nucleus (Plate I, Fig. 5). It consists of several heavy strands which form short loops in the cytoplasm. These loops do not extend very far from the nucleus and free ends from the network are rarely seen. In some instances, these cells contain a larger Golgi net which extends a considerable way out into the cytoplasm. The mitochondria in these cells are present throughout the cytoplasm, in the form of a fine granulation. Areas of condensation may be present on one side of the nucleus in the region of the Golgi net. The mitochondrial granules can easily be differentiated from the secretory granules, after proper destaining, by their lighter pink coloration.

The Golgi configuration present in the basophile is more strand-like and more extensive than that found in the acidophilic cells (Plate I, Fig. 7). Here again the Golgi material is limited to one side of the nucleus, but does not form a cap. Instead it appears to be free in the cytoplasm only occasionally touching the nucleus and then only at a point or two. The loops are large and made up of fine strands of osmiophilic material. The cytoplasm between the strands is finely granular and the large basophilic granules or spheroids are found completely outside the region of the net and along the borders of the cell. The mitochondria here are also granular and are dispersed throughout the cytoplasm. The finer granular chondriosomes are found nearest the nucleus while the coarser ones are toward the periphery and in between the basophilic secretory granulations. There does not appear to be any points of increased condensations.

The chromophobes present a series of extremely interesting Golgi configurations (Plate I, Fig. 6). All of these cells have a characteristic compact cap of osmiophilic substance which is limited to one side of the nucleus. This Golgi material forms either a high or low triangle. The high triangle Golgi network consists of fine strands of osmiophilic substance and appears to tend more toward fine loop formation while the low triangular form is made up of coarser strands, compactly arranged with only an occasional visible opening. Finely granular mitochondria are present in both these varieties of cells and are found to be unevenly dispersed in the narrow rim of cytoplasm surrounding the nucleus.

*Cell Counts.*

In the absence of any obvious difference between the two varieties of animals studied, it was deemed advisable to resort to the method of differential cell counts. This method should bring to light such differences in the numerical distribution of cell types which may be present and yet not be apparent under routine microscopical examination. Initial samplings of cell counts of the transitional lobes of many glands, chosen at random, were made first. Such studies yielded results which warranted a further and more careful examination of the percentages of chromophilic cells in the glands of both varieties. The transitional lobe was chosen for examination because it contained the different varieties of chromophiles in greater number.

Differential cell counts were made on the chromophilic cells of the transitional lobe of the pituitary glands of both varieties of goldfish. The animals compared were similar in weight and since they were purchased from local supply houses their ages could only be approximated. Pituitary glands removed from both sexes of each variety were studied. Care was taken to compare the glands which had been fixed and stained simultaneously, thereby eliminating any possible errors due to differences in techniques. The results of these cell counts showed that the transitional lobe of the pituitary gland in both male and female animals of the same variety, contained similar percentages of basophilic and acidophilic cells, thus indicating that the sex of the animal could be only, at best, a slightly modifying factor. The pituitary glands were removed from all the animals during a normally occurring sexually inactive period.

With the aid of an ocular counting chamber comparable areas were selected and the chromophilic cells in one hundred squares of the chamber counted. The following precautions were taken to insure a normal sampling and to minimize the possibility of selecting areas subjectively: Firstly, using low power magnification, the anterior end of the gland was always placed against the highest horizontal line of the counting chamber and the ventral surface of the gland oriented against the most lateral vertical line. Secondly, after the section to be studied had been oriented under low power, the oil immersion objective was placed in position and the cells falling within the one hundred squares were counted. Depending upon the thickness of the serial section, every third or fourth section was examined. The cell counts throughout the lobe were made at intervals of twelve micra. An average of 1,000 cells were counted from each gland. Table I gives the results of such counts.

A statistical method was used to evaluate the results obtained. Although many pituitaries were studied, only those in which every section of the gland was properly cut, mounted, and stained were used for calculation and analysis. The validity of the statistical results rests, in part, upon the perfectness and completeness of the sets of serial sections. In view of the extremely small coefficient of variation (see Table I) obtained in this work and the fact that the statistical method employed in this analysis permits the use of few determinations, seven different animals of each variety were employed. In addition, the rigid criteria of technique applied in the choice of the series used, made it expedient, without detracting from the validity of the analysis, not to increase the number of animals.

## Discussion.

The pituitary glands of the two varieties of goldfish studied in the present investigation are similar in their anatomical relationships and gross morphological subdivisions. These findings confirm the description which Bell (1938) gives for the common variety. The four different lobes described

for the goldfish are easily distinguished one from the other by their anatomical position and by their reactions to polychromatic stains. The presence of a pars nervosa, pars intermedia, pars anterior and a special portion referred to as the übergangsteil or transitional region is typical of the pituitary in all forms of fish thus far studied (Stendell, 1914; Bock, 1928; Matthews, 1936; and Bell, 1938).

The blood supply of the pituitary gland is intimately connected with the pars nervosa and no sizable vessels are found entering the gland from its surface. A similar condition has been reported by Stendell (1914) and Bock (1928) for the many form which they studied. Blood capillaries are present in the goldfish only where the nervosa fibers penetrate the substance of the gland.

TABLE I.

Differential cell counts on the transitional lobe of the pituitary gland of the goldfish.

| | Mean | S.E. | *Diff. of Means* / *S.E. of Diff.* | *Coeff. of variation* | *Number of pituitaries* |
|---|---|---|---|---|---|
| Acidophiles in Common | 45 | .54 | 9.2 | 3.1 | 7 |
| Acidophiles in Moor | 56 | 1.1 | | 5.0 | 7 |
| Basophiles in Common | 55 | .54 | 8.1 | 2.6 | 7 |
| Basophiles in Moor | 45 | 1.2 | | 6.7 | 7 |

In relation to the presence of the blood vessels in this part of the gland in the goldfish, it is interesting to note the occurrence of masses of colloid material. Herring (1908) was the first to describe colloid in the gland and he believed it to be a secretory product from one of the lobes. More recently, Matthews (1936) reported large masses of this material among the fibers of the stalk in *Fundulus*. The presence of large blood vessels in the pars nervosa of the goldfish together with Florentin's (1934) concept of a hypophyseal portal system which drains the epithelial portions of the gland, through these vessels in the pars nervosa, indicates that if secretions are poured directly into the blood stream they probably find their way into the pars nervosa. Thus, the presence of colloid between the fibers of the pars nervosa may be the result of a concentration of some secretory product and appears to support some of the earlier concepts of pituitary secretion.

Another point worthy of note in regard to the pars nervosa is its relation to the pars intermedia. In most forms, thus far reported, the nervosa is connected directly to the intermedia without coming into contact with any other portion of the pituitary gland. In the two forms of the family Cyprinidae (carp and goldfish) which have been studied, the pars nervosa must first pass through the transitional lobe before it reaches the pars intermedia.

In the cod an interesting condition exists (Herring, 1908) which may be interpreted as being intermediate between the more common arrangement and the apparently special situation occurring in the carp and its related form, the goldfish. In the cod the intermediate lobe is divided into two parts by a chromophilic band of cells and one part is invaded directly by strands of the pars nervosa while, to reach the other portion of the inter-

media, the strands of the nervosa must first go through the chromophilic band of tissue. It may very well be that this chromophilic band of tissue represents the transitional or übergangsteil portion of this gland. It should be noted in passing that recognition of that part of the pituitary did not occur until sometime after Herring's investigation (Stendell, 1913).

The cells of the intermediate lobe are described as small and taking a basic or acidic strain depending upon previous fixation. It was seen that if an osmic acid fixing solution is used the cells do not stain with acid fuchsin. Occasionally they retain some aniline blue which gives them a basophilic appearance. After the use of a non-osmic acid fixing solution these same cells stain red with acid fuchsin or eosin treatment. Gentes (1907), Herring (1908) and Matthews (1936) found that the cells in the intermediate lobe did not take any stain after the methods which they employed. Other workers, however, have reported acidophiles or basophiles and sometimes both to be present at one time. In the eel, Tilney (1911) and Stendell (1914) described small basophilic cells with clear cytoplasm. Stendell also found a few weakly staining eosinophiles present while Bock (1928) mentioned that the basophilic pars intermedia cells contained acidophilic granules in their cytoplasm. Matthews (1936) found not only acidophiles and basophiles in the intermediate lobe, but cells which took no stain and others which stained a pale lavender after azur carmine. As a result of these investigations, it can be seen that all types of cells have been reported in the intermediate lobe of the fish pituitary gland. The cells present may be of only one type or a mixture of several types. The fact that the affinity of the same cells for different stains can be modified by the type of fixing solution used has been overlooked by most workers. Uniformity in the types of fixing solutions employed is a necessary precaution before the results of different investigations can be compared.

In general, the Golgi network present in the cells of the pituitary gland of the goldfish appears to be characteristic for each epithelial lobe. In the intermediate lobe the Golgi network is present as a fine, heavily granulated structure capping the nucleus. Although the cells of the intermediate lobe are divided into granular and agranular types, the Golgi structure is the same in both forms. This may indicate that the cells are of the same kind and that the difference in granulation is due merely to phases of physiological activity. The same picture is seen in the acidophiles of the anterior lobe. The Golgi apparatus of the granular and non-granular cells, as well as that of the intermediate cell types, is exactly alike. There is a difference in the extent of blackening between the Golgi apparatus of the granular and agranular cells. On the basis of our present concept of the activity of the Golgi apparatus as related to cellular secretion, this change in stainability may be indicative of cellular activity.

The cells of the transitional lobe differ markedly among themselves in staining reaction, granulation, and in the form and position of the Golgi apparatus. The basophiles contain a Golgi network which is large, loosely arranged, free in the cytoplasm, and usually not in contact with the nucleus. The Golgi network of the acidophiles is compact, smaller, and caps the nucleus. The presence of two types of Golgi configurations in the chromophilic cells of the transitional lobe of the goldfish pituitary is a condition similar to that reported by Addison (1916), Atwell (1929) and Severinghaus (1933) for the anterior lobe of the mammal. Severinghaus (1933) has pointed out that the different Golgi structures present in the chromophilic cells can also be found in the chromophobic cells. This led him to state that the chromophobes could be divided into acidophilic chromophobes and basophilic chromophobes, suggesting that the acidophilic cells arise from the acidophilic and basophilic cells from the basophilic chromophobes. Kirkman (1937), in the guinea pig, also described two types of Golgi configurations in the chromophobes. Similarly in the present work, two types of Golgi configurations can be distinguished in the chromophobic cells of the transitional lobe. The

presence of two types of Golgi networks in the chromophobes suggests (on the basis of the work of Severinghaus), that a relationship exists between these cells and the chromophilic cells of the transitional lobe. The compact type of Golgi network in the chromophobes resembles the same structure in the acidophiles while the loose, more strandlike type can be associated with the loosely arranged, ramifying Golgi network of the basophilic cells.

From the above discussion it can be seen that the Golgi apparatus of the anterior lobe cells in the goldfish pituitary is different from that found in the cells of the transitional lobe. This may be used as added evidence in support of the contention that the cells of the transitional lobe are not related to the cells of the anterior lobe in the goldfish. The great similarity between the Golgi configurations present in the transitional lobe cells of the goldfish and the anterior lobe cells of higher forms gives a firmer basis for postulating a homology between the two lobes.

Another item of interest in the present investigation is the comparison of the pituitary glands from the two different varieties of goldfish studied on the basis of the differential counts of the chromophilic cells in the transitional lobe. A statistical analysis of these cell counts shows that a significant difference does exist in the percentages of chromophilic cells present in the transitional lobes of these two varieties. Table I shows that in the forms investigated, there are more basophilic cells present in this lobe of the common variety than are present in the same lobe of the black moor variety. This difference in cell counts may possibly be associated with the morphological differences existing in the two forms of goldfish under observation. The black moor has been shown to contain a greater number of acidophiles. These cells in the anterior lobe of the mammal are believed to be associated with growth, and changes in their number from the normal are related to abnormal changes in their morphology (Crew, 1923; Smith & MacDowell, 1930; Stockard, 1931; Cushing, 1932, a,b; and Vicari, 1937). All these workers found, after investigating a form which showed marked differences, anatomically, from others of the same species, that these differences were associated with a change in the pituitary gland. They concluded that differences in body structure may be reflections of cellular differences in the pituitary. The abnormal growth of the black moor as well as the presence of telescopic eyes and black pigmentation may also, in some way, reflect the differences in cell counts occurring in their pituitary glands.

In the goldfish, as well as in other forms examined, in which morphological differences occur, these differences in structure are not necessarily restricted to the individual animal but may be transmitted to the offspring. That is, of course, if the form being studied can survive to sexual maturity. Stockard's investigations have indicated that the inheritance of these abnormal forms, which may owe their abnormality to some changed activity of a gland in the organism, follows a definite genetic ratio.

Goldfish breeders have found that when two of the so-called fancy types of goldfish are mated, the offspring may range in form from that of the common variety to forms even more divergent, morphologically, than the parents. Many of the young are so abnormal that they die during the first few days of life. Others appear to be the common variety for several weeks and then begin to show atypical form. If this phenomenon is dependent on the glands of internal secretion, it is at this time that the glands causing the change in body types would be most apt to show the greatest variation from that found in the typical variety which undergoes no radical morphological change. If the pituitary is really the gland which is modifying body type, then an examination of that gland in the two varieties at that possible "critical" period should yield greater divergence of cell type, distribution, or number, than reported as the result of the present investigation. It is planned to obtain the necessary materials to carry out an examina-

tion of pituitaries in animals sacrificed at the "critical" periods of development.

## Summary and Conclusions.

1. Confirmation is offered for the anatomical position and relations of the goldfish pituitary gland and its morphological division into four lobes, the pars anterior, pars nervosa, pars intermedia and the transitional lobe.
2. The pars anterior contains acidophilic cells with a granular Golgi network applied to the nucleus.
3. The pars intermedia consists of both granular and agranular chromophobic cells each containing a similar granular Golgi apparatus which caps the nucleus.
4. The transitional lobe contains the following three types of cells:

   (a) A basophilic cell which contains large granules and an extensive loosely arranged Golgi network made up of fine strands and lying free in the cytoplasm.

   (b) An acidophilic cell which has a finely granular cytoplasm and contains a heavy strand Golgi network capping the nucleus.

   (c) Two varieties of chromophobes are present. Both have a scanty cytoplasm but can be differentiated by their Golgi configuration. One variety has a compact heavy Golgi apparatus while the Golgi apparatus of the other is looser and more strand-like. These cells are described as being related to the different chromophilic cells found in the transitional lobe of the gland in a way similar to that described by Severinghaus for the pars anterior of the mammal.
5. The pituitary glands of the two varieties of goldfish studied (the common and the black moor) are anatomically and histologically similar.
6. Statistical evaluation of cell counts made on the transitional lobe of both forms shows a significant difference in the proportion of chromophilic cells. The black moor contains a greater number of eosinophiles than does the common variety.
7. The morphological differences between the black moor and the common variety of goldfish may possibly be related to the differences in the proportional distribution of the different chromophilic cells in their pituitary glands.

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## EXPLANATION OF THE PLATE.

### PLATE I.

Fig. 1. Section of the pars intermedia showing the relationships of the granular and agranular cells to each other and to the invading strands of the pars nervosa. × 240 Champy. Masson stain.

Fig. 2. A group of cells from the pars intermedia showing the compact Golgi apparatus capping their nuclei. × 1350 Nassonov-Kolatchev. Masson stain.

Fig. 3. A group of cells from the pars anterior showing the granular Golgi apparatus next to the nuclei. × 1350 Nassonov-Kolatchev. Masson stain.

Fig. 4. A group of transitional lobe cells showing the large granules in the basophilic cells and the highly granular, heavily staining acidophilic cells. × 450 Champy. Masson stain.

Fig. 5. A section showing the heavy strand, compact Golgi apparatus capping the acidophilic cells of the transitional lobe. × 1350 Nassonov-Kolatchev. Masson stain.

Fig. 6. A group of chromophobic cells from the transitional lobe showing the types of Golgi apparatus present in these cells. One type is more loosely arranged and made up of thinner strands than the other. × 1350. Nassonov-Kolatchev. Masson stain.

Fig. 7. A group of basophilic cells from the transitional lobe containing a loosely arranged strand-like Golgi net in the cytoplasm of the cells. × 1350 Nassonov-Kolatchev. Masson stain (Compare with Fig. 5).

Fig. 8. A group of cells from the pars anterior showing the complete lack of cellular arrangement present here. × 600 Champy. Masson stain.

Fig. 9. A section of the gland showing the ramifications of the pars nervosa and its intimate connection with the large blood vessels of the gland. × 170 Champy. Masson stain.

FIG 1.

FIG. 2.

FIG. 3.

FIG. 4

FIG. 5

FIG. 6.

FIG. 7.

FIG. 8.

FIG. 9.

THE CYTOLOGY OF THE PITUITARY GLAND OF TWO VARIETIES OF GOLDFISH (CARASSIUS AURATUS L.).

# 5.

## Notes on Plumage Changes in the Quetzal.

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(Plate I).

On October 29, 1937, nine young Quetzals (*Pharomachrus mocinno mocinno* De la Llave) were received at the New York Zoological Park. Six were forwarded a few weeks later to the Zoological Society of London. Of the remaining three, one died on December 14, 1937, from a bacterial invasion of the lung. The second, which had suffered a wing injury before arrival, survived until June 16, 1938. The third bird, a male, lived until March 3, 1939, and it was on this specimen that the following observations were made.

Before the arrival of these birds, there appear to be no records of living specimens having reached either Europe or America. In 1914, when in San José, Costa Rica, I called on the late Señor José C. Zeledón who was closely connected with the development of Costa Rican ornithology. The discussion turned to Quetzals and I was informed that Señora Zeledón had possessed two birds of the Costa Rican form (*Pharomachrus mocinno costaricensis* (Cabanis)), at different times. Each had been kept without difficulty for six months but had been liberated in turn "because they smelled so bad." I know of no other instance of Quetzals having been kept in captivity.

The birds received at the Zoological Park had been taken from the nest in the mountains of Honduras and were hand-reared by Dr. Wolfgang von Hagen. Collections were made in July and August, the birds being still unable to fly at that time. On arrival, they checked well against the nestling plumage described by Ridgway[1] except that all showed some infusion of green in the scapulars and upper wing coverts. Since Ridgway's description was taken from a nestling of the Costa Rican form, this difference may be accounted for. In all, the bill was black, iris dark brown, feet gray-blue.

About January 1, 1938, a molt was begun by the bird under observation. By January 24, the upper plumage had become bright green, except for the head, which remained brown. The throat and upper breast were gray, scaled with green, the lower chest was clear gray, the abdomen and under tail coverts were rosy salmon. The elongated upper wing coverts reached a length of about two inches. Remiges and rectrices were not molted. The bill was black.

On March 15, it was noted that both upper and lower mandible were becoming suffused with yellow. The two bright green middle upper tail coverts, which had been growing slowly, now reached their maximum length, which was just short of the tips of the rectrices.

The brown feathers of the head began a slow process of replacement about April 15. By June 9, the change to bright green was complete,

[1] Ridgway, Robert. Birds of North and Middle America, part V, p. 737.

although the crest was but slightly developed. Yellow areas of the bill had increased, leaving only a dark spot over each nostril and at the tip of each mandible. At this stage, the bird checked closely with Ridgway's "immature male."

On July 10, a tail feather was dropped and on the 28th, another. Beginning on July 20, there was a general molting of body feathers. This continued for several days but then checked and was not resumed until about September 10. On the 16th of this month, a middle upper tail covert was dropped and was found to measure 185 mm. in total length.

By mid-October, the molt was in full swing, with body feathers, remiges and rectrices being rapidly replaced. The plumage change was complete by November 15, when the following description was taken: Upper parts golden green, crest well developed. Upper breast green, gray of lower chest interspersed with deep crimson. Vent and under tail coverts geranium red. The two middle upper tail coverts projected about three-quarters of an inch beyond the rectrices. Elongated greater wing coverts green for most of their visible length, the black bases barely discernible. Remiges black, primaries and outer secondaries edged with buff. Three inner pairs of rectrices black, three outer pairs white, the bases barred with black, white areas increasing outward. Bill clear yellow, feet pale gray-blue, iris dark brown.

This plumage appears to represent a stage intermediate between Ridgway's "immature male" and "adult male." It is quite possible that there may be further stages, since it seems unlikely that the superb beauty of the adult could be attained except by degrees. The molt of this bird is noteworthy for its almost continual progression, since there was hardly a time when change was not occurring in some part of its plumage. On the other hand, once the stage described above had been reached, on November 15, 1938, there were no changes up to the time of the bird's death on March 3, 1939.

Immediately after death, the following notes were made, measurements being in millimeters: length, to end of rectrices, 357; wing, 188; tail, 190; right middle upper tail covert, 203; left, 213; crest, 26; culmen, 16; tarsus, 16. Weight, 108 grams. Sex ♂.

## EXPLANATION OF THE PLATE.

**Fig. 1.** Nestling plumage, photographed November 18, 1937.
**Fig. 2.** First immature plumage, photographed July 5, 1938.
**Fig. 3.** Second immature plumage, front view, photographed February 20, 1939.
**Fig. 4.** Second immature plumage, rear view, photographed February 20, 1939.

FIG 1

FIG 2

FIG 3

FIG 4

NOTES ON PLUMAGE CHANGES IN THE QUETZAL

# 6.

# Deep-sea Fishes of the Bermuda Oceanographic Expeditions. Family Melanostomiatidae.[1]

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(Text-figures 1-77).

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[1] Contribution No. 580, Department of Tropical Research, New York Zoological Society. Contribution, Bermuda Biological Station for Research, Inc.

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## Introduction.

For detailed data in regard to nets, locality, dates, etc., concerning the capture of the deep-sea fishes treated in this monograph, refer to *Zoologica*, Vol. XIII, Nos. 1, 2 and 3 and Vol. XX, No. 1, pp. 1-2. For physical data, methods of measurement and general definitions of growth stages, see *Zoologica*, Vol. XVI, No. 1. For the related family Idiacanthidae, see *Zoologica*, Vol. XX, No. 4.

The majority of the drawings in the present paper are the work of Harriet Bennett; Figs. 8 and 12 are by George Swanson. For the dyeing and clearing of many specimens and for the tail drawings in Text-fig. 9 we are indebted to Gloria Hollister.

We wish to express our appreciation to the following persons for their generous cooperation in lending specimens and enabling us to examine and sex type material deposited in various museums: Dr. J. R. Norman of the British Museum; Dr. A. Vedel Tåning of the Carlsberg Foundation's Marine Biological Laboratories, Copenhagen; Dr. Clinton V. MacCoy of the Boston Society of Natural History; Dr. A. E. Parr of the Peabody Museum; Dr. William C. Schroeder of the Museum of Comparative Zoology, and Dr. Leonard P. Schultz of the U. S. National Museum.

## Summary of Important Points.

Material. The Bermuda collection of Melanostomiatidae, taken in a cylinder of water 8 miles in diameter and a mile deep, consists of 250 specimens belonging to 10 genera and 32 species. Previously known melanostomiatids number about 1,450 specimens belonging to 16 genera and, at a generous estimate, slightly less than 100 valid species. The advantages, therefore, of continued, concentrated collecting in a single, definite area of ocean are again evident, since from the Bermuda 8-mile circle have come more than 62% of all known genera and at least a third of the species taken in all seas.

In addition to the study of our own collection, we have examined (a) examples of all genera except *Opostomias* and *Pareustomias*, (b) all of the

melanostomiatids deposited on this side of the Atlantic and (c) a number of specimens on loan from abroad.

TAXONOMY. 1. The sub-division of the Stomiatoidea into Gymnophotodermi, Lepidophotodermi and Heterophotodermi, suggested by Parr in 1927, is adopted, except that the three groups are given the status of superfamilies instead of suborders.

2. Parr's family Melanostomiatidae, exclusive of the malacosteids, is maintained, the family Stomiatidae being limited to *Stomias, Macrostomias* and *Stomioides.*

3. The following genera are synonymized:

*Lamprotoxus* Holt & Byrne, 1913 = *Grammatostomias* Goode & Bean, 1895.

*Haplostomias* Regan & Trewavas, 1930 = *Melanostomias* Brauer, 1902.

*Stomiatella* Roule & Angel, 1930 (*part.*) = *Bathophilus* Giglioli, 1884, and *?Flagellostomias* Parr, 1927.

*Parastomias* Roule & Angel, 1931 = *Eustomias* Vaillant, 1888.

*Microdontostomias* Fowler, 1934 = *Stomias* Cuvier, 1817 (Family Stomiatidae).

*Pseudeustomias* Fowler, 1934 = *Stomias* Cuvier, 1817 (Family Stomiatidae).

*Photonectops* Chapman, 1939 = *Tactostoma* Bolin, 1939.

4. The following species are synonymized:

*Chirostomias lucidimanus* Beebe, 1932 = *C. pliopterus* Regan & Trewavas, 1930.

*Leptostomias problematicus* (Parr, 1927) = *L. gladiator* (Zugmayer, 1911).

*Leptostomias ramosus* Regan & Trewavas, 1930 = *L. gladiator.*

*Echiostoma ctenobarba* Parr, 1927 = *E. tanneri* Gill, 1883.

*Echiostoma guentheri* Regan & Trewavas, 1930 = *E. barbatum* Lowe, 1843.

*Echiostoma calliobarba* Parr, 1934 = *E. tanneri* Gill, 1883.

*Echiostoma ctenobarba ramifera* Parr, 1934 = *E. tanneri* Gill, 1883.

*Melanostomias bulbosus* Beebe, 1933 = *M. spilorhynchus* Regan & Trewavas, 1930.

*Melanostomias heteropogon* Regan & Trewavas, 1930 = *?M. valdiviae* Brauer, 1902.

*Melanostomias melanocaulus* Regan & Trewavas, 1930 = *?M. valdiviae* Brauer, 1902.

*Melanostomias albibarba* Regan & Trewavas, 1930 = *M. melanops* Brauer, 1902.

*Melanostomias stewarti* Fowler, 1934 = *M. valdiviae* Brauer, 1902.

*Melanostomias vierecki* Fowler, 1934 = *M. valdiviae* Brauer, 1902.

*Photonectes richardi* (Zugmayer, 1913) = *P. margarita* (Goode & Bean, 1895).

*Photonectes flagellatus* Parr, 1927 = *P. margarita* (Goode & Bean, 1895).

*Photonectes intermedius* Parr, 1927 = *P. margarita* (Goode & Bean, 1895).

*Photonectes ovibarba* Regan & Trewavas, 1930 = *P. braueri* (Zugmayer, 1913).

*Photonectes caerulescens* Regan & Trewavas, 1930 = *P. achirus* Regan & Trewavas, 1930.

*Photonectes monodactylus* Regan & Trewavas, 1930 = *P. margarita* (Goode & Bean, 1895).

*Lamprotoxus phanobrochus* Regan & Trewavas, 1930 = *Grammatostomias flagellibarba* Holt & Byrne, 1910.

*Lamprotoxus paucifilis* Regan & Trewavas, 1930 = *Grammatostomias flagellibarba* Holt & Byrne, 1910.

*Lamprotoxus angulifer* Beebe, 1932 = *Grammatostomias dentatus* Goode & Bean, 1895.

*Bathophilus alberti* (Roule & Angel, 1931) = *B. metallicus* (Welsh, 1923).

*Eustomias bibulbosus arborifer* Parr, 1927 = *E. bibulbosus* Parr, 1927.

*Eustomias bituberatus* Regan & Trewavas, 1930 = *?E. micraster* Parr, 1927.

*Eustomias schiffi* Beebe, 1932 = *E. dubius* Parr, 1927.

*Eustomias bigelowi paucifilis* Parr, 1927 = *E. bigelowi* Welsh, 1923.

*Eustomias bigelowi parvibulbus* Parr, 1927 = *E. bigelowi* Welsh, 1923.

*Eustomias dendriticus* Regan & Trewavas, 1930 = *?E. fissibarbis* Pappenheim, 1914.

*Eustomias frondosus* Regan & Trewavas, 1930 = *E. binghami* Parr, 1927.

*Eustomias satterleei* Beebe, 1933 = *E. silvescens* Regan & Trewavas, 1930.

*Eustomias triramis* Regan & Trewavas, 1930 = *?E. bigelowi* Welsh, 1923.

Other species, especially in the genera *Leptostomias* and *Eustomias*, will doubtless prove also to be synonymous.

COLOR AND LUMINESCENCE. Color notes and sketches were made from more than 100 freshly caught specimens belonging to 28 species; 10 individuals, representing 5 species, were living and their luminescence and behavior noted. This work was supplemented by observations made from the Bathysphere. Up to the present, only eight specimens in the entire family had been studied when freshly caught or recently preserved.

SEXUAL DIMORPHISM. In the majority of genera the postorbital light organ is almost or completely atrophied in adult females. Striking sexual differences are found in the barbels of *Eustomias;* similar differences are suspected in other genera. The importance of sexing type specimens in this family is obvious.

DEVELOPMENT. Larvae and post-larvae of the following species have been identified for the first time: *Flagellostomias boureei, Leptostomias gladiator, Melanostomias spilorhynchus, Melanostomias biseriatus, Photonectes parvimanus, Grammatostomias flagellibarba, Bathophilus brevis, Bathophilus metallicus, Bathophilus* near *longipinnis, Bathophilus* sp., *Eustomias bibulbosus, Eustomias dubius, Eustomias* spp. In addition, our collection includes adolescents of most other species taken by the Bermuda Expeditions. This material has been sufficient for the tabulations of family and generic juvenile characters.

A number of recorded species prove synonymous with others due to their being based on juvenile characters, such as partly developed barbels. Dissection alone can determine whether or not a specimen is wholly adult, with well developed gonads, fully pigmented stomach of relative length typical of the genus, and hour-glass-shaped centra.

SPECIAL CHARACTERISTICS. In the comparison of the form and development of various parts of the body in the different genera, certain structures have proved to be of unexpected phylogenetic or taxonomic importance. Among the most interesting are the form and distribution of gill-teeth in adults, the presence of spiny gill-rakers in larvae and post-larvae, the variation of larval pigment patterns and the development of the eye. Probable relationships of the genera to each other and to adjacent families are discussed.

VERTICAL DISTRIBUTION. As with most families of Bermuda deep-sea fish, the depths at which these fish are taken are greater than the average in other areas, practically none except very young melanostomiatids having been taken above 500 fathoms, although they were seen above this level from the Bathysphere.

### Suborder Stomiatoidea.

*Characteristics*: Oceanic isospondyls differing from the Clupeoidea and Salmonoidea in the presence of photophores, which are arranged typically in a double series along the abdomen and in a single series above the anal fin.

*Discussion*: It should now be generally agreed that the suborder Stomiatoidea be divided into eight families, namely, the Gonostomatidae, Sternoptychidae, Chauliodontidae, Stomiatidae, Astronesthidae, Melanostomiatidae, Malacosteidae and Idiacanthidae.

In 1927 (p. 1) and 1930 (p. 136), Parr proposed separating the smooth-skinned members of the old family Stomiatidae (including the malacosteids) from the scaly *Stomias* and placing the former in a family of their own, Melanostomiatidae. This new family he grouped with the other smooth-skinned stomiatoids, the Astronesthidae and Idiacanthidae, in a new suborder, Gymnophotodermi. A second suborder, Lepidophotodermi, was proposed to include the Stomiatidae proper (*Stomias* and *Macrostomias*) and, provisionally the Chauliodontidae. A third suborder, Heterophotodermi, was suggested to embrace the Gonostomatidae and Sternoptychidae.

Regan and Trewavas, on the other hand, in the *Dana* "Fishes of the Families Stomiatidae and Malacosteidae" (1930) employed the old classification, including *Stomias* (as an aberrant genus), *Idiacanthus*, and all the smooth-skinned fishes with posterior vertical fins and complete floors to their mouths in the single family Stomiatidae. The malacosteids were treated as a separate family.

From our own studies we draw the following conclusions:

1. Parr's three suborders, the Gymnophotodermi, Lepidophotodermi and Heterophotodermi, are valid and useful subdivisions of the stomiatoid isospondyls. However, since the apparently quite natural group of Stomiatoidea as defined on the preceding page is generally regarded as a suborder of the order Isospondyli, we propose that each of Parr's three divisions be given the rank of superfamily instead of suborder.

2. Parr's family Melanostomiatidae (excluding *Malacosteus*, *Aristostomias* and *Photostomias*), should unquestionably be maintained.

3. The three genera just mentioned, along with the more recent genus *Ultimostomias* described by Beebe in 1933, should form the family Malacosteidae, as suggested by Regan and Trewavas (1930).

4. The family Idiacanthidae should be maintained, due chiefly to its exceptional life-history (Beebe, 1934.1).

5. The family Stomiatidae should be limited to *Stomias*, *Macrostomias*, and *Stomioides* Parr, 1933.

### Superfamily Gymnophotodermi.

*Characteristics*: Naked Stomiatoidea with black skin, large mouths, barbel (except in *Malacosteus*), postorbital luminous organ present at least in males, serial photophores developed on branchiostegal membranes and isthmus as well as in the usual lateral and ventral rows on each side (vestigial in *Malacosteus* and *Bathophilus brevis*); these organs lacking lumen or duct; smaller organs usually scattered on skin. Parietals small and well separated or absent; orbitosphenoid absent; opisthotic absent; entopterygoid membranous or very thinly ossified; preoperculum slender; vertebral centra thin cylinders of bone enclosing notochord; parapophyses and at least anterior neural arches not ankylosed with centra; parapophyses with pleural ribs; epipleurals present or absent; epineurals present. Long caecal stomach present, giving off a short arm anteriorly which opens into the usually straight intestine.

*Key to the families*:

A. Dorsal fin not confined to caudal peduncle.
  B. Dorsal fin short, ending before anal origin....Astronesthidae.
  BB. Dorsal fin very long, extending almost to caudal base ..... Idiacanthidae.

AA. Dorsal fin confined to caudal peduncle.
  C. Lower jaw and hyoid arch joined by a membrane, forming a floor to the mouth..... .....Melanostomiatidae.
  CC. Lower jaw and hyoid arch not joined by a membrane, the symphysis and hyoid being connected only by a muscular cord ..... .....Malacosteidae.

## Family Melanostomiatidae.

### A. Taxonomic Discussion.

Thirty-two generic names have been proposed for fishes referred to this family, or to naked fishes of the old family Stomiatidae. Of these we recognize 16 as valid. In chronological order, the 32 names, along with their present standing and the type species, are as follows:

1. *Echiostoma* Lowe, 1843. Valid. Type: *E. barbatum* Lowe, 1843.

2. *Opostomias* Günther, 1878. Valid. Type: *O. micripnus* Günther, 1878.

3. *Pachystomias* Günther, 1878. Valid. Type: P. *microdon* Günther, 1878.

4. *Lucifer* Doderlein, 1882. = *Photonectes*. Name given by Günther, 1887, because *Lucifer* preoccupied. Type: *Lucifer albipinnis* Doderlein, 1882.

5. *Hyperchoristius* Gill, 1883. = *Echiostoma*. Synonymized by Parr, 1927. Type: *H. tanneri* Gill, 1883.

6. *Bathophilus* Giglioli, 1884. Valid. Type: *B. nigerrimus* Giglioli, 1884.

7. *Photonectes* Günther, 1887. Valid. Type: *P. albipinnis* (Doderlein, 1882).

8. *Eustomias* Vaillant, 1888. Valid. Type: *E. obscurus* Vaillant, 1888.

9. *Grammatostomias* Goode & Bean, 1895. Valid. Type: *G. dentatus* Goode & Bean, 1895.

10. *Dactylostomias* Garman, 1899. = *Bathophilus*. Synonymized by Parr, 1927. Type: *B. filifer* Garman, 1899.

11. *Melanostomias* Brauer, 1902. Valid. Type: *M. valdiviae* Brauer, 1902.

12. *Leptostomias* Gilbert, 1905. Valid. Type: *L. macronema* Gilbert, 1905.

13. *Neostomias* Gilchrist, 1908. = *Eustomias*. Synonymized by Parr, 1927. Type: *E. filiferum* Gilchrist, 1908.

14. *Nematostomias* Zugmayer, 1911. = *Leptostomias*. Synonymized by Parr, 1927. Type: *N. gladiator* Zugmayer, 1911.

15. *Trichostomias* Zugmayer, 1911. = *Bathophilus*. Synonymized by Parr, 1927. Type: *T. vaillanti* Zugmayer, 1911.

16. *Gnathostomias* Pappenheim, 1911. = *Bathophilus*. Synonymized by Parr, 1927. Type: *G. longifilis* Pappenheim, 1911.

17. *Lamprotoxus* Holt & Byrne, 1913. = *Grammatostomias*. Synonymized in present paper; see below. Type: *L. flagellibarba* (Holt & Byrne, 1910).

18. *Flagellostomias* Parr, 1927. Valid. Type: *F. tyrannus* Parr, 1927. = *F. boureei* (Zugmayer, 1911).

19. *Chirostomias* Regan & Trewavas, 1930. Valid. Type: *C. pliopterus* Regan & Trewavas, 1930.

20. *Trigonolampa* Regan & Trewavas, 1930. Valid. Type: *T. miriceps* Regan & Trewavas, 1930.

21. *Thysanactis* Regan & Trewavas, 1930. Valid. Type: *T. dentex* Regan & Trewavas, 1930.

22. *Haplostomias* Regan & Trewavas, 1930. = *Melanostomias*. Synonymized in present paper; see below. Type: *H. tentaculatus* Regan & Trewavas, 1930.

23. *Odontostomias* Norman, 1930. Valid. Type: *O. micropogon* Norman, 1930.

24. *Stomiatella* Roule & Angel, 1930 (*part.*). = *Bathophilus* (larva) and *Flagellostomias* (larva). Synonymized in present paper (pp. 74, 75).

25. *Stylophthalmella* Roule & Angel, 1930 (*part.*). = *Eustomias* (larva). Synonymized in present paper (p. 75).

26. *Pareustomias* Bailly, 1930. Probably valid, although apparently very close to *Eustomias*. Type: *P. chabanaudi* Bailly, 1930.

27. *Parastomias* Roule & Angel, 1931. = *Eustomias*. Synonymized in present paper. Type. *P. tetranema* (Zugmayer, 1911).

28. *Elapterostomias* Fowler, 1934. = *Borostomias*, family Astronesthidae. Synonymized by Myers, 1935 (in footnote, p. 2).

29. *Microdontostomias* Fowler, 1934. = *Stomias*, family Stomiatidae. Synonymized in present paper; see below.

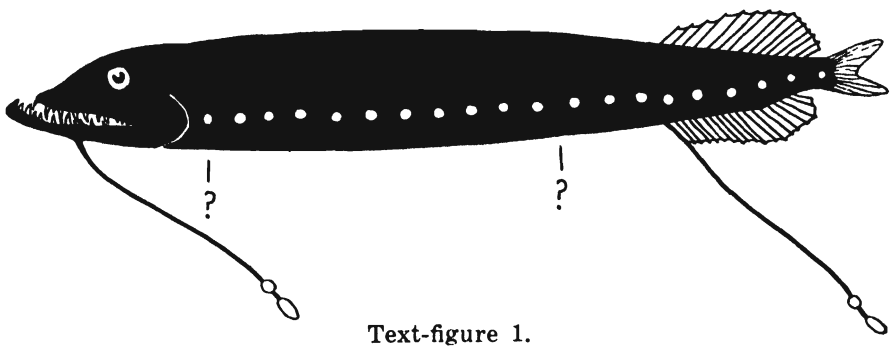
30. *Pseudeustomias* Fowler, 1934. = *Stomias*, family Stomiatidae. Synonymized in present paper; see below.

31. *Tactostoma* Bolin, 1939. Valid. Type: *T. macropus* Bolin, 1939.

32. *Photonectops* Chapman, 1939. = *Tactostoma* Bolin, 1939, the latter genus having priority by a few weeks. Type: *P. multipunctata* Chapman, 1939, probably synonymous with *T. macropus*.

The systematic position of the six-foot fish *Bathysphaera* Beebe, 1932, described from a specimen observed from the Bathysphere off Bermuda, is of course still uncertain, since no specimen has yet been taken. That it is a stomiatoid, near the Melanostomiatidae, seems certain, but in all probability it does not belong in this family, and is therefore omitted from systematic treatment in the present paper. For reference, however, we include herewith a copy of the type description:

"On the twentieth dive in the Bathysphere, at a depth of 2100 feet, we saw two large, elongate, barracuda-shaped fish, which twice passed within eight feet of the windows, once partly through the beam of our electric light. These were at least six feet in length.




Text-figure 1.

*Bathysphaera intacta*. Actual length about 6 feet. Numbers of photophores and finrays approximate.

"No direct lights were visible on the head, yet the rather large eye and the faint outline were distinct. There was a single row of strong, pale blue lights along the side, large and not far from twenty in number. The mouth, with strongly undershot jaw, and numerous fangs was illumined either by mucous or indirect internal lights along the branchiostegals.

"The fish reminded me in general of barracudas, with deeper jaws open all the time. Posteriorly placed vertical fins were seen when they passed through the electric beam. There were two ventral tentacles, each tipped with a pair of separate, luminous bodies, the superior reddish, the lower one blue. These twitched and jerked along beneath the fish, one undoubtedly arising from a mental base, the other so far back that its origin must have been at the anal fin. Neither the stem of the tentacles nor paired fins were distinguishable.

"I assume from the position of the vertical fins and the general facies, that the position of the fish must be somewhere near the Melanostomiatidae, but the single line of large, lateral photophores and the two ventral tentacles set it apart from any known species or genus.

"The depth was 2100 feet, the date September 22nd, 1932, the position 32°17′ No. Lat., 64°36′ West Long., 5 miles southeast of Nonsuch Island, Bermuda.

"Relying on this recognizable diagnosis I propose for it the name of *Bathysphaera intacta*, the Untouchable Bathysphere Fish." (Beebe, 1932.2 pp. 175-177).

We have compared specimens of *Lamprotoxus* with the type of *Grammatostomias dentatus* at the United States National Museum, and found the two genera to be unquestionably synonymous. For a detailed discussion, see p. 185.

Through the kindness of Dr. Norman, we have been able to examine a specimen of *Haplostomias* Regan & Trewavas from the British Museum. In view of the very slight differences between this genus and *Melanostomias*, compared with the large differences between these genera and their nearest relatives, we have little hesitation in synonymizing these two groups. (See p. 143.)

At the United States National Museum we have also examined the type specimens of *Microdontostomias* and *Pseudeustomias*. In his descriptions (1934) Fowler does not mention that both of these fish have the hexagonal scales of *Stomias*. They are, in fact, both clearly members of that genus. *Microdontostomias orientalis*, the type and unique species, is close to or identical with *Stomias nebulosus* Alcock. It is likely that a third barbel filament, which would make the synonymy certain, has been broken off. Similarly, *Pseudeustomias myersi*, the type and unique specimen, belongs unquestionably in the *elongatus-valdiviae-affinis* group of the genus *Stomias* (see Parr, 1934). The barbel bulb, instead of terminating in a single filament, as is stated in the description, ends in three of about equal length, as is usual in the genus. The figures (Fowler, *loc. cit.* figs. 21 and 22) of both the proposed genera are inexact in regard to the general appearance of the fish, since both specimens have the pronounced slenderness and strongly curved jaws characteristic of *Stomias*.

In regard to the advisability of dividing *Eustomias* into two or more genera, we agree with Regan and Trewavas that cleancut divisions cannot be made; also the groups of species are so much closer to one another than they are to other genera that any division seems wholly inadvisable. Therefore, we do not accept the proposal of Roule and Angel (1931) that the name *Parastomias* be given to the species which have branched barbels. (See p. 210.)

In addition to the 10 genera of Melanostomiatidae taken by the Bermuda Expeditions, we have examined specimens of *Trigonolampa, Odontostomias, Thysanactis, Haplostomias* (which we synonymize with *Melanosto-*

*mias*) and *Tactostoma* (the type of *Photonectops;* examination superficial). This leaves *Opostomias* and *Pareustomias* as the only valid genera which we have not examined; both are known from unique types.

A key to the genera of Melanostomiatidae as now understood will be found on page 109.

### B. Family Characters in Brief.

Gymnophotodermi, usually elongate and little compressed, with very short caudal peduncle, to which the vertical fins are entirely confined; lower jaw and hyoid arch joined by a membrane, forming a floor to the mouth; teeth in jaws highly developed, often depressible; premaxillary almost always with a small, anterior ascending process; maxillary usually much longer than premaxillary, forming posterior part of upper margin of mouth, and usually furnished with normal, erect teeth anteriorly and oblique denticles posteriorly; vomer with or without teeth; palatine usually toothed; gill-arch teeth usually present, often in pairs or groups; a series of teeth, usually strong, on third and fourth pharyngobranchials (= upper pharyngeals); branchiostegals 8 to 22; pectorals well developed, reduced or absent; pelvics typically of seven rays, their insertion usually at or behind middle of body, rarely in front of it; caudal fin very short, forked, the ventral lobe the longer; adipose fin absent except in *Chirostomias;* no pseudobranchiae; special grooves for barbel and pectoral fins often present.

Skeleton moderately well developed, the jaws always more strongly ossified than any other portion of the body. Mesethmoid with or without lateral process; frontals united by suture; parietals present or absent; hyomandibular and quadrate forming with the jaw an angle of 45 degrees or less; one supramaxillary; opercular apparatus weak, reduced or rudimentary; hyoid and branchial apparatus well developed; pectoral girdle moderately or feebly developed; post-temporal present or absent; upper and lower coracoids always present, mesocoracoid sometimes absent, all 3 elements often reduced; actinosts often reduced; caudal fin alone strongly supported; vertebrae moderately numerous, 35 to 82, an average number being around 60; anterior vertebrae usually more or less modified, permitting free movement of head.

Usually two pyloric caeca; gonads dorsal.

Sexual dimorphism usually apparent in development of postorbital photophore, sometimes in form of barbel.

*Size*: The largest known melanostomiatid is the unique specimen of *Opostomias*, measuring 380 mm. in length. The size records in the remaining genera are as follows: *Echiostoma*, 355 mm., (375 mm. when fresh); *Photonectes*, 340 mm.; *Odontostomias*, 290 mm.; *Tactostoma*, 280 mm.; *Leptostomias*, 270 mm. (285 mm. when fresh); *Melanostomias*, 242 mm.; *Trigonolampa*, 223 mm.; *Flagellostomias*, 222 mm.; *Grammatostomias*, 206 mm.; *Chirostomias*, 205 mm.; *Eustomias*, 204 mm.; *Pachystomias*, 165 mm.; *Bathophilus*, 140 mm.; *Thysanactis* 139 mm.; *Pareustomias*, 62 mm.

The specimens listed above of *Echiostoma, Leptostomias, Melanostomias, Grammatostomias* and *Chirostomias* were taken by the Bermuda Expeditions.

In *Leptostomias, Flagellostomias* and *Thysanactis*, at least, and doubtless in other genera as well, no fully adult specimens have been taken. Judging from this fact and from the number of melanostomiatids more than a foot long which were seen from the Bathysphere, it is probable that larger specimens of these swiftly swimming fishes escape the net. The largest *Echiostoma, Photonectes* and *Melanostomias*, however, were definitely in breeding condition, while others near the lengths given in the above paragraph had well developed gonads.

Larva, as far as known, moderately elongate, translucent, with the

posterior, unpaired fins of the adult; no yolk sac but a gut hanging below myomeral body and extending as a free tube beyond the anal fin; pigment spots usually present in a longitudinal series just below the dorsal mid-line, sometimes in additional rows above and/or below the lateral mid-line; temporary, small teeth present in jaws, and temporary gill-rakers, often bristling with minute spines, usually present; larval pectoral pad with raylets always present, even when pectoral is much reduced or absent in adult.

The family characters given above will be discussed in detail, after a general account of development.

### C. Development.

History and Taxonomy: Thanks to Lo Bianco, Jespersen & Tåning, Ege, Sanzo, Regan & Trewavas, Roule & Angel, and Beebe, developmental stages of a number of representative stomiatoids have been recognized and described. In some cases, complete series have been obtained; in others, only one or two stages, known from single specimens, have so far been identified. Exclusive of the Melanostomiatidae, the stomiatoid genera of which one or more juvenile stages have been identified include the following: the gonostomids *Gonostoma, Cyclothone, Maurolicus, Ichthyococcus* and *Vinciguerria;* the sternoptychids *Argyropelecus* and *Sternoptyx; Stomias; Chauliodus;* one or two astronesthids; a questionable *Malacosteus;* and *Idiacanthus.* Representative references are included in the bibliography.

Sanzo's (1931) account of *Chauliodus* is especially complete, since he succeeded in raising a larva from the last three days in the egg through the thirteenth day after hatching, at which stage it was apparent that the little fish was identical with a free-swimming larva taken at the surface. The latter specimen, in turn, unquestionably formed a link with older *Chauliodus* in which generic characters were well established. Sanzo's evidence for the continuity of the series is convincing, and of great interest to us in our study of the Melanostomiatidae, since *Chauliodus* is the most closely related genus of which the egg and pre-larva have been identified.

On the other hand, very little previous work has been done on the larvae of the Melanostomiatidae. In 1914 Sanzo (pp. 1-12) described the first known larval melanostomiatid, *Bathophilus nigerrimus.*

In 1930 Regan and Trewavas (p. 73) stated that Regan's larva described in 1916 (p. 136) as *Stylophthalmus macrenteron* was in all probability a larval *Eustomias.* They described briefly a number of similar young *Eustomias* from the *Dana* collection, including some metamorphosing and juvenile forms which could be subgenerically and sometimes specifically identified. Parr, in 1927, described as new species two immature *Eustomias* (adolescents) and Regan and Trewavas in the same *Dana* collection found a number of specimens belonging to other genera which could be specifically identified, or described, although they had juvenile characters remaining. It may also be remarked here that a majority of the *Dana* melanostomiatids, as well as those of other collections including our own, are immature—that is, in the transitional adolescent stage, in which most or all of the external characteristics of adults are present, but with immaturity apparent internally. These advanced specimens, however, obviously shed little light on the characteristics of early stages in the family.

In 1930 Roule and Angel described and figured a number of stomiatoid larvae under the general names of *Stomiatella* and *Stylophthalmella,* suggesting, where possible, their systematic positions. Thanks to our additional material, we are able to contribute further suggestions in regard to the identity of these larvae.

*Stomiatella* A Roule & Angel (1930, p. 14; pl. I, fig. 6): We agree with the authors and with Sanzo (1930, p. 89), that this larva should be referred to *Bathophilus.* We do not, however, agree with Sanzo that it is

*B. nigerrimus*, providing that the pelvic fin is shown correctly in the figure, since it is much too far forward and too high. Comparison with Sanzo's own figures of *B. nigerrimus* larvae (1931, pl. vii, figs. 7, 8) will show the difference. If the fin of Roule and Angel's specimen is accurately shown, it is very likely that this fish is *B. brevis* Regan & Trewavas, 1930.

*Stomiatella* D Roule & Angel (1930, p. 17; pl. I, figs. 10, 11): Roule and Angel suggest that both these larvae may be young *Malacosteus niger* Ayres. We agree that the specimen shown in their Fig. 11 should in all probability be referred to this species. We are certain, however, that their Fig. 10 represents a quite different form and belongs to some genus of Melanostomiatidae. Myomere counts are not given, but from the number shown in the figure (about 70 to the end of the anal), the distribution of the pigment, and the general facies, it appears very likely that the specimen should be referred to *Flagellostomias* or a closely related genus (cf. our Text-fig. 47).

*Stylophthalmella* B Roule & Angel (1930, p. 52; pl. III, figs. 62, 63): This larva almost certainly belongs to the genus *Eustomias*.

*Stylophthalmella* D Roule & Angel (1930, p. 53; pl. III, figs. 66, 67, 68): This larva remains a puzzle, and should be remembered by subsequent workers on the Melanostomiatidae and Malacosteidae, since in all probability it belongs to one or the other of those families.

The other *Stylophthalmella* larvae, as has already been pointed out (Beebe, 1934, p. 155) include argentinids (bathylagids), but no *Idiacanthus*. *Stylophthalmella* C (*loc. cit.*, p. 52, pl. III, figs. 64, 65) may be *Chauliodus* (cf. Sanzo, 1931, p. 82, pl. VI).

The most recent study of melanostomiatid larvae is by Sanzo who redescribes and figures early stages of *Bathophilus nigerrimus*, the only species of the family known to occur in the Mediterranean (1931, p. 89; pl. VII).

In the summary, up to the present time the only larvae and post-larvae of the Melanostomiatidae (as defined in the present paper) have been *Bathophilus nigerrimus*, *B. brevis?*, *Flagellostomias?* and *Eustomias* ssp.

PRESENT MATERIAL: To this list we add the following forms, of which larvae, post-larvae or both have been taken by the Bermuda Oceanographic Expeditions:

*Flagellostomias boureei*: larvae and post-larvae.
*Leptostomias gladiator*: larvae and post-larvae.
*Melanostomias spilorhynchus*: larva and post-larva.
*Photonectes parvimanus*: larva and post-larva.
*Grammatostomias flagellibarba*: post-larva.
*Bathophilus brevis*: post-larva.
*Bathophilus*, near *longipinnis*: larva.
*Bathophilus metallicus*: post-larva.
*Bathophilus* sp.: larva.
*Eustomias bibulbosus*: post-larva.
*Eustomias dubius*: post-larva.
*Eustomias* (*Nominostomias*) spp.: post-larvae.
*Eustomias* (*Dinematochirus*) spp.: post-larvae.
*Eustomias* spp.: larvae.

Only three of the ten genera of Melanostomiatidae taken by the Bermuda Expeditions are not represented in the collection by either larvae or post-larvae, namely, *Chirostomias*, *Pachystomias* and *Echiostoma*. We have, however, adolescent specimens of *Chirostomias* and young transitional adolescent specimens of every genus. Thanks to borrowed specimens, we have found under the skin remains of larval pigment spots in the genera *Odontostomias* and *Echiostoma* which will aid in the identification of the larvae of these genera in the future. (Text-fig. 2).

DIVISION OF DEVELOPMENTAL PERIOD INTO GROWTH STAGES: The growth stages of Stomiatoidea in general and Melanostomiatidae in particular fall easily into our accepted classification of larvae, post-larvae, adolescents and adults (see Beebe, 1933.3, p. 7; 1934.1, p. 158 ff.; Beebe & Crane, 1936, p. 80; 1937, p. 357).

In addition, the prelarval stage is more clearly defined in the Stomiatoidea than in the other groups we have previously studied, although no pre-larval melanostomiatids have been found in our collection. Roule & Angel (1930, p. 6) define the stage succinctly as the one immediately following hatching, often characterized by temporary traits which rapidly disappear. Their conception of larvae, post-larvae (*hemi-larves*), and adolescents (*alevins*), drawn from the work of their predecessors as well as from their own experience, corresponds well with our own, which will be redefined relative to the Stomiatoidea in succeeding pages. It seems that at last the unfortunate confusion in the nomenclature of the growth stages of fishes, and the definition of the boundaries of these stages, is becoming a thing of the past.

In spite of the number of stomiatoid young which have been previously described, there has been as yet no effort to characterize the larvae of the group as a whole, and this we propose to do, showing at the same time likenesses and differences of the young of the superfamily Gymnophotodermi, including the family Melanostomiatidae, to those of other stomiatoids. In this study of the young the importance of the recognition of the group Gymnophotodermi has become especially apparent.

DIAGNOSTIC CHARACTERISTICS OF STOMIATOID GROWTH STAGES: From a study of the published records discussed above and from our own material we find that the known early stages of all Stomiatoidea have in common the following characters: (1) transparency, or at least, translucence when freshly caught; (2) a somewhat compressed but non-leptocephalic body; (3) moderate to extreme slenderness; (4) well-developed finfolds; (5) a lack of pigment except for a few evanescent spots which, varying with the group are of great taxonomic importance; (6) with few exceptions, a large number of myomeres; (7) the early disappearance of the yolk sac, during the pre-larval stage; (8) the occurrence of a period, usually absent in the pre-larva and confined wholly to the larva, when the eyes are elongate and rotated more or less forward. This combination of characters does not seem to occur in the development of any other group of fishes.

The diagnostic characteristics of the various growth stages of Stomiatoidea in general and of Gymnophotodermi and Melanostomiatidae in particular are as follows:

### 1. PRE-LARVA.

*Stomiatoid Characters*: Yolk sac present throughout most of stage; special pre-larval pigment often present; teeth lacking; eye round; pectoral pad present; dorsal, anal and pelvic completely lacking.

*Gymnophotodermid Characters*: (Not known).

### 2. LARVA.

*Stomiatoid Characters*: True yolk sac absent, but intestine not yet enclosed by myomeres; typical larval pigment spots usually present; temporary larval teeth usually present; eye small, elongate, rotated forward; dorsal and anal appearing; pelvic rudiment usually appearing toward end of stage. A period of growth.

*Gymnophotodermid Characters* (Present in known larvae of Astronesthidae, Melanostomiatidae, Malacosteidae and Idiacanthidae): End of gut prolonged beyond anal origin, sometimes more than a third the total length

of the body; pigment in longitudinal series of spots, along full length of body, rarely absent; head strongly inclined; barbel absent; rudiments of photophores appearing at end of stage; temporary, small teeth present in jaws; temporary gill-rakers present or absent; these teeth and gill-rakers both reach their maximum development late in the stage; larval pectoral pad with a continuous frill of undifferentiated rays always well developed, even when pectoral is much reduced or absent in adult; dorsal and anal clearly visible in their normal positions, although some of the rays are often not developed (especially the anterior anal rays in fishes where this fin originates before the dorsal; and the anterior dorsal rays of *Idiacanthus*); finfolds usually very high in early part of stage, but dwindling as post-larval stage is reached; stomach absent.

The larvae of the family Melanostomiatidae may be distinguished from those of other gymnophotodermids by use of the following key:

A. Dorsal fin ending before anal origin — Astronesthidae.

AA. Dorsal and anal opposed, confined to caudal peduncle.

B. Eyes stalked; larval gill-rakers absent — Idiacanthidae.

BB. Eyes not stalked; larval gill-rakers present.

C. Pigment sparse or absent — Malacosteidae.

CC. Pigment spots almost always present in longitudinal series immediately below dorsal mid-line and sometimes in additional row or rows below the lateral mid-line — Melanostomiatidae.

It will be observed that the distinction between malacosteid and melanostomiatid larvae is not satisfactory; this is because, save for the specimen of *Malacosteus?* described by Roule and Angel (1930, pl. I, fig. 11) and for several transitional larvae and early post-larvae in the present collection of *Photostomias* and *Aristostomias* (an account of which will be published at a future date), the young of the family are unknown.

### 3. Post-larva.

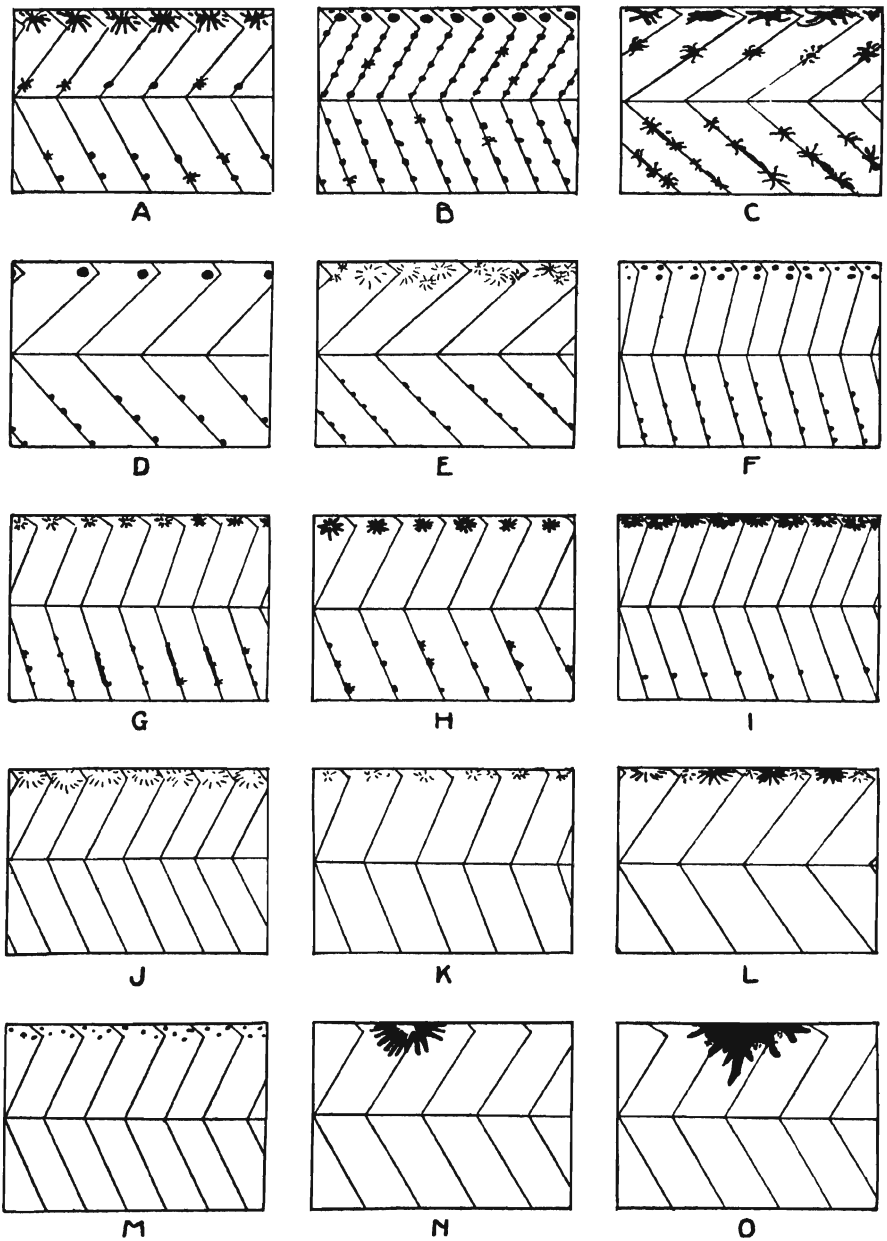
*Stomiatoid Characters*: Intestine partly enclosed by myomeres; larval pigment spots remaining; general body pigment appearing; light organs appearing; eye once more becoming round, directed laterally; all fins present, but rays not completely differentiated, nor full relative length attained; traces of finfolds remaining. A period of metamorphosis, often accompanied by shrinking in length.

*Gymnophotodermid Characters:* End of gut protruding only as a papilla; larval pigment spots remaining under the developing, lightly pigmented epidermis, sometimes more distinct and numerous than in larvae; depth greatest toward middle of length instead of at shoulder; barbel a stump; serial photophores well developed; larval teeth absent, but larval gill-rakers remaining throughout all or most of stage; permanent teeth and gill-arch teeth not yet apparent, or very rudimentary; caudal fin relatively larger than in larva or adult; stomach a papilla on wall of intestine.

Thanks to the presence of photophores and relatively well-developed fins in this and succeeding stages, melanostomiatid larvae can be easily distinguished from those of related families and referred to their proper genus.

### 4. Adolescent.

*Stomiatoid Characters:* Intestine completely enclosed in body cavity; larval pigment spots disappear during this stage; pigment, light organs, proportions and internal organs all gradually approaching adult conditions; fin rays fully developed, except, sometimes, in the case of highly specialized




Text-figure 2.

Pigment patterns of young Melanostomiatidae. Each diagram represents a typical series of myomeres from near the middle of the body, the upper and lower boundaries being, respectively, the dorsal mid-line and the upper level of the lateral serial photophores. A, *Leptostomias gladiator*, larva, standard length 14 mm.; B, same, post-larva, standard length 42 mm.; C, *Odontostomias microgogon*, transitional adolescent, standard length 42 mm. (pattern subdermal); D, *Melanostomias spilorhynchus*, post-larva, standard length 24 mm.; E, *Photonectes parvimanus*, larva, standard length 26 mm.; F, same, post-larva, standard length 25 mm.; G, *Photonectes braueri*, late adolescent, standard length 25 mm. (pattern subdermal); H, *Echiostoma tanneri*, adolescent, standard length 25 mm. (pattern subdermal); I, *Flagellostomias boureei*, post-larva, standard length 34 mm.; J, *Grammatostomias flagellibarba*, adolescent, standard length 80 mm.; K, *Bathophilus* sp., larva, standard length 7 mm.; L, *Bathophilus* sp., near *longipinnis*, larva, standard length 11 mm.; M, *Bathophilus metallicus*, post-larva, standard length 29 mm.; N, *?Eustomias* sp., larva, standard length 12 mm.; O, *Eustomias* sp., larva, standard length 13 mm. C, G and J, from specimens in the *Dana* collection of the British Museum; remainder from present collection.

fins, the details of which are gradually differentiated during this stage; caudal fin still relatively larger than in adult; finfold absent. The latter part of adolescence, which as in many fishes apparently lasts a long time, is conveniently referred to as "transitional adolescence"; it is characterized by the fish's being externally almost or completely adult in appearance, its immaturity being attested only by its size and undeveloped gonads, and by the incomplete development of any or all of the following characters: minute details of light organ and tooth development, skeleton (especially in form of vertebrae) and digestive organs. The entire period of adolescence is marked by growth.

*Gymnophotodermid Characters:* End of gut completely enclosed; subdermal larval pigment spots become reduced and vanish; barbel short and roughly formed; permanent teeth on both jaws and gill-arches growing slowly; stomach short, its pigment lacking or incomplete.

The transitional adolescent is especially well marked in this group, having completely developed external pigment, proportions and light organs, and the barbel more or less perfectly formed. This stage is sometimes reached when the fish is very small—at 18 mm., for example, in certain species of *Photonectes*. Immaturity, however, in the form of slightly developed gonads; few maxillary teeth; short, partially pigmented stomach; and often a different barbel, is shown as usual. Sometimes, too, immaturity is shown in the slow development of the specialization of an organ, such as a luminous or elongate pectoral fin. These transitional adolescents form by far the greater part of our collection, and it would seem that these fish are designed to win through to the safety of an adult external appearance as soon as possible.

IDENTIFICATION OF MELANOSTOMIATID LARVAE: We have found the following characters to be of the most diagnostic value in the identification of melanostomiatid larvae:

1. *Number of Myomeres*: These are counted only to the end of the anal fin, since in most cases the few segments occurring behind this point are too ill-defined to count. The myomere count thus gained is between one and four more than the vertebral count of the grown fish, and usually three to six more than the number of ventral serial photophores between pectoral origin and caudal base. Unlike the myomeres of some fish, such as nemichthyid eels, the full number found in the adult is present even in young larvae.

2. *Myomeres from Nape to Pelvic Rudiment*: The pelvic bud can often be detected by careful manipulation of lighting while it is still subdermal. The number of myomeres between the nape and this point, is of course, roughly equivalent to the number of vertebrae and to the future number of photophores in the P-V series; usually the count is two to four more than the photophore count.

3. *Myomeres from Pelvic Rudiment to Anal Origin*: The count will roughly equal the future number of photophores in the V-A series, minus, of course the number of organs in the series above the anal fin, and to the number of corresponding vertebrae.

4. *Pigment*: Although, next to myomere counts, the pigment pattern is the most persistent of larval characters, it must always be used only as a partial guide, since almost identical pigment patterns are sometimes found in closely related genera (e.g., *Melanostomias, Echiostoma* and *Photonectes*), while in others the arrangement of spots differs between species of the same genus (e.g., *Eustomias*) and in still other cases certain chromatophore rows are found in post-larvae which are absent in larvae of the same species (e.g., *Leptostomias*).

5. *Larval Teeth*: The larval teeth, since their appearance, growth and disappearance are all confined to this single growth stage, are not a good

identification character. We can see apparent differences between genera, but the material at present is far too scanty to make up a table of frequencies.

6. *Larval Gill-rakers*: Their number and form are a useful secondary check in larvae of doubtful position.

7. *Dorsal and Anal Fin Counts*: Except in the youngest larvae, approximate counts can be made, which either fall within, or slightly below, the generic or specific limits.

8. *Anal Origin with Reference to that of the Dorsal*: This character is very useful; it must always be remembered in using it that in larvae the anal origin usually is slightly behind its position in the adult; that is, in genera where the anal originates well in front of the dorsal, it starts only barely in front in the larva; similarly, when the adult origin is immediately below the dorsal, in the larva it is usually under the second to fourth dorsal ray.

9. *Length*: Metamorphosis begins at slightly different lengths in different genera. In most melanostomiatids in which the young stages are known, the larval period ends when the fish is around 20 mm. long, while post-larvae and adolescents (excluding transitional adolescents) measure between 20 and 30 mm. In *Flagellostomias*, *Leptostomias* and *Eustomias*, however, post-larvae and adolescents measure between 30 and 50 mm. or more.

Absolute specific identification always, of course, waits upon the study of intermediate forms, which retain characteristic larval pigmentation subdermally, along with recognizable adult characters. With the single exception of the youngest larva referred to *Eustomias*, we have series complete enough so that we are confident of generic identification in every case, and of specific in most of these.

Because of the evanescence of a number of characters—the change in pigment spots at different phases, of relative gut lengths and fin development, and the relatively few genera of which true larvae are known—we cannot yet give an adequate key. The accompanying table, however, used in conjunction with Text-fig. 2 and the full-length figures of larvae scattered throughout the text, should form a basis for future work.

### D. Form and Development of Separate Characters.

1. Color and Luminescence: Up to the present time the colors of the light organs in living and freshly dead Melanostomiatidae have been almost completely unknown. Lowe in 1843 (p. 88), in describing *Echiostoma barbatum*, the first known melanostomiatid, remarked that the postorbital was rose-colored. Murray, writing pioneer notes on the *Challenger* Expedition, observed that in *Opostomias* "the end of the barbel, which was thickened, was flesh colour with a rose tint; there was also a rose tint on the dorsal and anal fins. The rest of the animal was of a dark colour with a perceptible slate-coloured tint. The phosphorescent spots along the belly and lateral line were red, as was also that below the eye." (Tizard, etc., 1885, p. 412). In regard to *Pachystomias microdon*, which was living, he wrote (*ibid.*, p. 521), "It had one club-shaped spot of a rose colour directly below the eye, and another, about half the size, directly in front of this, of the same colour. . . . The two rows of probably phosphorescent dots along the body were red surrounded by a circle of pale violet."

Only one of the Monaco melanostomiatids seems to have been described while still fairly fresh. Zugmayer (1911.2, p. 78) reported in his description of *Trichostomias vaillanti* that the fish had the organs of the lateral series yellowish-white, and the suborbital (postorbital) pale red. The colored plates of the family in both the Monaco reports and in Brauer's *Valdivia*.*Tief-see Fische* (1906) were obviously not made from field sketches, since in none do the organs have the brilliant colors which we have found, by repeated observations in Bermuda, to be characteristic of these fishes.

TABLE I.

Characteristics of larvae and post-larvae in the Bermuda Collection[2].

| | Myomeres (nape to anal end) | Myomeres (nape to pelvic) | Myomeres (pelvic to anal origin) | Larval teeth, premaxillary | Larval teeth, maxillary | Larval teeth, each half mandible | Larval gill-rakers (Numbers refer to arches) | Length of larvae (mm.) | Length of post-larvae (mm.) |
|---|---|---|---|---|---|---|---|---|---|
| *Leptostomias gladiator* | 75–78 | 43–44 | 16–18 | 7 | 18 | 12 | Long on 1st, 2nd, 3rd. Mounds on 4th, 5th. | 12–30 | 38–45 |
| *Melanostomias spilorhynchus* | 49–52 | 29–30 | 10–12 | 7 | 15 | 7 | Long on 1st, 2nd, 3rd. Rudiments on 4th, 5th. | 17 | 21–32 |
| *Melanostomias biseriatus* | 55–56 | 33–34 | 10–12 | — | — | — | Long on 1st, 2nd, 3rd. Rudiments on 4th, 5th. | — | 23, 25 |
| *Photonectes parvimanus* | 64–67 | 39–41 | 12–13 | 5 | 10 | 7 | Long on 1st, 2nd, 3rd Mounds on 4th, 5th | 14, 26 | 25 |
| *Flagellostomias boureei* | 67–68 | 32–33 | 14–16 | 4 | 14 | 5 | Long on 1st, 2nd, 3rd. Mounds on 4th, 5th | 20–21 | 34, 39 |
| *Grammatostomias flagellibarba* | 55 | — | — | — | — | — | Short on 1st, 2nd Mounds on 3rd Absent on 4th, 5th. | — | 29 |
| *Bathophilus* sp. | 45–46 | — | — | — | 15 | 10 | None | 7 | — |
| *Bathophilus*, near *longipinnis* | 42–44 | 19–21 | 11–12 | 5 | 12 | 6–7 | Short on 1st, 2nd, 3rd. Mounds on 4th, 5th | 11, 12 | — |
| *Bathophilus metallicus* | 45 | 19 | 17 | — | — | — | Moderate on 1st, 2nd Absent on 3rd, 4th, 5th | — | 25, 29 |
| *? Eustomias* sp. | 55 | — | — | 6 | 18–19 | 9 | Short on 1st, 2nd, 3rd Mounds on 4th Absent on 5th. | 12 | — |
| *Eustomias* sp. | 77 | — | — | 8 | 10 | 10 | Rudimentary mounds on all 5. | 13, 15½ | — |
| *Eustomias bibulbosus* | *ca.* 72 | 37 | 14 | — | — | — | Moderate on 1st. Short on 2nd. Mounds on 3rd, 4th. Absent on 5th. | — | 42, 52 |
| *Eustomias* sp. (*Dinematochirus*) | 78 | 32 | 14 | — | — | — | Long on 1st. Short on 2nd, 3rd. Mounds on 4th. Absent on 5th | — | 43 |

[2] Fins and photophore counts of post-larvae, typical of species; diagrams of pigmentation in Text-fig. 2; typical teeth and gill-rakers in Text-figs. 5, 7; full length drawings in Text-figs. 21, 30, 42, 47, 57, 58, 61, 66, 67, 68.

The first notes on the actual luminescence of a living melanostomiatid were taken on the *Arcturus* by Beebe in 1926. Of *Echiostoma tanneri* (then identified as *E. barbatum*) the following observations were made: "It was alive and stayed so for several hours while we got movies. The most noticeable character of this otherwise brownish-black fish was a wedge-or-pear-shaped light organ of rich rose color below the eye. In the dark this gave forth a warm reddish glow. The lateral light organs were all tinged with rose." (Beebe, 1926, p. 422).

Finally, Borodin (1931, pp. 65 and 67) noted that the postorbital was red in *Echiostoma*, rose in *Photonectes*, while Bolin (1939, p. 41) describes this same organ as "pale luminous green" in *Tactostoma*.

This handful of observations apparently includes recently preserved as well as actually living fish, and all told represents only six out of the sixteen valid genera in the family. Except for the single *Arcturus* observation, the actual luminescence of the fish has never before been recorded.

The Bermuda observations which follow, while naturally incomplete, at least lay a sound foundation for future research, which will emphasize the functions of these organs. Our notes give hints of the relationship between the colors of the photophores in daylight and their luminescence in the dark, as well as of their respective uses, and on their appearance under natural conditions, as observed from the Bathysphere. The field notes and color sketches were all made while the fish were actually alive or else when they were freshly dead, still in water, and within two hours of the nets' having reached the surface. We have made these observations upon all 10 genera taken by the Expeditions and on 29 of the 32 species, or about one-third of the known forms. From one to more than a dozen individuals of each species were painted and described. In the case of the more common forms, such as *Melanostomias spilorhynchus*, the colors of the barbel and postorbital were so consistent and unvarying that after having made a number of sketches and notes, we simply checked the various organs mentally in order to devote more time to rarer forms taken in the same nets.

The colors usually faded with extreme rapidity, the organs often being almost or quite white after only a few minutes at the surface, so that the taking of notes was useless by the time they reached the laboratory. Occasionally, however, the serial organs retained traces of violet even after two years in alcohol, and the postorbitals of *Echiostoma* usually remained pink for several months.

Individuals of five of the species, *Chirostomias pliopterus*, *Pachystomias atlanticus*, *Echiostoma tanneri*, *Photonectes margarita* and *Eustomias bibulbosus*, were still alive when they reached the laboratory. In the case of *Echiostoma*, five specimens of both sexes came up alive, and two of them lived overnight. Thanks to these living examples, we could compare the colors in daylight with those soon after death. There was found to be no difference at all except, sometimes, in relative brilliancy, so that we may consider our notes on fresh fish very accurate. No dead fish, no matter how fresh, showed any luminescence in the dark-room. Since the functioning of the organs in the dark-room was exactly similar on a small scale to their functioning when seen from the Bathysphere, objections that our observations were made upon dying specimens are not as valid as they would be in the case of freshly caught shallow water fish, where the superficial coloration is known often to go through unusual or abnormal phases.

In the dark-room an ultra-violet lamp was sometimes used to help in the observation of luminescent areas.

A table, summarizing the observations on each species, will be found at the end of this section; detailed color descriptions are included under the headings of the various genera and species further on. We will now sum-

marize what we have learned of the general body color, and of the colors, luminescence and uses of the barbel and light organs.

*General Color*: When alive or recently dead, these fishes appear velvety, jet black in the shade; in direct sunlight, however, the color is dark brown. The presence and arrangement of the evanescent pigment spots of the translucent larvae has already been discussed above. The pigment of the adult begins to appear at the end of the post-larval or beginning of the adolescent stage; by early transitional adolescence it is nearly or quite as well developed as in adults; advanced transitional adolescents are invariably as deeply pigmented as mature fish. Pigmented skin, forming on top of the larval spots, appears first along the sides, last around the snout and end of the caudal peduncle.

Iridescence has been observed in the following fishes: *Chirostomias pliopterus*, green bronze on shoulder; *Bathophilus longipinnis* and *B. metallicus*, head and body iridescent in both males and females. In the latter species this iridescence is often completely lacking; it is obviously very easily damaged, however, and we consider it a normal, rather than a variable characteristic. It appears in transitional adolescence.

The fins of melanostomiatids are usually translucent, or whitish, because of luminous mucous (of which more will be said later). Often, however, the skin of the body, as in certain species of *Grammatostomias* and *Photonectes*, extends almost to the tips of the dorsal and anal, and often all of the fins are tinged with pink because of the coursing blood.

*Barbel*: This highly specialized and variable structure cannot be listed definitely as either a luminous or a tactile organ; in all probability it is sometimes one, sometimes the other, sometimes both, and perhaps always connected with one or more senses of which we have no knowledge whatever.

The Bathysphere observations on this subject were necessarily disappointing. "In the great majority of cases, it was quite impossible to make accurate generic identifications. By the time I had satisfied myself that I was looking at a member of this family, the Bathysphere or fish would move. So I invariably lost the chance of seeing the barbel and its light. In *Bathysphaera* I thought, on the occasion of their first passing, that a parti-colored jelly or small fish was swimming beneath. Only on their return did I suddenly realize that the bobbing red and blue lights terminated a dangling, invisible barbel thread. One other time I thought I saw a long strand of tissue studded with minute lights, but I am not certain, and so far as identification by barbels is concerned, my dives were quite ineffective. This may indicate that barbels in general subserve a tactile rather than a luminescent function." (Beebe, 1934.2, Appendix G, p. 312.)

The old suggestion that barbels in this family sometimes serve as luminous lures is more plausible than ever after these Bathysphere observations. In other cases, however, it is possible that luminescence of the organ is a purely secondary matter, or an accidental byproduct, its primary function being sensory. We have also found that, at least in the genus *Eustomias*, barbels differ in both form and color in males and females of the same species (see p. 211). In regard to sexual differences in barbel color, *Eustomias bigelowi* had the bulb and bulblets bright yellow in the male and brilliant bluish-green in the female. Unfortunately, these fish were not taken alive, so that comparison of luminescence in the two sexes could not be made.

As might be expected, the genera *Pachystomias*, *Grammatostomias* and *Bathophilus*, which have in common long, filamentous, bulbless barbels practically lacking in pigment, save for a few rudimentary photophores, showed no color tints and gave out no luminescence. Genera with more elaborate barbels, on the other hand, usually had the bulbs and bulblets brightly colored, often combining two or more contrasting hues. The structures were always more or less translucent, and the colors consequently wonderfully clear. They ranged from gleaming white and silver (*Chirostomias*) through

pinks, yellows, blues, greens and lavenders: only bright red was missing from the spectrum. In some, such as *Echiostoma*, the daylight tints were rather delicate, but in *Eustomias* and *Photonectes* they were often blazingly vivid, even in dead specimens. In the two last genera, the only ones with non-filamentous barbels on which we have observations on a number of species, we find that many colors are found in the same genus, although there is practically no variation (except sexual, as noted) within species.

One of the most interesting results of the dark-room studies is that barbel luminescence does *not*, in the two species observed, correspond to the color of the barbel in daylight. In *Chirostomias* the silver-white barbel bulb gave off a steady pink glow anteriorly and a white one posteriorly. In a male *Eustomias bibulbosus* the bulbs were bright pink, but gave a distinctly green light in three brilliant flashes. In *Echiostoma*, the barbel, though highly developed and colored in the young, was never observed to be luminous; similarly, there was no glow from that of *Photonectes margarita*. In *Bathysphaera intacta*, seen only from the Bathysphere, the proximal bulb glowed rosy red, the distal blue.

*Postorbital Light Organ*: The color of the postorbital in freshly caught specimens varies greatly, and includes all the colors of the spectrum as well as white and silver-white. The luminescence of these lights is known only for *Echiostoma*, the adults giving a rosy glow and a blue or white flash, while the young also gave a rosy glow (the anterior part of the organ being pink) but a distinctly green-white flash (the posterior portion being green). Silver or silver-white with opalescent reflections seems to be a generic character in the postorbital of *Eustomias*. *Bathophilus*, on the other hand, varies within the genus. Other multi-specific genera have not yet been sufficiently observed to draw any conclusions.

The postorbital is definitely under the control of the fish, can be rolled down out of sight, and made to glow steadily or emit sharp flashes of a different color, at least in *Echiostoma*. In the new *Tactostoma* Bolin, 1939, it apparently rotates forward, or forward and downward, instead of the usual downward. The following summary has been made of observations on this organ from the Bathysphere: "The cheek lights seemed under control, and were seen occasionally to blink. Their color, whenever a definite tint could be assigned, was yellow or red. Every time they were rolled up into sight, these organs illumined the fish's eye and most of its head. Why the creature is not momentarily blinded by the light is a question which has always puzzled me." (Beebe, 1934.2, Appendix G, p. 313.)

*Serial Photophores*: Throughout the superfamily Gymnophotodermi (Astronesthidae, Melanostomiatidae, Malacosteidae and Idiacanthidae) the color of the serial photophores in fresh specimens in all the observed genera save one is invariably purple or violet, sometimes verging on scarlet. The known exception is *Bathophilus* in which the organs in the two species observed were always golden yellow. This apparent color may have been due however to the inconspicuousness of the organs themselves in this genus and the relatively large size of the tinselly gilt reflectors. The latter characters are visible only in perfectly fresh specimens and consist apparently of small crescents or circles of specialized iridescent skin, always giving off bright golden reflections, which cap or completely surround the organs of the lateral series, the ventral or both. Their function is doubtless to magnify the light of the photophores, exactly as do tin reflectors placed behind the individual lights on a Christmas tree. Due to their evanescence, we have not been able to determine whether the crescentic caps above the organs in some species are the rule, or whether only the upper part of a complete gilt circle has survived capture.

The luminescence of serial photophores has been observed in the dark-room only in *Echiostoma*, in which case it was rosy to scarlet. They glowed steadily for a time, but were apparently under the control of the fish. From

the Bathysphere the serial photophores appeared as follows: "The two rows of lateral serial organs were usually distinct, though not brilliant, and as far as I could tell glowed steadily. I cannot generalize on their tint, except that they often seemed faintly yellowish. It is interesting to note that on freshly caught dead specimens these organs are always clear violet or purple." (Beebe, 1934.2, Appendix G, p. 312.)

In fresh specimens of *Malacosteus* and *Bathophilus brevis*, the only stomiatoids in which regular serial organs are lacking, certain of the numerous tiny, non-serial photophores were distinctly larger, brighter, and more violet than their fellows, and in roughly linear formation in the region where serial organs are usually found. The differences were not, however, clear enough for counting of these larger organs.

*Non-serial Photophores*: Their color, in fresh specimens, ranges from red or pink, through violet to bluish, differing in tint considerably from that of the clear violet photophores, and fading much more quickly than the serial organs. From the Bathysphere their importance was apparent: "One unexpected observation was the brightness of the tiny-non-serial organs scattered in large numbers over the heads and bodies of these fish. In newly caught specimens these are very inconspicuous in comparison with the much larger serial organs, and usually show no vestige of color. Yet a number of times in the Bathysphere I noted Melanostomiatids with these tiny pinpricks of light glowing with considerable brilliancy." (Beebe, 1934.2, Appendix G, p. 312). In the laboratory dark-room the non-serial lights of *Echiostoma* glowed with a rosy light.

*Other Luminous Areas*: The luminous tissue in which pectoral fins are often more or less imbedded is usually creamy white in fresh specimens. The highly specialized luminous line or loop on the side of *Grammatostomias* is bluish to bright metallic green-violet in fresh specimens. Yellow, purple, pink and green snout and jaw spots have been observed in freshly dead *Melanostomias*, *Photonectes* and *Bathophilus*. The whitish longitudinal body bands of *Echiostoma* gave off a bluish-white luminescence under ultraviolet light. Some genera, such as *Echiostoma* and *Melanostomias*, also certainly have the bases of the teeth luminous, the material being deposited in the soft portion which permits bending of the fang. Also, luminous granules are frequently present on the dorsal and anal fins, being sometimes more easily seen in the adolescent than in the adult. We have never observed luminescence in this region, however, in the dark-room.

Bathysphere observations show that a luminous mucous, of which we see few traces in captured specimens, may be a general family attribute. "Another point I cannot explain is how I could see outline after outline of the fish when they were in absolutely black water, while their lights had very little reflecting power. Perhaps there was a general coating of luminous mucous, as trawled specimens frequently exude a whitish slime, or a loose epidermal membrane." (Beebe, 1934.2, Appendix G, p. 313).

The table on pp. 86-87 gives in summarized form all that we know at present of the color and luminescence of melanostomiatid light organs. In all cases, unless prefixed by the word "luminescence," colors refer to those found on freshly dead, apparently unfaded, specimens. Detailed color descriptions will be found in the discussions of the individual species.

2. BODY FORM AND PROPORTIONS: With the exception of the highly specialized *Bathophilus brevis* (depth in length *ca.* 2.5), all melanostomiatids are moderately to excessively elongate in form; some species of *Leptostomias*, for example, are of anguilliform slenderness, the depth being contained in the length up to 17 times. Adult melanostomiatids are deepest at the shoulder except in the more specialized *Photonectes*, in which the fish is deepest toward mid-body, as in juvenile forms. The head is usually small, there being a distinct correlation between large heads and deep bodies; the extremes of head lengths range from about 2.5 (for *B. brevis*) to 11

## TABLE II.

Summary of melanostomiatid color notes taken on Bermuda Oceanographic Expeditions.

| GENUS AND SPECIES | POSTORBITAL | BARBEL | SERIAL ORGANS | OTHER LUMINOUS AREAS |
|---|---|---|---|---|
| *Chirostomias pliopterus* (including ♀ in life) | ♂. White; silver rim. | ♀. Bulb white and silver; greenish-yellow in yg. Luminescence pink anteriorly, white posteriorly. | Violet; gold frames. | Green bronze iridescence on shoulder. |
| *Pachystomias atlanticus* (in life) | Bright red. | Stem translucent white. | Purple; gold caps. | Antorbital yellow-green. |
| *Leptostomias bermudensis* | (No ♂ taken). | ♀. Bulb base lilac; bulb yellow. | Lateral, purple; ventral, maroon. Both with gold caps. | Non-serial organs purple; pale blue spots on abdomen. |
| *L. gladiator* | (No ♂ taken). | ? | Violet. | |
| *Melanostomias spilorhynchus* | ♂. Pink to purple. | ♀. Bulb greenish-yellow; flanges and bulblets pink or purple. | Violet; gold caps. | Non-serial organs, violet; base of teeth, pale blue; snout lights pink. |
| *Echiostoma tanneri* (in life) | Yg. Pink in front; green behind; rosy glow; green-white flash.<br>♂ and ♀. Pink in front, white behind; rosy glow; blue or white flash. | Yg. Bulbs and filaments green and purple, rufous core.<br>Adult. Washes of pink. No luminescence in either sex. | Yg. Violet.<br>Adult. Scarlet. Luminescence of both, rosy to scarlet. | 3 whitish, lateral bands.<br>Non-serial organs, purple to scarlet. Fins luminous. |
| *Photonectes dinema* | Yg. Silver-white with lower front corner, purple. | Bulb pinkish-purple at both ends, blue in middle, filaments pale yellow. | Violet; gold caps. | Snout light purple. |
| *P. leucospilus* | Yg. Blue or silver-white with lower front corner, yellow. | Bulb violet to violet-blue; lavender basally. | Violet; gold frames. | Non-serial organs violet. |
| *P. mirabilis* | Yg. Golden-yellow. | Bulb silver; bulblets golden-yellow. | Violet; gold frames. | Snout light golden-yellow. |
| *P. parvimanus* | Yg. White. | Bulb green, center peacock blue; appendage yellow-green. | Violet; gold frames. | |
| *P. bifilifer* | ? | Bulb lavender near tip. | ? | |

| | | | | |
|---|---|---|---|---|
| *P. margarita* (including ♂ in life) | ♀. Rosy.<br>♂. Yellow<br>Yg. Purple or magenta. | Yg. Bulb violet with pink spot posteriorly.<br>♀. Bulb purple. | Violet to purple. | Shoulder spots pale blue. |
| *Flagellostomias boureei* | ♂. Silvery white. | ♂. Bulb greenish-yellow. | Purple; gold caps. | Pectoral tips greenish-yellow. |
| *Grammatostomias dentatus* | ♂. Silvery. | Stem translucent white. | Purple; gold caps. | Non-serial organs pink; luminous hook bluish-white. |
| *G. flagellibarba* | ♂. Bright yellow. | Stem translucent white. | Purple. | Luminous loop blue-green; pectoral, milk-white. |
| *Bathophilus brevis* | Yg. Pale green with silver rim. | Stem translucent white. | —— | Non-serial organs bluish to violet. |
| *B. altipinnis* | ♂. Anterior part, deep red. | Stem translucent white. | ? | |
| *B. longipinnis* | ♂. Bright yellow.<br>♀. Pinkish-silver with silver rim. | Stem translucent white. | Golden. | Non-serial organs pink. |
| *B. metallicus* | ♀ and Yg. Pale greenish to lemon-yellow. | ♀. Stem translucent white with pink photophores near tip of barbel. | Golden. | Non-serial organs lavender. Maxillary patch purple. |
| *Eustomias bibulbosus* (in life) | ♂ Silver. | ♂. 2nd bulb pink giving off green light. | Purple; gold frames. | |
| *E. dubius* | ♀. Silver. | ♀. Peacock blue and turquoise. | Purple. | |
| *E. obscurus* | ♀. Silver. | ♀. Bulb violet basally, green distally. | ? | |
| *E. bigelowi* | ♂. Opalescent silver. | ♀. Bulbs bluish-green.<br>♂. Bright yellow. | Violet; gold frames. | ♂. Antorbital violet-blue. |
| *E. fissibarbis* | ♀. Greenish silver. | ? | Lavender; gold frames. | |
| *E. silvescens* | ♀. Opalescent white. | ♀ Bulbs and branches yellow and light green. | Violet; gold frames. | |
| *E. schmidti* | ♂. Silver-white, golden rim. | ♂. Bulbs pink, branches ochre. | Purple. | Non-serial organs pale, bluish-violet. |

(*Leptostomias*) in the length, the average being about 6 to 8. In *Pachystomias* the head is very broad as well as long. In all cases the eye is small, compared with those of fish in general, although as an organ it is well developed. The snout is noticeably short, excessively so in *Melanostomias* and related genera. In *Eustomias* and *Pareustomias*, and to a much lesser degree in *Flagellostomias*, the snout is protractile; traces of this tendency are also present in *Grammatostomias*. The thrust forward is accomplished by the dislocation of the upper jaw bones, which project the fleshy tip of the snout forward beyond the ethmoid region (see section on Osteology).

The body proportions of larval melanostomiatids are not greatly different from those of adults, if the finfolds and pendulous guts are disregarded. However, the trunk is usually slimmer (when the depth is measured exclusive of the coelomic organs), and the head and snout always longer throughout the larval and post-larval stages, the jaw angle being under or well in front of the eye instead of behind it. The deepest part of the body is toward the middle of the length, instead of at the shoulder. With the material at hand, we have not been able to deduce any satisfactory numerical ranges for these proportions in the various larvae which would be of help in identification. It may be remarked, however, that in *Eustomias* the snout (and with it the head) is relatively much longer than in other genera; the snout itself is more than half the length of the head, and of a flattened, duck-bill-like shape, very much as in *Idiacanthus*.

The elongate, forwardly rotated eye, which is confined to the larval stage of stomiatoids alone, is of especial interest. Apparently no larvae in other groups possess just this characteristic. The closest are certain young alepocephalids and myctophids, and in these forms the eyes are merely elliptical, and not at all turned toward the front. The vast majority of fishes pass through all phases of development with the round eye, often very large, which they have upon hatching. It seems likely that this transient, elongate eye of the stomiatoids is a phylogenetic character, reminiscent of ancestors which, like *Ichthyococcus* today—one of the least specialized of existing stomiatoids—had semi-telescopic eyes. Further evolution in that direction led to *Argyropelecus*.

3. BARBEL: This highly specialized organ is the most variable in the entire family. It ranges from simple forms similar to that of the astronesthids, with moderate stems and small, simple bulbs, to all extremes: to the attenuated, bulbless barbel of *Grammatostomias flagellibarba*, seven times as long as the fish; to the complex, tree-like organ characteristic of the eustomiad subgenus *Dinematochirus;* and, in the opposite direction, to the degenerate barbels of adult *Echiostoma* and *Photonectes*, and the almost atrophied organ of *Tactostoma*, which consists only of a minute black stem with the slightest of distal swellings.

Variability is great not only between genera, but, sometimes, between the species of one genus, as in *Eustomias* and *Photonectes*. In species having more or less complicated barbels, as in *Flagellostomias boureei, Leptostomias gladiator* and many forms of *Eustomias*, individual variation is the rule. Lack of adequate material to show specific ranges in this character has been another common cause for the erection of invalid species. Nevertheless, it is often true that closely related but valid species differ from each other solely in the form of the barbel; as such, this organ is the most useful single taxonomic character in the entire family.

In the genus *Eustomias* we have found a distinct sexual dimorphism in the shape of the barbel in most of the species which we have been able to study. In the subgenus *Nominostomias* the distal filaments tend to be branched in the females, but unbranched in the males. In the subgenus *Dinematochirus* the median posterior branch is short and tipped with a prominent bulb in the females, while in the males it is longer, with the

bulb small or absent; the main barbel bulb is smaller in the female than in the male.

The probable functions of barbels have already been discussed under the heading "Color and Luminescence" (p. 83).

Completely absent in the larva, a stump in the post-larva, and roughly formed in the adolescent, the barbel is often not fully formed until the completely adult stage is reached. This has been found to be especially true of the genera *Eustomias, Echiostoma* and *Photonectes*. Because it usually appears fully pigmented and apparently completely defined in transitional adolescence, a number of species in various genera (notably the same ones mentioned above) have been described on the basis of this character, whereas it merely represents a different stage in the development of a previously known species. It is interesting that in *Odonotostomias, Echiostoma* and the majority, if not all, species of *Photonectes*, the barbel bulb is relatively larger in young specimens than in older; in *Echiostoma*, at least, the entire barbel is apparently actually shortened in the adult.

In general, the relative length of the barbel increases with that of the fish until the proportion characteristic of the species is attained, sometime during transitional adolescence. In a few species, however, the barbel is longer relative to the length in the transitional adolescent than in the adult; that is, it grows faster than the rest of the body.

4. LIGHT ORGANS: *Antorbital*: This small photophore, situated at the lower front corner of the eye, is of phylogenetic interest, since it is well developed and functional in all the lower stomiatoids, while in adult melanostomiatids it is almost or completely atrophied. In young melanostomiatids, however, it appears with the other photophores in the post-larval stage, quickly develops at least one luminous center and sometimes two, and for a while may even be functional. In adolescence, however, it ceases to grow, and usually atrophies during transitional adolescence. In *Pachystomias* however, it is well developed and brightly colored even in adult fish. Also, a transitional adolescent *Eustomias bigelowi*, had an antorbital with a luminous center tinted violet-blue. Subdermal traces of the organ are sometimes found in fully adult melanostomiatids.

*Postorbital Organ*: The postorbital, which is small or absent in gonostomids, sternoptychids, stomiatids and *Chauliodus*, is well or highly developed in male melanostomiatids and sometimes in females. Unlike the barbel, this organ does not vary greatly in structure throughout the family, although there are large differences in its size and color, and in most genera it is reduced or entirely atrophied in the female. In general form it is a gigantic photophore, apparently always under the control of the fish, which nevertheless can also be rotated downward out of sight, so that the luminous face is replaced by the pigmented inner surface of the organ. The histology of the postorbital has been described by Brauer (1908, p. 87). In genera having very large postorbitals, such as *Echiostoma, Photonectes* and *Grammatostomias*, an overhanging "eye-brow" of skin protects the eye from receiving the full glare of the light; nevertheless, it is hard to understand how the fish can see when this organ is fully illumined.

Sexual dimorphism in the form of reduced or absent postorbital organs in females has previously been noted in the case of the malacosteid *Photostomias* (Regan & Trewavas, 1930, p. 134), of the melanostomiatid *Odontostomias* (Norman, 1930, p. 309) and of *Idiacanthus* (Beebe, 1934.1). We have found that it is present in varying degrees in the majority of genera of Melanostomiatidae. We have not, however, been able to check it in every genus, nor in all the species, due both to a lack of material, since many species are known only by immature examples which cannot be sexed, and to the impossibility of our examining many type specimens which are deposited in European museums. However, the evidence so far obtained gives the following results:

| Genus | No. Species Examined | Male Light | Female Light |
|---|---|---|---|
| *Chirostomias* | 1 out of 1 | Moderate | Atrophied |
| *Trigonolampa* | 1 out of 1 | Large | ? |
| *Pachystomias* | 1 yg. out of 2 | ? | ? |
| *Thysanactis* | 1 out of 1 | Moderate | ? |
| *Leptostomias* | 3 out of *ca.* 9 | Probably moderate | Atrophied |
| *Odontostomias* | 1 out of 2 | Moderate | Atrophied |
| *Melanostomias* | 3 out of *ca.* 12 | Large | Large |
| *Echiostoma* | 1 out of 1 | Large | Large |
| *Photonectes* | 3 out of *ca.* 15 | Large | Large |
| *Tactostoma* | 1 (yg.) out of 1 | ? | ? |
| *Opostomias* | .. | ? | ? |
| *Flagellostomias* | 1 out of 1 | Moderate | Atrophied |
| *Grammatostomias* | 2 out of 2 | Large | Almost atrophied |
| *Bathophilus* | 4 out of 16 | Moderate | Small but functional |
| *Eustomias* | 7 out of <50 | Moderate to large | Small or atrophied |
| *Pareustomias* | .. | ? | ? |

We surmise that *Melanostomias, Echiostoma, Photonectes* and possibly the closely related *Tactostoma,* will prove to be the only genera in which dimorphism in this organ is absent.

A preliminary survey of related families shows that similar postorbital sexual dimorphism is absent in at least two genera of Astronesthidae (*Astronesthes* and *Neonesthes*), present or absent in Malacosteidae, and present in Idiacanthidae.

The atrophying of the organ in the females is most interesting to trace through the developmental stages. The organ is always apparent, and even, possibly, functional in adolescence. In transitional adolescence, however, it ceases to grow with the fish, the protecting transparent skin becomes gradually pigmented, and the organ remains relaxed, rolled down almost out of sight. Finally, in adults in which it is completely atrophied, such as *Chirostomias,* the covering skin is indistinguishable from the surroundng epidermis, and dissection shows no trace of the organ except a cavity above the maxillary.

In the male, however, its growth like that of the serial organs is steady and fast. Colored (and presumably functional) postorbitals have been noted in early adolescence.

*Serial Photophores*: These organs are well developed and are ranged in regular rows except in *Bathophilus, Tactostoma* and some species of *Photonectes,* in which genera they are small and sunken (atrophied in *B. brevis*); notably in *B. irregularis* and *P. margarita,* those of the lateral series are placed high on the sides, out of alignment. Also, in *Pachystomias, Pareustomias* and *Eustomias obscurus* the photophores of the upper series are grouped, a similar condition being found in certain gonostomids, in *Aristostomias* and in *Pareustomias.*

The serial photophores appear almost simultaneously, with the lateral series a little in advance of the ventral, and the last A-C photophores a little behind the rest of the series, especially in the development of luminous centers. Unpigmented anlagen of the photophores are sometimes visible in advanced larvae. Pigmented frames appear in early post-larvae, with luminous centers following almost at once. Fully formed, violet photophores, presumably capable of giving off light, have been noted in advanced post-larvae.

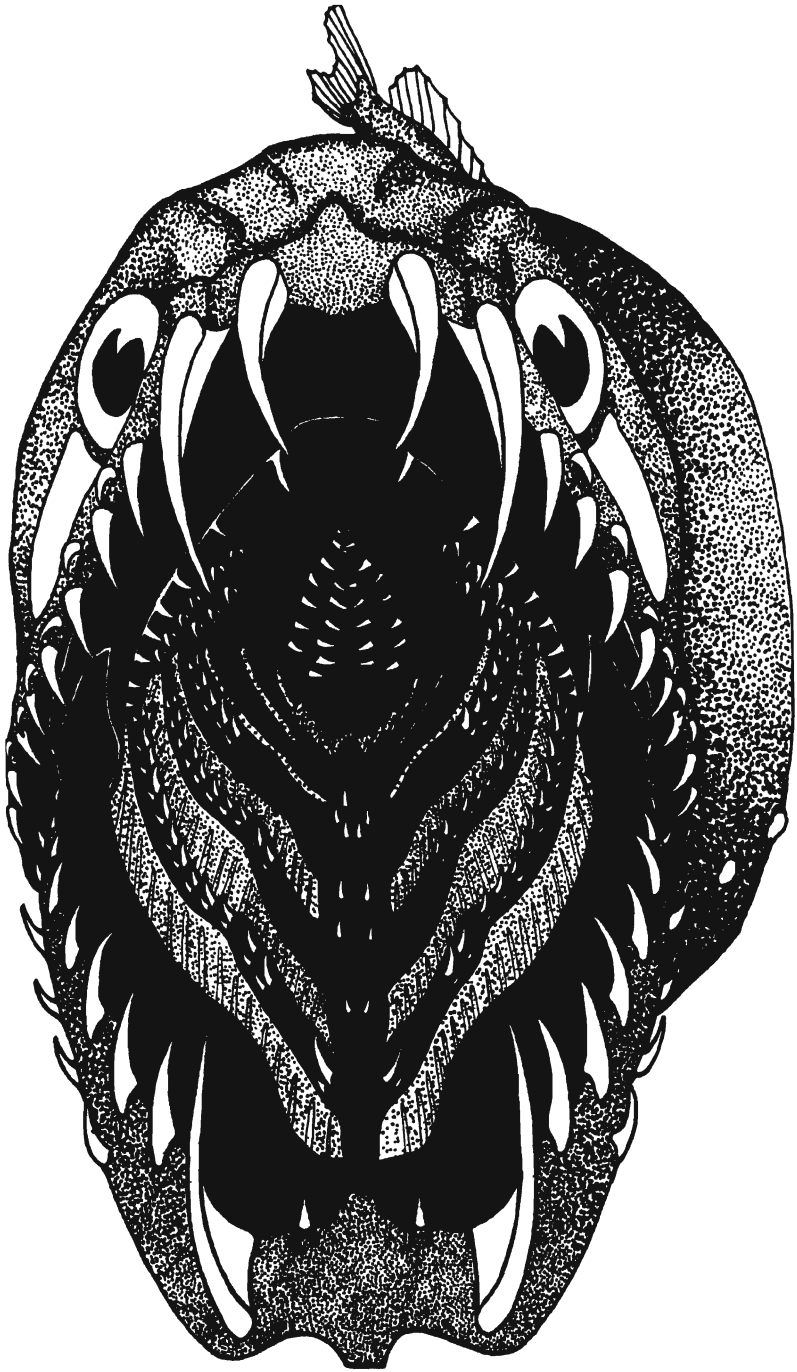
*Non-serial Photophores*: The tiny organs scattered over the head and

body of melanostomiatids vary greatly in number and prominence in the different genera. Sometimes they are located in definite patterns and sometimes no particular arrangement is discernible. Usually there are about three principal sizes of non-serial lights; the smallest of these are possibly not true photophores at all, but rather pores exuding luminous mucous. The number of lights on a good-sized melanostomiatid, such as a 12-inch *Echiostoma*, may total several thousand. They are sometimes found on the posterior side of the barbel and on the pectoral fins. Non-serial organs do not usually appear until adolescence, and are fully developed only in late transitional adolescence.

*Other Luminous Areas*: In most melanostomiatids, luminous tissue is not confined to barbels and typical photophores. *Chirostomias, Trigonolampa, Flagellostomias* and *Grammatostomias* all have large or small amounts of luminous tissue on the pectoral fins. Many species, chiefly of the genera *Melanostomias, Echiostoma, Photonectes, Grammatostomias* and *Bathophilus*, have characteristic spots, patches or bands of luminous tissue on the head and body. These areas usually appear in adolescence, but sometimes, as in the body bands of *Echiostoma*, they are apparent only in adults. It is likely that the exudation of luminous mucous is a family character.

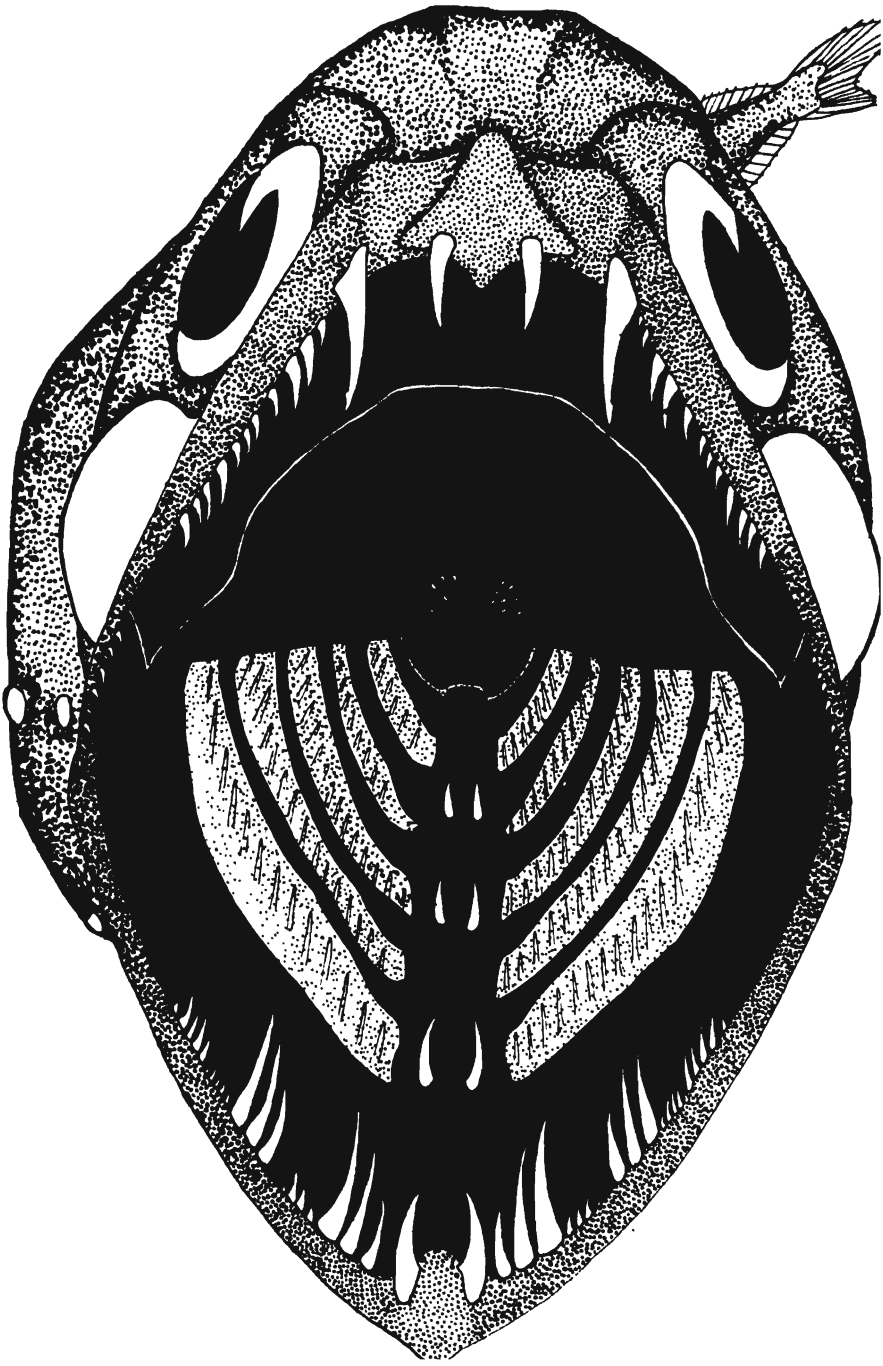
5. TEETH AND GILL-TEETH: The dentition of the jaws is exceptionally well developed in the Melanostomiatidae. It and the Idiacanthidae are the only families in which depressible teeth are developed. Except in *Chirostomias, Trigonolampa* and *Pachystomias*, at least one or two, and sometimes all of the teeth in premaxillaries and mandibles are depressible, an attribute which is undoubtedly of great aid in swallowing large fish. Usually the general proportion and arrangement of fixed and depressible teeth serve as useful generic distinctions, the more specialized genera having the most depressible teeth; in *Eustomias*, however, a highly specialized genus, the species run the gamut from almost all fixed to all depressible; in this genus too, the number and size of the teeth are very variable. In *Opostomias* and *Flagellostomias* the largest fang in the mandible is not depressible and fits, respectively, into a hole in the premaxillary or into a groove in the same bone. In *Echiostoma, Melanostomias* and *Photonectes* the teeth are strongly barbed or bicuspid; the same character is found to a lesser extent in *Flagellostomias* and *Grammatostomias*. The unossified central portions of the tooth bases, which enable them to bend, are often filled with luminous matter (see Beebe, 1934, p. 199, fig. 67). The jaw teeth are in single rows except in *Echiostoma* and *Tactostoma;* sometimes, however, especially in *Chirostomias*, the row is irregular, outer teeth alternating with inner ones; in genera with some teeth depressible, the fixed teeth are usually external to the depressible ones. Vomerine teeth are altogether absent only in *Grammatostomias, Bathophilus, Tactostoma*, and most species of *Eustomias*. Palatine and basibranchial teeth vary greatly in development throughout the family. Replacement teeth frequently develop before the loss of the tooth to be superseded.

The gill-teeth have turned out unexpectedly to be a character of great importance. They are paired or in groups of threes or fours in about half the genera in the family, including both primitive and specialized forms; single in other genera and altogether absent in *Bathophilus, Eustomias* and, presumably, *Pareustomias*. Whether paired or unpaired, they are strongest, most numerous and present on the most arches in the most primitive genera (see p. 105 ff.). Although they are almost invariable in their number and position within the genus, they are not identical in any two genera; hence they form a valuable generic character. Although the teeth on the posterior arches are often small, are almost covered by skin in large specimens, it is easy to determine their presence even in uncleared specimens. Along with the palatines, basibranchials and pharyngobranchials, the gill-teeth, except where much reduced, must be of considerable importance in gripping prey.



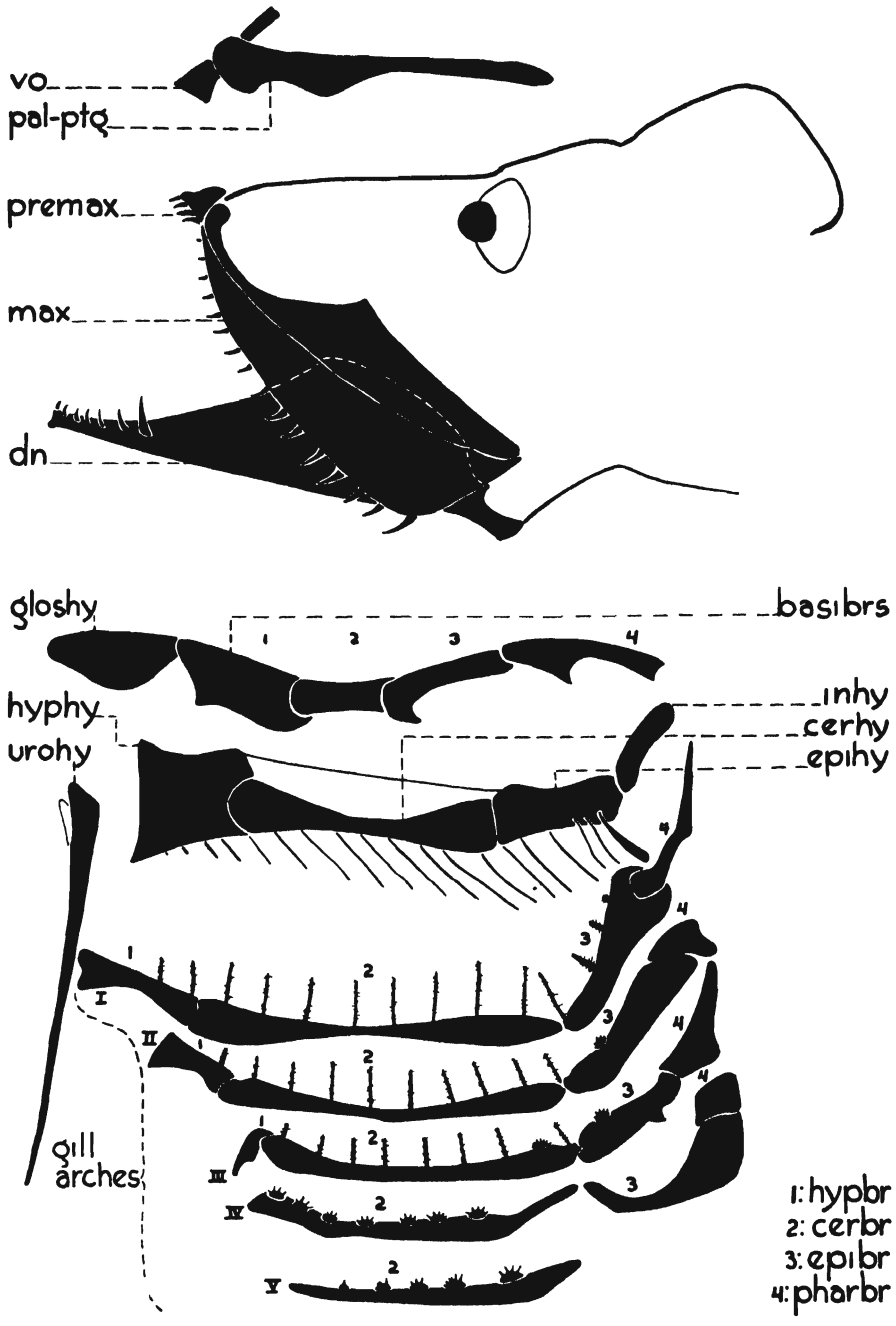
Text-figure 3.

*Chirostomias pliopterus.* Anterior view, showing abundance of teeth on floor and roof of mouth in a primitive genus. Standard length 205 mm.



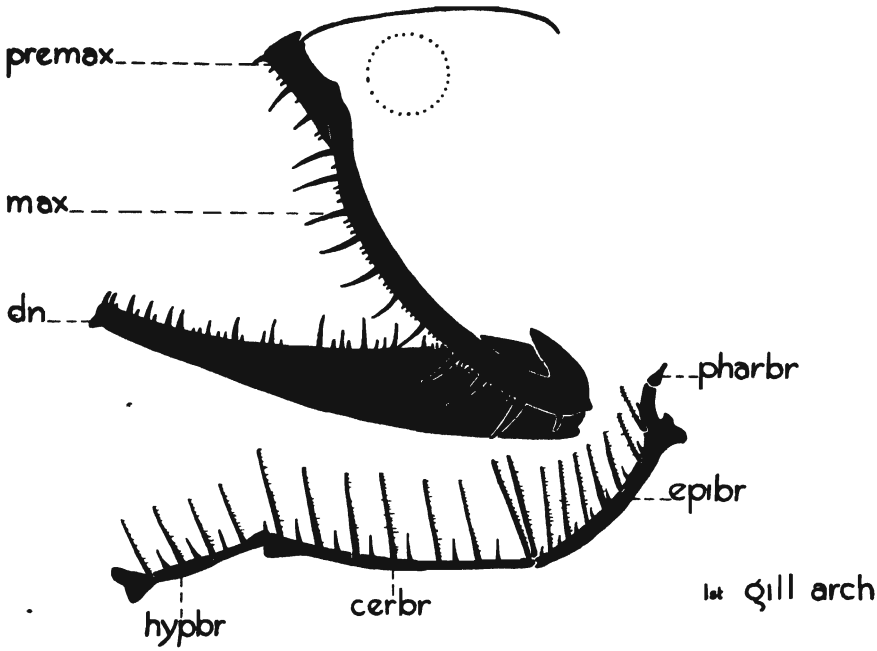
Text-figure 4.

***Eustomias bigelowi.*** Anterior view, showing paucity of teeth on floor and roof of mouth in a highly specialized genus. Standard length 134 mm.




Text-figure 5.

*Leptostomias gladiator*. Jaws, hyoid, and branchial arches of larva, standard length 23 mm. The general proportions of the cartilaginous elements and the character of the jaw- and gill-teeth are typical of melanostomiatid larvae. Abbreviations as in Text-fig. 18.




Text-figure 6.

*Gonostoma elongatum.* Jaws and first branchial arch, standard length 90 mm. For comparison with Text-fig. 5.

The temporary teeth of the larva present a problem of much interest. Doubtless they help the young fish in catching its minute planktonic food, but their resemblance to the permanent teeth of certain gonostomids is noteworthy (Text-figs. 5, 6). On the other hand, they have their counterpart in other larval fish, notably the enormous fangs of leptocephali.

The toothless post-larval stage, and the early periods of adolescence, when the permanent teeth are too few and too weak to be of any practical value, are, perhaps, accompanied by fasting on the past of the shrinking, metamorphosing young fish. In any case, these stages are probably of short duration. The growth of the permanent teeth is slow; maxillary teeth in particular often increase in number until very late in transitional adolescence.

Larval gill-rakers have apparently not been observed before in this family. They lag behind the larval teeth in development, appearing as mere stumps when the temporary teeth are already strong, and reaching their maximum development at the very end of the larval stage, when the teeth are already falling out, or even during the post-larval period, when the jaws are toothless. The rakers on the first arch usually are equal in number and position to the gill-teeth, found in the adult, each raker corresponding to a single tooth, pair or group, *i. e.*, the rakers are never paired, as is so often the case with the gill-teeth of adults. Also, they can generally be found on all five arches, although in the form of low, spiny mounds on the last two. We have found well developed gill-rakers in the larvae of *Eustomias* and *Bathophilus*, genera in which they are entirely lacking in the adult. These larval gill-rakers at maximum development are long and strong, with spines at irregular intervals, exactly like the rakers found in some adult gonostomids, such as *Photichthys* and *Gonostoma*. They are doubtless of use in straining out microscopic organisms from the water.

Text-figure 7.
*Leptostomias gladiator.* Tooth from first branchial arch of larva, standard length 23 mm.

6. BRANCHIOSTEGAL RAYS: As with the gill-teeth, the branchiostegal rays are in general most numerous and strongest in the less specialized genera. They are present on hypo-, cerato- and epihyals although often reduced on the first. They are of some use as a generic character, but, since the last three or four arise close together, and, moreover, tend to split and laminate, it is difficult to count them accurately except in cleared and stained specimens. Visible development begins in the post-larval period.

7. FINS: In the Melanostomiatidae the entire function of swimming and balancing must be relegated to the caudal peduncle and vertical fins, with balancing assistance from the pelvics, since pectorals are always modified beyond their usual function: they may be small (their usual condition) or absent, as in some *Photonectes* and *Eustomias;* imbedded in luminous tissue, as in *Chirostomias, Grammatostomias, Trigonolampa, Thysanactus* and *Flagellostomias;* or one or more rays may be long as in the tactile fins of certain bottom-dwelling fish, examples being *Echiostoma* and *Bathophilus.* The number of rays varies greatly often even in the same genus. The maximum is 47, in *Bathophilus nigerrimus;* however, 2 to 10 rays are most commonly found. Rudimentary, subdermal rays are often present in cleared specimens. The pelvic is far less variable; in all genera except *Echiostoma* and some *Eustomias,* which have 8 rays, and *Bathophilus,* which numbers up to 26, the pelvic is 7-rayed. The posterior rays are sometimes very long, and all seem to be fully webbed in well-preserved specimens. The dorsal and anal, being almost continuous with the caudal, form a powerful swimming organ; sometimes, as in *Chirostomias, Grammatostomias* and some *Photonectes,* the rays are covered almost to their tips with the thick, black skin of the body. The caudal fin, like the peduncle, is very short, usually between one-eighteenth and one-twentieth the length of the fish. The lower lobe is always considerably longer than the upper. The dorsal finfold persists longer than the anal fold, remains of one or both being present throughout the post-larval stage. The genera which are known at the present time to have the largest larval finfolds are *Flagellostomias* and *Bathophilus.*

The typical larval pectoral fins are large, even when, as has been noted, the pectoral is much reduced or absent in the adult. When the fin is highly specialized, as in *Grammatostomias,* the full length of the ray or formation

of the luminous material is not completed until transitional adolescence; when the fin is normal, as in *Melanostomias*, it is fully formed in the post-larval stage. Pelvic anlagen are often discernible in advanced larvae, but the rays are not differentiated before the post-larval stage; the fin does not reach its full length until adolescence or later. The majority of the rays of both dorsal and anal are distinguishable in the larvae. In *Flagellostomias* and *Eustomias*, in which the anal originates conspicuously in front of the dorsal, the anterior rays are the last to form. The caudal, even in late larvae, leaves the typical larval heterocercal form behind, goes through a homocercal stage, and immediately afterwards passes into the final phase, in which the lower lobe is longer than the upper. The entire fin, though small in the larva, is relatively much longer in the post-larva and adolescent than in the adult.

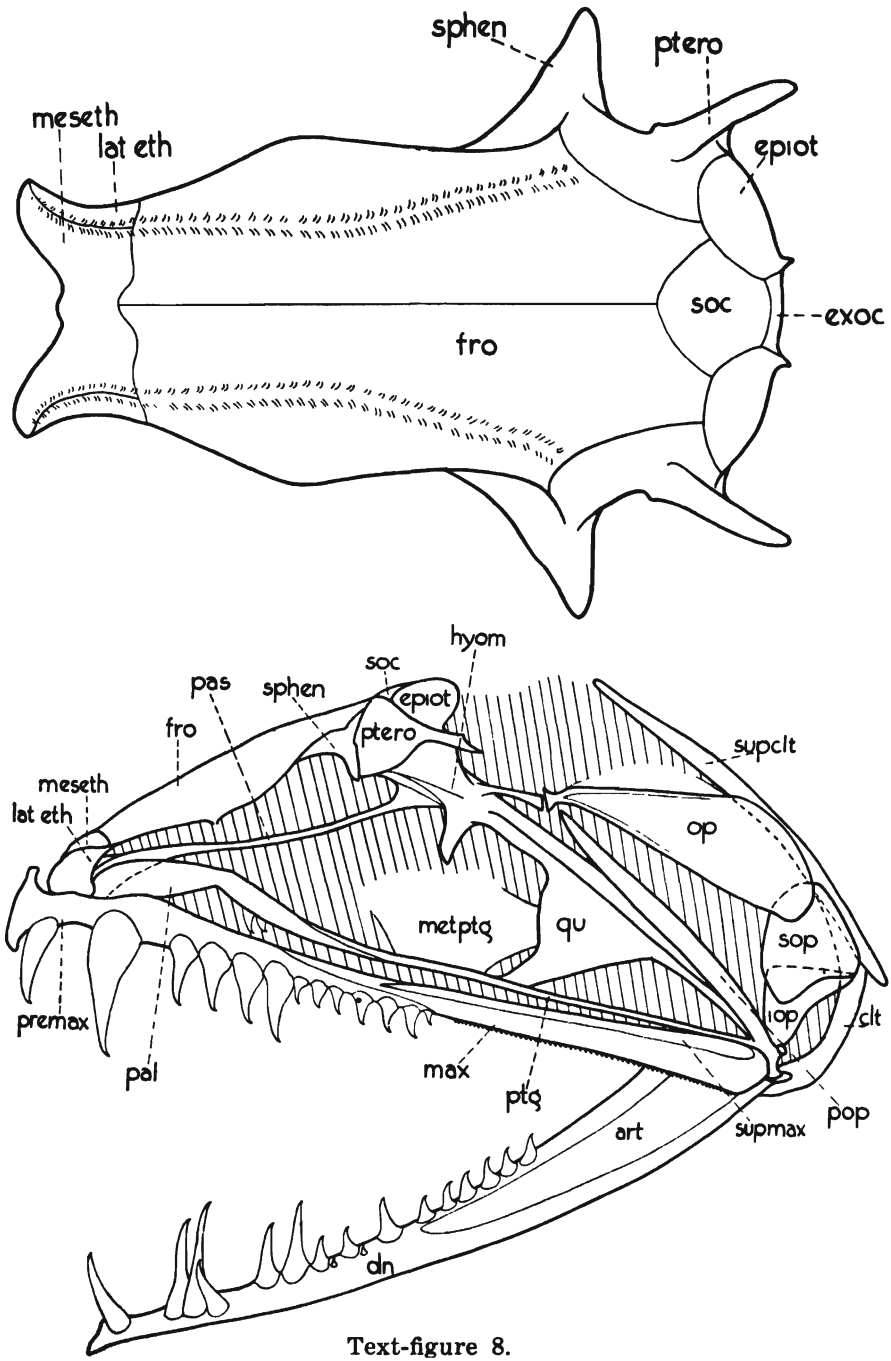
8. EPIDERMAL GROOVES: More or less well developed depressions are usually present along the isthmus to receive the barbel, or at least the basal part of its stem, when it is laid back. In long-barbeled forms, such as *Bathophilus*, a median groove runs to the anus and continues along one side of the anal fin. Similar grooves behind the pectoral insertion are the rule when the rays support luminous material, as in *Chirostomias* and *Grammatostomias*.

9. OSTEOLOGY: In the accompanying diagrams of osteology, we do not include, except for *Bathophilus* which will serve as an example, any dorsal views of skulls, since they have been figured already for most genera by Regan & Trewavas (1930). The same is true of the vertebral column. We have verified their findings in so far as possible, although the boundaries of skull bones are difficult to determine in cleared and stained examples of this family, the majority of which are immature. Our only major difference is that we have found the post-temporal to be present in a number of genera in addition to *Chirostomias* and *Trigonolampa* (see below). The following remarks and comparisons are necessarily derived only from cleared specimens of genera in the present collection, combined with the observations of Regan & Trewavas on apparently uncleared examples.

The skeleton of melanostomiatids is moderately well developed, but with apparently little calcium phosphate deposit and a great deal of calcium carbonate, judging from its usually feeble reaction to calcium phosphate stain.

In all general features the skeleton of *Idiacanthus* is typical also of that of the melanostomiatids, especially of the group including *Melanostomias*. We refer, therefore, to the detailed description of *Idiacanthus* already published in this series (Beebe, 1934). Due to the unsatisfactory reaction of most of the fish to alizarin stain, we can say little about relative degrees of ossification, both between genera at different growth stages and within the species. It is obvious, nevertheless, that as usual in deep-sea fish the jaws are the only really strongly ossified parts of the body, the gill-arches usually come next, then the tip of the caudal peduncle, while the skull proper, the rest of the vertebral column and the supports of the vertical fins are ossified very late, and then usually weakly. No ossification is ever found before transitional adolescence.

*Head*: The lack of parietals in most genera; the union of the frontals by suture; the mesethmoid usually with lateral expansions; the upward, median projection of the premaxillary in all except *Leptostomias;* the reduced, laminar mesopterygoid; and the weak opercular apparatus are the principal characteristics of this family. The skull, especially in *Melanostomias* and *Photonectes*, is very short in comparison with the length of the jaws. The hyoid and gill-arches in some genera, especially *Eustomias* and *Photonectes*, are also very short. The single supramaxillary (not differentiated from the maxillary in Text-fig. 11, varies in its boundaries and degree of attachment to the maxillary; the relative lengths of premaxillary




Text-figure 8.

***Bathophilus metallicus.*** Skull. Upper, dorsal view; lower, lateral view. Standard length 105 mm. Boundaries of bones approximate. General facies typical of the Melanostomiatidae. *art*, articular; *clt*, cleithrum; *dn*, dentary; *epiot*, epiotic; *exoc*, exoccipital; *fro*, frontal; *hyom*, hyomandibular; *iop*, interopercle; *lat eth*, lateral ethmoid; *max*, maxillary; *meseth*, mesethmoid; *metptg*, metopterygoid; *op*, opercle; *pal*, palatine; *pas*, parasphenoid; *pop*, preopercle; *premax*, premaxillary; *ptero*, pterotic; *ptg*, pterygoid; *qu*, quadrate; *soc*, supraoccipital; *sop*, subopercle; *sphen*, sphenotic; *supclt*, supracleithrum; *supmax*, supramaxillary.

and maxillary bordering on the gape also vary; the premaxillary is shortest in *Chirostomias, Leptostomias* and *Photonectes margarita,* longest in *Eustomias.* In the latter genus, the palatine and ectopterygoid are loosely attached by ligaments to the mesethmoid and quadrate respectively, but firmly fastened to the upper jaw; this arrangement permits the forward projection of the jaw. There are 3 hypohyals.

*Pectoral Girdle*: According to Regan & Trewavas (1930) post-temporals are present only in *Chirostomias* and *Trigonolampa.* We have found small ones, however, brightly stained, but not connected with the skull, in *Flagellostomias, Leptostomias* and *Echiostoma.* In addition vestigial slivers (sometimes absent on the opposite side of the same specimen) are occasionally found in *Photonectes.* The supra-cleithrum is reduced in *Melanostomias* and *Photonectes* and entirely absent in *Eustomias.* The mesocoracoid is usually present, but sometimes has the upper arm reduced, and is entirely absent in *Eustomias* and *Photonectes.* Upper and lower coracoids usually well developed, laminar. The actinosts tend to be reduced in number and of peculiar shapes and positions, corresponding to the various modifications of the pectorals. The rays themselves are laminate and strongly ossified basally in *Grammatostomias,* doubtless to support the weight of the luminous tissue.

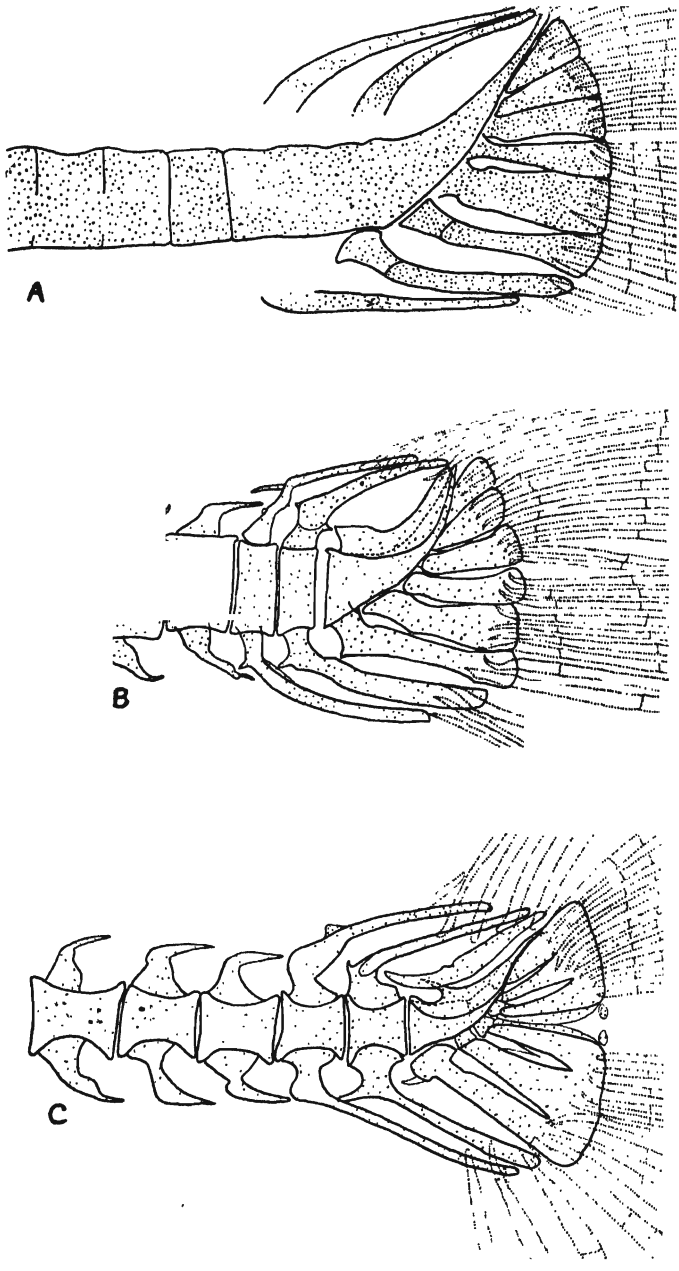
*Vertebral Column*: Regan & Trewavas have already described and figured the extraordinary modifications in the anterior part of the vertebral column in some of the melanostomiatids. *Chirostomias* and *Trigonolampa* alone are completely unmodified, with the first centrum fixed firmly to the skull. Most genera have the first one or two centra represented only by spinal nerves, there being a tough fibrous sheathing around the notochord. *Leptostomias* has similar modifications of seven vertebrae and *Eustomias* is the extreme with 9 or 10 specially adapted. The use of the modification in all, of course, is for the increase of the gape in grasping prey; the separation of the post-temporals from the skull and their atrophy are closely connected with this adaptation.

*Posterior Part of Vertebral Column and Caudal Fin*: The last 2 or 3 vertebrae before the urostyle are the first to be markedly modified, with prolonged neural and haemal arches reinforced with laminar expansions. There are 6 hypurals, 3 dorsal and 3 ventral to the median axis. Each gives rise to from 2 to 5 rays, the fifth and third hypurals being usually broadest, and supporting the most rays. This part of the vertebral column often becomes ossified before the rest. The sequence of raylets and rays, counting from the anterior dorsal raylet around to the corresponding ventral one, is as follows: 5 to 10 + 9 to 11 + 9 to 10 + 3 to 5 (*i. e.,* 18 to 21 true rays).

10. COELOMIC ORGANS: The general plan of the body cavity of melanostomiatids is identical with that found in female *Idiacanthus* (Beebe, 1934.1, p. 218, fig. 75). The stomach varies from about 20% to 45% of the length of the fish, being shortest in *Leptostomias,* longest in *Echiostoma.* A straight intestine with two pyloric caeca is the rule, although in *Chirostomias* and *Pachystomias* the caeca are rudimentary, and in *Opostomias, Flagellostomias, Thysanactis* and *Leptostomias* an anterior pouch gives rise to a single caecum; in *Odontostomias* there is a second caecum in addition to the pouch structure.

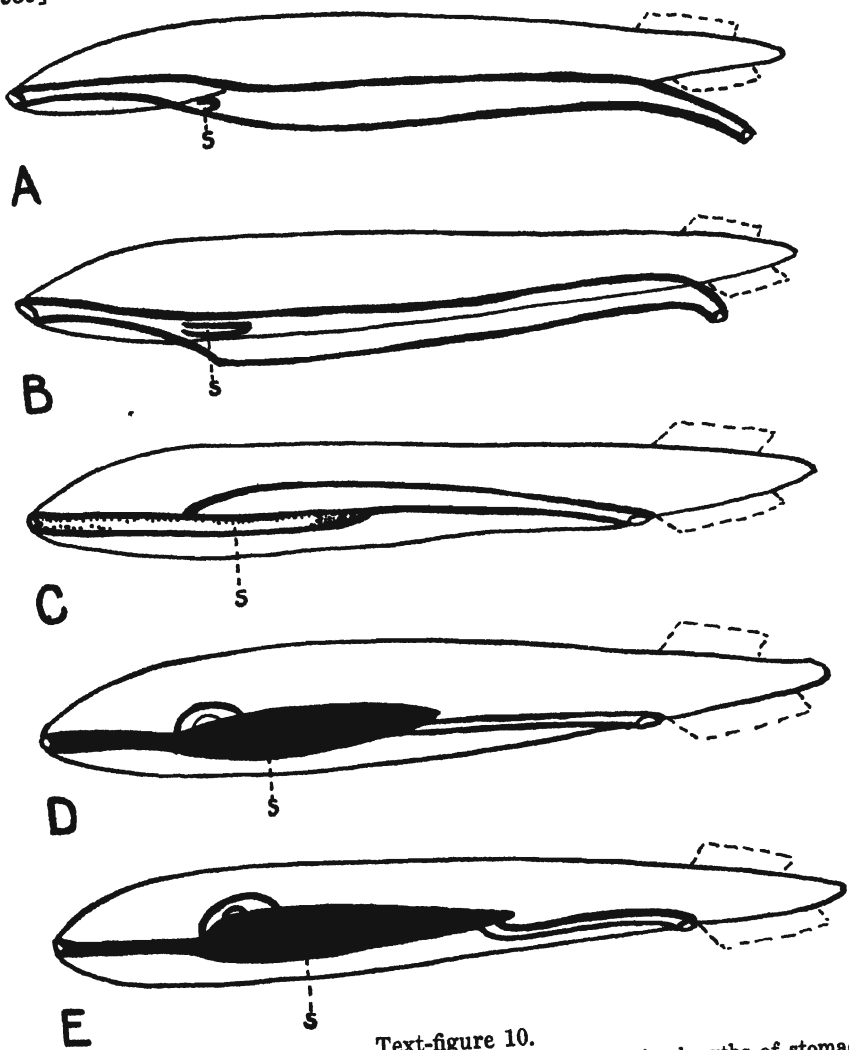
The great posterior extension of the gut, free of the body during the larval stage, is apparently confined to and characteristic of all of the Gymnophotodermi. This phenomenon is probably a specialization connected with the lack of the yolk sac at this stage plus the absence of a stomach; therefore the gut is large in diameter and projects behind, so as to give additional absorptive surface. Sometimes it is more or less gathered in humps in the middle of its length, which accordingly presents still more digestive area. Subsequently, during the post-larval shrinking period, it is gradually absorbed.

The stomach is certainly never large enough to be used until the




Text-figure 9.

*Bathophilus metallicus*. End of vertebral column in **A**, post-larva, standard length 25 mm.; **B**, adolescent, 30 mm.; and **C**, transitional adolescent, 96 mm. Principal characteristics typical of the Melanostomiatidae.




Text-figure 10.

*Melanostomias spilorhynchus*. Diagrams showing relative lengths of stomach and intestine, and position of anal fin, in respect to standard length. **A**, larva, standard length 17 mm.; **B**, post-larva, 24 mm.; **C**, adolescent, 31 mm.; **D**, transitional adolescent, 35 mm.; **E**, adult, 222 mm. This series is typical of the Melanostomiatidae.

adolescent stage. It does not reach its full pigmentation and length until sometime during transitional adolescence—often very late in the stage (as in *Leptostomias* and *Flagellostomias*) and is one of the most useful means of determining immaturity.

The gonads also develop very tardily, and we have not found it possible to distinguish sex earlier than transitional adolescence. When the gonads have developed to more than transparent ribbons of tissue, it is easy to determine the sex, since the eggs of the female are distinct from the very first, whereas testicular tissue is in contrast superficially homogeneous. However, in adults near breeding condition ripe testicles can easily be mis-

taken for unripe ovaries by workers not familiar with the group, since the testicles have a semi-granular appearance similar to that of partially developed ovaries in certain other fishes. However, dissection and microscopical examination at once disclose their true nature. On the other hand, under low power, the ovaries of immature fish often resemble testicles; therefore a small piece of gonad should always be dissected and high power used, to avoid mistakes in this important subject.

11. SHRINKING: Reduction in length during the post-larval, metamorphosing stage appears to be relatively slight in the melanostomiatids, compared with that found in *Chauliodus*, in *Stomias* and in eels. We have found no evidence in the present material that more than 10 mm. in length is lost during this period. Whereas the reduction in length in eels takes place during early adolescence, in this family it occurs chiefly during the post-larval period.

It may be stated here that good-sized melanostomiatids, around 300 mm. in length, shrink up to 20 mm. after preservation in 70% alcohol, and specimens of other lengths in proportion. There is a corresponding loss of depth, usually greater in proportion than the length; the head, eye and snout shrink little, however. Measurements given in the following pages, unless otherwise stated, are made from preserved specimens.

## E. ECOLOGY.

1. HORIZONTAL DISTRIBUTION: Only 7 of the 16 genera of Melanostomiatidae have been taken outside the Atlantic Ocean: *Opostomias* and *Tactostoma*, known only from Australia and the eastern Pacific, respectively; *Leptostomias*, from Hawaii and both North and South Atlantic; *Pachystomias*, from Australia and the North Atlantic; *Photonectes*, from Japan and the North Atlantic; *Melanostomias*, from the Indian Ocean and both North and South Atlantic; and *Bathophilus*, from the Indian Ocean and both North and South Atlantic. *Odontostomias*, *Echiostoma*, *Flagellostomias* and *Eustomias* are known from the North and South Atlantic. The remaining genera—*Trigonolampa*, *Chirostomias*, *Thysanactis*, *Grammatostomias* and *Pareustomias*—have so far been taken only in the North Atlantic. Some genera will doubtless be found to have a wider distribution when intensive trawling is carried out in other oceans.

Ten of the genera or 62½% have been taken by the Bermuda Expeditions. These include every genus previously recorded from the western Atlantic except *Thysanactis* and *Trigonolampa*, the former being apparently a tropical form and the latter boreal. Of the remaining four genera, two (*Odontostomias* and *Pareustomias*) are known from the eastern Atlantic only; while *Opostomias* and *Tactostoma*, as remarked above, have been taken only in the Pacific.

For observations on the distribution of species, see Regan & Trewavas, 1930, p. 34. The absence of *Trigonolampa*, *Bathophilus pawneei* and several species of *Melanostomias* in the Bermuda collection is added evidence to their suggestion that these forms are tropical and Antillean, rather than subtropical, in distribution.

It seems worthwhile to reemphasize the fact that the 250 specimens, 32 species and 10 genera composing the present collection, and forming respectively more than a sixth, a third and five-eights of the known specimens, species and genera, were all obtained in what is scarcely more than a drop of water in the Atlantic Ocean: in an area 5 miles south of Nonsuch Island, Bermuda, 8 miles wide and 1 mile deep.

2. VERTICAL DISTRIBUTION: As is the case with other families of deep-sea fish, the melanostomiatids around Bermuda seem to live at greater depths than elsewhere. Excluding a few colorless larvae, members of the family were not taken in the trawling nets above 300 fathoms (549 metres), and

most were taken far below this level, between 500 and 1,000 fathoms (914 to 1,829 metres, whereas other expeditions, notably the *Dana*, took a great number of specimens "with nets fishing at 200 metres or less below the surface" (Regan & Trewavas, 1930, p. 34). Thanks to our tests with the pressure gauge (Beebe, 1930, p. 244), we are convinced that the great majority of the Bermuda specimens were taken at the level trawled, and not when the net was on the way to the surface. Because of Bathysphere observations, however, it is also clear that these families are not absent from the upper layers here, but can merely avoid the net better, because of the fact that some light penetrates to these depths. From the Bathysphere, in its dives between the surface and 3,028 feet, members of the family were recognized 26 times, between 750 and 2,750 feet (125 and 458 fathoms or 228 and 835 metres), ranging in length from one inch to six feet (counting the six-foot *Bathysphaera intacta*).

Larvae and post-larvae were taken in the nets between the surface and 1,000 fathoms; it is likely that the few taken at the greater depths were among the minority caught on the way upward.

3. ABUNDANCE: About 1,450 specimens of Melanostomiatidae have been taken, including the 250 in the present collection. The total number is distributed among 16 genera and, in the light of the synonymies proposed in the present paper, about 115 species. We are certain, however, that many of these, especially in the genera *Leptostomias* and *Eustomias*, will prove to be invalid, so that the total number of true species known at present comes actually to considerably under 100.

In numbers of individuals, *Bathophilus* and *Eustomias*, with about 500 and 400 specimens, respectively, are the most abundant; *Echiostoma*, *Melanostomias* and *Photonectes* are each known from between 100 and 160 specimens, and *Leptostomias* from 49; less than 25 examples have been taken of every remaining genus. The best known species are *Eustomias obscurus* and *Bathophilus metallicus*, of which about 200 and 185 specimens have been taken, respectively.

Melanostomiatids are among the rarest groups of deep-sea fishes taken off Bermuda. In contrast to the thousands of *Cyclothone*, myctophids and *Sternoptyx* taken, a total of only 250 melanostomiatids came up in the nets, belonging to 10 genera and 32 species. Of these, *Melanostomias spilorhynchus*, of which we have 51 specimens, was the most numerous, *Photonectes dinema* (26 specimens) next, *Bathophilus metallicus* (22 specimens) third, and *Leptostomias gladiator* (20 specimens) fourth. Of the remaining species, a dozen are represented only by single examples.

In regard to number of species, as opposed to individuals, the Melanostomiatidae are surpassed in the collection only by the Myctophidae, of which about 57 species were taken, as opposed to the 32 species of the present family.

It is interesting to note that in number of individuals it is the plankton eaters—*Cyclothone*, myctophids and sternoptychids—that are numerically far ahead of eaters of fish and shrimps, such as the large-toothed stomiatoids (*Stomias*, melanostomiatids, *Chauliodus*, astronesthids, *Idiacanthus*), the lyomerids, large-mouthed pediculates, *Chiasmodon*, etc., just as on land, large carnivores are surpassed in numbers by their herbivorous prey, such as rodents and ungulates.

4. FOOD AND ENEMIES: The food of melanostomiatid larvae is, of course, confined to small organisms such as diatoms and copepods. Toothless, transforming, post-larvae and adolescents, however, probably do not eat at all for a short while; at least, we have found no food in their intestines. Transitional adolescence, however, is again a period of growth, the stomach is well developed, and the food represents on a small scale the food of adults, namely myctophids and other small fish, and good-sized shrimp.

Although more than 40 stomachs of transitional adolescent and adult melanostomiatids were examined, less than half contained any food at all, although finely digested matter was usually present in the intestine. The likelihood is that these strong fishes digest their food rapidly, even just before death. Myctophids were present in nine stomachs, unidentified small fish in three, *Luciosudis* in one, *Cyclothone microdon* in one, a shrimp in one, and ostracods in one. Without exception the fish were swallowed whole, head first, and measured one-half to five-sixths the length of the melanostomiatid.

We have not found melanostomiatids in the stomach of any Bermuda fish. A specimen, the second known, of *Trigonolampa* was, however, found in the stomach of a swordfish (Parr, 1933, p. 178).

5. ACTIVITY: From the Bathysphere these fish appeared agile and eel-like, with rather slow twistings in progression. None of them seemed to be affected by the search-light. Usually only one of these fishes was seen at a time, but occasionally two or three appeared swimming together. When brought up alive they swam about and snapped with all the accuracy of balance and swiftness of surface fish. As with other living deep-sea fish, they would try to burrow downward, bumping their snouts against the bottom of the pan. Always they could be greatly revived by being placed in a pan of ice-cold salt water in the refrigerator. A young *Pachystomias atlanticus*, 37 mm. long, was the smallest member of the family, and, in fact, the smallest deep-sea fish, taken alive.

## F. PHYLOGENY.

We agree with Parr (1927, p. 4) and Gregory & Conrad (1936, p. 23, fig. 2) that an astronesthid-like form or forms were the ancestors of the Gymnophotodermi, and hence of the Melanostomiatidae. In common with the more primitive stomiatoids, the Astronesthidae have fixed teeth, unspecialized fins and vertebral column, and an adipose fin. Yet they have the barbels, well developed postorbital organs and naked black skin of the Gymnophotodermi. Parr pointed out the variability of the position of the dorsal fin in the Astronesthidae. The later work of Regan & Trewavas (1929) showed the diversity of other characters in the same family—characters which are found in similar diversity in the Melanostomiatidae, such as the form of teeth on the maxillary and gill-arches. All erect maxillary teeth are found in several astronesthid genera, exactly as in the melanostomiatid *Chirostomias*, whereas all oblique teeth occur in others—as in the more specialized melanostomiatids. Similarly, both double and single gill-arch teeth occur in the family, just as in the Melanostomiatidae. Double gill-teeth are found as well far down the stomiatoid scale in *Photichthys*, whereas single, raker-like teeth and actual spiny rakers occur in such genera as *Gonostoma*, as well as in melanostomiatid larvae. In summary, the existing genera of Astronesthidae show all the elements needed by a hypothetical ancestor of the Melanostomiatidae — the various types of maxillary and gill-teeth, a variable dorsal fin trending backwards, and unspecialized finrays, combined with the already specialized naked black skin, barbel and well-developed postorbital organ. The remaining Gymnophotodermi—the Idiacanthidae and Malacosteidae—are doubtless off-shoots of the Melanostomiatidae.

As a family, the Melanostomiatidae have specialized in slenderness, with increased numbers of vertebrae and elongation of the stomach, in elaborate and elongate barbels, in sexual dimorphism in the development of the postorbital cheek light, in specialized luminous or elongate pectoral fins, in the acquisition of depressible teeth, in the reduction and loss of parietals, in the reduction of the opercles and pectoral girdle, in modifica-

tions of the anterior part of the vertebral column, and in the shortening of the caudal peduncle and fin.

*Primitive, Specialized and Adventitious Characters*: In determining the relationship of the genera to one another, the following characters may unquestionably be considered primitive, with their roots far back in the stomiatoid stock, since they are the rule among the more primitive of existing stomiatoids: Fixed, barbless teeth; an adipose fin; pectoral girdle well developed with a strong post-temporal and a related lack of modification in the anterior part of the vertebral column; pelvics near the middle of the body; parietal present; single or double gill-arch teeth strongly developed, present on all five, or at least four, arches, including hypobranchials and epibranchials as well as ceratobranchials.

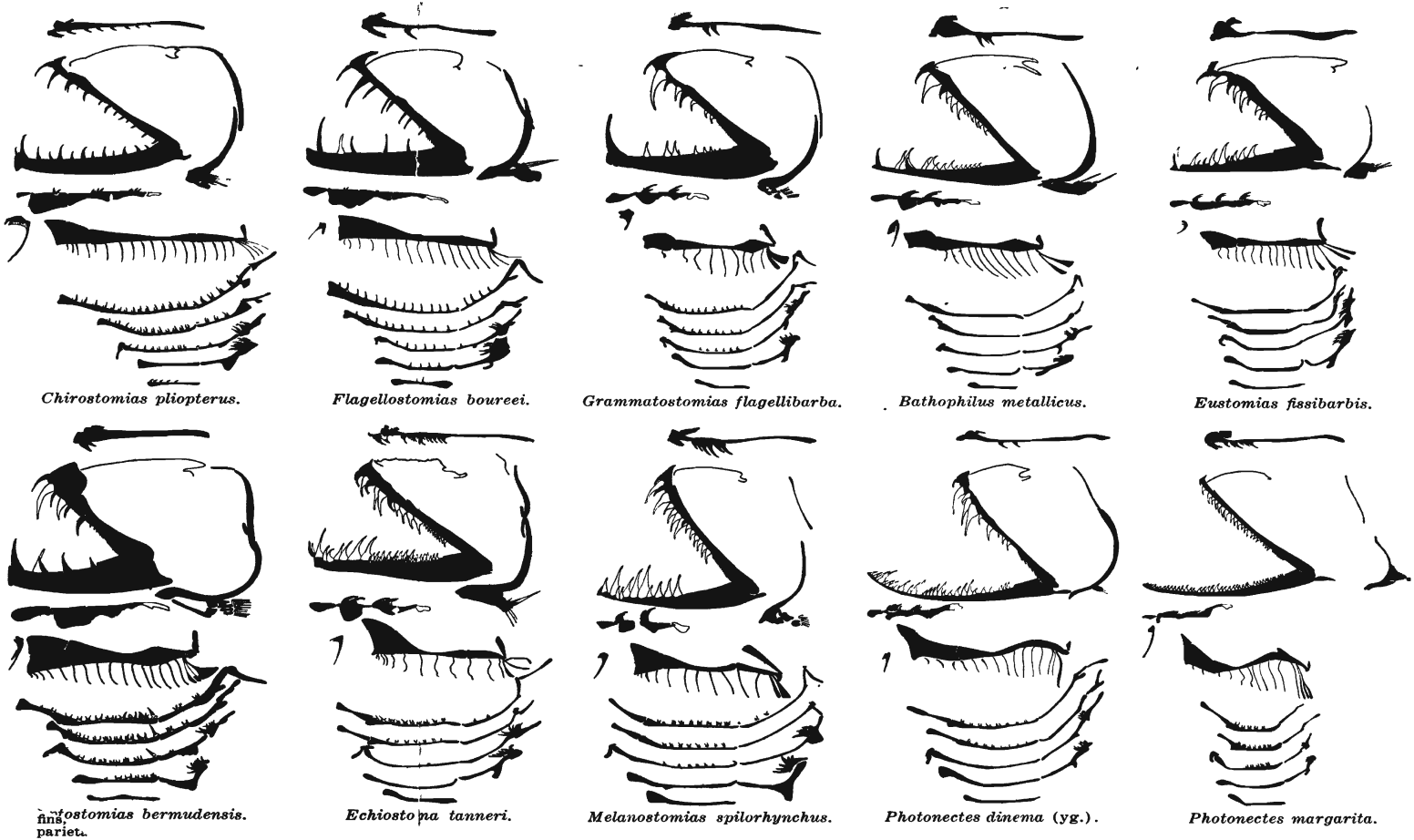
The following characters, on the other hand, prove to be of almost no use in determining relationships, since each of them varies greatly, not only in closely related genera, but even within the same genus: body proportions, notably depth and head length; (examples: *Leptostomias, Bathophilus*) ; barbel length and form (example: *Eustomias*) ; pectoral development (example: *Bathophilus, Eustomias*) ; presence and distribution of superficial luminous tissue (examples: *Photonectes, Bathophilus*). Also, these variable characters crop out in specialized form in the most primitive genera, and *vice versa*. For example, *Chirostomias*, unquestionably the most primitive genus in the family in fundamental structural characters, is equipped with a highly complex barbel and pectoral fin. Similarly, *Bathophilus* and *Tactostoma*, two of the most specialized end-genera, have simple or degenerate barbels.

Several distinct characters may be termed adventitious, since they occur sporadically throughout the family and, indeed, throughout the stomiatoids as a whole. Such are grouped serial photophores, which are common among the gonostomids and sternoptychids, and present in the astronesthid *Heterophotus*, in the malacosteid *Aristostomias* and in the melanostomiatids *Pachystomias, Eustomias obscurus* and *Pareustomias*. A more or less elongate anal fin, present in *Flagellostomias* and *Eustomias* in the Melanostomiatidae and in other genera scattered through related families, is a similar character. An exceptionally high number of vertebrae is a third; among melanostomiatids *Leptostomias, Tactostoma* and *Eustomias*, although they have practically nothing else in common besides general family characters, all have many more vertebrae than the average of 50 to 60.

The atrophy of the postorbital cheek light in females is a most puzzling character, since it does not, as far as is known, occur in lower stomiatoids, and yet is the rule in otherwise primitive melanostomiatids, while in females of the most specialized genera the organ is again functional and even (as in *Melanostomias, Echiostoma* and *Photonectes*) as large as in males.

*Generic Interrelationships*: We support in general the groupings of genera suggested by Regan & Trewavas (1930). That is, we agree that *Chirostomias* and *Trigonolampa* are closely related and the most primitive known genera; that *Leptostomias, Thysanactis, Flagellostomias* and *Opostomias* along with Norman's *Odonotostomias* (1930) form a natural group intermediate in degree of specialization; that *Bathophilus* is close to *Grammatostomias;* that *Melanostomias, Echiostoma* and *Photonectes* are closely related; and that *Pachystomias* and *Eustomias* are both aberrant.

In addition, with our study of characters, such as gill-arch teeth and larval stages, other than those emphasized by these authors, we are able to give a tentative but plausible sketch of the relationships of the groups to each other. As we see it, *Bathophilus* could not possibly have come from a *Chirostomias*-like form except insofar as such a form was probably ancestral to the entire family, nor *Eustomias* from an *Echiostoma*-like fish—




**Text-figure 11.**

Jaws, hyoid and branchial arches, and pectoral girdles of typical Melanostomiatidae. Depressible jaw-teeth unshaded; divisions between palatine and pterygoid, and maxillary and supramaxillary not shown; fourth basibranchial, always unossified, unshaded. For the same illustrations, enlarged and labeled, see Text-figs. 13, 18, 23, 28, 33, 34, 45, 50, 55 and 64.

*Echiostoma* itself being one of the most specialized genera, and not at all on the same line of development as that followed by *Eustomias*. Both of these suggestions have been made by Gregory & Conrad (1936, p. 26). Parr's (1927) pioneering suggestions as to relationships within the group have of course been largely superseded by the osteological study of the large *Dana* collection.

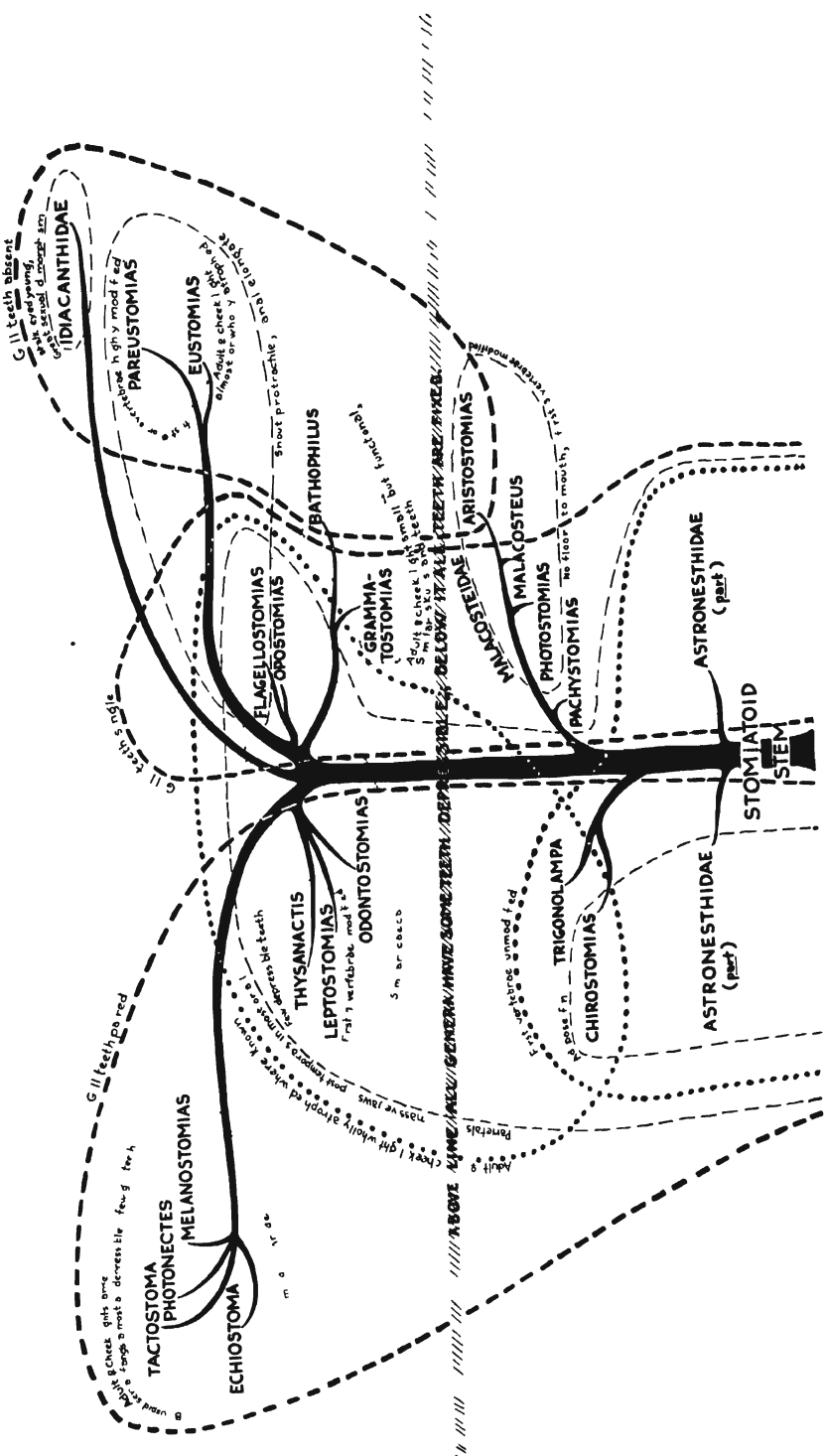
From the accompanying diagram (Text-fig. 12) it will be seen that we recognize a number of generic groups, with *Tactostoma* on the one hand and *Bathophilus* and *Pareustomias* on the other as the most specialized end forms in the Melanostomiatidae. The family shows a natural division into genera in which the gill-arch teeth are paired, and those in which they are single or absent. Another main division is into the primitive forms with all of the jaw teeth fixed, and the remaining genera, in which at least a few are depressible. We will now consider the various groups in detail.

*Chirostomias, Trigonolampa*: These genera, both having paired gill-arch teeth, are, as has been said, the most primitive. Their basic, generalized characters are fixed teeth, well-developed parietals, numerous gill-teeth, unspecialized vertebral column, short stomach, strong post-temporal and pectoral arch and, in *Chirostomias*, an adipose fin. In contrast, the variable characters of barbels and pectoral fins are highly specialized. The post-orbital organ is completely atrophied in the female in *Chirostomias;* its condition in female *Trigonolampa* is unknown.

*Pachystomias,* with its small, fixed teeth and unspecialized fins, is placed next on the tree. As Parr, judging only from external appearances, suggested (1927), we think it is close to the line of malacosteid development, with its somewhat similar suborbital lights; exceptionally large, massive head; strong, backwardly-extended jaws joined by only a thin membrane; its general shape and fin arrangement; and its single-gill-arch teeth. In the malacosteids the gill-teeth are single or absent, teeth in the jaws are fixed, the jaw membrane is entirely absent, and the grouped photophores of *Aristostomias* are similar in pattern to those of *Pachystomias*. The absence of parietals, post-temporals and pyloric caeca are other characters in common, and although the skulls are dissimilar, they present no significant differences to preclude relationship. The development of the postorbital light organ in females is unknown in *Pachystomias*.

*Odontostomias, Thysanactis, Leptostomias, Opostomias, Flagellostomias*: These genera form the somewhat heterogeneous base for the remaining melanostomiatids, just as the dissimilar Astronesthidae form a similar base for the more specialized of the Gymnophotodermi. The five genera have in common the primitive and semi-primitive characters of parietals, massive head and jaws, few depressible teeth, a pair of teeth on the vomer, many gill-teeth on four or five arches, moderately short stomachs, rudimentary caeca, and, with the exception of *Thysanactis* and *Leptostomias,* a vertebral column almost unmodified anteriorly, but usually with many vertebrae. We have found small but well ossified post-temporals, not connected with the skull, in both *Flagellostomias* and *Leptostomias;* these bones were not discernible in the *Dana* specimens described by Regan & Trewavas (1930), probably because those specimens were not cleared and stained; the bone may prove to be present in all five genera. The post-orbital organ is atrophied in the adult female at least in *Odontostomias, Leptostomias* and *Flagellostomias*. It is probable that the members of this group attain maturity at a greater length than others in the family.

There is a natural division into two sub-groups, the first (*Odonotostomias, Thysanactis* and *Leptostomias*) having the gill-teeth paired or in threes and fours on all arches except the last, and the second (*Opostomias* and *Flagellostomias*) with all the gill-teeth single. The ancestors of the first division probably gave rise to the *Echiostoma-Melanostomias-Photonectes-Tactostoma* group, while from *Opostomias-Flagellostomias* roots came




Text-figure 12.
Suggested phylogeny of the Melanostomiatidae.

offshoots ending today in *Grammatostomias* and *Bathophilus* and in *Eustomias* and *Pareustomias*.

*Echiostoma, Melanostomias, Photonectes, Tactostoma*[3]: These four genera have in common large but usually slender jaws with numerous teeth, almost all depressible, and with strongly barbed tips; paired or grouped teeth in reduced numbers on only two or three gill-arches; similar, very short skulls without parietals; post-temporals reduced or absent and the rest of the pectoral girdle weakened; anterior part of vertebral column slightly modified; a long stomach with two well-developed caeca; and pelvic inserted far behind the middle of the length. In *Melanostomias, Echiostoma* and *Photonectes* the cheek light is exceptionally and equally large in both males and females, apparently the only genera in the family of which this is true, and the larvae are very similar. (Neither of these characteristics is known as yet in *Tactostoma*, except that the postorbital is not large in the known specimens). *Echiostoma* and *Tactostoma* are the only genera in the family having the teeth multi-rowed, although the single rows of other genera are rarely perfectly regular). The teeth of adult *Photonectes* and of *Tactostoma* are small, but those of immature *Photonectes* bear a striking resemblance to those of adult *Melanostomias* (Text-fig. 9). In all except the latter genus the barbel tends to reduction, being better developed in the young than in the old, and vestigial in *Tactostoma*.

*Grammatostomias, Bathophilus, Eustomias, Pareustomias*: The first two and the last two form closely related sub-groups; in fact, *Pareustomias* may prove to be a sub-genus of *Eustomias*. *Grammatostomias* is the only genus in which any gill-teeth at all are found, and these are few and single. Parietals and post-temporals are absent, teeth (except in some *Eustomias*) are mostly depressible, moderately large and sometimes with rudimentary barbs; stomach moderately elongate; two caeca; postorbital light organs usually large in male, always smaller, sometimes atrophied, in female. *Bathophilus* is highly specialized in development of fins and body depth, with vestigial serial organs. The semi-primitive genus *Flagellostomias* has the beginning of the protractile snout which is carried to such high development in *Eustomias*. There is a questionable trace of the same character in *Grammatostomias*. All the genera have a tendency toward elaborate barbels, either through simple elongation or through the development of ornate branches and filaments.

*Comparison of Specialized End-Genera*: Comparison of the two groups of offshoots from the five central genera is interesting. Group A (*Echiostoma*, and its allies) has kept paired gill-teeth, while Group B (ending in *Bathophilus* and *Pareustomias*) has single, *Flagellostomias*-like gill-teeth or has lost them altogether. In both A and B the arch teeth, whether paired or unpaired, are reduced in number, being present at most on the first three ceratobranchials and first epibranchial. In Group A the jaw teeth become all depressible, more or less barbed and very numerous, the extreme being reached in the multi-rowed teeth of *Tactostoma*, and both the vomerine teeth[4] and an erect series on the maxillary are kept; in Group B a number of fixed teeth is always kept, the jaw teeth are never numerous, barbs are rudimentary or absent, and both vomerine teeth and erect maxillary teeth are lacking. In Group A the skull is reduced, although there is no jaw reduction, while in Group B the skull remains little shorter than the jaws, as in primitive genera. In both groups the pectoral girdle is reduced, and the anterior part of the vertebral column modified to allow a backward and upward movement of the head, increasing the gape. Sometimes there is a forward thrusting of the lower or upper jaw in capturing food. In *Photonectes* the curved lower jaw is dislocated and thrust forward, while in *Eustomias* it is the snout and upper jaw. The pelvics are inserted far back in Group A, while in Group B they have remained near the middle of the

[3] Osteological and internal characteristics not yet known in *Tactostoma*.
[4] Except in *Tactostoma*.

body. In Group A the barbel tends toward secondary reduction approaching atrophy, while in Group B are found the most elaborate and elongate barbels in the family. Both groups have elongate stomachs and two well-developed caeca.

On the chart the Idiacanthidae are shown as a highly specialized offshoot of the main melanostomiatid stock. The skull and teeth are similar to those of *Melanostomias*, while the general form, lack of gill-arch teeth, shape and pigmentation of the larva, and unequal development of the postorbital organ in males and females show some resemblance to the *Flagellostomias-Eustomias* axis.

*Conclusions*: Most of the specializations of the Melanostomiatidae, both beyond those of the lower stomiatoids and within the family, are in the direction of increased efficiency in the capture, swallowing and digestion of large, living prey. To this end, the body becomes elongate and streamlined with the vertical fins forming a single, powerful, swimming organ. The jaw teeth are enlarged, and efficiency is further increased through the development of depressibility and of barbs. Teeth on the vomer, palatines, basibranchials and gill-arches assume great functional importance. The gape is enlarged both by the flexibility of the jaw angle and by the modification of the anterior vertebrae and the related disconnection of the pectoral girdle from the skull, which enables the head and upper jaw to be swung backward and upward; through these devices the mouth can often be opened to an angle of fully 180 degrees. In addition, the upper jaw with its strong fangs can sometimes be thrust forward; in other cases a similar movement can be made with the lower jaw through the swinging forward of the elements of the hyomandibular arcade. In the genera having these highly specialized modifications, all teeth except those in the jaws themselves are reduced in size and number, in direct ratio: the greater the depressibility of the teeth, the modification of the vertebral column, and the distensibility of snout or mandible, the fewer the teeth on the roof and floor of the mouth. The stomach becomes elongate for the reception of large, whole prey, which is invariably swallowed head first.

Some specializations of luminous organs are probably also concerned in increased efficiency in the hunt for food, but the development of the postorbital organ, at least, is unquestionably of sexual significance, while the same is sometimes true of the barbel.

The following key to the genera of Melanostomiatidae attempts both to be of practical use and to indicate relationships.

## G. Synopsis of the Genera.

A. All teeth in jaws firmly fixed.
  B. Teeth on first gill-arch in pairs; parietal present; post-temporal present.
    C. Adipose present — *Chirostomias* (p. 111).
    CC. Adipose absent — *Trigonolampa*.
  BB. Teeth on first gill-arch single, parietal absent; post-temporal absent . .. . — *Pachystomias* (p. 117).

AA. Some teeth in jaws depressible.
  D. Gill-teeth present at least on first 4 arches, and usually on all 5; lower jaw with only 1 or 2 depressible teeth; parietal present; post-temporal small or absent.
    E. Gill-teeth on first arch mostly in pairs.
      F. An isolated pectoral ray; gill-teeth present on 5th arch — *Thysanactis*.
      FF. No isolated pectoral ray.

G. Gill-teeth present on 5th arch; 32-35 O-V photophores *Odontostomias.*

GG. Gill-teeth absent on 5th arch; 39-47 O-V photophores *Leptostomias* (p. 121).

EE. Gill-teeth on first arch single; an isolated pectoral ray.

H. Mandibular fangs perforating premaxillaries; dorsal and anal commencing at same vertical *Opostomias.*

HH. Mandibular fangs not perforating premaxillaries; anal commencing well in front of dorsal *Flagellostomias* (p. 179).

DD. Gill-teeth never present on more than first 3 arches; sometimes absent; lower jaw with more than 2 teeth depressible (or, if only 2, the gill-arches are toothless); parietal absent; post-temporal rudimentary or absent.

I. Teeth on first gill-arch paired, or in groups of 3 or 4; vomerine teeth present; some erect teeth on maxillary; jaw teeth slightly or sharply bicuspid.

J. Pectoral of 5 or 6 normal external rays; post-temporal sometimes present *Melanostomias* (p. 142).

JJ. Pectoral of less than 5 rays.

K. Pectoral of 4 external rays, the first isolated and produced; cleft of mouth straight; post-temporal present *Echiostoma* (p. 130).

KK. Pectoral of 0 to 3 rays; cleft of mouth more or less strongly curved upward.

L. Jaw teeth in a single row; post-temporal sometimes present *Photonectes* (p. 154).

LL. Jaw teeth in many rows or groups; post-temporal? *Tactostoma.*

II. Gill-teeth all single or entirely absent; no erect maxillary teeth; vomerine teeth absent; post-temporal absent; jaw teeth slightly or not at all barbed.

M. Gill-teeth present; a line or loop of luminous tissue on side *Grammatostomias* (p. 185).

MM. Gill-teeth absent; no line or loop of luminous tissue on side.

N. Dorsal and anal beginning at same vertical; upper jaw not protractile; several teeth on palatines; supracleithrum present *Bathophilus* (p. 196).

NN. Anal originating well in advance of dorsal; upper jaw protractile; palatines toothless; supracleithrum absent.

O. Premaxillary normal *Eustomias* (p. 210).

OO. Premaxillary free of maxillary, curving upward above jaw line *Pareustomias.*

## H. Report on the Collection of the Bermuda Oceanographic Expeditions, Including Revisions of Genera and Species.

### Genus ***Chirostomias*** Regan & Trewavas, 1930.

(See also pp. 71, 73, 82-86, 90, 91, 96-99, 102, 104-106, 109).
(Text-figs. 3, 11, 12, 13-16 incl.).

#### General Discussion.

Upon reexamination of the type specimen of *Chirostomias lucidimanus* Beebe, 1932, and comparison with immature specimens in the same Bermuda collection, we have decided to synonymize it with *C. pliopterus* Regan & Trewavas, 1930, the only other species which has been described. Our reasons for this step are as follows:

1. The barbel differs from that of *C. pliopterus* only in a manner consistent with growth. The largest specimen described by Regan & Trewavas was 115 mm. long; *C. lucidimanus* measures 205 mm.; the next largest Bermuda specimen measures 118 mm. and is immature, with a barbel intermediate between that of *lucidimanus* and *pliopterus;* barbels of all small specimens (35 to 41 mm.) in the Bermuda collection agree excellently with typical *pliopterus*. The greater length of the stem in the largest specimen, and the greater number of anterior bulb filaments, are both perfectly normal growth differences; it is possible that the third, rather surprising difference —that of the *smaller* number of *posterior* bulb filaments—is due to their being literally rubbed gradually away, by contact of the barbel bulb with the isthmus, when the barbel is laid back in its groove. Minor details may also be sexual characters, but since we have only one male, an immature 118 mm. specimen, more material is needed in order to settle the question.

2. A recount of the dorsal fin rays in the type specimen of *C. lucidimanus* gives 18 rays, as in *pliopterus*, instead of 16, as stated in the description of *C. lucidimanus*.

3. Although the eye of *C. lucidimanus* is relatively smaller than in *pliopterus*, this characteristic again may logically be attributed to the difference in size; in our intermediate, 118 mm. specimen, the proportionate size of the eye is as in typical *pliopterus*.

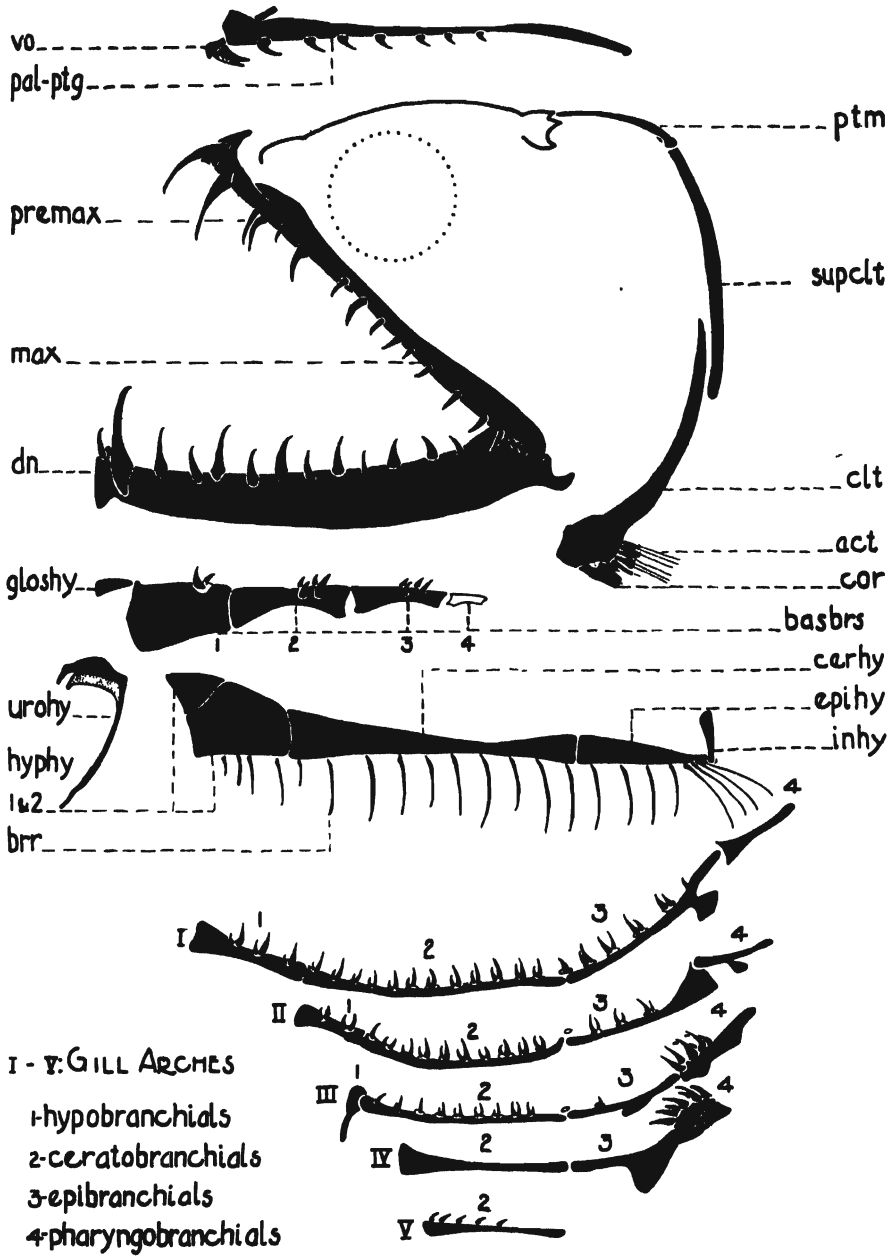
*Distribution*: *Chirostomias pliopterus*, the single known species, has been taken only in the Atlantic Ocean north of 20°, at depths between 55 and 700 fathoms. Known altogether from 13 specimens, including the present series.

#### Generic Characters.

(Since only one valid species is known in this genus, the following characters are also those of the unique species, *C. pliopterus* Regan & Trewavas).

*Color* (from freshly caught immature male and two immature and 1 adult females, the adult being alive): General color, velvety black with greenish bronze iridescence on shoulder; iris black; postorbital organ of male white, rimmed dorsally with silver; barbel bulb white and silver with pinkish luminescence anteriorly, white posteriorly (see below under "Barbel"); this organ is greenish-yellow and silver in young females, with no glow observed; serial photophores violet, the lights of the lateral series having gilt caps divided into five successive small sections and, below the lights, single, undivided smaller patches of gilt.

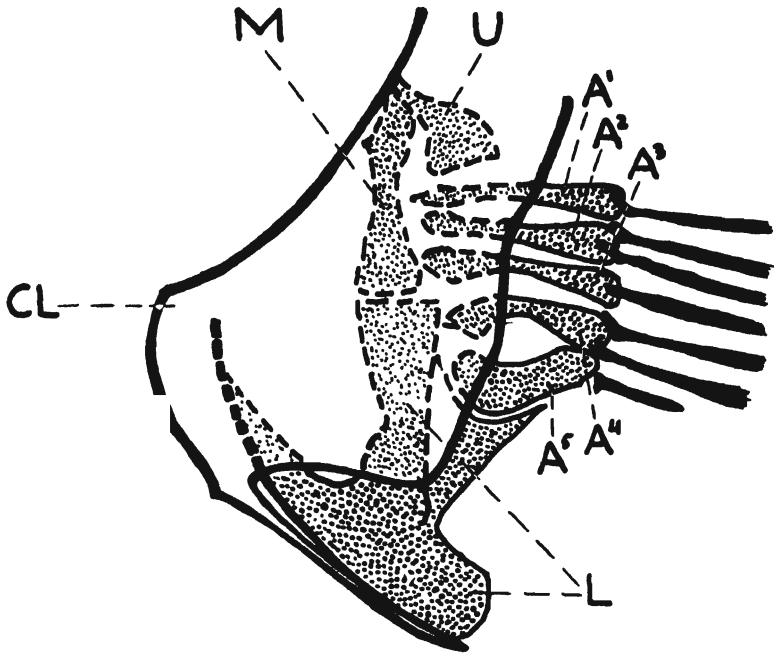
*Proportions*: Moderately elongate melanostomiatids with adipose fin; depth in length 6 to 7.7 (13% to 16.7%); head in length 5 to 6 (16.7% to 20%); eye in head 4 to 5.8 (2.9% to 3.9% of length); snout to pelvic in length 1.7 to 1.9 (53% to 59%).




Text-figure 13.

*Chirostomias pliopterus*. Jaws, hyoid and branchial arches and pectoral girdle of transitional adolescent, standard length 118 mm. Explanation and abbreviation as in Text-fig. 18.

*Barbel*: Shorter than head, with stout black stem ending in a large, ovate swelling, which is black spotted with luminous tissue, and cleft distally; a terminal, anterior series of simple and compound translucent projections, and a posterior, translucent, fringed flange.

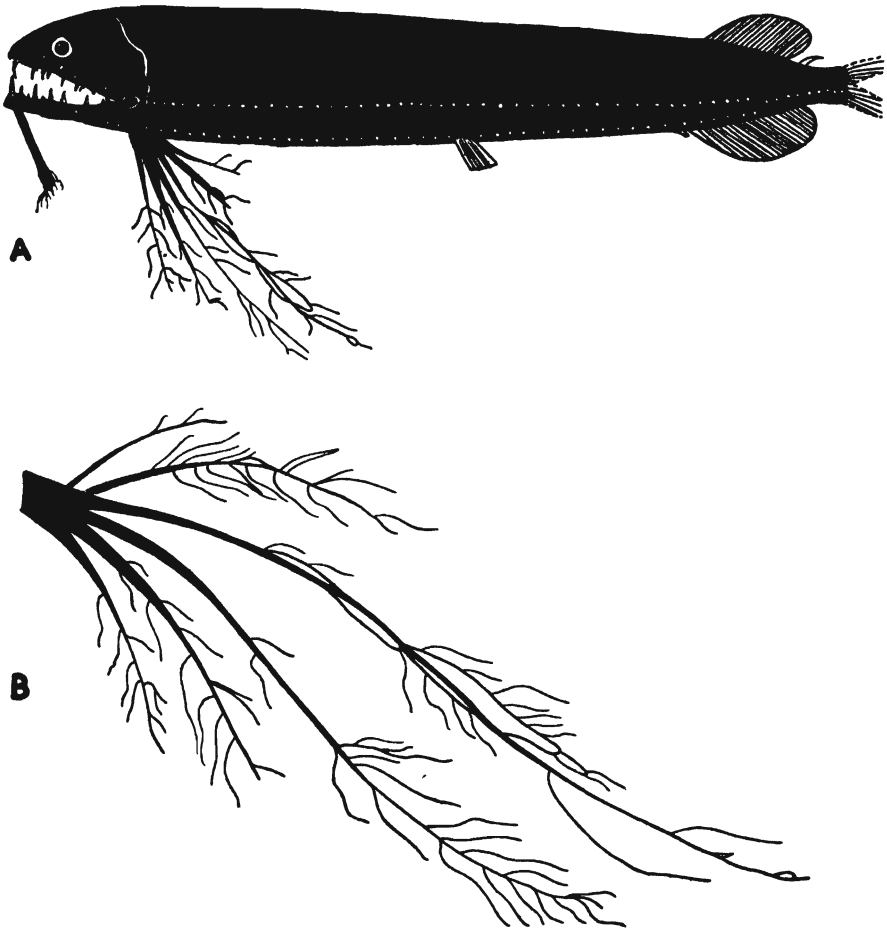



Text-figure 14.

*Chirostomias pliopterus.* Supporting bones of pectoral fin. $A^1$, $A^2$, $A^3$, $A^4$, $A^5$, actinosts; **CL**, cleithrum, **L**, lower coracoid; **M**, mesocoracoid; **U**, upper coracoid; fin-rays in solid black; short ray rudimentary, invisible externally. From a transitional adolescent, standard length 118 mm.

The barbel of the largest specimen known, a 205 mm. Bermuda female in breeding condition, differs slightly from those of previously known, younger examples, and hence a description is given in full below. This specimen was formerly described as *C. lucidimanus* Beebe, 1932 (see under "Discussion," p. 111).

The bulb is blue-black, elongate and somewhat compressed. The terminal part is cleft, forming two large, tubular divisions, the anterior the broader, each tipped with a pair of sharp, tooth-like structures opening toward one another. From the front of the anterior division arises a tuft of 7 filaments from a single base, the upper ones being longest, longer than the bulb itself. Under the ultra-violet light, while the fish was still feebly alive, these filaments gave off a pinkish glow. At the tip of the anterior division, in the position of the club-shaped appendage found in smaller specimens, is a thick, beaded tubercle, while from each of the two extreme distal teeth-like structures arise two or three short filaments. The posterior surface of the bulb shows a number of isolated spots of luminous tissue which consolidate into a thick, luminous, white comb or flange, with only a few very short filaments at the tip in place of the bushy fringe found in smaller specimens; the most distal of these is, however, as usual, a longer, beaded structure. The luminous tissue, which gave off a white glow in this area, dies out on the surface of the mid-bulb in an ever-thinning mass of scattered spots and dots. There is at least a single muscle at the tip of the bulb, which has the power of separating the terminal structures widely, the four tooth-like protuberances showing up strongly through the translucent pink luminous tissue.



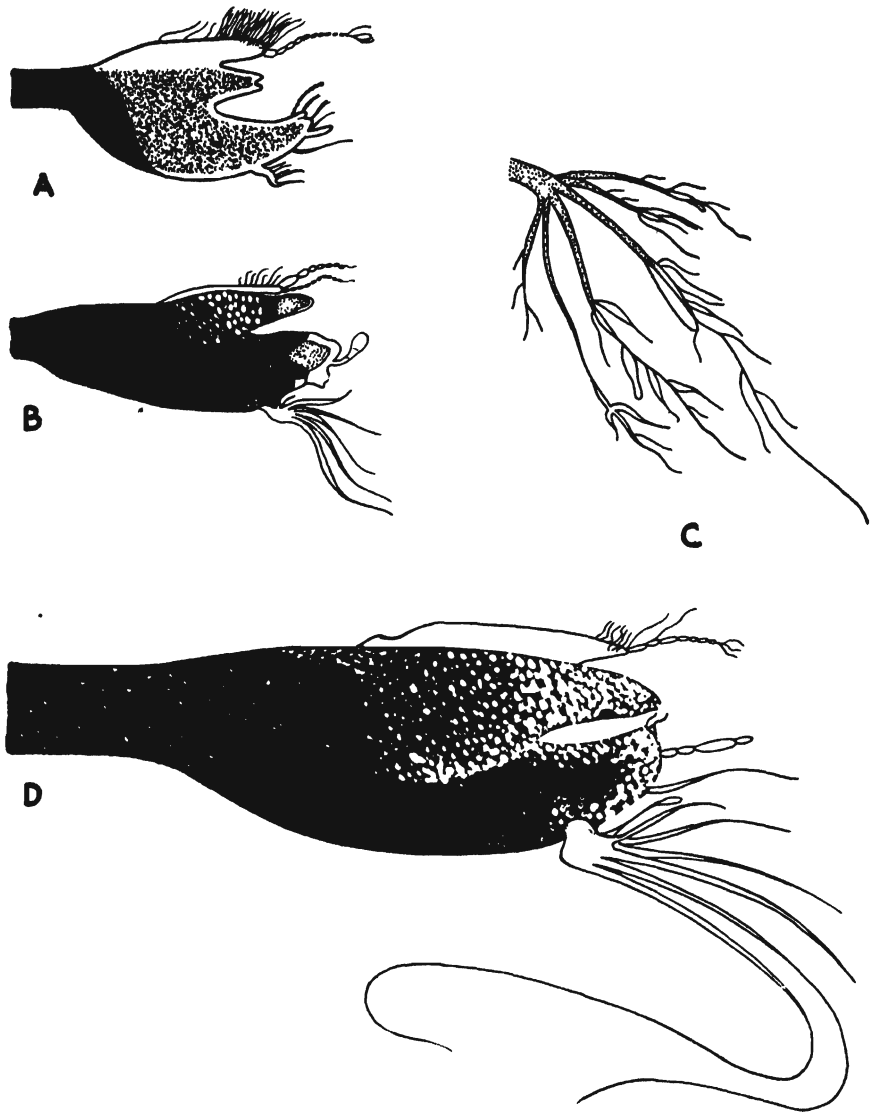

Text-figure 15.

*Chirostomias pliopterus*. **A**, adult female, standard length 205 mm.; **B**, same, pectoral fin, showing luminous material on fourth and fifth rays.

*Light Organs*: Postorbital moderately large in male, completely atrophied in female. Serial photophores with the following counts: ventral series, I-P 9, P-V 26 to 28, V-A 18 to 20, of which 5 to 6 are above the anal, A-C 10 to 11; lateral series, O-V 23 to 24, V-A 18 to 20. Pectoral fin with luminous tissue.

*Teeth*: Cleft of mouth straight; all teeth fixed; premaxillary and mandible with about 7 to 13 curved fangs each, set in 2 irregular rows; maxillary with 7 to 12 fangs and several small, oblique teeth at end; a pair of teeth on the vomer; a series of 7 to 9 on each palatine, extending onto the ectopterygoid. Usually 5 to 6 pairs of teeth on basibranchials. Teeth in pairs present on all gill-arches except fourth: on first and second hypobranchials; on first, second, third and fifth ceratobranchials; and on first, second and third epibranchials; 11 to 12 pairs present on first ceratobranchial.

*Branchiostegal Rays*: 22.




Text-figure 16.

*Chirostomias pliopterus*. **A**, end of barbel in adolescent, standard length 41 mm.; **B**, end of barbel in transitional adolescent male, 118 mm.; **C**, pectoral fin of same; **D**, end of barbel in adult female, 205 mm.

*Fins*: Pectoral of 6 slender rays, the longest more than twice length of head, all branched distally, with one or more luminous swellings; inserted far forward and very low, under opercle; pelvic 7, inserted slightly behind middle of length at about 29th myomere; dorsal 18 to 20; anal 22 to 26; dorsal and anal beginning at same vertical, but anal extending farther back; adipose present.

*Epidermal Grooves*: There is a deep groove in the isthmus for the reception of the barbel, and one in the side for the pectoral fin.

*Osteology*: Parietals present; mesethmoid with lateral processes; posttemporal present; supracleithrum and cleithrum strong; upper coracoid rudimentary; lower coracoid large; upper arm of mesocoracoid rudimentary, lower arm large; actinosts 5; vertebrae about 54 (myomeres to end of anal about 56); anterior vertebrae unmodified, the first centrum articulating with skull.

*Coelomic Organs*: Stomach 26.5 of length of fish, not reaching pelvic origin; 2 pyloric caeca. Nearly ripe ovarian eggs, preserved in alcohol, measure .5 mm. in diameter.

*Sexual Dimorphism*: Postorbital light organ well developed in male, atrophied in female.

*Size*: The largest known specimen measures 205 mm. in length (225 mm. when freshly caught), and is a female near breeding condition; the next largest is a male 118 mm. long, which is immature; both were taken by the Bermuda Oceanographic Expeditions.

*Development*: Larva and post-larva unknown. Adolescent with no traces of dorsal subdermal pigment blotches; barbel stem short; anterior filaments on barbel bulb few and short; filaments forming fringe on posterior comb of bulb more numerous than in adult; postorbital light organ of females gradually atrophying: In an adolescent measuring about 35 mm. the postorbital organ, although already covered with partly pigmented skin, shone through in the fresh specimen and was blue-white in color; in an older adolescent it was not visible externally, but a small organ, rolled downward, was found upon dissection; in the largest (adult) female, the organ is completely atrophied, leaving a gaping hole beneath the skin, well separated from the eye, surrounded only by muscle fibers. Sex cannot be determined by examination of the gonads of adolescents; we have stated that the specimens in question are females on the basis of their atrophying postorbitals.

*Viability*: The large female lived for half an hour after reaching the laboratory.

## ***Chirostomias pliopterus*** Regan & Trewavas, 1930.

(See also p. 111).

### Specimens Taken by the Bermuda Oceanographic Expeditions.

8 specimens; May to August, 1929 to 1931; 300 to 700 fathoms; from a cylinder of water 8 miles in diameter (5 to 13 miles south of Nonsuch Island, Bermuda), the center of which is at 32° 12′ N. Lat., 64° 36′ W. Long.; standard lengths from 35 to 205 mm.

### Specimens Previously Recorded.

5 specimens; *ca.* 55 to 273 fathoms; eastern and western North Atlantic, between 20° and 44° N. Lat.; standard lengths from 33 to 115 mm.

### Description of Adult.

With the characteristics of the genus.

### Development.

*Material*: The Bermuda collection of *Chirostomias pliopterus* is divided as follows:

6 adolescents; 35 to 41 mm.; 300 to 700 fath.; June, July; females.
1 transitional adolescent; 500 fath.; August; male.
1 adult; 500 fath.; August; female, near breeding condition.

All are typical representatives of their respective growth stages, (see pp. 000-000). The specific characters of the adolescents have already been given on page 000.

### Study Material.

The following list gives the catalogue number, depth in fathoms, date, length and growth stage of each specimen of *Chirostomias pliopterus* taken by the Bermuda Oceanographic Expeditions. All were caught in the cylinder of water off the Bermuda coast described in *Zoologica*, Vol. XVI, No. 1, p. 5 and Vol. XX, No. 1 p. 1.

No. 10,738; Net 194; 600 F.; June 20, 1929; 41 mm.; Adolescent.
No. 10,956; Net 219; 700 F.; June 25, 1929; 35 mm.; Adolescent.
No. 11,464; Net 297; 500 F.; July 13, 1929; 37 mm.; Adolescent.
No. 11,752; Net 316; 600 F.; July 23, 1929; 40 mm.; Adolescent.
No. 15,053; Net 587; 500 F.; May 17, 1930; 35 mm.; Adolescent.
No. 21,259; Net 1071; 300 F.; July 10, 1931; 39 mm.; Adolescent.
No. 22,029; Net 1143; 500 F.; Aug. 7, 1931; 118 mm.; Trans. Adolescent.
No. 22,200; Net 1157; 500 F.; Aug. 10, 1931; 205 mm.; Adult.

### Synonymy and References.

*Chirostomias pliopterus*:

Regan & Trewavas, 1930, p. 54; pl. I, fig. 1; text-figs. 6B, 8B and 30. (5 specimens; 33 to 115 mm.; 150-1,000 m. wire; Atlantic between 20° and 40° N. Lat.).

Beebe, 1933.1, p. 180. (Preliminary list of Bermuda specimens).

Beebe, 1937, p. 199. (Preliminary list of Bermuda specimens).

*Chirostomias lucidimanus*:

Beebe, 1932.2, p. 52. (4 specimens from Bermuda included in the present account of *C. pliopterus*).

## Genus **Pachystomias** Günther, 1878.

(See also pp. 70, 73, 82, 83, 86, 88, 90, 91, 99, 105, 106, 109).
(Text-figs. 12, 17).

### General Discussion.

Only 4 specimens belonging to this genus are known at the present time, including the single, 37 mm. example taken by the Bermuda Oceanographic Expeditions. Two species have been erected, *P. microdon* (Günther, 1878), for the 215 mm. specimen taken by the *Challenger* off Australia, and *P. atlanticus* Regan & Trewavas, 1930, for the 165 mm. *Dana* specimen taken from the Caribbean Sea. The latter species is distinguished from *P. microdon* by the longer teeth, broader interorbital region and longer barbel. Differences in photophore and fin counts are very small, and would normally fall within the range of variation of one species. The third specimen, measuring 90 mm. and taken off Nova Scotia, is recorded by Roule & Angel, 1933 (p. 17), without comment, save that it is in poor condition; they refer it to *P. microdon*.

The present young specimen taken off Bermuda differs from both the described species in a number of ways—the depth is less, head and eye both larger, snout longer, interorbital broader, basibranchial teeth fewer, grouping of serial photophores different, and barbel relatively much longer (1.3 times head instead of two-thirds of it). All except the last two characters are regular characteristics of immature melanostomiatids. Since

the grouping of the photophores is different even on the two sides of the present specimen, these distinctions cannot be called specifically important. Finally, it is known that in some other genera the barbel grows relatively more rapidly than the standard length during adolescence, hence this peculiarity does not seem a basis for the establishment of a new species; also, it is likely that the delicate barbel is broken in the previously known specimens.

It is probable that the Atlantic and Australian forms will prove to be conspecific when more material has been acquired. For the present, however, we shall regard them as separate species, referring the Atlantic example recorded by Roule & Angel and our own specimen to *P. atlanticus.*

### Generic Characters.

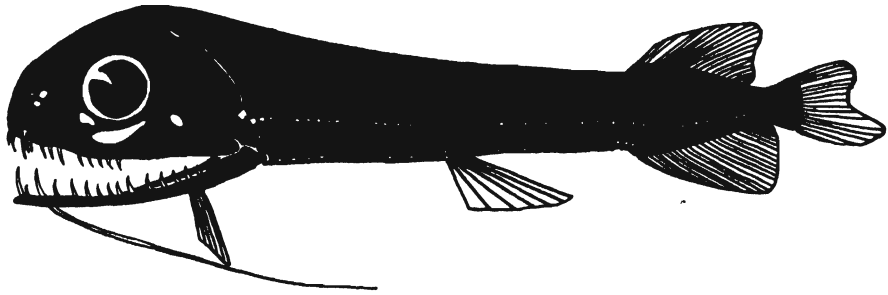
*Color* (from Murray's observation on the living type specimen of *P. microdon* and notes by the present authors on a living immature *P. atlanticus*): General color, velvety brownish-black; both antorbitals rose (*microdon*) *or* greenish-yellow (*atlanticus*); postorbital red (*microdon*); serial photophores violet to red.

*Proportions* (from the 2 largest known specimens): Moderately elongate melanostomiatids with large, broad heads and large eyes; depth in length 5 (20%); head in length 4.5 to 4.7 (21% to 22.3%); eye in head 4; snout a little shorter than diameter of eye; snout to pelvic in length *ca.* 1.7 (58%); interorbital width 4 to 6 in head.

*Barbel*: Simple, slender, tapering, apparently shorter than head in adult.

*Light Organs*: A large mass of luminous tissue forming a cushion on each side of palate, and appearing externally as a small luminous patch anteriorly, in the usual position of an antorbital, and a much longer, spindle shaped organ immediately behind, falling directly beneath the eye. Regular postorbital organ small, well separated from eye. Serial photophores in groups with the following counts: ventral series, I-P 8 (1+2+-2+3), the last group beginning between the diverging pairs of the preceding, P-V 16 to 17 (in 2 or 3 groups) V-A 14 to 15 (9 to 10+5, the last 5 in a close-set series above or ending at the vent), A-C 9; lateral series O-V 17 to 18 (in 4 groups), the first 2 ascending obliquely from the isthmus, V-A 13 to 14 (in 2 or 3 groups) ending above vent.

*Teeth*: Cleft of mouth slightly curved; jaws slender; premaxillary and mandible with rather small, slender, curved acute, unequal teeth, all fixed; maxillary with small oblique teeth; vomer toothless; 2 to 5 teeth on each palatine; well developed teeth on basibranchials; single teeth present on gill-arches, arrangement not recorded.



Text-figure 17.

*Pachystomias atlanticus.* Transitional adolescent, standard length 37 mm.

*Fins*: Pectoral 5 to 6; pelvics 7, inserted a little behind middle of length, about equidistant from eye and base of caudal; dorsal 21 to 24; anal 25 to 27; dorsal and anal beginning at same vertical, but anal extending farther back.

*Osteology*: Parietals absent; mesethmoid with lateral processes; posttemporal absent.

*Coelomic Organs*: Pyloric caeca represented by 2 pouches.

*Sexual Dimorphism*: Unknown.

*Size and Development*: Larva, post-larva and adolescent unknown; a specimen of 37 mm. is in transitional adolescence; the other known specimens measure 90, 165 and 215 mm., respectively.

## **Pachystomias atlanticus** Regan & Trewavas, 1930.

(See also p. 117).

### Specimen Taken by the Bermuda Oceanographic Expeditions.

1 specimen (Cat. No. 17,769, Net 836); September 3, 1930; 500 fathoms; from a cylinder of water 8 miles in diameter (5 to 13 miles south of Nonsuch Island, Bermuda), the center of which is at 32° 12′ N. Lat., 64° 36′ W. Long.; standard length 37 mm.

### Specimens Previously Recorded.

2 specimens; between 0 and 2,200 fathoms; Caribbean Sea and off Nova Scotia; standard lengths 90 and 165 mm.

### Specific Characters.

(From the description of the type specimen, 165 mm. in length). With the characters of the genus.

This species differs from the 215 mm. type specimen of *P. microdon* Günther from Australia in the following particulars: teeth in jaws longer; 2 teeth, not 5, on each palatine; 2 pairs, not 5, on first basibranchial; 4 pairs, not 2, on second; interorbital breadth contained 5, not 6 times in length of head; barbel longer, two-thirds, not one-fourth, length of head; pectoral 6, not 5; dorsal 21, not 24; anal 25, not 27. Serial photophores with following counts: ventral series, I-P 8 (1+2+2+3), P-V 16 (4+12), V-A 15 (10+5), A-C 9; lateral series, O-V 18 (2+4+4+8), V-A 13 (9+4).

### Development.

The transitional adolescent from Bermuda will be described in detail.

*Color in Life*: Skin velvety brownish-black; both antorbital light organs yellow-green; postorbital organ blazing dark red; serial photophores purple. Luminescence not observed in dark-room, although all organs appeared fully capable of functioning. Barbel colorless, translucent.

*Measurements and Proportions*: Total length 41 mm.; standard length 37 mm.; depth 5.3 mm. (in length 7 or 14.2%); depth in front of vertical fins 3.5 mm. (in length 10.6 or 9.4%); head 11.7 mm. (in length 3.1 or 32%); eye 3.1 mm. (in head 3.8 or 8.4% of length); snout 3.1 mm. (in head 3.8 or 8.4% of length); interorbital 2.5 (in head 4.7 or 6.8% of length);

interocular 4.8 mm. (in head 2.45 or 13% of length); snout to pelvic 20 mm. (in length 1.85 or 54%); anterior orbital light 1 mm.; median cheek light 2.5 mm.; posterior cheek light 1.1 mm.; barbel 15.5 mm. (1.3 times head, 42% of length).

The outstanding characters of the fish are the very large, thick head, much thicker than the body, and the large, protuberant eyes, which project 1.2 mm. from the side of the head. The frontal crests divide the interorbital space into thirds.

*Barbel*: The barbel, contained 2.4 times in the length, is slender, unpigmented and tapers gradually to a thread-like tip.

*Light Organs*: The first of the three orbitals is directly beneath the lower anterior part of the eye, and is a small oval; the second is two and one-half times as long, and slightly broader, starting under the posterior corner of the first, and ending just before the vertical from the posterior border of the orbit; the third, corresponding to the usual postorbital of melanostomiatids, is very slightly larger than the first and is obliquely set behind the end of the second. Serial photophores with the following counts and groupings: ventral series, both sides of fish, I-P 8 (1+2+2+3), P-V 17 (5+5+7), V-A 14 (9+5), A-C 9; lateral series, O-V right side 18 (1+5+4+8), left side 18 (1+5+5+7), V-A right side 14 (6+3+5), left side 14 (4+4+6). Numerous small organs are scattered over head and trunk.

*Teeth*: The teeth, all fixed, are arranged as follows: 13 moderate-sized teeth in each premaxillary, the first, second, third and eighth somewhat enlarged, and the first, second and fifth external. There are about 20 small, oblique denticles on each maxillary; each mandibular ramus holds 16 or 17 teeth similar to those of the upper jaw, the first tooth a fang, the largest in the mouth, the third next largest and external; there are one or two replacement teeth; 2 teeth on right palatine, 3 on left. One pair of teeth on first basibranchial, 1½ pairs on second. No teeth yet developed on gill-arches, but their anlagen appearing beneath the gill-arch skin.

*Fins*: The pectorals are placed far forward on the body, beneath the posterior part of the maxillary, and are moderately short. The pelvics are well developed, originating behind the middle of the length and extending about two-thirds of the distance between their origin and that of the anal fin. The dorsal and anal have their proximal portions encased in a thick black membrane. Their rays are long, those in the posterior part of the fin reaching well beyond the caudal origin when laid back.

*Coelomic Organs*: The stomach is fully pigmented, but short, 5.5 mm. long (15% of length of fish), and reaching only about three-fifths of distance between pectoral and pelvic insertions. There is no trace of the two rudimentary caeca described for adult fish of this genus by Regan & Trewavas (1930, p. 44). The gonads are slender, transparent threads.

*Viability*: This specimen was alive when caught, but died a few minutes after its arrival in the laboratory, about one hour and a half after capture. This is the smallest deep-sea fish ever brought up alive by the Bermuda Expeditions.

## References and Synonymy.

*Pachystomias atlanticus*:

Regan & Trewavas, 1930, p. 70; pl. VI, fig. 1; (1 specimen; 3,500 m. wire; Caribbean Sea west of St. Lucia; standard length 165 mm.).

Beebe, 1937, p. 199. (Preliminary listing of Bermuda specimen).

*Pachystomias microdon* (*non* Günther):

Roule & Angel, 1933, p. 17. (1 specimen; 0 to 4,000 m.; southeast of Nova Scotia; standard length 90 mm.).

## Genus **Leptostomias** Gilbert, 1905.

(See also pp. 70, 73, 75, 79, 80, 81, 85, 86, 88, 90, 97, 99, 101-103, 105, 106, 110).

(Text-figs. 2, 5, 7, 11, 12, 18-22 incl.).

### General Discussion.

Some authors have included the genus *Leptostomias*, with or without subgeneric standing, in *Melanostomias*. Regan and Trewavas, however, in their monograph on the family (1930) established the validity of the genus, and worked out its relationships. *Nematostomias* Zugmayer, 1911, is a synonym of *Leptostomias*.

Eleven species of Melanostomiatidae are at present referable to *Leptostomias*, two, *L. macropogon* Norman and *L. bermudensis* Beebe, having been described since the publication of the above mentioned monograph. The delineation of all of the species is most unsatisfactory. Only two characters have been found to be specifically important, the number of P-V photophores and the form of the barbel; both are of dubious value, since the barbel has been found to be very variable in the only species, *L. ramosus*, of which more than four examples have hitherto been taken, and the number of photophores serves merely to separate groups of species; slight differences in finray counts and proportions cannot be regarded as useful until much more material is obtained. Finally, individuals of this genus do not mature until they attain a considerably greater length than others of the family, judging from the largest specimens we have been able to examine, namely, the holotypes of *L. problematicus* (Parr) and *L. bermudensis* Beebe, and the largest examples in the type series of *L. longibarba* Regan & Trewavas and *L. ramosus* Regan & Trewavas. These fish measure from 172 to 270 mm. in length, yet their gonads are so undeveloped as to be almost invisible in all but the 250 mm. specimen of *L. longibarba*, while the stomachs are all short and distally unpigmented. Since only a single other large specimen has been recorded (the type of *L. gladiator*, 255 mm.), and the majority are much smaller, probably no fully adult *Leptostomias* has ever been taken. It is almost certain that a number of the species will prove to be synonymous, with the apparently specific differences being due instead to individual variation, age and, possibly, sex.

For the convenience of future students, we include the following annotated list of species, although we can attempt no complete revision ourselves with available material, and feel justified at present in synonymizing only *L. gladiator*, *L. problematicus* and *L. ramosus*.

1. *L. macronema* Gilbert, 1905, p. 607. Known only from the type specimen, 74 mm. long, from Hawaii. We have examined it in the U. S. National Museum and, in addition to the pair of filaments at the base of the barbel figured by Gilbert and described by Parr (1927, p. 49), we have found a pair of simple, short filaments on the stem near the bulb, and a single, unpaired one just above the bulb. The bulb itself is somewhat damaged, but, as both Gilbert and Parr have observed, is apparently simple; the tip is narrowed, almost papilla-like. There is no question, however, in spite of the presence of these hitherto unnoticed filaments, that the species, which is the only one so far reported from the Pacific, is distinct from the known Atlantic forms.

2. *L. gladiator* (Zugmayer, 1911.1, p. 76). Hitherto known from 2 specimens from the eastern Atlantic in the Monaco collection, the 255 mm. type and a 70 mm. example recorded by Roule & Angel (1933, p. 17). Referred originally to the genus *Nematostomias*, erected for it; to *Melanostomias* by both Parr (subgenus *Leptostomias*) (1927) and Roule & Angel; correctly placed in *Leptostomias* by Regan & Trewavas, 1930, p. 61. Not seen

by us, but there seems to be no reason for not considering *L. problematicus* and *L. ramosus* synonymous with it. The type is a male, judging from the postorbital organ "of moderate size," described and figured in the type description. (See p. 127).

3. *L. problematicus* (Parr, 1927, p. 46). Known only from the type specimen, 172 mm. long, from the western Atlantic. We have examined it in the Peabody Museum and find that the barbel appears as figured, save for the following details: there are a number of short, unbranched filaments scattered along the stem, distal to the large basal filament described and figured in the type description. The tip of the barbel bulb is certainly broken off, so that at least one distal papilla is missing, and possibly a good-sized bit of the bulb itself. One of the distal papillae is not at the extreme end, as shown in the figure. Altogether, in spite of a slightly longer barbel, slimmer form, and 1 or 2 more dorsal and anal rays, it appears certain that this form and *L. ramosus* (species no. 9, below) are identical, and that both of them should be synonymized under *L. gladiator* (species no. 2, above). Distally the barbel stem has lost a considerable amount of skin, taking, perhaps, one or more filaments with it. The postorbital is almost completely atrophied externally, and though it is impossible to determine the sex from the condition of the internal organs, due to their immaturity, the specimen is doubtless a female, judging from the atrophy of the postorbital organ. There are 21, not 20, V-A photophores in both lateral and ventral series. There is a small pair of teeth in the vomer. Placed originally in *Melanostomias*, subgenus *Leptostomias*.

4. *L. haplocaulus* Regan & Trewavas, 1930, p. 59. Known from a single specimen from the North Atlantic, 100 mm. long. Not seen by us.

5. *L. gracilis* Regan & Trewavas, 1930, p. 59. Known from the 4 specimens in the type series from the North Atlantic, 70 to 75 mm. long. Not seen by us.

6. *L. longibarba* Regan & Trewavas, 1930, p. 60. Known from the 3 specimens in the type series from the North Atlantic, 53 to 250 mm. long. A 250 mm. immature female examined by us.

7. *L. leptobolus* Regan & Trewavas, 1930, p. 60. Known from the 2 specimens in the type series, 68 and 95 mm. long, from the North Atlantic. Not seen by us.

8. *L. analis* Regan & Trewavas, 1930, p. 61. Known from a single specimen, 168 mm. long, from the North Atlantic. Not seen by us.

9. *L. ramosus* Regan & Trewavas, 1930, p. 61. Known from 12 specimens in the type series from the North Atlantic, 56 to 180 mm. long. We have examined three, including the largest. All are immature, but females, judging from the atrophying postorbital organs. The variability of the barbel is adequate proof that this species and *L. problematicus* should be synonymized with *L. gladiator*.

10. *L. macropogon* Norman, 1930, p. 311. Known from a single specimen from the South Atlantic, 165 mm. long. Norman suggests it may prove to be identical with *L. gracilis*. Not seen by us.

11. *L. bermudensis* Beebe, 1932, p. 59. Known from a single specimen from Bermuda, 270 mm. long, in the present collection. May prove to be synonymous with *L. longibarba, L. gracilis* or *L. macropogon*. (See p. 125).

*Distribution*: *Leptostomias* is one of the seven genera in the family which have been recorded outside the Atlantic Ocean. *L. macronema* is known only from Hawaii, and *L. macropogon* only from the South Atlantic. All the rest have been taken in the North Atlantic. The depth range of the genus as known at present is undefined, between 0 and 1,500 fathoms. Including the present series, 49 specimens have been recorded, 35 of which are referred to *Leptostomias ramosus*.

GENERIC CHARACTERS.

(The immaturity of all specimens from which these characters are derived must be kept in mind).

*Color* (from fresh specimens of *L. gladiator* and *L. bermudensis*): General color dark brownish-black; barbel bulb yellow; serial photophores violet to maroon.

*Proportions*: Very elongate melanostomiatids with short heads. Depth in length 10 to 17 (5.9% to 10%); head in length 7.5 to 11 (9.1% to 13.3%); eye in head 4.5 to 6; snout longer than eye; snout to pelvic in length *ca.* 1.5 to 1.6 (62.5% to 66.5%).

*Barbel*: One-fourth to as long as fish; stem with or without filaments; bulb an elongate oval from which arise short filaments and papillae in varying numbers, combinations and arrangements.

*Light Organs*: Postorbital probably completely atrophied in adult female, moderate in male; serial photophores with the following counts: ventral series, I-P 10 to 11, P-V 39 to 48, V-A 20 to 23, A-C 11 to 14; lateral series, O-V 39 to 48, V-A 20 to 23. Accessory light organs inconspicuous.

*Teeth*: Cleft of mouth straight, jaws massive; premaxillaries and mandible with a few moderate fangs, each tapering to a point, mostly fixed; first premaxillary tooth moderate, fixed; second long and depressible, followed by several smaller fixed outer teeth and 1 or 2 inner, depressible teeth; maxillary with a few small erect teeth followed by a series of about 20 to 30 oblique denticles. Mandible with a strong, fixed fang followed by a depressible tooth and several smaller fixed teeth. A pair of teeth on the vomer and 0 to 1 on each palatine; 1 to 2 pairs (sometimes rudimentary) on the basibranchials; short, stout teeth present in pairs, three's and four's on first 4 gill-arches: on first and second hypohals, first 4 ceratohyals, and first 3 epihyals; about 9 groups present on first ceratobranchial, the last being elongate and single.

*Branchiostegal Rays*: 17 to 19.

*Fins*: Pectoral with 10 to 11 simple, moderately short rays; pelvics 7, placed well behind middle of length; dorsal 16 to 21; anal 20 to 28, beginning below or very slightly in advance of dorsal and extending farther back.

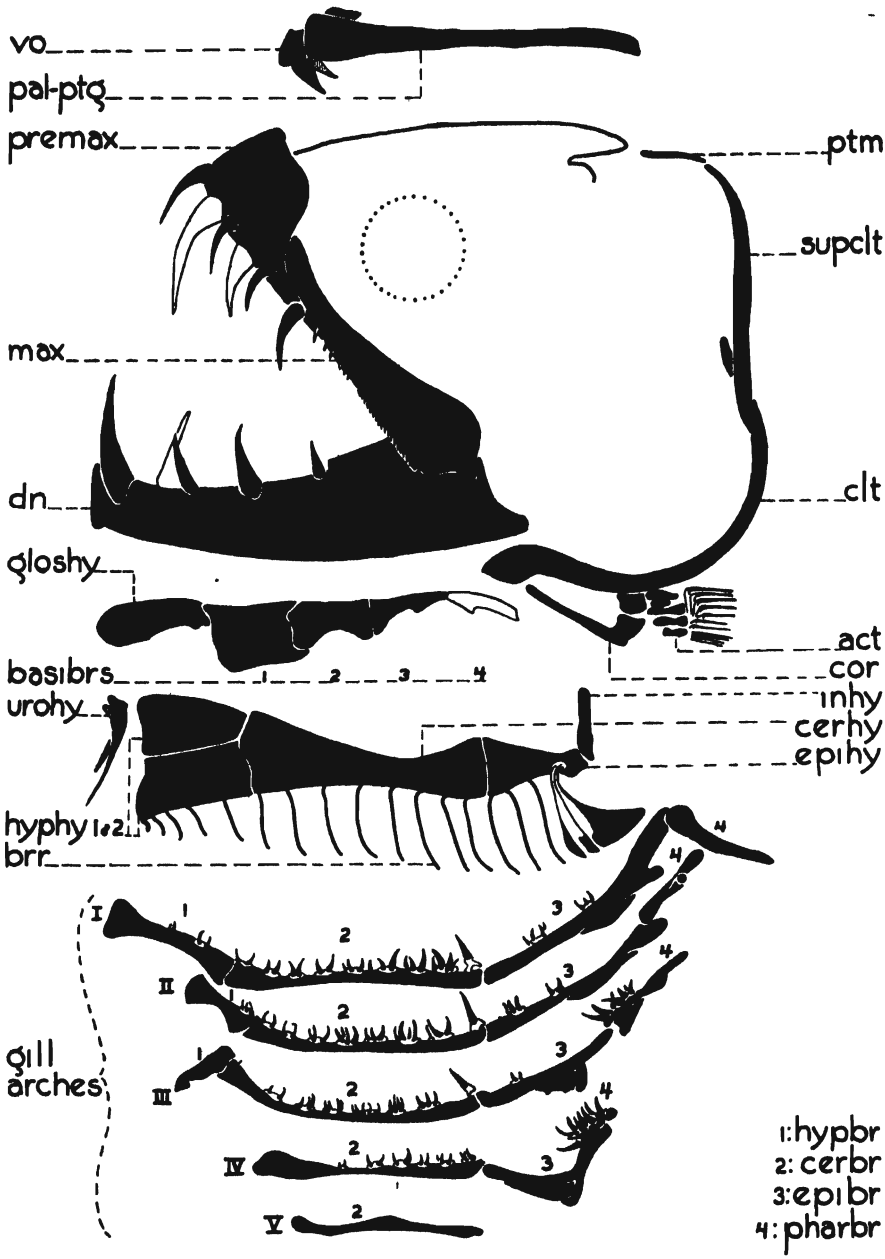
*Epidermal Grooves*: A pronounced groove in the isthmus for grasping the stem of the barbel.

*Osteology*: Premaxillary without median process, but with well developed lateral flanges instead; parietals present; mesethmoid with lateral processes; post-temporal present (at least in both Bermuda species), but weak, not attached to skull; supracleithrum and cleithrum strong; upper coracoid moderate, lower large; mesocoracoid with rudimentary upper arm but well developed lower arm; vertebrae about 75 to 83; first 7 vertebrae highly specialized, their centra being absent, and there being only 6 parapophyses; first neural arch represented by a pair of small bones articulating with exoccipital; second neural arch much enlarged; third through eighth smaller, but larger than succeeding ones, and directed straight upward, instead of backward.

*Coelomic Organs*: Stomach 19% to 23% of length, not nearly reaching pelvic fins; distal portion lightly and incompletely pigmented in all specimens examined; gonads rudimentary. Intestine with an anterior pouch and a single caecum.

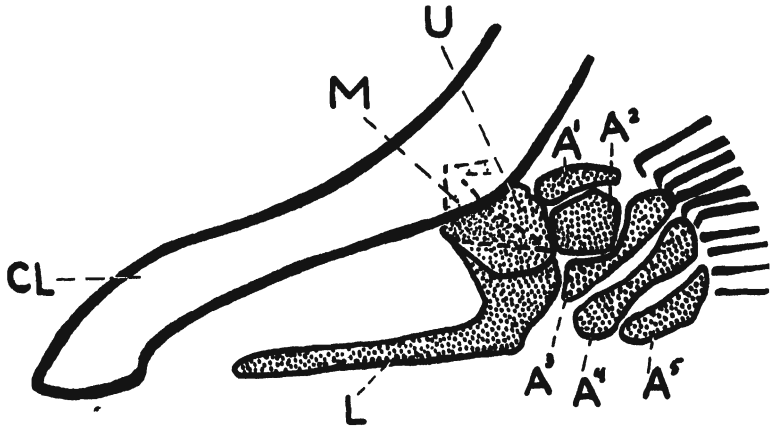
*Sexual Dimorphism*: Postorbital light organ completely atrophied in females of 250 mm. and over; male postorbital of moderate size, judging from type description and illustration of *L. gladiator* (Zugmayer, 1911, pl. III, fig. 5).

*Size*: The largest known specimen of *Leptostomias* is *L. bermudensis*, taken by the Bermuda Expeditions, and measuring 270 mm. long (285 mm. when fresh). The gonads are so immature as to be barely distinguish-




Text-figure 18.

*Leptostomias bermudensis.* Jaws, hyoid and branchial arches, and pectoral girdle of transitional adolescent, standard length 270 mm. Depressible jaw-teeth unshaded; divisions between palatine and pterygoid, and maxillary and supramaxillary not shown; fourth basibranchial, always unossified, unshaded; *act*, actinost; *basibrs*, basibranchials; *brr*, branchiostegal ray; *cerbr*, ceratobranchial; *cerhy*, ceratohyal; *clt*, cleithrum; *cor*, coracoid; *dn*, dentary; *epibr*, epibranchial; *epihy*, epihyal; *gloshy*, glossohyal; *hypbr*, hypobranchial; *hyphy*, hypohyal; *inhy*, interhyal; *max*, maxillary; *pal-ptg*, palato-pterygoid; *pharbr*, pharyngobranchial; *premax*, premaxillary; *ptm*, post-temporal; *supclt*, supracleithrum; *urohy*, urohyal; *vo*, vomer.




Text-figure 19.

*Leptostomias bermudensis.* Supporting bones of pectoral fin. From the transitional adolescent holotype, standard length 270 mm. Abbreviations as in Text-fig. 14.

able in this specimen, in the 180 mm. *Dana* example of *L. ramosus*, in the 170 mm. type of *L. problematicus* and in all smaller examples examined; these organs are only slightly more developed in a 250 mm. specimen of *L. longibarba*, although eggs are distinctly visible. Metamorphosis also occurs when the young are larger than usual (between 30 and 50 mm., instead of between 20 and 30). The indications are, therefore, that members of this genus attain relatively large size.

*Development*: A series of growth stages of *L. gladiator* has been taken by the Bermuda Expeditions, which is probably typical of the genus. The characteristics in brief are, a large number of myomeres (*ca.* 75 to 78) between nape and end of anal (the count is probably greater in other species with higher photophore counts); pigment in a row of blotches immediately below the dorsal mid-line, and from 3 to 10 rows of compact pigment spots, the number of rows depending on the length of the fish; anal fin beginning slightly behind dorsal origin.

### ***Leptostomias bermudensis*** Beebe, 1932.

(See also p. 122).

TYPE.

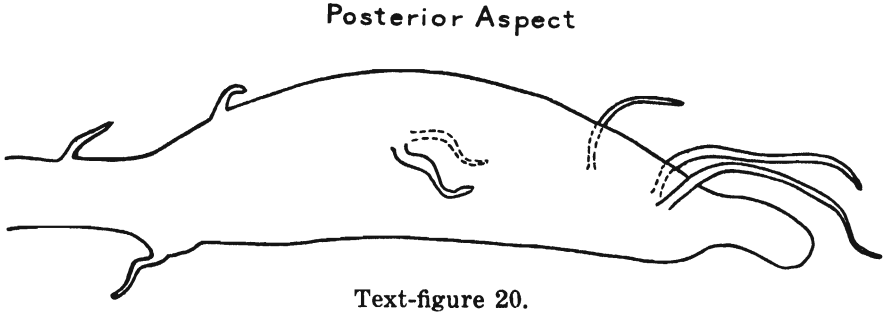
(The unique specimen).

Department of Tropical Research No. 20,826; Bermuda Oceanographic Expeditions of the New York Zoological Society; Net 1015; June 15, 1931; 7½ miles southeast of Nonsuch Island, Bermuda; 500 fathoms; standard length 285 mm. when fresh, 270 mm. after being preserved in alcohol.

DESCRIPTION.

With the characteristics of the genus.

*Color* (from fresh specimen): General color dark, brownish-black; barbel stem proximally pigmented, distally lilac; barbel bulb bright, clear picric yellow, filaments white. Photophores of ventral series maroon with gilt caps, lateral series pale purple, also with gilt caps; small, non-serial photophores pale purple.




Text-figure 20.

*Leptostomias bermudensis*. End of barbel in holotype, standard length 270 mm.

*Measurements and Proportions* (at present): Total length 281 mm.; standard length 270 mm.; depth 17 (in length 15.8 or 6.2%); head 26 (in length 10.4 or 9.6%); eye 4.3 (in head 6, or 1.6% of length); snout 7.2 (in head 3.6 or 2.7% of length); upper jaw 17 (in head 1.5, in length 15.9 or 6.3%); snout to pelvic 176 (in length 1.53 or 65.4%).

*Barbel*: Length 200 mm. (1.35 in length or 74%). Stem without filaments near base, but with at least three short ones, far separated from each other, in the distal three-fourths of stem. The latter is black for about 4/5 of the proximal portion, then this pales and grays, and changes into brilliant lilac with a dark core running through it. The bulb, in the fresh specimen, was abruptly bright, clear, picric yellow, and the filaments translucent white with a scattering of black specks. The bulb arises abruptly from the stem, the lilac and the dark center ceasing at once. The bulb is slender, slightly curved, tapers gently from its center, and resembles in shape a diminutive cucumber. It narrows abruptly near the distal end, forming an elongate, rounded, terminal stem. There are three short, thin, median filaments given off, one from the back of the stem, and the other two from the proximal part of the bulb. Halfway down the bulb a pair of larger filaments arises, one from each side. Still farther a single one appears from the right side and, at the point of narrowing into the terminal stem, there arises a final pair of filaments, the longest of all, about 4 mm. in length.

*Light Organs*: The postorbital is atrophied. Serial photophores: ventral series, I-P 10, P-V 48, V-A 21, A-C 12; O-V 47 to 48, V-A 22.

*Teeth*: Premaxillary with 6 moderately large teeth, the second largest, the second and fourth depressible; maxillary with 5 to 6 tiny erect teeth followed by about 21 oblique denticles on the left side; right side with additional denticles discernible above the erect maxillary teeth; mandible with a moderately large fixed fang followed in turn by a slightly smaller depressible fang and 3 still smaller fixed teeth. Vomer with 1 pair of teeth; palatine toothless; 1 pair of rudimentary teeth on basibranchials.

*Branchiostegal Rays*: 19.

*Fins*: Pectoral rays 11 (not 12 as in type description), 12 mm. long; pelvic rays 7; 33 mm. long; dorsal rays 20, anal rays 25, commencing opposite dorsal and continuing slightly behind it.

## Discussion.

This species closely resembles *L. macropogon* Norman and *L. longibarba* Regan & Trewavas, but it may be distinguished from both by the structure of the bulb of the barbel and by the presence of 48 P-V photophores. As has been said, however, it is extremely likely that, when additional material is secured, some of the described species will prove synonymous; the present species will perhaps be included among them.

REFERENCES.

*Leptostomias bermudensis*:

Beebe, 1932.2, p. 59, fig. 10. (Type description, slightly amended and amplified in the present paper).

Beebe, 1937, p. 199. (Record of above specimen in preliminary Bermuda list).

## ***Leptostomias gladiator*** (Zugmayer, 1911).

(See also pp. 121-122).

SPECIMENS TAKEN BY THE BERMUDA OCEANOGRAPHIC EXPEDITIONS.

20 specimens; May to September, 1929 to 1931; 50 to 1,000 fathoms; from a cylinder of water 8 miles in diameter (5 to 13 miles south of Nonsuch Island, Bermuda), the center of which is at 32° 12′ N. Lat., 64° 36′ W. Long.; standard lengths from 12 to 52 mm.

SPECIMENS PREVIOUSLY RECORDED.

15 specimens; 0 to 2,680 fathoms; North Atlantic between 20° and 40°; standard lengths from 56 to 180 mm.

DESCRIPTION.

With the characteristics of the genus.

*Color* (from fresh, immature, Bermuda specimens): General color blackish-brown; barbel bulb creamy yellow; photophores violet.

*Proportions*: Depth in length 10 to 13 (7.7% to 10%); head in length 7.5 to 8.5 (11.8% to 13.4%); eye in head 5 to 6 (16.7% to 20%).

*Barbel*: About ½ length of fish; stem black with luminous patches; 1 or 2 pairs of filaments and usually an unpaired one at base; others scattered variably and irregularly along stem, including a pair slightly above bulb; bulb unpigmented, more than half length of head, slender, scarcely compressed, usually with narrowed, papilla-like tip and bearing 1 or 2 pairs of stout filaments near the base and 1 to 4 short, swollen filaments, often a pair near the tip and another a little behind them.

*Light Organs*: Serial photophores with the following counts: ventral series, I-P 10 to 11, P-V 39 to 43, V-A 21 to 22, the last 4 being above the anal fin, A-C 11 to 12; lateral series O-V 39 to 42, V-A 20 to 22.

*Fins*: Dorsal 19 to 22; anal 23 to 26.

DEVELOPMENT.

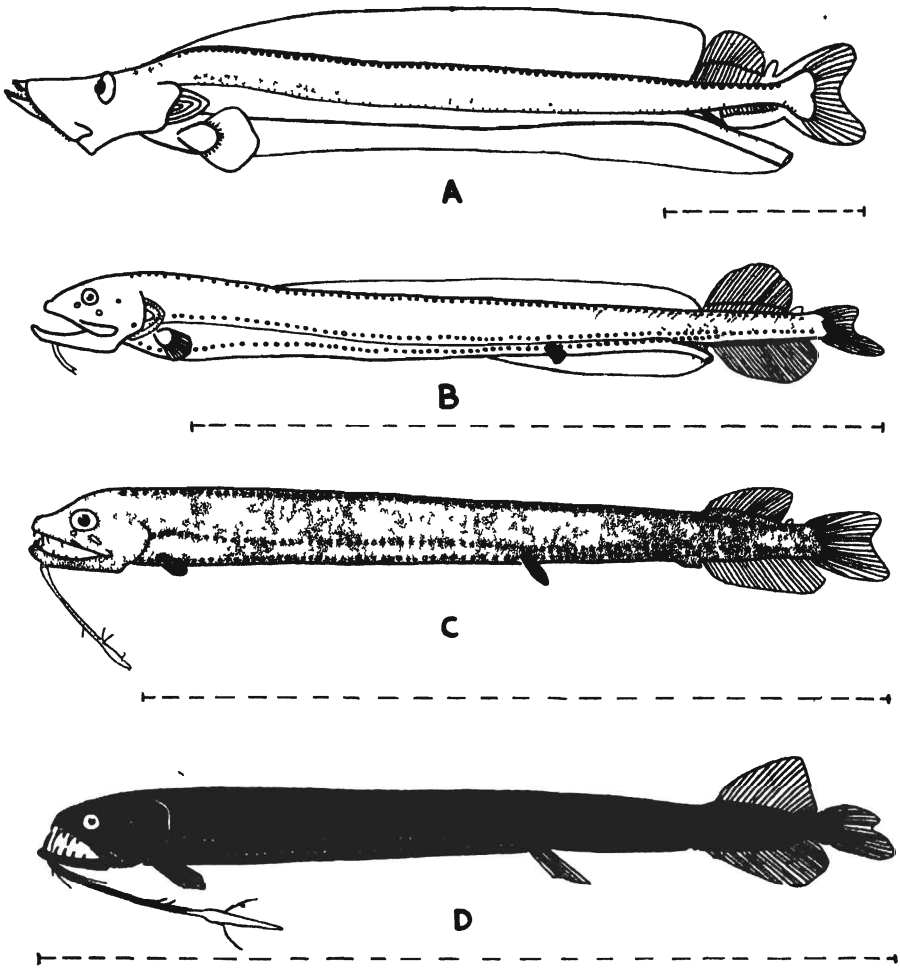
*Material*: The Bermuda collection of *Leptostomias gladiator* is composed entirely of immature fish, a well-graduated series ranging from young larvae to transitional adolescents and measuring between 12 and 52 mm. in length. They are distributed as follows:

9 larvae; 12 to 30 mm.; 50 to 1,000 fath.; May to Sept.
8 post-larvae; 38 to 45 mm.; 300 to 1,000 fath.; June to Aug.
1 adolescent; 45 mm.; 500 fath.; July.
2 transitional adolescents; 50, 52 mm.; 600, 1,000 fath.; Sept.

All are typical representatives of their respective growth stages (see pp. 76-79). Their special characteristics are as follows:

*Myomere Counts*: To end of anal 75 to 78; from nape to pelvic rudiment (when present) 42 to 44; from pelvic rudiment to anal origin 16 to 18.

*Pigment*: Larval pigment is traceable subdermally even in early transitional adolescence; it reaches its most advanced condition not in the larva




Text-figure 21.

*Leptostomias gladiator.* **A**, larva, standard length 12 mm.; **B**, post-larva, 42 mm.; **C**, adolescent, 45 mm.; **D**, transitional adolescent, 52 mm. See also Text-fig. 2, A and B.

but in the post-larva. In the larva there are four major longitudinal rows on each side: (1). There is a series of stellate blotches along each side of the dorsal profile from nape to immediately beyond the vertical from the end of the anal fin; each spot occupies an entire myomere and almost fuses with its neighbors, so that the general effect is of a dorsal band of pigment. (2). Well below this, just above the lateral line, are small, compact chromatophores in a sometimes single, sometimes double, line; they extend from the last gill-arch to the vertical from the end of the dorsal fin. (3 and 4). Between the lateral line and the intestine, which lies beneath the myomeral body, are two rows of chromatophores, similar, but longer, lying on the lines of myomeral demarcation so that each spot in the upper row is slightly ahead of the corresponding one below. Anteriorly the majority are dendritic, and there is a small amount of pigment between the rows throughout the series. Small chromatophores are sparsely scattered on the crown of the head, on the posterior portion of the ventral finfold, on the

dorsal surface of the end of the gut and on the anal fin; the isthmus is rather densely pigmented.

In the post-larva the 3 lateral rows of subdermal pigment spots are increased to 8 or 9, while the dorsal profile series of spots is supplemented by an irregular line of much smaller dots between and above them. All of the lateral spots follow the outlines of the myomeres, as in the larvae, and the main profile series still contains one blotch to each myomere. There is, in addition, a light general coating of pigment. In subsequent stages these chromatophores gradually disappear, the dorsal series remaining longest. In our 50 and 52 mm. transitional adolescents the dorsal row is still visible externally through the skin, and, when the skin is removed, this row alone is sharply marked; the lateral rows are traceable only as dull blotches.

Text-figure 22.

*Leptostomias gladiator.* Typical barbel of late transitional adolescent (after Regan & Trewavas).

*Larval Teeth*: Premaxillary with 7 pairs of teeth all directed straight forward; the maxillary holds 18 teeth, all erect; they are minute and close-set anteriorly, but increase in size posteriorly with progressively larger spaces between; in each half of the mandible are 12 teeth, in the front of the jaw only, placed close together; they are all directed straight outward and increase in size posteriorly.

*Larval Gill-rakers*: Long, spiny rakers present on first 3 arches, and low, spiny mounds on last 2; 8 or 9 rakers on first ceratobranchial.

*Fins*: Dorsal and anal rays not of complete number in larva, the anal beginning under the second third of the dorsal, instead of beneath its origin or slightly in advance, as in mature fish. Finfolds moderately deep.

## Study Material.

The following list gives the catalogue number, depth, in fathoms, date, length and growth stage of each specimen of *Leptostomias gladiator* taken by the Bermuda Oceanographic Expeditions. All were caught in the cylinder of water off the Bermuda coast described in *Zoologica*, Vol. XVI, No. 1, p. 5 and Vol. XX, No. 1, p. 1.

No. 10,197; Net 131; 800 F.; May 27, 1929; 13 mm.; Larva.
No. 10,481; Net 171; 600 F.; June 6, 1929; 41 mm.; Post-larva.
No. 10,992; Net 218; 600 F.; June 25, 1929; 45 mm.; Post-larva.
No. 11,751; Net 316; 600 F.; July 23, 1929; 45 mm.; Post-larva.
No. 11,942; Net 341; 700 F.; July 30, 1929; 39, 42 mm.; Post-larvae.
No. 13,105a; Net 424; 600 F.; Sept. 5, 1929; 50 mm.; Trans. Adolescent.
No. 13,396; Net 456; 1,000 F.; Sept. 10, 1929; 52 mm.; Trans. Adolescent.
No. 13,888; Net 518; 1,000 F.; Sept. 28, 1929; 30 mm.; Larva.
No. 16,174; Net 725; 500 F.; June 26, 1930; 18 mm.; Larva.
No. 16,928; Net 776; 500 F.; July 5, 1930; 45 mm.; Adolescent.
No. 16,865; Net 794; 800 F.; July 9, 1930; 13 mm.; Larva.
No. 17,743; Net 834; 400 F.; Sept. 4, 1930; 14 mm.; Larva.
No. 20,863; Net 1021; 600 F.; June 16, 1931; 42 mm.; Post-larva.
No. 21,316; Net 1075; 50 F.; July 11, 1931; 23 mm.; Larva.
No. 21,314; Net 1077; 300 F.; July 11, 1931; 38 mm.; Post-larva.
No. 21,340; Net 1079; 50 F.; July 14, 1931; 12, 16 mm.; Larvae.
No. 21,508; Net 1095; 600 F.; July 24, 1931; 20 mm.; Larva.
No. 24,052; Net 1209; 1,000 F.; Aug. 20, 1931; 45 mm.; Post-larva.

SYNONOMY AND REFERENCES.

*Nematostomias gladiator*:

Zugmayer, 1911.1, p. 76; pl. III, fig. 5. (1 specimen; 270 mm.; 4,900-0 m.; eastern North Atlantic).

*Melanostomias problematicus*:

Parr, 1927, p. 46, figs. 26, 27, 28A. (1 specimen; 172 mm.; 7,000 ft. wire; Bahamas). Examined by present authors.

*Melanostomias gladiator*:

Parr, 1927, p. 48, fig. 28 (Résumé of type description of *N. gladiator*).

Roule & Angel, 1933, p. 17. (1 specimen; 70 mm.; 0-250 m.; Monaco Deep).

Fowler, 1936, p. 210. (Résumé of type description of *N. gladiator*).

*Leptostomias problematicus*:

Regan & Trewavas, 1930, p. 61, fig. 41A. (Résumé of type description of *M. problematicus*).

*Leptostomias gladiator*:

Regan & Trewavas, 1930, p. 61, fig. 41B. (Résumé of type description of *M. gladiator*).

*Leptostomias ramosus*:

Regan & Trewavas, 1930, p. 61, figs. 10B, 11C, 12B, 42. (12 specimens, 56 to 180 mm.; 150 to 1,000 m. wire; north Atlantic between 20° and 40° N. Lat.). Several specimens, including the largest, examined by present authors.

Beebe, 1933.1, p. 180. (Preliminary list of Bermuda specimens).

Beebe, 1937, p. 199. (Preliminary list of Bermuda specimens).

## Genus ***Echiostoma*** Lowe, 1843.

(See also pp. 70, 73, 75, 79, 80, 82, 84-86, 88-91, 96, 99, 102, 105, 106, 108, 110).

(Text-figs. 2, 11, 12, 23-27 incl.).

GENERAL DISCUSSION.

Five species of melanostomiatids properly referable to *Echiostoma* have been described, namely, *E. barbatum* Lowe, 1843; *E. tanneri* Gill, 1883; *E. ctenobarba* Parr, 1927; *E. guentheri* Regan & Trewavas, 1930; and *E. calliobarba* Parr, 1934. In addition, Parr described a subspecies, *E. ctenobarba ramifera*, in 1934.

The type specimens of *E. barbatum* and *E. guentheri* differ from the others in having a single, unbranched, terminal appendage at the distal end of the barbel. From each other they differ chiefly in that *E. guentheri* has longer, more numerous and more extensive stem filaments and a more swollen bulb.

Specimens referred to *E. tanneri* are distinguished by the presence of two well-developed bulbs and very long stem filaments.

*E. ctenobarba* and *E. calliobarba* were erected for specimens each having only one terminal bulb, or none at all, and relatively short stem filaments. *E. calliobarba* and the subspecies of *E. ctenobarba* were differentiated on the basis of details of the extent and length of the lateral filaments, of the branching of the terminal filaments, and of the apparent presence or absence of a whitish body near the end of the barbel, and of the relative size of the postorbital light organ. As our series of barbels shows (Text-fig. 26), all of the barbel characters merge into one other, and may logically be laid to

individual variation, and to the different lengths at which individuals lose their juvenile characters. Variation, and, to a small extent, sexual dimorphism, is also found in the relative length of the postorbital organ.

The Bermuda specimens divided themselves very readily into this *ctenobarba-calliobarba* form and into typical *E. tanneri*. When the internal organs were examined, however, it was found that every one of the 8 *ctenobarba-calliobarba*-like examples (measuring between 268 and 355 mm. in length) was an adult near breeding condition, while the 5 typical specimens of *E. tanneri* (between 60 and 195 mm. in length) were transitional adolescents with scarcely developed gonads and short, partially pigmented stomachs. Furthermore, our 268 mm. specimen, the smallest that could be called an adult, showed distinct remains of 2 barbel bulbs and stem filaments intermediate in length between those of the largest *tanneri* example and the other adults. Similarly, the type and other specimens of *E. tanneri* at the U. S. National Museum are all small specimens measuring under 200 mm., and the largest *Dana* example of the species is recorded as being 223 mm. long. In addition, Dr. Parr has permitted us to open his series of *E. ctenobarba* and *E. calliobarba*, measuring 275 to 297 mm., with the result that they prove to have adult characters.

In view of the identity of proportions, counts, teeth and osteological characters (allowing only for differences, such as number of maxillary teeth, which are definite age characters), we think it unquestionable that these three species are identical, and hence synonymize them under *E. tanneri*, the oldest name. An exactly similar case of a reduction of the barbel bulb in adults is found in *Photonectes margarita,* (see p. 177), and of the reduction of lateral filaments in *Chirostomias pliopterus* (p. 111).

By analogy, it seems certain that *E. guentheri* Regan & Trewavas, 1930, is a young specimen of *E. barbatum* Lowe, 1843.

*E. microdon* Günther, 1878 is the genotype of *Pachystomias; E. richardi* Zugmayer, 1911, and *E. margarita* Goode & Bean, 1895, belong in the genus *Photonectes* (see p. 155).

*Distribution*: *E. barbatum* (including *E. guentheri*) is known only from 2 specimens, both taken at Madeira. *E. tanneri*, of which more than 100 specimens have been captured, occurs in both north and south Atlantic, between about 65 and 959 fathoms.

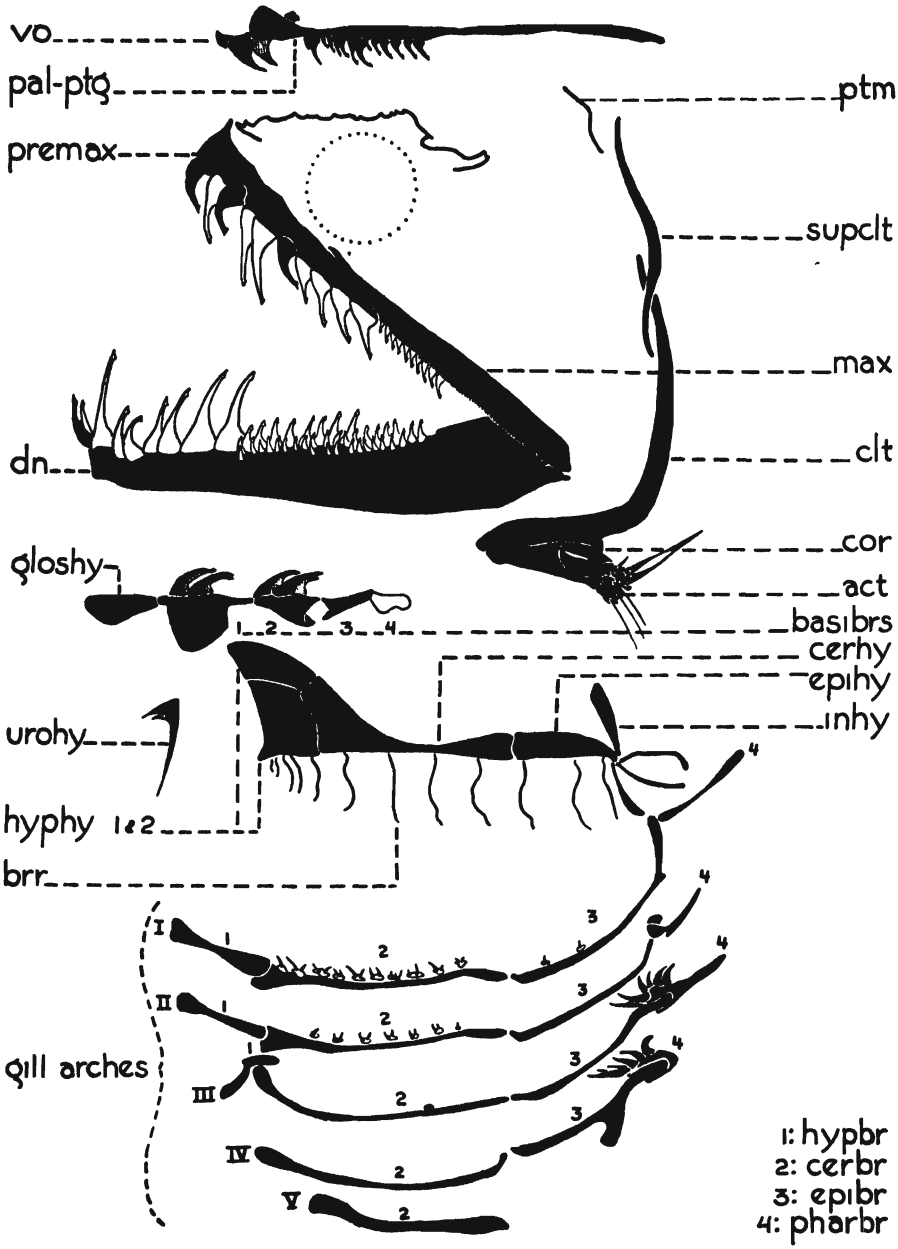
## Generic Characters.

*Color* (summarized from observations on 6 living adult specimens of *E. tanneri* taken by the Bermuda Oceanographic Expeditions; postorbital light organ color of *E. barbatum* recorded by Lowe, 1843, rosy red): General color blackish-brown. Postorbital rosy red anteriorly, white posteriorly. End of barbel bulb pinkish. Serial and non-serial photophores violet to scarlet; longitudinal luminous bands, bluish-white.

*Proportions*: Moderately elongate melanostomiatids; depth in length 5.7 to 8 (12.5% to 17.5%); head in length 6.2 to 7 (14.3% to 16%); eye in head 5 to 7 (2.1% to 2.6% of length); snout less than twice length of eye; snout to pelvic origin in length 1.7 to 1.8 (56% to 59%).

*Barbel*: Shorter than head with a row of filamentous or papilliform processes (sometimes almost atrophied) on each side of distal part of stem; two bulbs well developed in young, almost or completely atrophied in adults; one or more moderately thick terminal filaments.

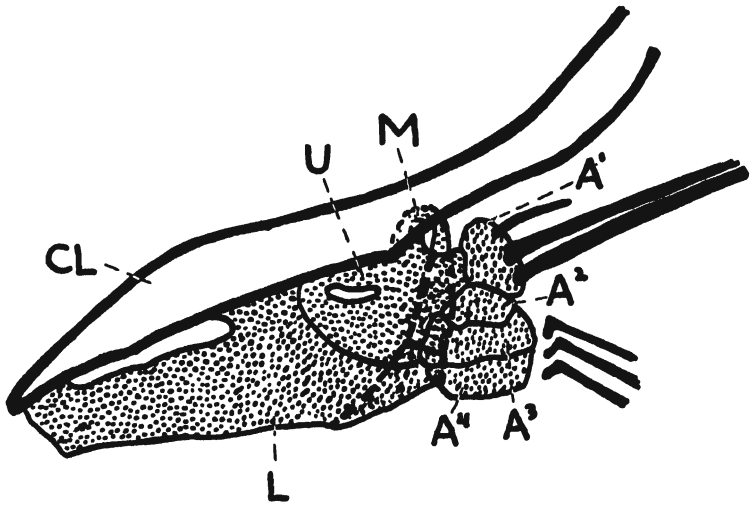
*Light Organs*: Postorbital (measured as length of area of transparent skin) about 1¼ to 2 times diameter of eye in both sexes, contained 3 to 5 times in head. Serial photophores with the following counts: ventral series, I-P 8+2, P-V 25 to 27, V-A 16 to 18, of which only the last one is above the anal fin, A-C 11 to 13; lateral series, O-V 24 to 26, V-A 16 to 18. Tiny, non-serial photophores well developed.




Text-figure 23.

*Echiostoma tanneri.* Jaws, hyoid and branchial arches, and pectoral girdle of adult, standard length 325 mm. Explanation as in Text-fig. 18.

*Teeth*: Cleft of mouth straight. Premaxillaries and mandible with close-set, curved, bicuspid fangs, all depressible except 1 to 3 in each jaw; mandibular teeth in 2 or 3 rows posteriorly; maxillary with 5 to 10 erect teeth and a long series (up to 50) of oblique denticles,




Text-figure 24.

*Echiostoma tanneri.* Supporting bones of pectoral fin in adult, standard length 325 mm. Abbreviations as in Text-fig. 14.

the anterior ones usually placed above the last few erect teeth; a pair of teeth on the vomer; a series of 3 to 12 teeth on each palatine. Usually 4 pairs on the basibranchials. Teeth, practically all in pairs, present on first and second gill-arches only: on first and second ceratobranchials and on first epibranchial; about 10 pairs on first ceratobranchial.

*Branchiostegal Rays*: 13 to 15.

*Fins*: Pectoral with 4 rays apparent externally; 1 isolated and produced, and 3 short rays; cleared and stained specimens, however, show that the isolated ray is composed of two rays united by a common sheath; in addition there is a rudimentary, subdermal ray in front of the isolated pair; the fin is inserted far forward; under the opercle. Pelvic 8, inserted well behind the middle of the length at about the 32nd vertebra. Dorsal 12 to 16; anal 15 to 19; dorsal and anal beginning at same vertical, but anal extending farther back.

*Epidermal Grooves*: There is a pronounced groove in the isthmus for the reception of the barbel.

*Osteology*: Mesethmoid without lateral processes; frontal ridges and pterotic canal-and-pore system strongly developed, with superficial patches of ossification around nostrils and behind pterotics; parietals absent; posttemporal rudimentary; supra-cleithrum and cleithrum moderately strong; all coracoid elements large except upper arm of mesocoracoid; actinosts 3; vertebrae 57 to 59; first vertebra represented only by a fibrous ring, shorter than a centrum, enclosing the notochord and by a spinal nerve.

*Coelomic Organs*: Stomach 45% of standard length, reaching well beyond pelvic origin; 2 pyloric caeca. Apparently ripe ovarian eggs, preserved in alcohol, measure .72 mm. in diameter.

*Sexual Dimorphism*: Postorbital light organ of female, although well developed and functional, slightly smaller than that of male.

*Size*: The largest known specimen measures 355 mm. in length (375 mm. long, weight 12 oz., when freshly caught), and is a female in or close to breeding condition, taken by the Bermuda Oceanographic Expeditions.

*Development*: Larva and post-larva unknown. Adolescent of *E. tanneri* with subdermal series of pigment spots as follows: Each myomere has, typically, a dorsal, dendritic blotch immediately below the dorsal mid-line, and an obliquely vertical row of 3 to 5 dots, following the myomeral boundary, between the lateral mid-line and the series of photophores. Adolescent and transitional adolescents have two large barbel bulbs which almost or completely disappear in the adult; some of the barbel stem filaments similarly often partially or completely atrophy.

SYNOPSIS OF THE SPECIES.

The following key may be adopted:

A. Barbel with a single, simple, terminal appendage ..... *E. barbatum.*

AA. Barbel with one or more compound terminal appendages.

B. Barbel with two distinct bulbs; stem filaments well-developed *E. tanneri*, young.

BB. Barbel without bulb, or with a single, small one; stem filaments reduced in length, and often also in number . . . *E. tanneri*, adult.

## ***Echiostoma tanneri*** (Gill, 1883).

(See also p. 130).

SPECIMENS TAKEN BY THE BERMUDA OCEANOGRAPHIC EXPEDITIONS.

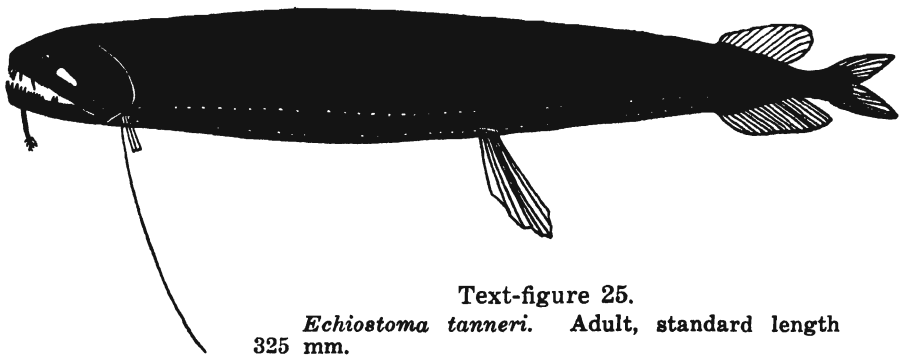
13 specimens; May to September, 1929 to 1931; 500 to 900 fathoms; from a cylinder of water 8 miles in diameter (5 to 13 miles south of Nonsuch Island, Bermuda), the center of which is at 32° 12′ N. Lat., 64° 36′ W. Long.; standard lengths from 61 to 355 mm.

SPECIMENS PREVIOUSLY RECORDED.

More than 100 specimens; between *ca.* 65 and 959 fathoms; north and south Atlantic; standard lengths from 20 to 297 mm.

DESCRIPTION OF ADULT.

With the characteristics of the genus. Barbel with one or more, compound, terminal filaments. Papillae or filaments on stem numbering from one to about a dozen pairs. Three longitudinal bands of luminous material running the entire length of the body from opercle to tail; one, the broadest, immediately below the dorsal mid-line; one, narrow, between the lateral



Text-figure 25.

*Echiostoma tanneri.* Adult, standard length 325 mm.

and ventral series of photophores; and one, also narrow, between the ventral series and the ventral mid-line.

*Color, Luminescence and Behavior*: These three topics are so closely connected that it is advisable to treat them together. Five adults, including both males and females, and the largest transitional adolescent (192 mm. long) were captured alive and, with the aid of the refrigerator and, in two cases of adrenalin injections, lived between two and six hours after reaching the laboratory. In the dark-room an ultra-violet lamp was used to aid in the observation of luminous areas. Several fish were in especially good condition, twisting and snapping continually during the entire time they remained alive. Between periods of observation, the fish were placed in the refrigerator, which always revived them greatly. Excellent moving pictures were made.

In the dark-room the fish gave a most wonderful display of lights, from which the following deductions were made. In general, direct correlation was found between the color of the various organs in daylight, and the luminescence given off by them.

General Skin Color: In daylight, blackish-brown. A broad band of whitish tissue along each side of upper part of body, and two duller, narrow stripes on lower part of side (see below).

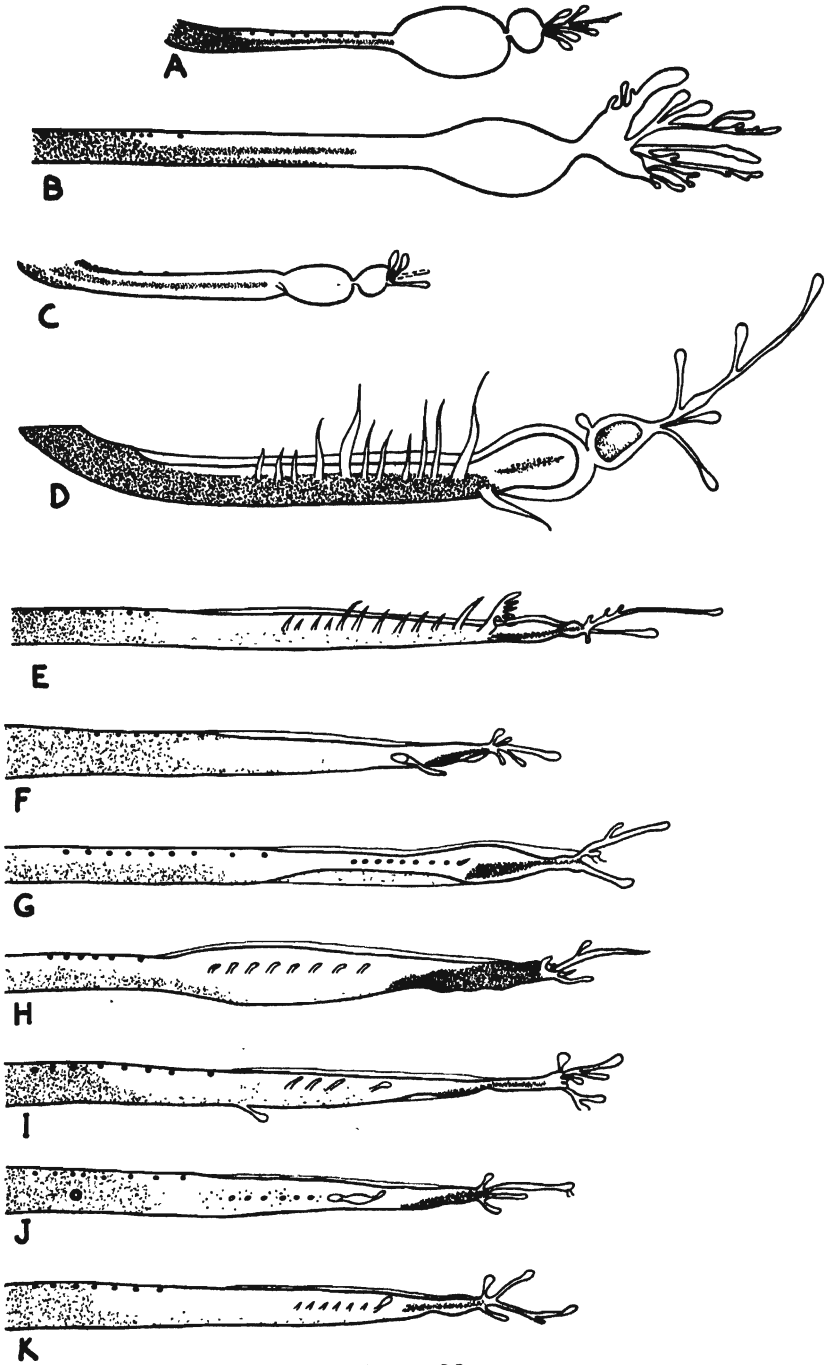
Barbel: The barbels of adults showed very little color, only faint washes of pink through the unpigmented portions. On the other hand, the barbel bulbs of all of the transitional adolescents taken were emerald green with a buffy sheath, while the stem and terminal filaments were violet blue tipped with bright mallow purple. No luminescence was observed from this organ in young or adults, although the least touch, or even a slight stirring of the water near the barbel, would arouse the fish to the utmost, so that it thrashed about and snapped, striving to reach and bite the source of irritation. Again and again we proved the astonishing sensitiveness of this organ. Obviously the barbel is primarily an organ for detecting vibrations in the water.

Postorbital Light Organ: In the adults, in daylight, the upper anterior portion of this light, and sometimes the entire anterior half, was invariably bright phlox pink and the remainder creamy white, the whole organ having a glistening, waxy look. In the dark room, however, both with and without the use of the ultra-violet lamp, this organ in two cases gleamed dully with a pinkish glow. In two other individuals it gave forth strong bluish or bluish-white flashes, sometimes at long intervals, sometimes almost between winks, both with and without stimulation.

In the living transitional adolescent, on the other hand, while the anterior portion of the organ was pink, as in adults, the posterior was distinctly silvery green, instead of creamy white. Whenever the fish twisted and turned and snapped, the cheek lights blazed out. Eight times this happened and eight times there shot forth a strong, clear, greenish-white light which momentarily lighted up all our faces. Twice we saw a distinct rosy or deep pink light from the same organ. As two-thirds of the photophore is pink in color, there must be an extremely delicate and localized control of the area, and of the color of the light.

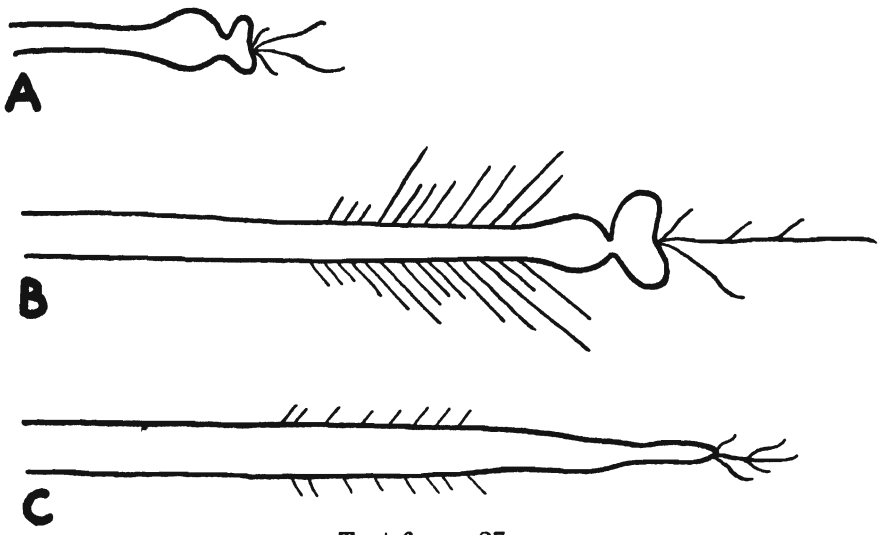
The cheek light did not revolve down into its socket, although this movement is possible, in order to obliterate or interrupt a steady gleam, but, as in all the other body lights, the luminescence was thoroughly under the control of the fish. The overhanging, pigmented "eave" of the organ protects the eye from the direct glare. When viewed from directly above, both cheek lights could sometimes be seen full on at once. In one case, the most powerful flashes occurred immediately before death.

Serial and Non-serial Photophores: The organs in daylight were violet in the young with silver or gold caps, and scarlet in the adults. The luminescence in all, however, was rosy to deep scarlet, deepest in the adult.




Text-figure 26.

*Echiostoma tanneri*. Lateral views of barbels. A, transitional adolescent, standard length 39 mm.; B, same, 61 mm.; C, same, 115 mm. (female); D, same, 192 mm. (male); E, F, G, H, adult males, 268 mm., 273 mm., 285 mm. and 302 mm., respectively; I, J, K, adult females, 315 mm., 333 mm. and 375 mm., respectively. A, after Regan & Trewavas; others from specimens in present collection. A and B, × 9.6; C-K, incl., × 3.9.




Text-figure 27.

*Echiostoma tanneri.* Diagrams of barbels, anterior views. **A**, adolescent and early transitional adolescent; **B**, late transitional adolescent; **C**, adult. In the adult the barbel becomes literally reduced in size and is actually smaller than that of moderate-sized transitional adolescents (see Text-fig. 26, D and F).

The small cephalic and trunk photophores of all were rosy red to deep purple. Every light was directed downward. See p. 138 for a description of the distribution of these small organs.

Luminous Tissue: The body light seemed to be of two kinds, illumination of the photophores, which we could see with a hand lens placed close to the surface of the water, and a general illumination of the whole skin by a greenish-white glow, although in the young the actual back was always dark, without a trace of the dorsal luminous bands observed in adults.

When the adults were placed under the fluorescent screen of the ultraviolet lamp, the luminescent areas were very distinct. Down the middle of the back two widely separated lines of bluish-white extended from nape to tail. These were broad and very irregular, narrowing and expanding and sending out short lines at irregular intervals. Below these were two additional pairs of the same type of line, but much narrower and more linear; one pair extended between the lateral and ventral series of photophores, and the second pair close together, on each side of the ventral profile. Over the cheek were scattered small, irregular blotches formed of grayish-white.

All of the fins were unquestionably luminous, and all the rays were permeated with scarlet blood vessels, the corpuscles moving regularly. Even the short webs of the pectoral were luminous, while the long, isolated ray was shining bluish-white, except for an external, broad band of skin which was, in daylight, brown with a series of a dozen or more photophores on its proximal portions; the second or third of these photophores was at least twice as large as the others. The membranes connecting the three short rays contained one or two layers of white, oval, luminous granules; down each ray were scattered about a dozen small glands, probably giving out mucous. Touching or moving the pectorals drew no apparent response from the fish, although a touch on the side of the body, especially near the tail, usually aroused an immediate reaction.

The bases of the teeth appeared pale blue in daylight, and were faintly luminous in the dark-room.

One specimen gave out a brilliant flash, at least a third as bright as that from the postorbital organ, from an undetermined spot near the beginning of the anal fin.

*Special Activity Observations*: All of the living specimens were vigorous, swimming strongly and snapping until a short while before death. In the most lively, the breathing was at a rate of 2 to 3 respirations a second; when feeble, only half as fast. The mouth was not seen to close, and the gill openings were never quite shut, the gills protruding beyond the opercle.

Viewed from above, when the fish was swimming normally upright, the gill covers were seen to open widely with all the gills showing expanded and deep red, being much more visible than is the case with any ordinary, adult fish.

When adrenalin was injected, the point of puncture became luminous at once, and little by little the illumination—yellowish in this single case—spread along the side. The small organs even along the dorsal profile became distinctly luminous and the hyoid line especially so, while the round granules along the short pectoral rays and all of the pelvic rays shone out clearly. (See Harvey, 1931, p. 67 ff.).

In the light of the above experiences with this species, Gill's only specific description of the fish, although not very scientific, was exceedingly vivid and quite characteristic: "a black fish with formidable teeth, which was so lively when brought to the surface that it twisted itself around in its attempt to bite the commander of the vessel, Captain Tanner."

*Arrangement of Small, Non-serial Photophores*: An adult male, in or near breeding condition, and measuring 325 mm. in length, was depigmentized in potassium hydroxide solution for about 36 hours, so that even the smallest organs were clearly visible in the now pallid skin. Since the exact arrangement and distribution of these lights has never been described, the following detailed account is given:

Head: In addition to the minute, apparently atrophied, suborbital and the large postorbital photophores, the light organs of the head are of four types:

1. On each side there is an irregular, broken line of about 14 small, dark organs, each about a third the size of a nostril; the line extends, just above the level of the eye, from the nostrils to the upper base of the opercular flap. The separate organs of the two sides correspond to one another in position.

2. The second type, forming the majority of the cephalic photophores, consists of organs also dark, but much smaller, the largest being not more than a fourth as large as the preceding. They are scattered without discernible pattern over the sides of the snout, along the margins of both upper and lower jaws, on the inside of the maxillary, on the roof of the mouth at least as far back as the palatines, around the eye in a close-massed ring (except for a short section of the anterior upper margin), on the cheeks and on the opercles. The organs are densest along the snout and mandible, scarcest in a small area on the posterior portion of the cheek, and completely absent on the top of the snout and head between the two series of larger organs (type 1, above). There are altogether about 300 of these small organs on each side of the head, not counting those on the inside of the mouth. They vary slightly in size and are not found in exactly the same relative position on the two sides.

3. The third variety is infinitesimal in size and only visible to the naked eye as vertical, pale golden streaks formed by the collection of innumerable organs into irregular lines of varying length, the individuals in each line being set very close together. These are found all over the head, jaws and opercles.

4. Finally, there are numbers of small, whitish luminous patches scat-

tered over the whole head (with the exception of the cheeks), jaws and opercles. These are thickest and most conspicuous on the snout, between the eyes and around the mandible.

Trunk Organs: (Above the regular, lateral series of photophores): The organs of the trunk may be divided into the same groups as those of the head, except that there are none corresponding in size to those of the first group described above.

Those corresponding to the second group (small, dark, and visible to the naked eye) are arranged in about sixty vertical series which extend from the opercles to the caudal, and from about a fifth of the distance from the dorsal mid-line to immediately above the lateral series of photophores—one series to each myomere. Each series consists of one or two dorsal photophores separated by a considerable gap from the 10 to 20 organs below them. The latter are sometimes arranged in a single, unevenly spaced line, but more often in an irregularly double row. The number in each series decreases toward the tail, and it is there that single rows are dominant.

The smallest, light-colored organs, as on the head, are innumerable, and in general are confined to outlining the myomeres, although there are a few odd ones scattered in the interspaces, and along the back.

The luminous patches seem confined to the broad, longitudinal band described earlier in this account (p. 137).

Ventral Organs: The same groups are found as on the trunk.

The small, dark organs are closely massed in a roughly double row down the midline of the isthmus. Between the lateral and ventral rows of serial photophores they are extremely numerous and quite irregular, the only semblance of arrangement being in the semi-circular arch of six or seven organs above each photophore of the ventral series. Each of the serial photophores is surrounded by a clear space.

The smallest, light-colored organs are comparatively few, and are grouped into short, broken lines similar to those on the head and without apparent pattern, except that a line of them runs between each two photophores.

Two bands of the small, whitish luminous patches present below lateral and ventral series, respectively, as described on p. 000.

Fins: A single row of small, dark organs, the second or third at least twice as large as the others, extends out along the isolated ray of the pectoral fin for a distance at least equal to the length of the head. The webbings of all the fins contain one or more layers of whitish, luminous granules.

It is probable that the smallest organs described above on both head and body are not strictly photophores, but glands giving off luminous mucous.

## Development.

The Bermuda collection contains no very young specimens, the youngest being five transitional adolescents measuring between 61 and 192 mm., and differing from adults in the usual details typical of transitional adolescence (see p. 000). Their own particular characteristics are the pronounced development of 2 barbel bulbs and the great number and length of the stem filaments, which pass through a stage when they are literally longer than in the adult. Also, there is an actual shrinking in length of the whole barbel after the specimen becomes adult. The remaining specimens in the collection consist of 5 males between 268 and 325 mm. in length, and 3 females between 315 and 355 mm. All may be counted as adults, since the gonads are very well developed, those of the 2 largest males and 2 largest females being apparently in full breeding condition. The smallest counted as an adult (268 mm.) shows unmistakable connections in the form of the barbel with the

double-bulbed transitional adolescents (Text-fig. 26E). We were able to determine sex in all specimens of 115 mm. and over.

The *Dana* collection fortunately contains specimens as small as 20 mm. in length, and Regan & Trewavas (1930, p. 117) give the following details of the growth of barbels and maxillary teeth in adolescents and transitional adolescents: postocular small (from about 1/20 of head, or half diameter of eye); no filaments above barbel bulb in specimens under 90 mm., or, between 75 and 90 mm., the distal pair may be represented by buds; 2 or 3 pairs of short filaments in specimens of 95 and 96 mm.; at 133 mm. there are 3 or 4 long filaments on each side and 4 to 6 buds; in larger specimens, 142 to 153 mm., there are 12 or 13 pairs of filaments, and in the 223 mm. specimen 15 to 18, several being branched. Thus the maximum barbel development occurs during late transitional adolescence. It will be noted that in adults it is the more distal stem filaments which persist; often vestiges of the more proximal pairs can be detected subdermally. Maxillary with a few oblique teeth, 6 to 9 in examples of 35 mm.; in specimens of 75 to 95 mm. there are 3 or 4 fangs and 15 oblique teeth; in specimens of 130 to 223 mm., 6 or 7 fangs and 18 to 25 oblique teeth. As has been said, in our largest female (355 mm.) there are more than 50 oblique maxillary teeth.

Thanks to the kindness of Dr. Norman, we have been able to examine two of the smallest of the *Dana* series from the British Museum, and to determine the presence of subdermal larval pigment spots. Each myomere is marked by one large stellate blotch immediately below the dorsal mid-line, and an oblique row of 3 to 5 small dots, following the myomeral boundary, between the lateral mid-line and the lateral series of photophores. (Text-fig. 2H).

## Ecology.

*Vertical and Season Distribution*: The 13 specimens were taken singly from May to September between 500 and 900 fathoms. Specimens apparently in full breeding condition were taken in July and August.

*Food*: Only two of the stomachs or intestines showed any food. The first, a specimen of 115 mm., contained one fish eye and a piece of crustacean cuticulum; the second, 154 mm. long, held a 67 mm. *Lampanyctus polyphotis* Beebe, described in 1932 and previously known from the Bermuda type alone, a specimen only 40 mm. in length.

Since six of the specimens were alive and active after trawling, it is reasonable to suppose that at least some of the others may have lived for a time in the net; this would have allowed time for digestion of food before death, which seems a better explanation for the lack of food than the alternative one that these active, well-armed fishes feed only at long intervals. This is especially likely since the abdominal wall is very thick and not as greatly distensible as in some forms, such as *Chiasmodon*, which can swallow such enormous fish that the food supply thus obtained is presumably adequate for long periods.

*Enemies*: A specimen of *Echiostoma* has been taken from the stomach of a swordfish (*Xiphias gladius*) (Kingsley, 1922, *Science*, N. S., Vol. LVI, pp. 225-226).

*Parasites*: Several small round worms, probably nematodes, were usually present in the intestine.

## Study Material.

The following list gives the catalogue number, depth in fathoms, date, length and growth stage of each specimen of *Echiostoma tanneri* taken by the Bermuda Oceanographic Expeditions. All were caught in the cylinder of water off the Bermuda coast described in *Zoologica*, Vol. XVI, No. 1, p. 5 and Vol. XX, No. 1, p. 1.

No. 10,125; Net 116; 900 F.; May 18, 1929; 315 mm.; Adult Female.
No. 10,882; Net 212; 600 F.; June 24, 1929; 302 mm.; Adult Male.
No. 11,183; Net 245; 800 F.; July 1, 1929; 333 mm.; Adult Female.
No. 12,976; Net 412; 800 F.; Sept. 3, 1929; 154 mm.; Trans. Adolescent Male.
No. 15,054; Net 587; 500 F.; May 17, 1930; 115 mm.; Trans. Adolescent Female.
No. 15,651; Net 657; 700 F.; June 2, 1930; 192 mm.; Trans. Adolescent Male.
No. 17,792; Net 815; 900 F.; Aug. 28, 1930; 285 mm.; Adult Male.
No. 20,141; Net 839; 700 F.; Sept. 3, 1930; 273 mm.; Adult Male.
No. 21,603; Net 1102; 500 F.; July 25, 1931; 325 mm.; Adult Male.
No. 22,528; Net 1194; 700 F.; Aug. 18, 1931; 82 mm.; Trans. Adolescent.
No. 22,559; Net 1194; 700 F.; Aug. 18, 1931; 355 mm.; Adult Female.
No. 22,798; Net 1228; 500 F.; Aug. 27, 1931; 61 mm.; Trans. Adolescent.
No. 22,974; Net 1243; 700 F.; Aug. 31, 1931; 268 mm.; Adult Male.

## Synonymy and References.

*Hyperchoristus tanneri*:

Gill, 1883, p. 256. (1 specimen; 959 fathoms; 660 miles northwest of Bermuda). Examined by present authors.

*Echiostoma barbatum*:

Goode & Bean, 1895, p. 109; pl. XXXV, fig. 130. ("Numerous specimens;" east of New Jersey and Old Bahama Channel). Several examples examined by present authors.

Parr, 1927, p. 53, fig. 31. (3 specimens, 28 to 48 mm.; 800, 8,000 ft. wire; south and southeast of Nassau, Bahamas). Examined by present authors.

Borodin, 1931, p. 65 (*part.*) (1 female, 255 mm.; 1,500 m.; off Bermuda). Examined by present authors.

*Echiostoma tanneri*:

Regan & Trewavas, 1930, p. 117; fig. 113. (92 specimens; 20 to 223 mm.; 50 to 2,000 m. wire; Gulf of Mexico, Caribbean and North Atlantic). 2 small examples examined by present authors.

Norman, 1930, p. 314. (2 specimens; 170, 200 mm.; 850 to 950 m. wire; off Cape Town, South Africa).

Beebe, 1937, p. 199. (Preliminary note on specimens treated in the present paper).

*Echiostoma ctenobarba*:

Parr, 1927, p. 55, figs. 32 and 33. (1 male; 285 mm.; 4,000 to 7,000 ft. wire; Bahamas, southeast of Nassau). Examined by present authors.

Regan & Trewavas, 1930, p. 117, fig. 112c. (Résumé of type description).

Harvey, 1931, p. 67. (Results of stimulation by adrenalin of 2 specimens in the present collection).

Parr, 1934, p. 16, fig. 4a. (Supplementary description of the type specimen).

*Echiostoma ctenobarba ramifera*:

Parr, 1934, p. 17, fig. 4b. (1 female; 297 mm.; 1,050 to 1,100 m.; off Bahamas). Examined by present authors.

*Echiostoma calliobara*:

Parr, 1934, p. 15, fig. 4c. (1 female; 290 mm.; 610 to 930 m.; off Azores).

The two small specimens (70 to 75 mm.) described by Borodin (1931, p. 65) under the heading *Echiostoma barbatum* prove, upon examination by us, to be *Photonectes margarita* (see p. 000).

## Genus ***Melanostomias*** Brauer, 1902.

(See also pp. 70, 72, 73, 75, 79, 81, 82, 85, 86, 88, 90, 91, 97, 102, 103, 105, 106, 108-110).

Text-figs. 2, 10, 11, 12, 28-32 incl.).

### General Discussion.

Nineteen species of Melanostomiatidae have been referred in original descriptions to the genus *Melanostomias*. In addition, the two species for which Regan & Trewavas erected the genus *Haplostomias* (1930, p. 109) should also be referred to *Melanostomias*, as will be shown below. Hence a total of 21 species of *Melanostomias* have been described.

In addition to our study of the specimens taken by the Bermuda Oceanographic Expeditions, all of which prove to be *M. spilorhynchus* and *M. biseriatus*, we have examined all of the specimens of *Melanostomias* deposited in American museums, as well as two on loan from the British Museum.

Difficulties in the delineation of species are greater than usual in this genus, because only 2 characters have been found to be specifically significant, namely, the number of P-V photophores, which usually serves only to separate groups of species, and the form of the barbel. The latter is one of the last organs to achieve adult shape, since it often continues development far into transitional adolescence; also, it is frequently variable. We are convinced that many of the so-called specific differences between barbels in *Melanostomias* will prove to be due to growth stage characteristics and to individual variation; it is also likely that sex may be a controlling factor in barbel form, as in the genus *Eustomias*. Unfortunately, however, an adequate revision of the genus is impossible until additional material has been acquired, particularly fully adult examples, and specimens in European museums examined.

The following annotated list of species described up to the present may be of help to future investigators.

1. *M. melanops Brauer*, 1902, p. 284. Six specimens have hitherto been referred to this species: the 183 mm. type from the Indian Ocean, 4 small specimens from the Bahamas (Parr, 1927, p. 42), and 1 specimen, 242 mm. long from the Caribbean (Regan & Trewavas, 1930, p. 114). We have examined Parr's material and decided that his nos. 2,066 and 2,067 are rightly referred to *M. melanops*, while the other two are *M. melanopogon* (species no. 15 below). In addition, *M. albibarba* (species no. 13), of which we have examined one of the type series, is in all probability the transitional adolescent phase of *M. melanops*.

2. *M. valdiviae* Brauer, 1902, p. 285. Three specimens have hitherto been referred to this species: 2 from the Indian Ocean (55 and 165 mm.), and one taken by the *Dana* in the Caribbean (24 mm.). Not seen by us. Probably *M. melanocaulus, M. heteropogon, M. stewarti* and *M. vierecki* (species nos. 10, 11, 18 and 20 below) will prove to be synonymous with *M. valdiviae*. If they are thus synonymized, a hitherto unrecorded female, 101 mm. long, in the U. S. National Museum taken by the *Albatross* off Brazil (U. S. N. M. No. 2,761) also belongs to this species.

3. *M. braueri* Zugmayer, 1913, p. 3. Already rightly referred to the genus *Photonectes* by Regan & Trewavas, 1930 p. 121.

4. *M. niger* Gilchrist & von Bonde, 1924, p. 6. Known only from the type specimen, 220 mm. long, from South Africa. Not seen by us.

5. *M. bartonbeani* Parr, 1927, p. 45. Described from a specimen in the U. S. National Museum in which the specifically important barbel is broken off above the bulb. We have examined it, and find that it is impossible to tell whether it is conspecific with *M. spilorhynchus*, or with *M. valdiviae*, or is actually a different species.

6. *M. problematicus* Parr, 1927, p. 46. Already rightly referred to the genus *Leptostomias* by Regan & Trewavas, 1930, p. 61.

7. *M. tentaculatus* (Regan & Trewavas, 1930, p. 109). It was for this and the following species that the genus *Haplostomias* was erected. Seven specimens have been referred to this species, 6 measuring between 20 and 100 mm. in the type series, from the North Atlantic and Caribbean, and one, 204 mm. long, from the South Atlantic (Norman, 1930, p. 314). We have examined the latter specimen. By definition, the newer genus differs from *Melanostomias* chiefly in having the fangs "simple, or with a rudimentary cusp;" the proportions, photophores and finray counts all fall within the limits set by typical species of *Melanostomias;* also, the barbel is of the same general type—mid-way, in fact, between the simple, terminal bulb of *M. niger* and the more complicated form, with luminous bodies before and behind the terminal axis, found in other species, since in the present species luminous bodies occur only behind the terminal axis. Our examination of the 204 mm. specimen shows that a number of the fangs have cusps considerably more pronounced than shown by Regan & Trewavas, p. 110, fig. 105 a, although smaller than in typical *Melanostomias;* also, the tips of a number of the fangs are obviously broken, as is often the case in bicuspid-fanged genera, so that it seems altogether probable that in adult specimens small cusps are present on all the teeth. Also, the number and arrangement of the teeth in both jaws and gill-arches are typical of those occurring in true *Melanostomias.* Finally, the proposed genus *Haplostomias* is so much closer to *Melanostomias* than to any other genus, and the differences so much slighter than those between any other two genera in this family, that the advisability of uniting them seems unquestionable. Hence, we propose to place *Haplostomias* in synonymy with *Melanostomias* so that its two species will become *Melanostomias tentaculatus* and *M. bituberatus,* respectively.

8. *M. bituberatus* (Regan & Trewavas, 1930, p. 110). See preceding species (no. 7). Known from a single specimen, 20 mm. long, taken in the tropical North Atlantic. Not seen by us.

9. *M. spilorhynchus* Regan & Trewavas, 1930, p. 112. All except 4 of the specimens in the Bermuda collection are referred without question to this species, the best known in the genus; it appears to be the species typical of the subtropical, as opposed to the tropical Atlantic. A full discussion begins on p. 148. *M. bulbosus* Beebe, 1933, is a synonym of *M. spilorhynchus* (see species no. 17, below).

10. *M. melanocaulus* Regan & Trewavas, 1930, p. 113. Known only from the type specimen, 55 mm. long, from the Caribbean Sea. Not seen by us. It is likely that this will prove to be conspecific with *M. valdiviae.*

11. *M. heteropogon* Regan & Trewavas, 1930, p. 113. Known only from the 2 or 3 specimens in the type series, measuring up to 62 mm. long, from the tropical and subtropical west Atlantic, including a station near Bermuda. Not seen by us, but we think it most likely that this species will also prove to be a synonym of *M. valdiviae.*

12. *M. biseriatus* Regan & Trewavas, 1930, p. 113. Known only from 4 specimens, 20 to 25 mm. long, from a single station east of Bermuda, and from 4 Bermuda post-larvae and adolescents in the present collection (see p. 152). *M. margaritifer* (species no. 14, below) or an allied species will probably prove to be a more advanced stage of *M. biseriatus.*

13. *M. albibarba* Regan & Trewavas, 1930, p. 114. Known from 11 specimens, 20 to 60 mm. long, in the type series, chiefly from the tropical, rarely the subtropical, Atlantic. Regan & Trewavas also refer to this species two of the series identified by Parr (1927, p. 42, nos. 2064 and 2065) to *M. melanops.* We have examined the latter specimens, as well as one of the series described by Regan & Trewavas, and are fairly certain that *M. albibarba* represents merely the young of *M. melanops.* Our basis for this

conclusion is the fact that in small examples of *M. spilorhynchus* the rounded luminous bodies of the barbel end are much larger and more distinct than in adult specimens; the same is true of barbel bulbs in related genera (e.g. *Echiostoma* and *Photonectes*).

14. *M. margaritifer* Regan & Trewavas, 1930, p. 115. Known only from the 2 specimens, 52 and 80 mm. long, in the type series, from the north Atlantic. Not seen by us. May prove to be a more advanced stage of *M. biseriatus*.

15. *M. melanopogon* Regan & Trewavas, 1930, p. 115. Known from 3 or 4 specimens, 27 to 153 mm. long, in the type series from the North Atlantic, and by 2 specimens, 66 and 95 mm. long, from the Bahamas. The latter examples were recorded by Parr (1927, p. 42, nos. 2066 and 2067), who referred them to *M. melanops*. We have examined no. 2067 (66 mm. long), and find that without question it should be referred to *M. melanopogon*, as suggested by Regan & Trewavas.

16. *M. macrophotus* Regan & Trewavas, 1930, p. 115. Known from the 9 specimens, in the type series, 20 to 62 mm. long, from the north Atlantic. Not seen by us.

17. M. *bulbosus* Beebe, 1933.2, p. 166. A reexamination of the type, the unique specimen, shows that it is in reality an example of *M. spilorhynchus* in which the barbel has been broken between the distal end of the pigmented swelling and the luminous, terminal expansion. The lateral series of V-A photophores actually numbers about 13, as in typical *spilorhynchus*, instead of 11, as stated in the type description, the first 2 or 3 in the series being rudimentary in this specimen on the left side of the fish, which is in all other respects normal.

18. *M. stewarti* Fowler, 1934, p. 262. Known from a single specimen, 215 mm. long, from the Philippine Islands. After examining this form in the U. S. National Museum, we conclude that *M. stewarti* should be synonymized with *M. valdiviae*. Fowler differentiates it from *M. valdiviae* chiefly because of the presence of apparently only one pair of teeth, not 2, on the basibranchials. We find, however, that there is a small second pair underneath the skin. The barbel agrees with the figure given by Regan & Trewavas (1930, p. 112, fig. 108 A), except that the posterior luminous bodies are relatively larger with respect to the anterior one, and there is a minute, second, anterior body immediately in front of the tip of the axis. Finally, there are 5, not 4, pectoral rays. The specimen is somewhat shriveled, the measurements not entirely agreeing with those given in the description.

19. *M. globulifer* Fowler, 1934, p. 263. Known from a single specimen, 180 mm. long, from the Philippine Islands. Examined by us in the U. S. National Museum, and found to be valid, as far as present knowledge goes. Except for the tiny ovoid white bodies along the stem the barbel is, however, exceedingly close to those of *M. valdiviae* and *M. melanocaulus* (see Regan & Trewavas, 1930, p. 112, fig. 108 A and C): at the distal end of the barbel there are 2 luminous bodies behind the axis, the proximal slightly the longer, and 1 in front, short but very slender. Contrary to the statement in the type description, there is a small terminal filament, arising as usual from the posterior translucent portion. Another correction is that when the V-A series is counted, in the customary fashion, to include the 3 to 5 organs which continue the row above the anal fin, there are 13, not 11 organs in the ventral V-A series, and 10, not 13, in the A-C series; similarly, there are 12, not 10, in the lateral V-A series. We count 15, not 14, dorsal rays.

20. *M. vierecki* Fowler, 1934, p. 265. Known from a single specimen, 118 mm. long, from the Philippine Islands. After examining this form in the U. S. National Museum, we see no reason why it should not be referred to *M. valdiviae*. The barbel is exactly as figured by Regan & Trewavas (1930, p. 112, fig. 108 A), except that the posterior bulbs are relatively larger, as in *M. stewarti*, the distal being considerably larger than the proximal;

there is a short, posterior filament in the usual position. There is no trace of a tiny, anterior, terminal body, such as is found in *M. stewarti*. There are 5, not 4, pectoral rays. Counting the photophores in the customary manner gives the following results, perfectly concordant with the counts for *M. valdiviae*: ventral series, I-P 8+2 or 3, P-V 27 or 26, (depending upon in which series a subpectoral organ is counted), V-A 12, A-C 10; lateral series as given in the type description (O-V 25, V-A 12). The specimen is somewhat shriveled, and the present measurements do not entirely agree with those given in the description.

21. *M. pauciradius* Matusubara, 1938, p. 39. Known from a single specimen, 98 mm. long, taken off Japan. Not seen by us. Apparently valid.

*Distribution*: *Melanostomias* is one of the 7 genera in the family which have been recorded outside the Atlantic Ocean. Two of the species, *M. valdiviae* and *M. melanops*, occur in both the Atlantic and Indian Oceans. Another, *M. pauciradius*, has been taken only off Japan. The depth range as known at present is between approximately 22 and 1,100 fathoms. Including the present collection, 160 specimens of *Melanostomias* have been taken, of which 99 are referred to *M. spilorhynchus*.

## Generic Characters.

*Color* (summarized from observations on about 15 transitional adolescent and 2 adult male specimens of freshly caught *Melanostomias spilorhynchus*): General color brownish-black; antorbital organ yellow; postorbital and snout lights pink to purple; end of barbel with greenish-yellow core, and pink or purple flanges and luminous bodies; serial photophores violet with gold caps; bases of teeth pale blue.

*Proportions*[5]: Elongate melanostomiatids with very short, rounded snout; depth in length 8.5 to 11 (9.1% to 11.8%); head in length 5 to 8 (12.5% to 20%); eye in head 4 to 6; snout no longer than eye, sometimes shorter; snout to pelvic in length *ca.* 1.55 to 1.7 (59% to 67%).

*Barbel*: Five-sixths to 3 times length of head, with a simple stem ending in an ovate bulb or a flattened, terminal expansion enclosing one or more luminous bodies; terminal filament present or absent.

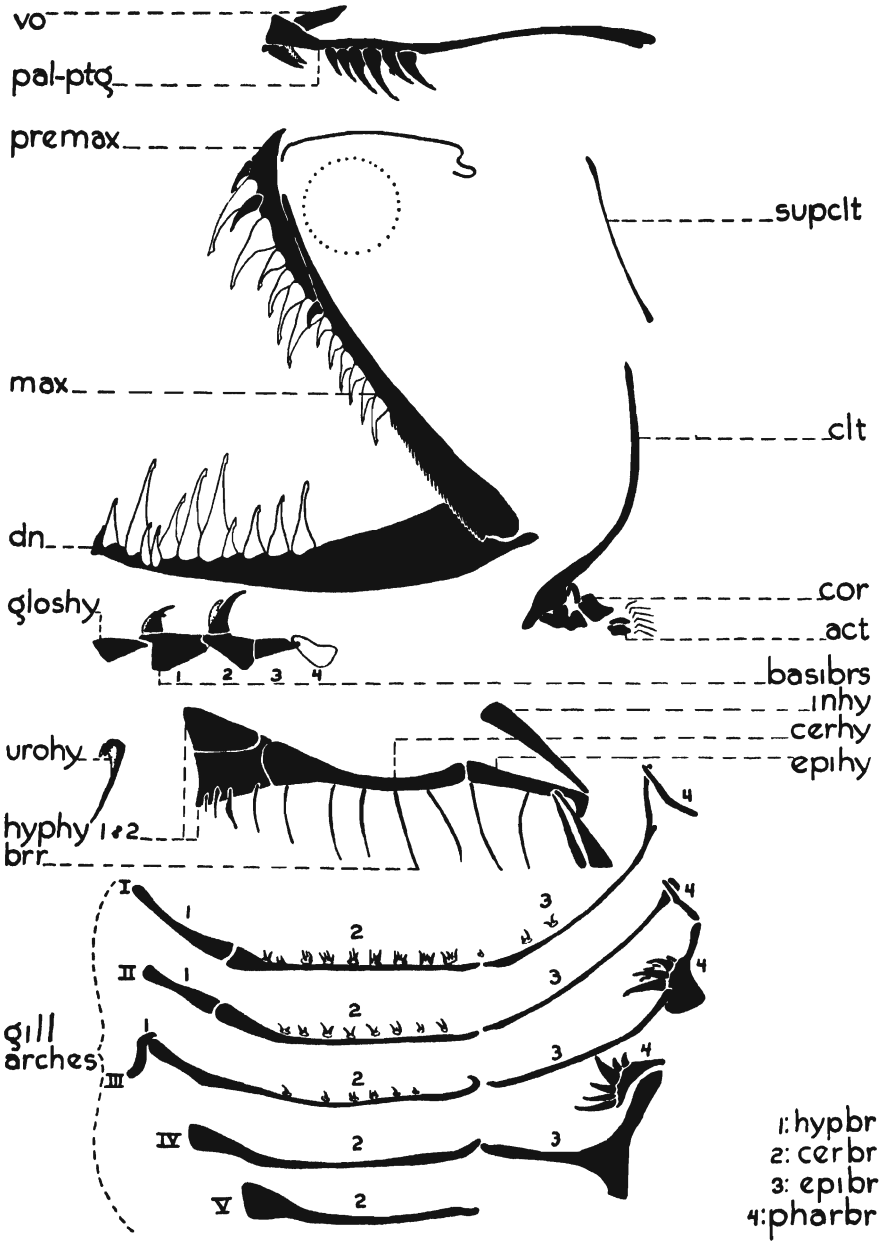
*Light Organs*: Postorbital (measured as length of area of transparent skin) *ca.* .75 to 1.5 times diameter of eye in both sexes. Serial photophores with the following counts: ventral series, I-P 8+1 to 3, P-V 23 to 29, V-A 12 to 15, of which 3 or 4 are above the anal fin, A-C 9 to 11; lateral series, O-V 23 to 28, V-A 12 to 15. Tiny, non-serial photophores well developed. Luminous matter in bases of teeth and on fins usually conspicuous.

*Teeth*: Cleft of mouth straight, or slightly curved at symphysis; premaxillaries and mandible with depressible, curved, fangs arranged in a single row in 2 or 3 series, the teeth of each series progressing in size posteriorly; barbs usually strongly developed, sometimes weak; 1 or 2 pairs of small, fixed teeth in anterior part of each jaw; maxillary with about 3 to 9 erect teeth and a long series (up to about 45) of oblique denticles; a pair of teeth on the vomer; a series of 3 to 6 teeth on each palatine. Typically 2 pairs of teeth on the basibranchials. Teeth, in pairs, with a few individual teeth single, and in threes and fours, present on first 3 gill-arches only: on first, second and third ceratobranchials and on first epibranchial; 9 or 10 groups on first ceratobranchial.

*Branchiostegal Rays*: *ca.* 12 to 13.

*Fins*: Pectoral with 3 to 6 rays, normal, short. Pelvic 7, much longer than pectoral, inserted far behind middle of length. Dorsal 13 (10?-*M. niger*) to 16; anal 16 to 20; dorsal and anal beginning at the same vertical, but anal extending farther back.

[5] The proportions given include those of some obviously immature specimens upon which species have been founded.

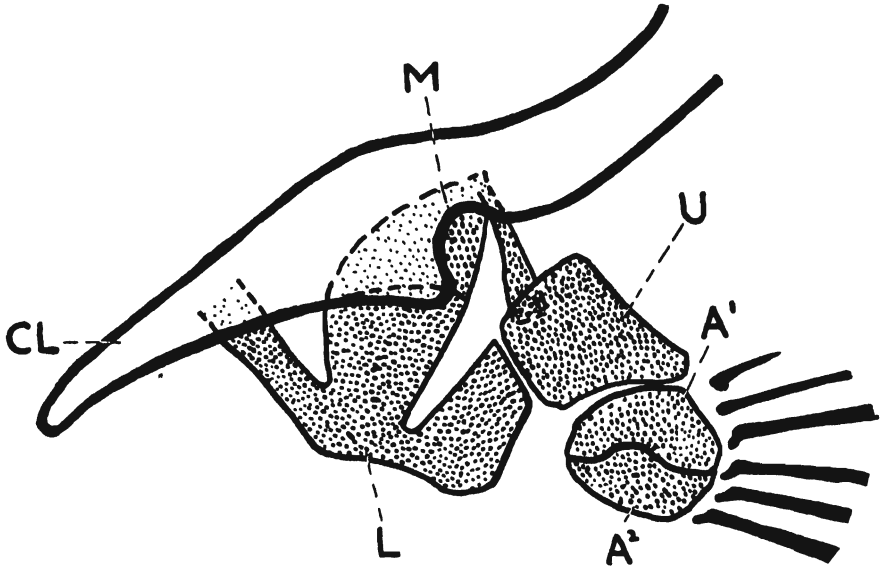



Text-figure 28.

*Melanostomias spilorhynchus*. Jaws, hyoid and branchial arches, and pectoral girdle of adult, standard length 222 mm. Explanation as in Text-fig. 18.

*Epidermal Grooves*: There is a shallow groove in the isthmus for the reception of the barbel stem.

*Osteology*: Mesethmoid with lateral processes; parietals absent; post-




Text-figure 29.

*Melanostomias spilorhynchus.* Supporting bones of pectoral fin in adult, standard length 222 mm. Abbreviations as in Text-fig. 14.

temporal absent; supracleithrum and cleithrum moderately strong; all coracoid elements large; actinosts 2; vertebrae about 50 to 55; first vertebra represented only by a fibrous ring, shorter than a centrum, enclosing the notochord, and by a spinal nerve.

*Coelomic Organs*: Stomach *ca.* 40% of standard length, reaching almost to the pelvic origin; 2 pyloric caeca.

*Sexual Dimorphism*: Apparently none, but should be watched for in structure of barbel, and for slight differences in relative size of postorbital.

*Size*: The largest known specimen is an *M. melanops* 242 mm. long, taken by the *Dana* in the Caribbean. Examples of 4 or 5 other species, which measure more than 200 mm. in length, have been taken. Sex can be determined in transitional adolescents measuring 100 mm. or more. Male Bermuda specimens of *M. spilorhynchus* of 222 and 240 mm. appear to be adult, although not in full breeding condition. The same is true of the 204 mm. *M. tentaculatus*, also a male, in the British Museum.

*Development*: A series of growth stages of *M. spilorhynchus*, from late larva to adult, has been taken by the Bermuda Expeditions; the pigment spots of the early stages are identical with those in post-larval and adolescent *M. biseriatus* and with those remaining subdermally in a borrowed *Dana* specimen of *M. albibarba* (probably young *M. melanops*—see p. 143) in the adolescent stage, and of those in young *Echiostoma*: each myomere has, typically, a dorsal spot immediately below the dorsal mid-line, and an obliquely vertical row of three dots, along or near the myomeral boundary, between the lateral mid-line and the series of photophores. The length of the barbel apparently increases with the length of the fish.

## ***Melanostomias spilorhynchus*** Regan & Trewavas, 1930.

(See also p. 143).

### Specimens Taken by the Bermuda Oceanographic Expeditions.

51 specimens; May to September, 1929 to 1931; 400 to 1,000 fathoms; from a cylinder of water 8 miles in diameter (5 to 13 miles south of Nonsuch Island, Bermuda), the center of which is at 32° 12′ N. Lat., 64° 36′ W. Long.; standard lengths from 17 to 240 mm.

### Specimens Previously Recorded.

48 specimens; *ca.* 18 to 275 fathoms; North Atlantic; Bermuda and eastward to Azores, Madeira and Canaries; standard lengths from 23 to 206 mm.

### Description of Adult.

With the characteristics of the genus.

This species is distinct among the members of the genus in having a characteristic barbel (see below), only 23 to 25 P-V photophores, and 3 luminous spots on the snout.

*Color* (from observations on about 15 transitional adolescent and 2 adult males, all freshly caught): General color brownish-black. Barbel stem and proximal part of swollen end black; usually 1 or 2 white spots at base of stem; barbel bulb with greenish-yellow core and flanges and luminous bodies phlox pink or purple. Antorbital pale yellow; postorbital and snout lights bright pink to true purple. Serial photophores bluish-violet or violet, with gilt caps. Luminous bases of teeth pale blue.

*Proportions*: Depth in length 8.5 to 11 (9.1% to 11.8%); head in length 6 to 8 (12.5% to 16.7%); eye in head 5 to 6 (2.3% to 2.7% of length); snout as long as or slightly shorter than eye.

*Barbel*: 1.2 to 1.5 times length of head with the flattened, terminal expansion enclosing the straight, central axis and two strips of loose, luminous tissue, one in front and one behind the axis; a small ovoid body at proximal end of anterior strip, a second at distal end of posterior strip, at the base of a tapering terminal appendage which usually ends in a filament; a few speckles of pigment at distal end of axis. Stem black, with a row of photophores down posterior side; distal part of stem swollen immediately above junction with the terminal expansion.

*Light Organs*: Antorbital tiny but apparently functional in transitional adolescent, atrophied in adult; postorbital 1.2 to 1.5 times diameter of eye. Serial photophores with the following counts: ventral series, I-P 8+2 or 3, P-V 22 to 25, V-A 13 to 14, the last 2 or 3 being above the anal fin, A-C 9 to 10; lateral series, O-V 22 to 24, V-A 13 to 14.

The non-serial organs of both head and trunk are of two sizes, the first considerably smaller than the serial photophores but clearly visible to the naked eye, the second microscopic. A third variety of luminous organ is the luminous matter. All three kinds are as found in *Echiostoma* (see p. 138).

Head: The photophores of the larger type (Group A) are scattered without special arrangement all over the head, except on the crown and interorbital region. They are most dense on the lower jaw. The second type (Group B) are everywhere, always arranged in short, irregular lines. On top of the head they run transversely; on the cheeks and opercles they continue transversely (vertically), but less regularly and more obliquely. They are least conspicuous on the lower jaw. There is an unpaired luminous patch in the middle of the snout and a pair of similar ones, almost as large, one in front of each eye, in addition to about six pairs of smaller, but exactly

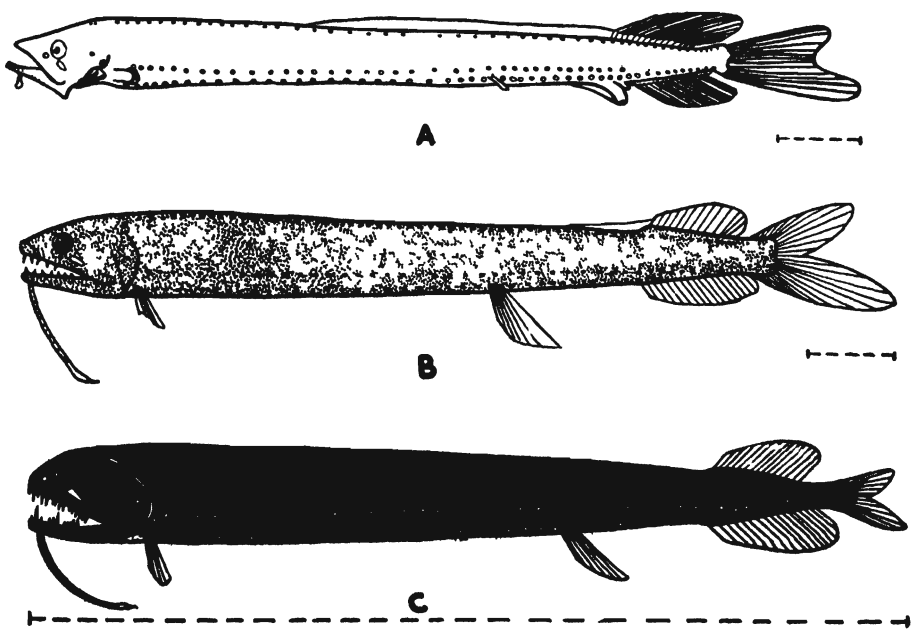
similar spots, in front of and below the eye and close to the front teeth; usually a conspicuous unpaired luminous patch in center of crown of head, behind the level of the eyes.

Trunk Series (above the regular lateral photophore series): In the middle of each myomere is a group of A-type organs in a roughly irregular double line. They commence on a level with the opercle and extend to the serial photophores. Between 20 and 30 lights are usually found in each myomeral group. The dorsal part of the fish lacks them entirely. The B-type group of microscopic organs outline in solid, single rows the lines of demarcation between myomeres. Short rows of them similar to those found on the head are scattered through the myomeres themselves. These organs continue without interruption across the dorsal profile.

Ventral Series: A-type organs are massed without special arrangement on the isthmus. Midway between the lateral and ventral series runs a fairly continuous line, extending from opercles to the anal fin, dying out at this point. Above and below this line many other organs of the same type are distributed without apparent arrangement except that scallops are formed below each large, lateral light and above each large ventral one, a short tongue of the small lights thrusting up between each two serial organs. In the ventral midline this same scalloped formation is found but shows no special arrangement except that the lines of segmentation between the myomeres are devoid of organs. B-type organs are here distributed as on the trunk, between myomeres and in short strings.

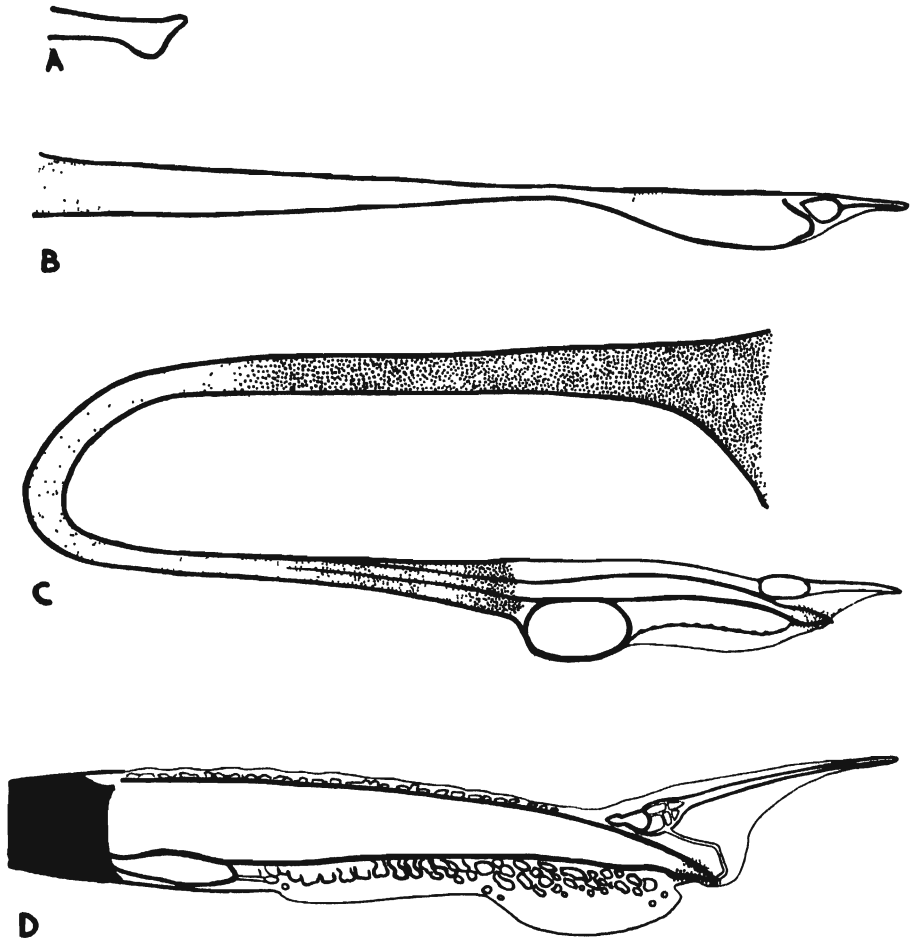
In general it may be noted that the concentration of organs from snout to caudal is ventral, and that the organs are sparser toward the caudal fin. On each side of the fish there are about 50 to 70 organs in the areas of deepest concentration.

*Fins*: Pectoral 5 to 6; dorsal 14 to 15; anal 18 to 20.




Text-figure 30.

***Melanostomias spilorhynchus***. **A**, post-larva, standard length 24 mm.; **B**, adolescent, 25 mm.; **C**, adult, 222 mm. See also Text-fig. 2 D.




Text-figure 31.

*Melanostomias spilorhynchus.* Barbels, lateral views. **A**, post-larva, standard length 24 mm.; **B**, adolescent, 25 mm.; **C**, transitional adolescent, 36 mm.; **D**, adult, 222 mm. (end of barbel only).

## Development.

*Material*: All stages are represented in the Bermuda collection, and are distributed as follows:

1 larva; 17 mm.; 500 fath.; July. (In poor condition; identification certain from myomere counts and pigment, but impossible to take body measurements).

12 post-larvae; 21 to 32 mm.; 400 to 1,000 fath.; July to Sept.

8 adolescents; 22 to 31 mm.; 500 to 900 fath. July to Sept.

27 transitional adolescents; 24 to 36 mm.; 400 to 1,000 fath.; Aug., Sept.

3 adults; 222 to 240 mm.; 500 to 900 mm.; May to Sept.; males.

All are typical representatives of their respective growth stages (see pp. 77). The special characteristics of their young stages are as follows:

*Myomere Counts*: To end of anal 49 to 52; from nape to pelvic rudiment (when present) 29 or 30; from pelvic rudiment to anal origin 10 to 12.

*Pigment*: The characteristic larval pigment spots of the genus (p. 147) are visible externally or subdermally even well into transitional adolescence.

*Larval Teeth*: In each premaxillary of the single larva are 7 pairs of larval teeth, all minute, and all directed straight outwards; the maxillary holds 15 teeth, increasing slightly and progressively in size toward the posterior part of the jaw; in each half of the mandible are 7 teeth, corresponding to those of the premaxillary, directed outward and set in the anterior part of the jaw only.

*Larval Gill-rakers*: Long, spiny rakers present on first 3 arches, vestigial or absent on fourth and fifth, continuing throughout post-larval stage; on the first ceratobranchial they number 11 or 12.

*Fins*: Dorsal and anal rays of full number in larva, but in this stage and early post-larvae the anal commences slightly behind the dorsal, under about the fourth dorsal ray.

The barbel of adolescents and transitional adolescents differs from that of the adults noticeably in the relatively large size and conspicuousness of the 2 ovoid, luminous bodies. The stem is only lightly pigmented, and the entire barbel length relatively less than in fully grown fish. The postorbital organ grows slowly, being smaller than the eye well into transitional adolescence.

## Ecology.

*Seasonal Distribution*: The majority of specimens, practically all of which are young, having been taken in August and September, a summer breeding period may be indicated.

*Abundance*: The 51 specimens in the collection indicate that this species is by far the most common melanostomiatid off Bermuda. About 1 in 5 of the melanostomiatids was an *M. spilorhynchus*, the rest being distributed among more than 30 species.

*Food*: Of 12 stomachs examined, only 1, that of a transitional adolescent 34 mm. long, contained food, a *Myctophum laternatum* measuring more than half the length, and almost twice the thickness, of the *Melanostomias*.

## Study Material.

The following list gives the catalogue number, depth in fathoms, date, length and growth stage of each specimen of *Melanostomias spilorhynchus* taken by the Bermuda Oceanographic Expeditions. All were caught in the cylinder of water off the Bermuda coast described in *Zoologica*, Vol. XVI, No. 1, p. 5 and Vol. XX, No. 1, p. 1.

No. 10,235; Net 136; 700 F.; May 30, 1929; 222 mm.; Adult Male.
No. 11,418; Net 277; 1,000 F.; July 9, 1929; 222 mm.; Adult Male.
No. 11,867; Net 311; 600 F.; July 22, 1929; 25 mm.; Post-larva.
No. 11,877; Net 315; 500 F.; July 23, 1929; 26 mm.; Post-larva.
No. 11,919; Net 330; 900 F.; July 27, 1929; 25 mm.; Adolescent.
No. 11,920; Net 334; 500 F.; July 29, 1929; 23 mm.; Post-larva.
No. 11,936; Net 339; 500 F.; July 30, 1929; 25 mm.; Adolescent.
No. 12,110; Net 355; 600 F.; Aug. 8, 1929; 31 mm.; Adolescent.
No. 12,339; Net 373; 500 F.; Aug. 15, 1929; 30 mm.; Trans. Adolescent.
No. 12,346; Net 374; 600 F.; Aug. 15, 1929; 26 mm.; Trans. Adolescent.
No. 12,403; Net 378; 500 F.; Aug. 16, 1929; 30 mm.; Trans. Adolescent.
No. 12,464; Net 384; 500 F.; Aug. 17, 1929; 28, 28 mm.; Trans. Adolescents.
No. 12,475; Net 385; 600 F.; Aug. 17, 1929; 35 mm.; Trans. Adolescent.
No. 12,559; Net 391; 600 F.; Aug. 19, 1929; 25 mm.; Adolescent.
No. 12,815; Net 397; 700 F.; Aug. 31, 1929; 36 mm.; Trans. Adolescent.
No. 12,953; Net 410; 600 F.; Sept. 3, 1929; 25, 26 mm.; Post-larva, Adolescent.
No. 12,969; Net 412; 800 F.; Sept. 3, 1929; 26, 32 mm.; Trans. Adolescents.
No. 13,049; Net 417; 600 F.; Sept. 4, 1929; 24, 32 mm.; Post-larva, Trans. Adolescent.
No. 13,098; Net 423; 500 F.; Sept. 5, 1929; 27, 27 mm.; Trans. Adolescents.

No. 13,105; Net 424; 600 F.; Sept. 5, 1929; 28 mm.; Trans. Adolescent.
No. 13,158; Net 430; 500 F.; Sept. 6, 1929; 28, 36 mm.; Trans. Adolescents.
No. 13,211; Net 437; 500 F.; Sept. 7, 1929; 26, 31 mm.; Trans. Adolescents.
No. 13,368; Net 451; 500 F.; Sept. 10, 1929; 22 mm.; Post-larva.
No. 13,376; Net 452; 500 F.; Sept. 10, 1929; 23, 24 mm.; Post-larvae.
No. 13,589; Net 481; 800 F.; Sept. 20, 1929; 26 mm.; Trans. Adolescent.
No. 13,766; Net 500; 900 F.; Sept. 24, 1929; 24 mm.; Trans. Adolescent.
No. 14,969; Net 574; 500 F.; May 14, 1930; 240 mm.; Adult Male.
No. 17,189; Net 804; 500 F.; July 16, 1930; 17 mm.; Larva.
No. 17,874; Net 842; 600 F.; Sept. 4, 1930; 34, 36 mm.; Trans. Adolescents.
No. 20,140; Net 868; 900 F.; Sept. 10, 1930; 22 mm.; Adolescent.
No. 18,349; Net 869; 1,000 F.; Sept. 10, 1930; 21 mm.; Post-larva.
No. 18,494; Net 882; 700 F.; Sept. 12, 1930; 28 mm.; Trans. Adolescent.
No. 21,676; Net 1113; 400 F.; July 29, 1931; 28 mm.; Post-larva.
No. 22,307; Net 1170; 800 F.; Aug. 12, 1931; 26 mm.; Adolescent.
No. 22,752; Net 1181; 600 F.; Aug. 15, 1931; 24 mm.; Adolescent.
No. 22,696; Net 1187; 400 F.; Aug. 17, 1931; 27 mm.; Trans. Adolescent.
No. 22,796; Net 1227; 400 F.; Aug. 27, 1931; 24, 24 mm.; Post-larvae.
No. 24,053; Net 1228; 500 F.; Aug. 27, 1931; 29 mm.; Trans. Adolescent.
No. 23,290; Net 1287; 1,000 F.; Sept. 10, 1931; 28 mm.; Trans. Adolescent.
No. 23,307; Net 1291; 600 F.; Sept. 12, 1931; 29 mm.; Trans. Adolescent.
No. 23,461; Net 1312; 400 F.; Sept. 16, 1931; 26 mm.; Trans. Adolescent.

### Synonymy and References.

*Melanostomias spilorhynchus*:

Regan & Trewavas, 1930, p. 112, fig. 107; pl. X, fig. 1. (48 specimens, the type series, 23 to 206 mm.; 65 to 1,000 m. wire; North Atlantic, Bermuda and eastward to Azores, Madeira and Canaries).

Beebe, 1937, p. 199. (Preliminary list of Bermuda specimens).

*Melanostomias bulbosus*:

Beebe, 1933.2, p. 166. (Description of a single Bermuda specimen, synonymized with *M. spilorhynchus* in the present paper).

Beebe, 1937, p. 199. (Record of the above specimen in a preliminary list of Bermuda specimens).

## ***Melanostomias biseriatus*** Regan & Trewavas, 1930.

(See also p. 143).

### Specimens Taken by the Bermuda Oceanographic Expeditions.

4 specimens; September only, 1929; 500 to 900 fathoms; from a cylinder of water 8 miles in diameter (5 to 13 miles south of Nonsuch Island, Bermuda), the center of which is at 32° 12′ N. Lat., 64° 36′ W. Long.; standard lengths from 21 to 25 mm.

### Specimens Previously Recorded.

4 specimens; *ca.* 22 to 42 fathoms; north Atlantic, east of Bermuda; standard lengths from 20 to 25 mm.

### Description.

(From the description of the type series, none of which can be more advanced than early transitional adolescence; serial photophore counts supplemented by those of our younger examples).

*Proportions*: Depth in length about 10 (10%); head in length 5 to 6 (16.7% to 20%); eye in head 5.

*Barbel*: About twice as long as head; proximal 2/5 pigmented; distal

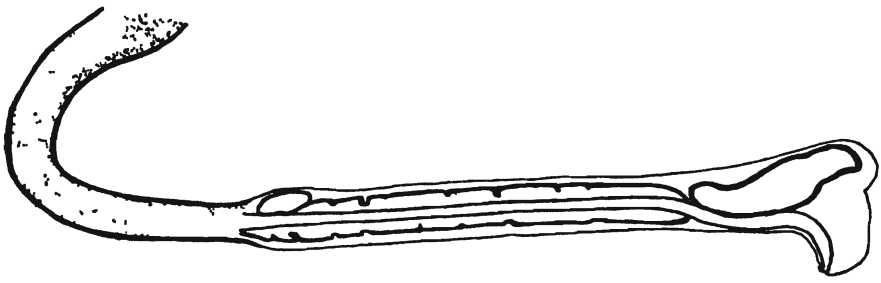
part a white axis, with a narrow, translucent band in front and behind, each including a series of white luminous bodies; the posterior series starting proximally with a rather large white body, and ending with a larger one that curves the axis; beyond this white bulb and the end of the axis is an expansion without a filament.

*Light Organs*: Postorbital longer that diameter of eye. Serial photophores with the following counts: ventral series, I-P 8+2 to 3, P-V 26 to 28, V-A 13 to 14, A-C 9 to 11: lateral series, O-V 26 to 27; V-A 12 to 13.

*Fins*: Pectoral 5; dorsal 13 to 16; anal 16 to 17.

## Development.

The 4 Bermuda specimens of *M. biseriatus*, though comparable in size to those of the type series, are obviously even younger, 2 (23, 25 mm.) being in the post-larval stage and 2 (21, 24 mm.) in the adolescent. They are typical of their stages in every way, (see p. 77), and their pigmentation is typical of the genus (see p. 147). They differ from corresponding stages of *M. spilorhynchus* in the following details: P-V and O-V photophores number 26 to 28, not 22 to 25; myomeres to pelvic origin number 33 to 34, not 29 to 30; myomeres to end of anal number about 55, instead of 49 to 52; the barbel of the adolescents shows clearly the specific characters of *M. biseriatus* distally (it differs in lacking stem pigment and in having the proximal luminous bodies very rudimentary and scarcely distinguishable, although the entire distal half of the stem is noticeably expanded; also, the barbel in the most advanced is only a little longer than the head, instead of twice the head length). The post-larvae, too, have the single, oblong, terminal luminous body, anteriorly directed end of barbel core, and non-filamented distal tissue. In this species the barbel seems to develop specific characters earlier and to grow faster than in *M. spilorhynchus*. The present post-larvae could be referred to some closely allied species with the same photophore counts, but they appear to form a continuous series with the adolescents in every particular. It is, of course, probable that *M. biseriatus* will prove to be the young of some other species, also described by Regan & Trewavas, such as *M. margaritifer*, in which case *M. biseriatus* will take precedence.



Text-figure 32.

*Melanostomias biseriatus*. Barbel, lateral view, of adolescent, standard length 24 mm.

## Ecology.

It is interesting to note that all 4 specimens of *M. biseriatus* were taken in the single month of September, 1929.

## Study Material.

The following list gives the catalogue number, depth in fathoms, date, length and growth stage of each specimen of *Melanostomias biseriatus* taken

by the Bermuda Oceanographic Expeditions. All were caught in the cylinder of water off the Bermuda coast described in *Zoologica*, Vol. XVI, No. 1, p. 5 and Vol. XX, No. 1, p. 1.

No. 24,172; Net 444; 500 F.; Sept. 9, 1929; 23 mm.; Post-larva.
No. 13,376a; Net 452; 500 F.; Sept. 10, 1929; 25 mm.; Post-larva.
No. 13,758; Net 499; 800 F.; Sept. 24, 1929; 24 mm.; Adolescent.
No. 13,772; Net 502; 900 F.; Sept. 24, 1929; 21 mm.; Adolescent.

REFERENCE.

*Melanostomias biseriatus*:

Regan & Trewavas, 1930, p. 113, fig. 109A. (4 specimens, the type series, 20 to 25 mm.; 80 and 150 m. wire; north Atlantic east of Bermuda).

## Genus **Photonectes** Günther, 1887.

(See also pp. 70, 73, 75, 79, 81-91, 96, 97, 99, 102, 103, 105, 106, 108, 110).
(Text-figs. 2, 11, 12, 33-44 incl.).

GENERAL DISCUSSION.

The first species referable to this genus was *P. albipinnis*, described by Doderlein in 1882 (p. 26) for a specimen taken off Japan, for which he erected the genus *Lucifer*. Since the latter name was preoccupied, Günther in the *Challenger* report substituted the name *Photonectes*. Afterwards, several species were originally referred wrongly to other genera, *Photonectes braueri* to *Melanostomias*, and *P. richardi* and *P. margarita* both to *Echiostoma*. Parr (1927) and Regan & Trewavas (1930) in their monographs correctly relegated all of these to *Photonectes*.

The genus as now understood includes some species, usually recognized as members of different subgenera, which are so diverse that we considered for a time separating *Photonectes* into at least two distinct genera. Study of the family as a whole, however, shows that all of the species of *Photonectes* are so much more closely related to each other than they are to even their closest generic relatives (e.g. *Echiostoma, Melanostomias* and *Tactostoma*) that we agree with the above mentioned authors that only a single genus should be recognized, although the maintenance of two subgenera is convenient.

Nineteen species of *Photonectes* have been recorded, including the two new species taken by the Bermuda Expeditions, which have been described (Beebe, 1933.2) since the publication of the Regan & Trewavas monograph. As in the case of a number of other genera, we are convinced that some of these species represent merely growth stages or variations of others. We have been able to prove this in several species. The following annotated list, in chronological order, gives the standing of the species as far as known. We are as usual hampered by the immaturity of the majority of recorded specimens.

1. *P. albipinnis* (Doderlein, 1882, p. 26). Known only from the type specimen, 240 mm. long, from Japan. Not seen by us.

2. *P. margarita* (Goode & Bean, 1895, p. 109). Only the type specimen, 320 mm. long, from the Gulf of Mexico and one, 340 mm. long, recorded by Borodin (1931, p. 66), from the western Atlantic, have been previously referred to this species. We have examined both, as well as the unique specimen of *P. flagellatus* (species no. 6, below), and several specimens of *P. intermedius* (species no. 7). All of these we have compared with our own representative series of specimens referable to these species, and with the descriptions of *P. richardi* (species no. 5) and *P. monodactylus* (species no. 17), with the result that we are certain that the differences between *P. margarita, P. flagellatus, P. richardi* and *P. monodactylus* are due solely to

size, individual variation, and damaged barbels, while *P. intermedius* represents only the early transitional adolescent stage of the same species (see Text-fig. 44 for complete barbel series, and p. 175 for a description of the species and the details in regard to our examination of the specimens in other museums). *P. margarita* was referred originally to *Echiostoma.*

3. *P. gracilis* Goode & Bean, 1895, p. 112. Known only from the type, 167 mm. long, in the U. S. National Museum, and one, 170 mm. long, in the Peabody Museum, recorded by Parr (1927, p. 113). In both the barbel is broken off short. The type is temporarily not available, but we have examined the second specimen, and find that only the extreme tip of the barbel is missing. In addition to the characteristic, conspicuous, horizontal band of metallic blue, there are also definite traces of similar markings in exactly the regions where they occur in *P. achirus, P. caerulescens* and *P. mirabilis. P. gracilis* is definitely set off from related species, however, by the forward position of the pelvic fins. In *P. gracilis,* the only available large example of the genus which does not belong to the subgenus *Trachinostomias,* the premaxillary and mandibular teeth are relatively small and even, exactly as in large *P. margarita* (subgenus *Trachinostomias*), as opposed to the very uneven, relatively large, *Melanostomias*-like form of the same teeth in young transitional adolescents throughout the genus. (cf. Text-figs. 32 and 33).

4. *P. braueri* (Zugmayer, 1913, p. 3). Only the type, 115 mm. long, from the eastern Atlantic, has been previously referred to this species, which was originally placed in the genus *Melanostomias.* We have a smaller specimen which, by the intermediate form of its barbel, teeth, etc., shows that the 11 specimens, 22 to 31 mm. long, of *P. ovibarba* (species no. 11) should also be referred to *P. braueri.* (For description, see p. 165).

5. *P. richardi* (Zugmayer, 1913, p. 4). Only the type, 170 mm. long, from the eastern Atlantic, has been referred to this species, which was originally placed in *Echiostoma.* Not seen by us, but from the descriptions we consider it identical with *P. margarita* (see species no. 2, above and p. 175).

6. *P. flagellatus* Parr, 1927, p. 107. Only the type, 280 mm. long, from the Bahamas has been referred to this species. We have examined it and consider it identical with *P. margarita* (see species no. 2, and p. 175).

7. *P. intermedius* Parr, 1927, p. 109. Previously known from the two specimens in the type series and 22 recorded by Regan & Trewavas (1930, p. 125), all measuring between 20 and 86 mm. in length from the north Atlantic. Unquestionably these represent the early transitional adolescent stage of *P. margarita* (see species no. 2 and p. 175). The type specimens, as well as one from the *Dana* collection and two from the *Atlantis* collection have been examined by us.

8. *P. mirabilis* Parr, 1927, p. 111. Known only from five transitional adolescents up to 60 mm. in length, including three in the present Bermuda collection. Type specimen examined by us.

9. *P. dinema* Regan & Trewavas, 1930, p. 120. Known from 36 specimens, in the type series and the present Bermuda collection, all young transitional adolescents measuring between 23 and 51 mm. in length, from the North Atlantic. (See p. 162).

10. *P. leucospilus* Regan & Trewavas, 1930, p. 121. Known from 14 specimens, in the type series and the present Bermuda collection, all young transitional adolescents measuring between 25 and 50 mm. in length; from the North Atlantic. (See p. 164).

11. *P. ovibarba* Regan & Trewavas, 1930, p. 121. Known only from the type series, 11 specimens, 22 to 31 mm. long, from the North Atlantic. We have examined one of the series and find that these represent unquestionably the young transitional adolescent stage of *P. braueri* (see species no. 4 and p. 166).

12. *P. achirus* Regan & Trewavas, 1930, p. 122. Known only from the type series, four specimens, 20 to 62 mm. long, from the western North Atlantic. We have examined the largest specimen and are sure that this series represents the young transitional adolescent stage of *P. caerulescens* (species no. 13), the barbel and barbel bulb being larger in these more juvenile forms, as in *P. margarita* and *P. braueri* (species nos. 2 and 4).

13. *P. caerulescens* Regan & Trewavas, 1930, p. 122. Known from a single specimen, 116 mm. long, from the Caribbean Sea. Not seen by us, but from the figure and description it seems certain that this specimen is a more advanced stage of *P. achirus*, above.

14. *P. phyllopogon* Regan & Trewavas, 1930, p. 122. Known only from the type specimen, 21 mm. long, from the Caribbean Sea. Not seen by us.

15. *P. parvimanus* Regan & Trewavas, 1930, p. 124. Known from 17 specimens in the type series and the present Bermuda collection, all young specimens from larvae to transitional adolescents, measuring between 14 and 55 mm. in length; from the North Atlantic. It is possible *P. fimbria* (species no. 16) and *P. bifilifer* (species no. 18) will prove to be synonymous with *P. parvimanus*. (See p. 170).

16. *P. fimbria* Regan & Trewavas, 1930, p. 125. Known only from the type specimen, 55 mm. long, from the North Atlantic. Not seen by us. From the description and figure it differs from *P. parvimanus* only in details of the barbel bulb and in having 30 to 34, not 34 to 38 P-V and O-V photophores. Our series of *P. parvimanus* shows specimens with barbels intermediate in form, therefore the photophore distinction alone remains.

17. *P. monodactylus* Regan & Trewavas, 1930, p. 127. Known only from 5 specimens in the type series, 180 to 255 mm. long, from the North Atlantic. Not seen by us, but from the description and figure we consider this species identical with *P. margarita* (see species no. 2, and p. 175).

18. *P. bifilifer* Beebe, 1933.2, p. 167. Known only from the type specimen, 245 mm. long, from Bermuda, in the present collection. Allowing for the difference in size and growth stage, this adult upon reexamination differs from *P. parvimanus* (species no. 15, above) only in the lack of a crest on the barbel bulb and in the great length of the 2 pectoral rays. Both may prove also to be growth characters, or the barbel crest may have been torn away. Until intermediate stages are secured, however, it seems best to keep the two forms separate (see p. 173).

19. *P. cornutus* Beebe, 1933, p. 169. Known only from the type specimen, 19 mm. long, from Bermuda, in the present collection. In poor condition, and exceedingly close to *P. mirabilis*, but apparently distinct. (See p. 169).

It is possible that sexual differences will be found to have significance in the proper delineation of species.

A synopsis of the species, as now understood, will be found on p. 161.

*Distribution*: *Photonectes* is one of the 7 genera in the family which have been recorded outside the Atlantic Ocean, *P. albipinnis* having been taken off Japan. Otherwise it is known only from the North Atlantic. The depth range indicated at present is between approximately 25 and 1,400 fathoms. A total of 146 specimens of *Photonectes* are now known, of which almost half (71) were taken by the Bermuda Expeditions.

## Generic Characters.

*Color* (summarized from observations on about 20 freshly caught, including one living, transitional adolescent and adult specimens of 6 species): General color blue-black, the skin being very fragile in adult specimens of the subgenus *Trachinostomias;* barbel bulbs blue, pink, purple, yellow, green or silvery; postorbital organ white, yellow, rose or violet; serial organs violet to purple with gold caps or frames; non-serial organs violet;

luminous patches on snout and jaws, when present, yellow or purple; luminous shoulder patches, when present, pale blue.

*Proportions*[6]: Melanostomiatids of moderate to excessive slenderness, with very short snouts and strongly curved jaws, the mandibles projecting in front of snout. Depth in length 6.5 to 15.5 (6.4% to 15.4%); head in length 6.5 to 9 (11.1% to 15.4%); eye in head 4 to 7.7; snout about as long as, or a little longer than, diameter of eye; snout to pelvic in length 1.5 to 1.9 (52% to 67%).

*Barbel*: Usually shorter than head, rarely as long, or slightly longer, almost always unbranched above the bulb, but usually with a distal appendage, varying in shape and degree of branching with the species; the bulb itself may be almost or completely atrophied in the adult.

*Light Organs*: Postorbital (measured as length of area of transparent skin) .67 to 1.8 times diameter of eye in both sexes, probably always larger than eye in fully adult specimens. Serial photophores with the following counts: ventral series, I-V 30 to 48, V-A 11 to 18, A-C 9 to 15; lateral series, O-V 17 to 36; V-A 11 to 17. Non-serial photophores usually not conspicuous. Luminous tissue usually present in one or more of the following areas: in spots on snout, jaws, or shoulder; in bands or stripes on body.

*Teeth*: Cleft of mouth strongly curved upward anteriorly; jaws remarkably slender; the lower projecting far in front of upper premaxillaries and mandible with numerous close-set curved, slightly barbed teeth, all depressible, not large in adults; they are arranged in a single row in 3 to 6 series in each jaw, the teeth of each series increasing in size posteriorly; up to about 25 erect teeth on the maxillary followed by up to 50 very fine, oblique denticles; 1 or 2 pairs of teeth on the vomer; a series of 1 to 7 teeth on each palatine. Six to 10 pairs of teeth on the basibranchials. Teeth, in pairs, with a few individual teeth singly or in threes, present only on first 2 or 3 gill-arches, and only on the ceratobranchials. About 5 to 8 pairs on first ceratobranchial.

*Branchiostegal Rays*: *ca.* 14 to 15.

*Fins*: Pectoral with 0 to 3 rays, either short or long; pelvic 7, well developed, long; inserted far behind middle of length; dorsal 15 to 22; anal 15 to 24; membranes of dorsal and anal in some species very thick and black with only the tips of the rays visible in the adult; dorsal and anal commencing opposite each other, but anal extending farther back.

*Epidermal Grooves*: There is a well defined groove in the isthmus for the reception of the barbel stem.

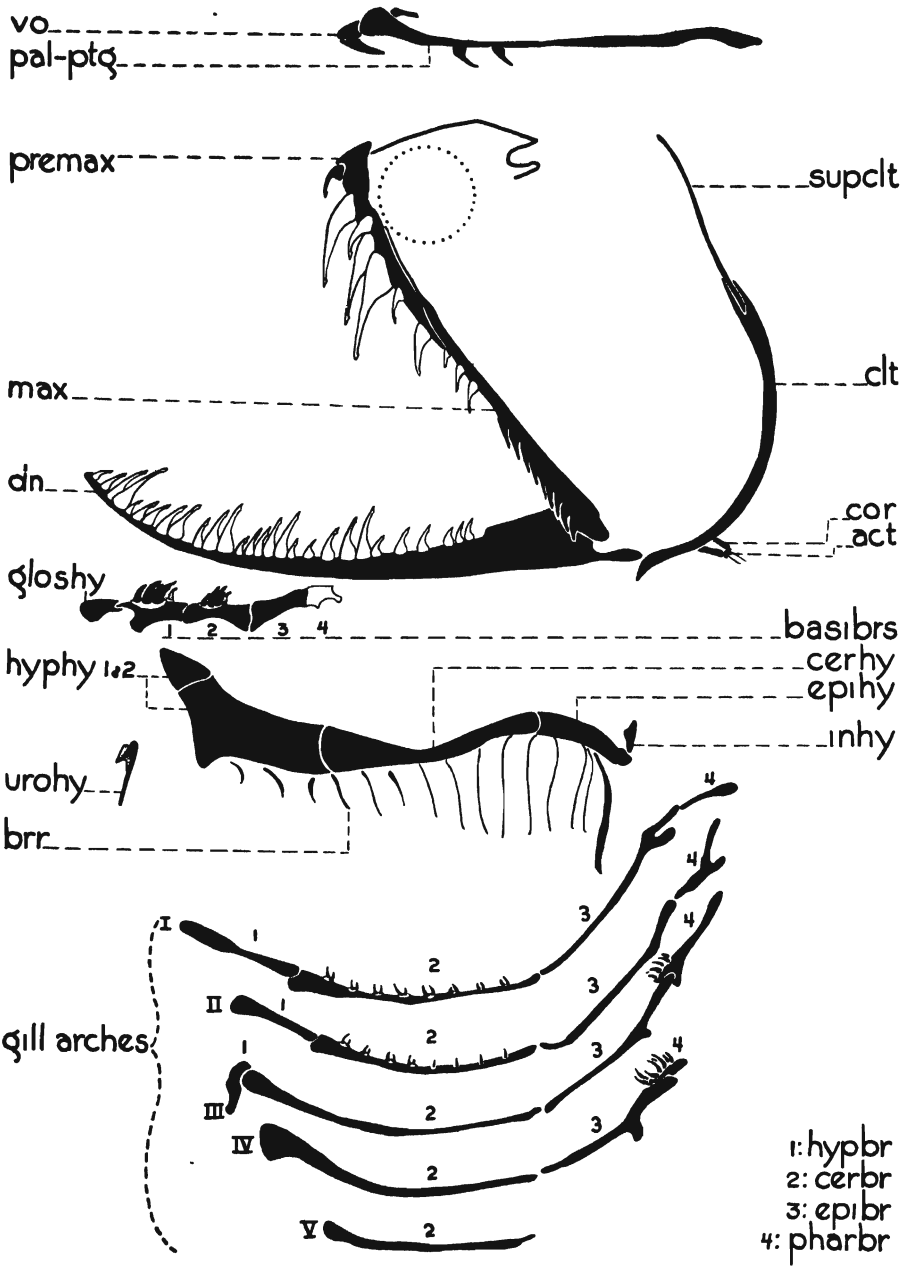
*Osteology*: Mesethmoid with lateral processes; parietals absent; skull exceedingly short, less than half the length of the upper jaw; mandible with an elongate posterior process projecting behind the end of the maxillary; hyoid and gill-arches short; pectoral girdle much reduced, the postemporal usually absent, rarely vestigial, the supracleithrum and cleithrum weak, sometimes separated from each other, and the mesocoracoid absent; upper and lower coracoids well developed, laminar; actinosts 1 to 4; vertebrae 49 to 64; first vertebra represented only by a fibrous ring, enclosing the notochord, and by a spinal nerve.

*Coelomic Organs*: Stomach *ca.* 33% of standard length, not reaching pelvic origin; 2 pyloric caeca.

*Sexual Dimorphism*: Apparently none.

*Size*: The largest known specimen is a specimen of *P. margarita* about 340 mm. in length taken by the *Atlantis* (Borodin, 1931, p. 66); the measurement is ours, 100 mm. more than given in the record which is probably a misprint; the example is a female apparently in full breeding condition. Other specimens of the same species of both sexes, examined may be counted as

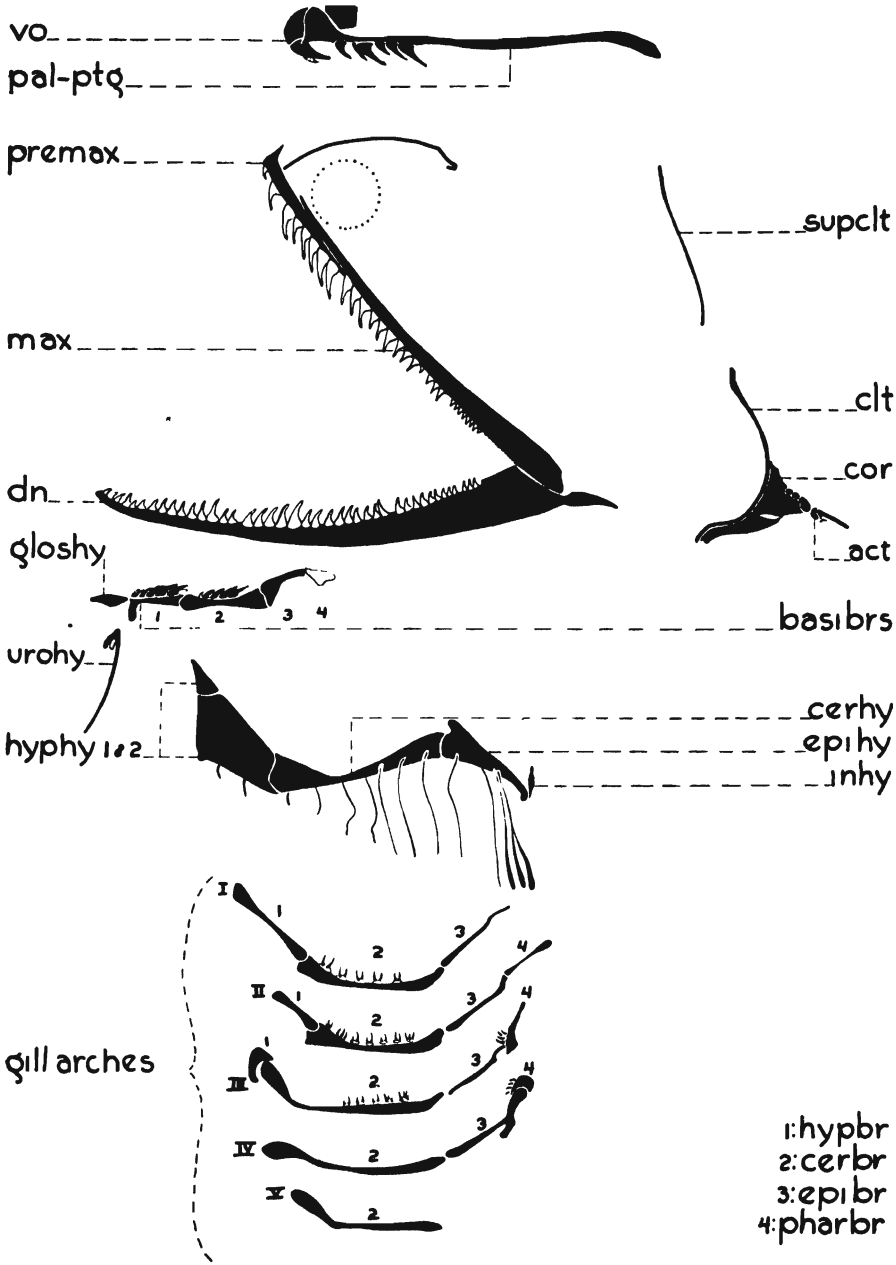
[6] The proportions given include those of some obviously immature examples upon which species have been founded.




Text-figure 33.

*Photonectes dinema.* Jaws, hyoid and branchial arches, and pectoral girdle of transitional adolescent, standard length 38 mm. Explanation as in Text-fig. 18.

adult from about 250 mm. on. A 170 mm. specimen of *P. gracilis* is a slightly immature female; *P. bifilifer,* 245 mm. long, is an adult male, not ready for breeding. Small specimens belonging to about 8 species, measuring less than

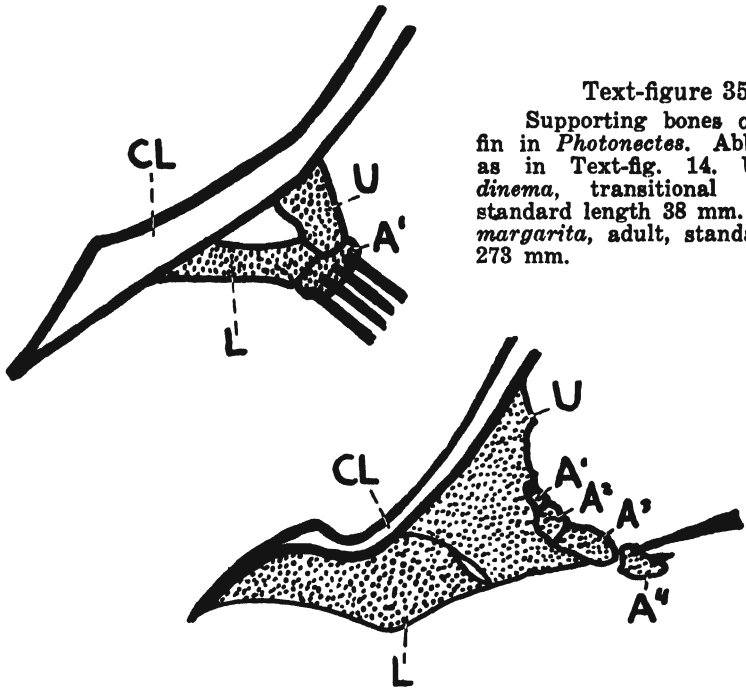



Text-figure 34.

*Photonectes margarita*. Jaws, hyoid and branchial arches, and pectoral girdle of adult, standard length 273 mm. Explanation as in Text-fig. 18.

60 mm. have been examined, and all are so immature that sex cannot be distinguished.

*Development*: A growth series of *P. parvimanus* from larva to transi-




Text-figure 35.

Supporting bones of pectoral fin in *Photonectes*. Abbreviations as in Text-fig. 14. Upper, *P. dinema*, transitional adolescent, standard length 38 mm.; lower, *P. margarita*, adult, standard length 273 mm.

tional adolescent has been recognized in the present collection. The pigment spots of the early stages are very similar to those found in young *Echiostoma* and *Melanostomias;* the only distinguishable difference is that the dorsal series of chromatophores, instead of numbering only one large spot or blotch to the myomere, are broken up into small dots; (in transitional adolescents of other species of *Photonectes* however, are remains of the customary blotches); oblique, lateral rows, 3 or 4 dots, following the outline of the myomeres, are as in the neighboring genera. Identification is based on the number of myomeres, and the tracing of the pigment pattern in specifically identifiable transitional adolescents. (See p. 79). In *P. leucospilus, P. braueri, P. parvimanus* and *P. margarita* we have shown definitely that the barbel bulb becomes both relatively and actually smaller with growth; we think that the same is doubtless true of *P. gracilis* and *P. achirus*. Sometimes the relative length of the barbel decreases with age—i.e., it attains its full length sooner than the rest of the fish.

## Synopsis of Subgenera.

Parr in 1927 (p. 105) recognized two subgenera, *Dolichostomias* and *Trachinostomias,* which Regan & Trewavas (1930, p. 119) increased to five. In the light of our additional material, we consider that two are sufficient, but adopt the name *Photonectes* for the first, as taking precedence over Parr's *Dolichostomias.*

In the subgenus *Photonectes* we place all those species having only about 49 to 54 vertebrae (30 to 37 I-V photophores), the pectoral absent, or with 2 or 3 small rays, and the membrane of the dorsal and anal fins thin. This grouping will thus include the subgenera *Melanonectes* and *Dolichostomias* as defined by Regan & Trewavas.

In the subgenus *Trachinostomias* we place all those species having about 62 to 64 vertebrae (I-V 42 to 48), 1 to 2 pectoral rays, often (perhaps

always, in adult) very long, and the membrane of the dorsal and anal fins thick and black, with only the tips of the rays visible in the adult. This subgenus will now include the subgenus *Microchirichthys* of Regan & Trewavas.

### Synopsis of Species.

Following the tentative synonymy adopted in pp. 154 to 156, we submit this key, adapted from that of Regan & Trewavas, and applicable both to transitional adolescents and to the known adults.

A. Membrane of dorsal and anal fins thin; rays conspicuous; I-V photophores 30 to 37.

B. Pectoral fin of 2 rays, and sometimes a minute third ray.

Barbel with small bulb bearing a slender translucent appendage ending in a second bulb, nearly as large as the first, with a pair of short filament; P-V 20 ..... *P. dinema* (p. 162).

Barbel with rather large bulb bearing a slender translucent appendage ending in a minute bulb without filaments; P-V 23 to 24 *P. leucospilus* (p. 164).

Barbel with a large or very small bulb, bearing a minute knob-like or ovoid appendage; P-V 21 to 23 ..... *P. braueri* (p. 165).

BB. Pectoral fin absent.

C. Depth 6 to 9 in length; dorsal and anal fins relatively short; pelvics much nearer to caudal fin than to head.

D. Barbel without posterior branch.

Barbel shorter than head; bulb atrophied or absent; a slender, unpigmented terminal appendage ..... *P. achirus.*

Barbel shorter than head; bulb large, white; distal appendage with stalk and translucent leaf-like expansion. *P. phyllopogon.*

Barbel as long as head; stem short, black; bulb white; distal part long, tapering, with luminous bodies; a terminal translucent expansion with minute white body. *P. mirabilis* (p. 167).

Barbel longer than head; stem tapering; bulb small, white, with terminal filament ..... *P. albipinnis.*

DD. Barbel with posterior branch; otherwise similar to *P. mirabilis* ..... *P. cornutus* (p. 169).

CC. Depth 10½ or more in length; dorsal and anal fins long and low; pelvics nearer to head than to caudal fin ..... *P. gracilis.*

AA. Membrane of dorsal and anal fins thick, black; only tips of rays visible in adult; I-V photophores 42 to 48.

C. Two pectoral rays; barbel bulb without pigmented distal appendages.

E. Pectoral rays minute; barbel bulb with a compressed comb-like unpigmented distal appendage, with a fringe of filaments except in very young specimens.

E. O-V 30 ..... *P. fimbria.*

EE. O-V 34 to 36 ..... *P. parvimanus.* (p. 170).

EE. Pectoral rays elongate; barbel bulb without terminal appendage, except microscopic posterior filaments. *P. bifilifer.* (p. 173).

CC. One very elongate pectoral ray (sometimes, in young, a second ray); barbel bulb with an anterior cluster of short, pigmented filaments, and a posterior appendage in the form of a long, branched, pigmented filament; tips of most filaments with minute, unpigmented bulbs; major bulb sometimes almost or completely atrophied in adult ..... *P. margarita.* (p. 175).

## ***Photonectes dinema*** Regan & Trewavas, 1930.

SPECIMENS TAKEN BY THE BERMUDA OCEANOGRAPHIC EXPEDITIONS.

26 specimens; April to September, 1929 to 1931; 300 to 1,000 fathoms; from a cylinder of water 8 miles in diameter (5 to 13 miles south of Nonsuch Island, Bermuda), the center of which is at 32° 12′ N. Lat., 64° 36′ W. Long.; standard lengths from 24 to 50 mm.

SPECIMENS PREVIOUSLY RECORDED.

10 specimens; *ca.* 41 to 1,375 fathoms; North Atlantic between 25° and 36° N. Lat.; standard lengths from 24 to 38 mm.

DESCRIPTION OF TRANSITIONAL ADOLESCENT.

(No adult known.).

With the characteristics of the genus.

*Color* (from field notes made upon 10 specimens): Skin brownish-black. Proximal and distal barbel bulbs from bright phlox pink to mallow purple; intervening appendage deep blue to violet proximally, changing distally to pale lemon yellow or whitish; terminal filaments pale yellow speckled thickly with black except for perfectly white tips; all or part of the entire bulb and appendage area may be traversed by scarlet lines (blood vessels?). Postorbital light organ brilliant silvery white, with a small, round, purple light at anterior, inferior end. Serial photophores bright violet or purple with gilt caps above in both lateral or ventral series. Small, non-serial photophores: purple, densely scattered over head, jaws and body. Snout light, bright mallow purple.

*Proportions*: Depth in length 6.5 to 9 (11.1% to 15.4%); head in length 5.9 to 7 (14.3% to 17%); eye in head 5 to 6; snout shorter than eye; snout to pelvic in length *ca.* 1.8 (56%).

*Barbel*: About 2/3 length of head; bulb scarcely thicker than the short, pigmented stem, with a long, translucent appendage; at the end of the latter is a somewhat smaller bulb bearing a pair of short filaments.

*Light Organs*: Postorbital 2/3 to as long as diameter of eye. Serial photophore counts: ventral series, I-P 7 to 8+2, P-V 20, V-A 14 to 18, A-C 11 to 12; lateral series, O-V 17 to 20, V-A 14 to 17. Non-serial photophores conspicuous. A median luminous spot on snout.

*Teeth*: Premaxillary with about 8 teeth; mandible with about 22; maxillary with 1 to 4 erect and 4 to 10 oblique teeth; 2 pairs on vomer; 1 to 3 teeth on each palatine; 6 pairs on basibranchials; teeth on first and second ceratobranchials only.

*Fins*: Pectoral 2, short; with sometimes a minute third ray; dorsal 15 to 18; anal 18 to 21.

DEVELOPMENT.

All of the specimens in the Bermuda collection, (and presumably those in the type series, which are all of comparable length), are typical young

transitional adolescents (see p. 79 for a definition of the stages), measuring from 24 to 50 mm. in length. Myomeres to the end of the anal fin number about 53. In the younger specimens there are subdermal traces of larval pigment patterns: a row of dendritic blotches, 1 to each myomere, beneath the dorsal profile, and remains of obliquely vertical rows of dots on the lower part of the sides, as usual in this and related genera. Sex cannot be determined, the stomach is only partially pigmented, and the skeleton except for the jaws is but feebly ossified.

Text-figure 36.

*Photonectes dinema.* Barbel of transitional adolescent, standard length 43 mm.

## Study Material.

The following list gives the catalogue number, depth in fathoms; date, length and growth stage of each specimen of *Photonectes dinema* taken by the Bermuda Oceanographic Expeditions. All were caught in the cylinder of water off the Bermuda coast described in *Zoologica*, Vol. XVI, No. 1, p. 5 and Vol. XX, No. 1, p. 1.

No. 9,539; Net 32; 600 F.; April 24, 1929; 30 mm.; Trans. Adolescent.
No. 9,596; Net 39; 600 F.; April 25, 1929; 27 mm.; Trans. Adolescent.
No. 9,719; Net 45; 500 F.; April 29, 1929; 25 mm.; Trans. Adolescent.
No. 10,315; Net 146; 500 F.; June 1, 1929; 26 mm.; Trans. Adolescent.
No. 10,278; Net 147; 600 F.; June 1, 1929; 38 mm.; Trans. Adolescent.
No. 10,693; Net 194; 600 F.; June 20, 1929; 33 mm.; Trans. Adolescent.
No. 10,833; Net 210; 1,000 F.; June 22, 1929; 28 mm.; Trans. Adolescent.
No. 11,151; Net 239; 600 F.; June 29, 1929; 25 mm.; Trans. Adolescent.
No. 11,130; Net 241; 800 F.; June 29, 1929; 40 mm.; Trans. Adolscent.
No. 11,294; Net 260; 500 F.; July 7, 1929; 43 mm.; Trans. Adolescent.
No. 11,433; Net 278; 500 F.; July 10, 1929; 26 mm.; Trans. Adolescent.
No. 11,615a; Net 303; 500 F.; July 16, 1929; 50 mm.; Trans. Adolescent.
No. 11,921; Net 334; 500 F.; July 29, 1929; 24 mm.; Trans. Adolescent.
No. 12,366; Net 377; 1,000 F.; Aug. 8, 1929; 40 mm.; Trans. Adolescent.
No. 13,122; Net 426; 800 F.; Sept. 5, 1929; 38 mm.; Trans. Adolescent.
No. 14,736; Net 539; 600 F.; May 6, 1930; 26 mm.; Trans. Adolescent.
No. 14,968; Net 573; 400 F.; May 14, 1930; 33 mm.; Trans. Adolescent.
No. 15,129; Net 596; 600 F.; May 19, 1930; 32 mm.; Trans. Adolescent.
No. 15,393; Net 634; 600 F.; May 26, 1930; 28 mm.; Trans. Adolescent.
No. 15,409; Net 635; 600 F.; May 26, 1930; 31, 32 mm.; Trans. Adolescents.
No. 16,034; Net 703; 900 F.; June 13, 1930; 35 mm.; Trans. Adolescent.
No. 20,673; Net 997; 500 F.; June 5, 1931; 34 mm.; Trans. Adolescent.
No. 21,023; Net 1,043; 300 F.; June 26, 1931; 31 mm.; Trans. Adolescent.
No. 22,874; Net 1,238; 800 F.; June 29, 1931; 40 mm.; Trans. Adolescent.
No. 23,359; Net 1297; 700 F.; Sept. 14, 1931; 44 mm.; Trans. Adolescent.

## Reference.

*Photonectes dinema*:

Regan & Trewavas, 1930, p. 120, fig. 114, 115B. (10 specimens: 24 to 38 mm.; 150 to 5,000 m. wire; app. 300 miles northwest of Bermuda; 400 to 900 miles southeast of Bermuda and 300 miles north of Cape Verde Islands).

Beebe, 1933.1, p. 180. (Preliminary list of Bermuda specimens).

Beebe, 1937, p. 199. (Preliminary list of Bermuda specimens).

## ***Photonectes leucospilus*** Regan & Trewavas, 1930.

### Specimens Taken by the Bermuda Oceanographic Expeditions.

15 specimens; April to September, 1929 to 1931; 300 to 1,000 fathoms; from a cylinder of water 8 miles in diameter (5 to 13 miles south of Nonsuch Island, Bermuda), the center of which is at 32° 12′ N. Lat., 64° 36′ W. Long.; standard lengths from 25 to 33 mm.

### Specimens Previously Recorded.

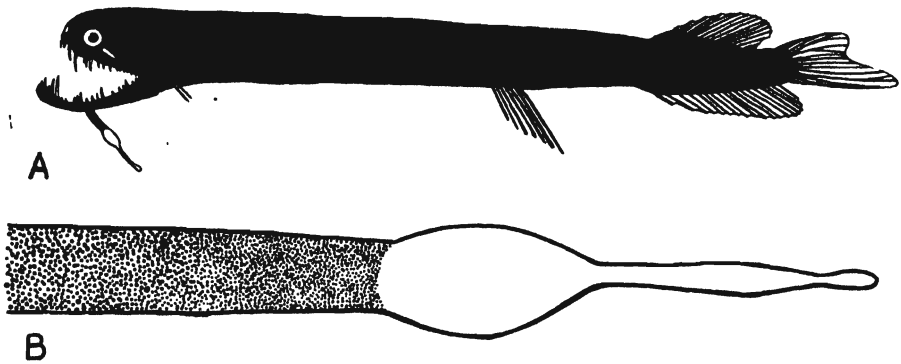
2 specimens; *ca.* 83 to 550 fathoms; 400 miles southeast of Bermuda and 200 miles southwest of Cape Verde Islands; standard lengths 28 and 50 mm.

### Description of Transitional Adolescent.

(No adults have been taken).

With the characteristics of the genus.

*Color* (from field observations upon 5 specimens): General color deep brownish-black. Barbel stem black; bulbs amythyst violet to violet blue, sometimes with pinkish-orange blood vessels showing beneath surface of proximal bulb; core of proximal bulb and entire connecting appendage phlox (lavender) pink. Postorbital light organ bluish or silver white with an anterior, faintly yellow depression. Serial photophores pinkish-purple to amythyst violet with large gilt frames; non-serial photophores violet. Median snout light white.




Text-figure 37.

*Photonectes leucospilus.* **A**, transitional adolescent, standard length 28 mm.; **B**, barbel of same.

*Proportions*: Depth in length 8 to 9 (11.1% to 12.5%); head in length 7 (14.3%); eye in head 4.7 to 6 (1.7% to 2.1%); snout shorter than diameter of eye; snout to pelvic in length *ca.* 1.75 (57%).

*Barbel*: ½ to 2/3 times length of head, the pigmented stem occupying about half its total length; a large proximal bulb is connected with a minute distal bulb by a translucent appendage; no terminal filaments.

*Light Organs*: Postorbital ½ to 2/3 as long as eye. Serial photophores with the following counts: ventral series, I-P 8 + 2; P-V 23 to 24, V-A 14 to 15, A-C 10 to 12; lateral series, O-V 21 to 23, V-A 12 to 14. Non-serial organs conspicuous. A luminous spot in middle of snout.

*Teeth*: Premaxillary about 8; mandible about 20; maxillary with 0 to 3 erect and 5 to 7 oblique teeth; 2 pairs on vomer; 2 teeth on each

palatine; usually 4 pairs of teeth on basibranchials; gill-teeth on first 2 ceratobranchials only.

*Fins*: Pectoral 2, short, sometimes with a minute third ray; dorsal 16; anal 18 to 20.

### Development.

All of the 15 Bermuda specimens, measuring between 25 and 33 mm., are typical young transitional adolescents. The remarks on p. 162-3 concerning the comparable stage of *P. dinema* apply equally well to *P. leucospilus*.

### Study Material.

The following list gives the catalogue number, depth in fathoms, date, length and growth stage of each specimen of *Photonectes leucospilus* taken by the Bermuda Oceanographic Expeditions. All were caught in the cylinder of water off the Bermuda coast described in *Zoologica*, Vol. XVI, No. 1, p. 5 and Vol. XX, No. 1, p. 1.

No. 9,603; Net 35; 800 F.; April 24, 1929; 29 mm.; Trans. Adolescent.
No. 9,986; Net 101; 700 F.; May 14, 1929; 29 mm.; Trans. Adolescent.
No. 10,381; Net 160; 700 F.; June 12, 1929; 30 mm.; Trans. Adolescent.
No. 10,858; Net 204; 1,000 F.; June 21, 1929; 28 mm.; Trans. Adolescent.
No. 10,937; Net 211; 500 F.; June 24, 1929; 25 mm.; Trans. Adolescent.
No. 10,955; Net 219; 700 F.; June 25, 1929; 29 mm.; Trans. Adolescent.
No. 11,012; Net 225; 600 F.; June 26-27, 1929; 26 mm.; Trans. Adolescent.
No. 11,945; Net 342; 800 F.; July 30, 1929; 33 mm.; Trans. Adolescent.
No. 20,142; Net 437; 500 F.; Sept. 7, 1929; 31 mm.; Trans. Adolescent.
No. 14,852; Net 563; 600 F.; May 10, 1930; 25 mm.; Trans. Adolescent.
No. 14,892; Net 566; 600 F.; May 12, 1930; 27 mm.; Trans. Adolescent.
No. 21,103; Net 1051; 300 F.; July 6, 1931; 31 mm.; Trans. Adolescent.
No. 21,104; Net 1052; 300 F.; July 6, 1931; 28 mm.; Trans. Adolescent.
No. 21,260; Net 1071; 300 F.; July 10, 1931; 28 mm.; Trans. Adolescent.
No. 21,971; Net 1141; 800 F.; Aug. 6, 1931; 25 mm.; Trans. Adolescent.

### Reference.

*Photonectes leucospilus*:

Regan & Trewavas, 1930, p. 121, fig. 115a. (2 specimens; 28 and 50 mm.; 300 and 2,000 m. wire; North Atlantic).

Beebe, 1933.1, p. 180. (Preliminary list of Bermuda specimens).

Beebe, 1937, p. 199. (Preliminary list of Bermuda specimens).

## ***Photonectes braueri*** (Zugmayer, 1913).

### Specimen Taken By the Bermuda Oceanographic Expeditions.

1 specimen (Department of Tropical Research No. 16,068; Net 717); June 17, 1930; 900 fathoms; 8 miles south of Nonsuch Island, Bermuda (32° 12′ N. Lat., 64° 36′ W. Long.); standard length 62 mm.

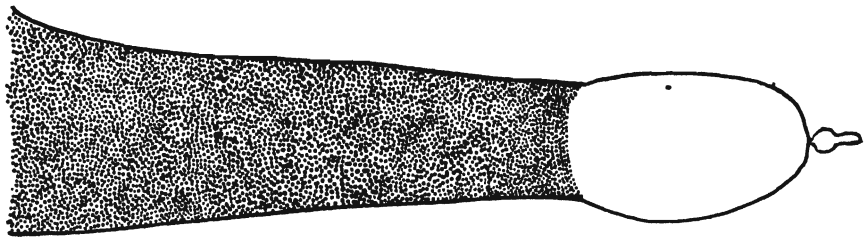
### Specimens Previously Recorded.

12 specimens; between 0 and 1,100 fathoms; North Atlantic; standard lengths from 22 to 115 mm.

### Description.

(Proportions from the descriptions of the type, 115 mm. long, the largest known; photophore and finray counts from small specimens in addition).

With the characteristics of the genus.



Text-figure 38.

*Photonectes braueri.* Barbel of transitional adolescent, standard length 62 mm.

*Proportions*: Depth in length 8 (12.5%); head in length 7.7 (13%); eye in head 4.3 or 4.6; snout to pelvic in length 1.63 (61%).

*Barbel*: 1/5 or 1/6 length of head with a stout black stem and a small white bulb, not thicker than stem, bearing a minute terminal knob (in smaller specimens this bulb is much larger than the diameter of the stem and the entire bulb is relatively longer).

*Light Organs*: Postorbital equal to or greater than diameter of eye. Serial photophores with the following counts: ventral series, I-P 8 + 2 to 3, P-V 21 to 23, V-A 14 to 15, A-C 10 to 12; lateral series, O-V 20 to 23, V-A 12 to 14. Non-serial photophores moderately conspicuous. Entire body and unpaired fins sprinkled with minute luminous granules, more apparent than usual in this genus. No luminous spot on snout.

*Teeth*: Upper jaw with 10 strong teeth, then 7 or 8 of moderate height, followed by minute denticles; mandible with 34 or 35 small teeth, arranged in series of 4, increasing in size backward; gill-teeth on first 3 ceratobranchials.

*Fins*: Pectoral 2, short; dorsal 15 to 18; anal 17 to 21.

## Development.

The single Bermuda specimen, standard length 62 mm., is a perfect intermediate form between the type specimen (115 mm.) and the 22 to 31 mm. type series of *P. ovibarba* Regan & Trewavas, 1930, p. 121. This is true both of proportions and barbel structure. The length of the barbel, half the length of the head in *P. ovibarba* and 1/5 to 1/6 in the type of *P. braueri*, is slightly over ¼ in the present specimen; similarly, the barbel bulb is considerably larger than the stem, in which it differs from the type of *P. braueri*, but not nearly so large as in *P. ovibarba*. Therefore, we are certain that the enlarged barbel bulb and relatively faster growth of the stem are merely growth characters, similar to those found in other species of this genus and in *Echiostoma*, and that *P. ovibarba* should be synonymized with *P. braueri*.

The present 62 mm. specimen is a transitional adolescent so immature that sex cannot yet be determined; it is probable that the type also is not adult.

## Synonymy and References.

*Melanostomias braueri*:

Zugmayer, 1913, p. 3. (Brief preliminary description; 1 specimen; 115 mm.; 1,000-0 m. wire; west of Azores).

Parr, 1927, p. 42. (Résumé of type description).

*Photonectes ovibarba*:

Regan & Trewavas, 1930, p. 121. (11 specimens; 22 to 31 mm.; 100 to 4,000 m. wire; North Atlantic).

*Photonectes braueri*:

Regan & Trewavas, 1930, p. 121, pl. XII, fig. 1. (Description of *M. braueri* after an examination of type specimen).

Roule & Angel, 1933, p. 19, pl. I, fig. 10. (Description of *M. braueri* after an examination of type specimen).

Beebe, 1937, p. 199. (Preliminary listing of Bermuda specimen).

## ***Photonectes mirabilis*** Parr, 1927.

SPECIMENS TAKEN BY THE BERMUDA OCEANOGRAPHIC EXPEDITIONS.

3 specimens; August and September, 1930; 600 fathoms; from a cylinder of water 8 miles in diameter (5 to 13 miles south of Nonsuch Island, Bermuda), the center of which is at 32° 12′ N. Lat., 64° 36′ W. Long.; standard lengths from 18 to 26 mm.

SPECIMENS PREVIOUSLY RECORDED.

2 specimens; *ca.* 83 to 660 fathoms; off Cape Hatteras and Bahamas; standard lengths 18 to 60 mm.

DESCRIPTION.

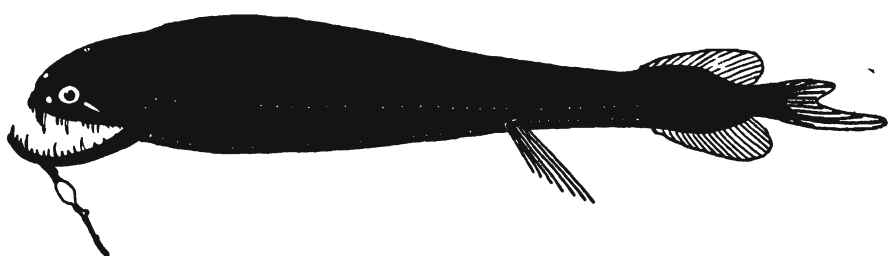
(Proportions from the 60 mm. type, the largest known specimen; barbel form, photophore and finray counts supplemented by those of smaller specimens).

With the characteristics of the genus.

*Color* (from a small Bermuda specimen): General color brownish-black; major barbel bulb silvery white; small barbel bulblets golden yellow; snout lights, jaw lights and serial photophores all golden yellow.

*Proportions*: Depth in length 6.7 (15%); head in length 7.5 (13.3%); eye in head 4 (3.3% of length); snout to pelvic fin in length 1.5 (66.7%).

*Barbel*: Slightly longer than head; major bulb more or less elongate, shorter than stem in type, longer than stem in small specimens; a tapering terminal appendage, pigmented proximally, which is longer than stem and bulb combined; from the posterior side of the terminal appendage arises a small bulblet, attached by a very short stem, somewhere near the middle of the length of the appendage; usually 2 still smaller bulblets scarcely more than luminous spots, placed anteriorly and posteriorly on the appendage



Text-figure 39.

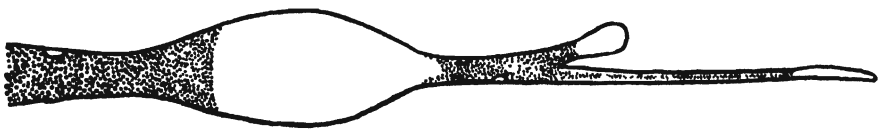
*Photonectes mirabilis*. Transitional adolescent, standard length 26 mm.

between the major bulb and the median bulblet just described; extreme tip of appendage ending in a more or less well defined bulblet. On the posterior side of the barbel stem, near the middle of its length, is another luminous spot or bulblet.

*Light Organs*: Postorbital organ longer than diameter of eye. Serial photophores with the following counts: ventral series, I-V 32 to 34, V-A 11, A-C 11; lateral series, O-V 21 to 24, V-A 10. A luminous patch in front of each eye, and 3 pairs, very well developed, on the floor of the mouth, just inside the anterior parts of the lower jaw; the latter series are very symmetrically arranged, the anterior pair smallest and the others increasing in size backwards. Our own reexamination of the type specimen shows the presence of the remains of a line of luminous tissue, below the lateral midline, from the anterior portion of which short vertical bands of similar tissue arise at intervals, exactly as in *P. gracilis*.

*Teeth*: In the type (which shows obviously immature dental characters) there are about 7 to 8 teeth in each premaxillary, and 25 in each mandibular ramus; maxillary with 4 erect teeth and 15 oblique denticles; 2 pairs of teeth on vomer; 2 on each palatine; 6 pairs on basibranchials; gill-teeth on first 3 ceratobranchials.

*Fins*: Pectoral 0; dorsal 16 to 17; anal 19 to 20.



Text-figure 40.

*Photonectes mirabilis*. Barbel of transitional adolescent, standard length 26 mm.

## Development.

The 3 Bermuda specimens, measuring between 18 and 26 mm. long, are all young transitional adolescents with characteristics typical of their respective growth stages (see p. 79). The bulb is relatively longer in respect to the stem length than in the 60 mm. type. There are remains of dorsal pigment blotches, one on each myomere. The type specimen is a transitional adolscent, with the gonads too immature to show the sex.

## Study Material.

The following list gives the catalogue number, depth in fathoms, date, length and growth stage of each of the specimens of *Photonectes mirabilis* taken by the Bermuda Oceanographic Expeditions. All were caught in the cylinder of water off the Bermuda coast described in *Zoologica*, Vol. XVI, No. 1, p. 5 and Vol. XX, No. 1, p. 1.

No. 17,437; Net 812; 600 F.; Aug. 29, 1930; 18 mm.; Trans. Adolescent.
No. 18,002; Net 842; 600 F.; Sept. 4, 1930; 18 mm.; Trans. Adolescent.
No. 18,398; Net 875; 600 F.; Sept. 11, 1930; 26 mm.; Trans. Adolescent.

## References.

*Photonectes mirabilis*:

Parr, 1927, p. 111, figs. 59 and 60. (Type specimen, 60 mm.; 8,000 ft. wire; south of Nassau; examined by present authors).

Regan & Trewavas, 1930, p. 123, fig. 117B. (1 specimen, 18 mm.; 300 m. wire; *ca.* 200 miles off Cape Hatteras).

Beebe, 1937, p. 199. (Preliminary list of Bermuda specimens).

## ***Photonectes cornutus*** Beebe, 1933.

### TYPE.

(The unique specimen).

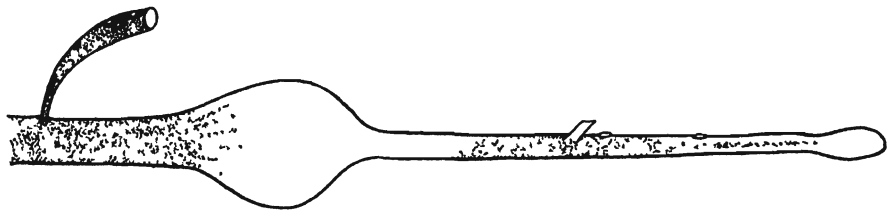
Department of Tropical Research No. 17,875; Bermuda Oceanographic Expeditions of the New York Zoological Society; Net 842; September 4, 1930; 600 fathoms; 10 miles south of Nonsuch Island, Bermuda (32° 12′ N. Lat., 64° 36′ W. Long.); standard length 19 mm.

### DESCRIPTION.

With the characteristics of the genus.

*Color* (fresh specimen): General color dark brown; barbel bulb white.

*Measurements and Proportions*: Total length 23 mm.; standard length 19 mm.; depth 2.4 mm. (in length 7.9 or 12.6%); head 3 mm. (in length 6.3 or 15.9%); eye 0.7 mm. (in head 4.3 or 3.7% of length); snout 0.6 mm.; (in head 5 or 3.15% of length); snout to pelvic measurement impossible on account of damage to specimen.



Text-figure 41.

*Photonectes cornutus*. Barbel of transitional adolescent, standard length 19 mm.

*Barbel*: Length 4.3 mm., longer than head, which is contained 1.4 times in barbel length; stem black, giving off a thick, short, black, club-shaped appendage posteriorly with several small, proximal photophores, 2 larger distal organs and a large pore at the extreme tip. Below this branch the stem expands into a large, white bulb, then narrows abruptly into a long, terminal filament, pigmented throughout most of its length, with several very small, roundish appendages and a flattened, irregularly rounded tip.

*Light Organs*: Postorbital inconspicuous, about equal to eye in length. Serial photophores with the following counts: ventral series, I-V ?, V-A 12, A-C 11; lateral series, O-V ?, V-A 12. There is a pair of luminous spots, close together, on the tip of the snout and 2 more pairs on the anterior part of the floor of the mouth. The rudiments of a third pair are located in front of these at the symphysis.

*Teeth*: There are 8 teeth in each premaxillary, of which the fifth is the largest, and an equal number in the premaxillary, 5 erect and 3 oblique; the mandible holds 15 teeth on each side, the sixth the longest; 2 pairs of teeth on the vomer; 1 on each palatine, set far back; 6 pairs of teeth on basibranchials.

*Fins*: Pectoral completely absent; pelvic 7; pelvic length 1.9 mm.; dorsal rays 15; anal rays 18. Caudal still very long, as usual in young fish, being more than a fifth of the standard length.

### DISCUSSION.

In spite of its youth and of serious damage to the fish in the region of the pectoral girdle, the specimen seems unquestionably to represent a

hitherto undescribed species. It belongs to the subgenus *Photonectes*, composed of species with the I-V photophores numbering from 30 to 37 mm., and the dorsal and anal fins having thin membranes. It is very close to *P. mirabilis* Parr, but differs in the presence of a well-developed, pigmented branch which springs posteriorly from the stem of the barbel in place of the small, white, luminous spot or knob found in that position in *P. mirabilis*. There are also minor differences between the two species in the more rounded form of the bulb. In development, it is a young transitional adolescent with the characteristics typical of that growth stage (see p. 79). Differences in the teeth and proportions as compared with Parr's 60 mm. type of *P. mirabilis* may thus be attributed to age. Comparison with our own specimens of *P. mirabilis*, which are of comparable size with *P. cornutus*, proves that the form of the barbel in the present specimen is not a juvenile character of *P. mirabilis*.

REFERENCES.

*Photonectes cornutus*:

Beebe, 1933.2, p. 169, fig. 6. (Preliminary description of the specimen described above).

Beebe, 1937, p. 199. (Preliminary listing of the specimen described above).

## ***Photonectes parvimanus*** Regan & Trewavas, 1930.

SPECIMENS TAKEN BY THE BERMUDA OCEANOGRAPHIC EXPEDITIONS.

10 specimens; May to July, 1929 to 1934; 0 to 800 fathoms; from a cylinder of water 8 miles in diameter (5 to 13 miles south of Nonsuch Island, Bermuda), the center of which is at 32° 12′ N. Lat., 64° 36′ W. Long.; standard lengths from 14 to 44 mm.

SPECIMENS PREVIOUSLY RECORDED.

10 specimens; *ca.* 27 to 250 fathoms; North Atlantic, approximately 400 miles southwest to 1,500 miles southeast of Bermuda; standard lengths from 26 to 55 mm.

DESCRIPTION OF TRANSITIONAL ADOLESCENT.

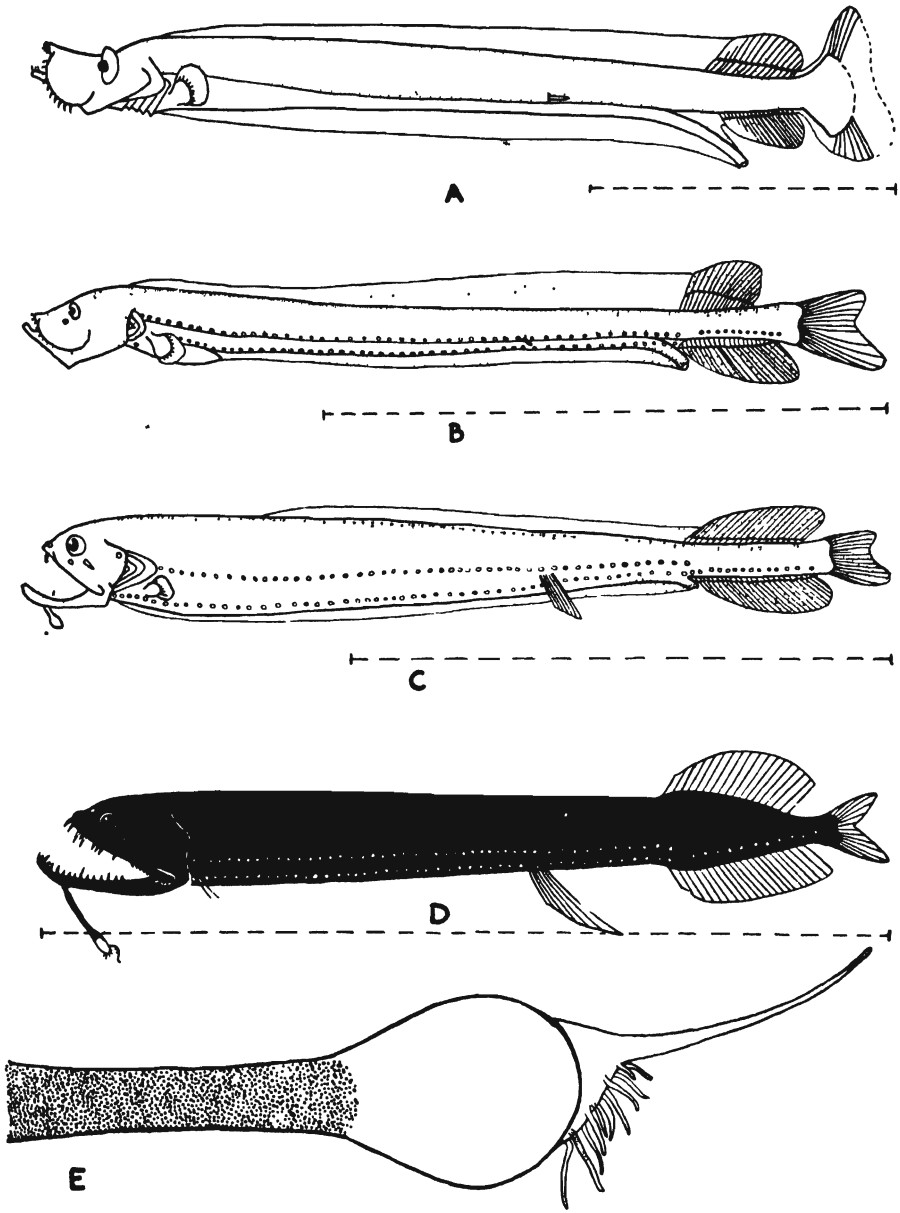
(No adult known).

With the characteristics of the genus.

*Color* (from 3 fresh specimens): General color brownish-black; postorbital light organ white; barbel bulb bright green, with bluish-green or turquoise core; distal barbel appendage pale green or yellow-green, with black dots at posterior tip, and filaments translucent; serial photophores violet, the ventral series having gilt frames.

*Proportions*: Depth in length 8 to 10 (10% to 12.5%); head in length 6.6 to 8 (12.5% to 15.2%); eye in head 6 to 7; snout to pelvic in length 1.83 (58%).

*Barbel*: About half length of head; stem black; bulb spherical, or slightly oblong, much less than half the length of the stem, bearing a translucent, compressed distal appendage, which contains a network of branching threads, and, in all except very small specimens, a fringe of filaments along the posterior edge, terminating in a long filament with 1 or 2 pairs of branches; the latter, like the filaments of the fringe, may end in luminous swellings.




Text-figure 42.

*Photonectes parvimanus*. **A**, larva, standard length 14 mm.; **B**, late larva, 26 mm.; **C**, post-larva, 25 mm.; **D**, transitional adolescent, 44 mm.; **E**, same, end of barbel. See also Text-fig. 2, E and F.

*Light Organs*: Postorbital smaller than eye. Serial photophores with the following counts: ventral series, I-P 10 to 11, P-V 35 to 38, V-A 12 to 14, 2 or 3 being above anal fin, A-C 11 to 13; lateral series, O-V 34 to 36, V-A 12 to 13. A small white luminous spot on shoulder.

*Teeth*: Maxillary with 2 to 6 erect teeth and 5 or 6 oblique; 2 pairs of teeth on vomer; 4 to 6 teeth on each palatine; gill-teeth present on first, second and third ceratobranchials, there being about 7 pairs on the first.

*Fins*: Pectoral 2, very short; dorsal 17 to 19; anal 22 to 24.

## DEVELOPMENT.

*Material*: The Bermuda collection is composed entirely of juvenile specimens, distributed as follows:

2 larvae; 14, 26 mm.; 0, 800 fath.; June.
1 post-larva; 25 mm.; 700 fath.; May.
7 transitional adolescents; 30 to 44 mm.; May to July.

All are typical representatives of their respective growth stages (see pp.76-79). Their special characteristics are as follows:

*Myomere Counts*: To end of anal 64 to 65; from nape to pelvic rudiment (when present) 29 to 41; from pelvic rudiment to anal origin 12 to 13.

*Pigment*: In this species larval pigment seems to be a specific rather than a generic character, since in the other species of *Photonectes* in which traces of pigment pattern remain, the most dorsal pigment area on each myomere is a single compact or stellate blotch, instead of being broken into several or more dots as in the present species. In detail, the pigment pattern is as follows: (a) a dorsal band immediately below the profile, made up of dendritic and non-dendritic spots, usually of from 3 to 6 per myomere, with the 2 most dorsal spots largest and succeeding each other, and the remainder dwindling in size ventrally; (b) a second series, between lateral mid-line and lateral serial organs, of the usual oblique rows of 3 or 4 small, equal chromatophores placed in or near the intra-myomeral lines, and frequently underlaid by deeply imbedded, continuous lines of pigment. This pigment pattern is still well defined in young transitional adolescents. The finfolds and the anal fin are sprinkled sparingly with tiny dendritic chromatophores.

*Barbel*: The filaments on the barbel develop in early transitional adolescence.

*Larval Teeth*: In each premaxillary of the 13.6 mm. larva are 5 teeth all directed outwards; the maxillary holds 10 teeth, with small spaces between, all erect and increasing in size posteriorly; each half of the mandible holds 7 teeth, all in the anterior part of the jaw and directed upward (not outward, as in the premaxillary); the more posterior are slightly larger than the others. The 26 mm. larva is passing into the post-larval stage, having few teeth left.

*Larval Gill-rakers*: Rakers are present on first 3 arches, mounds on last 2; rakers short in 14 mm. larva, but long and spiny in a 26 mm. late larva and in a 25 mm. post-larva.

*Fins*: Dorsal and anal rays of full number in larva, but the anterior ones not clearly marked. Finfolds moderately deep.

## ECOLOGY.

*Food*: Six stomachs of transitional adolescents were examined, of which 2 contained food: a specimen 36 mm. long held a 20 mm. *Myctophum laternatum*, while the second, 44 mm. long, held 2 *Cyclothone microdon*. There was a considerable amount of material in the intestines of all 6 specimens.

## STUDY MATERIAL.

The following list gives the catalog number, depth in fathoms, date, length and growth stage of each specimen of *Photonectes parvimanus* taken by the Bermuda Oceanographic Expeditions. All were caught in the cyl-

inder of water off the Bermuda coast described in *Zoologica*, Vol. XVI, No. 1, p. 5 and Vol. XX, No. 1, p. 1.

No. 10,425; Net 165; 600 F.; June 14, 1929; 31 mm.; Trans. Adolescent.
No. 11,172; Net 243; 600 F.; July 1, 1929; 30 mm.; Trans. Adolescent.
No. 11,887; Net 329; 800 F.; July 27, 1929; 30 mm.; Trans. Adolescent.
No. 15,120; Net 597; 700 F.; May 19, 1930; 25 mm.; Post-larva.
No. 15,276; Net 618; 500 F.; May 22, 1930; 36 mm.; Trans. Adolescent.
No. 17,331; Net 797; 500 F.; July 15, 1930; 31 mm.; Trans. Adolescent.
No. 20,580; Net 989; 0 F.; June 3, 1931; 14 mm.; Larva.
No. 20,629; Net 993; 800 F.; June 4, 1931; 26 mm.; Larva.
No. 21,372; Net 1083; 300 F.; July 14, 1931; 35 mm.; Trans. Adolescent.
No. 24,363; Net 1501; 400 F.; July 25, 1934; 44 mm.; Trans.Adolescent.

REFERENCES.

*Photonectes parvimanus*:

Regan & Trewavas, 1930, p. 124, figs. 118, 119A, 119B. (10 specimens; 26 to 55 mm.; 100 to 1,000 M. wire; North Atlantic).

Beebe, 1933.1, p. 180. (Preliminary list of Bermuda specimens).

Beebe, 1937, p. 199. (Preliminary list of Bermuda specimens).

## ***Photonectes bifilifer*** Beebe, 1933.

TYPE.

(The unique specimen).

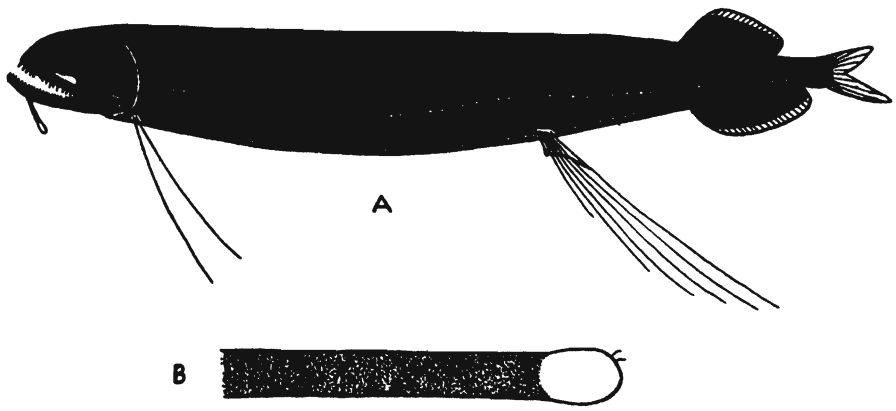
Department of Tropical Research No. 15,146; Bermuda Oceanographic Expeditions of the New York Zoological Society; Net 598; May 19, 1930; 9 miles south of Nonsuch Island, Bermuda; (32° 12′ N. Lat., 64° 36′ W. Long.); 800 fathoms; standard length 245 mm.

DESCRIPTION.

(With the characteristics of the genus).

*Color* (in fresh specimen): Barbel bulb white at base, rich lavender distally.

*Measurements and Proportions*: Total length 260 mm.; standard length 245 mm.; depth 37 mm. (in length 6.6 or 15.1%); head 35 mm. (in length 7 or 14.2%); mandible 37 (in length 6.6 or 15.1%); eye 5 mm. (in head 7,




Text-figure 43.

*Photonectes bifilifer*. A, adult, standard length 245 mm.; B, barbel of same.

or 2.04% of length); snout 6 mm. (in head 5.8 or 2.45% of length); snout to pelvic 156 mm. (1.6 in length or 64%).

*Barbel*: Length 11 mm. (in head 3.2). Stem thick and black, four-fifths the length of the entire barbel; bulb only slightly broader than diameter of stem; 2 very short, thread-like filaments on the posterior surface near tip, with a few specks of pigment on the bulb at their base. Along the posterior side of the stem is a row of half a dozen small photophores.

*Light Organs*: Postorbital 1.8 times diameter of eye. Serial photophores with the following counts: ventral series, I-P 10, P-V 36, V-A 14, A-C 15; lateral series, O-V 36, V-A 13. A luminous spot on shoulder.

*Teeth*: All small, depressible, typical of the teeth of adults in this genus. In the left premaxillary are 6 teeth, the first very small, well separated from the succeeding 5 equal fangs; the left maxillary holds 16, depressible, erect teeth in graduated series of 4, 2, 3, 3 and 4; the posterior oblique denticles number about 35 and are very small and closely-set. The maxillary teeth of the right side are slightly different in their grouping. In the left side of the mandible are 35, in the right side 38; they are in the usual *Photonectes*-like groups of from 3 to 5. There is a single pair of teeth on the vomer and 5 teeth on each palatine. On the basibranchials are 9 pairs, 6 on the first, 3 on the second, the teeth of each group increasing in length backwards. Gill-arch teeth present on first, second and third ceratobranchials, there being 7 groups on the first.

*Fins*: The pectoral consists of 2 elongated, thread-like rays, widely separated at the base, more than 1½ times as long as head. The pelvic, placed far back on the body, has the basal portion of the 7 rays covered with a thick, black membrane similar to those which almost completely enclose the rays of the dorsal and anal; the most anterior pelvic ray is very short, scarcely projecting beyond the membrane, but the succeeding rays increase in length posteriorly, until the seventh reaches the caudal base. Dorsal rays 20; anal rays 24.

*Sex*: The specimen is an adult male, with the gonads about half developed.

## Discussion.

In form this *Photonectes* is characteristic of the subgenus *Trachinostomias*, the body being deep for a melanostomiatid, and thickest toward the middle of its length, while the head is small, lower than the shoulders and somewhat concave dorsally. When the specimen is laid alongside an example of similar size of *P. margarita* there is no apparent difference save for the barbel and the 2 long pectoral rays. Even the skin is fragile, with a characteristic blue-grayness in preservative, which is apparently common to adults of both species. A reexamination of the specimen since the preliminary description shows that, except for differences obviously due to its greater age, *P. bifilifer* differs from *P. parvimanus*, (of which the largest known specimen measures 55 mm.), only in the lack of a crest on the barbel bulb and in the great length of the 2 pectoral rays. Both may prove also to be growth characters, or the barbel crest may have been torn away in the present specimen. Until intermediate stages are secured, however, it seems best to keep the two forms separate.

## References.

*Photonectes bifilifer*:

Beebe, 1933.2, p. 167, fig. 5. (Preliminary description of the specimen described in detail above.)

Beebe, 1937, p. 199. (Preliminary listing of above specimen.)

## ***Photonectes margarita*** (Goode & Bean, 1895).

### General Discussion.

As already indicated on page 154, it is now clear that the following species should be regarded as synonymous with *P. margarita*: *P. richardi* (Zugmayer, 1913); *P. flagellatus* Parr, 1927; *P. intermedius* Parr, 1927, and *P. monodactylus* Regan & Trewavas, 1930. The only significant differences attributed to these various species were the forms of the barbel. We have examined the types of all except *P. richardi* and *P. monodactylus*, comparing them with Bermuda specimens, with the following results:

1. *P. margarita* (Goode & Bean, 1895). 320 mm. long, in the U. S. National Museum. The tip of the barbel has in all probability been broken off and, perhaps, a portion regenerated; the unpigmented distal portion seems to be damaged tissue rather than a true second bulb; parallel instances are found in the present collection except for the shortness of the barbel, (*ca.* 19 mm. or about half the length of the head, instead of about as long as the head, as in other large specimens), and its slenderness (an established growth character); this organ is identical in basic pattern with the other known forms. Finally, there are indubitable evidences that pectorals were once present, since there are skin pockets for their insertion in exactly the location found on our specimens; in several of the latter, as in two of the *Dana* specimens of *P. monodactylus* (see Regan & Trewavas, 1930, p. 127), a ray is missing from one side of the fish leaving no more trace than in the type of *P. margarita*.

2. *P. flagellatus* Parr, 1927. 280 mm. long. In the Peabody Museum, New Haven, Conn. The barbel measures 30.5 mm. (head and lower jaw lengths: 37 mm.) in total length. There is an unmistakable bulb in the usual position, immediately proximal to the first tuft of filaments; its anterior (ventral) surface is, as usual in adult specimens, pigmented, so that the bulb is only apparent posteriorly (dorsally); Text-fig. 44H is from a redrawing of the barbel. The specimen is an adult male near breeding condition.

3. *P. intermedius* Parr, 1927. These small specimens (44 to 58 mm. long) in the Peabody Museum fit in perfectly with our growth stage series, showing that *P. intermedius* is the young of *P. margarita*.

4. Specimens recorded by Borodin, 1931.

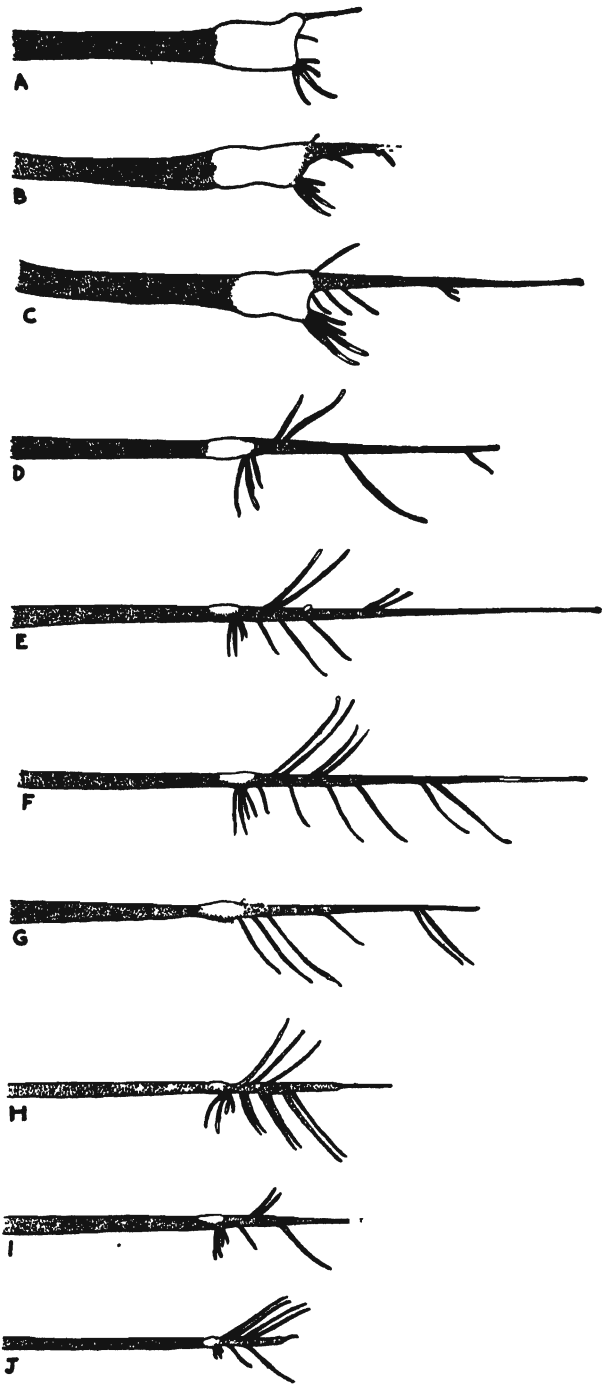
a). *Photonectes margarita* (p. 66). This specimen, 340 mm. long, is a female in full breeding condition. The end of the barbel (Text-fig. 44I) is obviously broken off, so that its short length (23 mm., the mandible measuring 50 mm.) is readily explained.

b). *Echiostoma barbatum* (p. 65), *part*. The two smaller specimens, 70 and 75 mm., (Text-fig. 44C), are young *P. margarita* with barbels in perfect transitional stages between the juvenile *intermedius*-type and adult *margarita* type. The large *Echiostoma* is *E. tanneri* (see p. 141).

In view of the above comparisons and our own specimens, we have no hesitation in synonymizing both *P. richardi* (Zugmayer, 1913), and *P. monodactylus* Regan & Trewavas, 1930, as well, with *P. margarita*. Of the 5 specimens of *P. monodactylus* in the type series, only one, according to the authors, has a complete barbel; the apparent lack of a barbel bulb is doubtless due to its inconspicuousness, as in some of the present series, or the especial density of the pigment which more or less conceals the bulb, at least anteriorly, in large specimens.

### Specimens Taken by the Bermuda Oceanographic Expeditions.

10 specimens; May to September, 1929 to 1931; 400 to 1,000 fathoms; from a cylinder of water 8 miles in diameter (5 to 13 miles south of Nonsuch




Text-figure 44.

*Photonectes margarita.* Barbels, lateral views. **A**, transitional adolescent, standard length 55 mm.; **B**, same, 70 mm.; **C**, same, 75 mm. (from Museum Comparative Zoology specimen No. 31,602); **D**, type specimen of *P. richardi*, 170 mm. (after Regan & Trewavas); **E**, adult male, 235 mm.; **F**, adult male, 257 mm.; **G**, adult female, 274 mm.; **H**, adult male, type of *P. flagellatus*, 280 mm. (from the specimen in the Peabody Museum); **I**, adult female, 340 mm. (from Museum Comparative Zoology specimen, *Atlantis* Sta. 321); **J**, type of *P. margarita* (after Parr). A, B, E, F and G, from specimens in present collection. All drawn in proportion to a fixed stem length (to base of bulb). Paired appendages directed dorsally.

Island, Bermuda), the center of which is located at 32° 12′ N. Lat., 64° 36′ W. Long.; standard lengths from 49 to 300 mm.

### Specimens Previously Recorded.

36 specimens; *ca.* 41 ( -0) to 1,100 fathoms; eastern and western North Atlantic; standard lengths from 20 to 320 mm.

### Description of Adult.

With the characteristics of the genus.

*Color* (from 7 fresh Bermuda specimens): general color black; postorbital light organ rosy in female, yellow in male; barbel bulb purple; serial photophores violet to purple; luminous shoulder spot pale blue.

*Proportions*: Depth in length 6.5 to 7.6 (13.2% to 15.4%); head in length 6.5 to 7.8 (12.8% to 15.4%); eye in head 6 to 7.7; mandible almost exactly equal to head; snout to pelvic in length 1.57 to 1.6 (63% to 64%).

*Barbel*: Slightly longer than head when complete; stem usually less than half entire length of barbel, without branches, densely pigmented; bulb progressively reduced with age, scarcely or not at all thicker than stem; anterior portion, and sometimes all of bulb becoming covered with pigment. From the bulb arises a long, tapering, branched, pigmented terminal filament, proximally as thick as the bulb, distally very slender; with an unpigmented tip; traces of a second bulb toward its end have proved, in every example seen, to be merely a damaged section of the appendage. From the anterior (ventral) side of the base of the terminal appendage arises a tuft of short filaments, usually 2 in number, 2 long and 2 short; distal to these, scattered at irregular intervals along the appendage are other filaments or branches, longer than the basal tuft, of varying length, number and arrangement; typically, however, there seem to be 2 paired and 3 to 6 unpaired filaments, the majority arising from the proximal half of the appendage; all of the filaments are pigmented, and almost all have unpigmented (luminous?) tips.

*Light Organs*: Postorbital longer than eye; serial photophores with the following counts: ventral series, I-P 8 to 11; P-V 30 to 35; V-A 11 to 13; A-C 11 to 12; lateral series, O-V 28 to 34; V-A 11 to 13; all serial organs reduced and inconspicuous, often difficult to count accurately, especially since the delicate skin is usually in bad condition. A small luminous spot on shoulder, sometimes surrounded by a few similar but much smaller spots.

*Teeth*: All teeth small, not very unequal; in typical *Photonectes* series; premaxillary 5 to 8; erect maxillary teeth 14 to 25; oblique maxillary denticles rudimentary, 12 to 25; mandibular teeth 24 to 37; usually 2 pairs of teeth on vomer; 3 to 6 teeth on each palatine. 10 pairs of teeth on basibranchials; teeth on first, second and third ceratobranchials; 5 or 6 pairs on first ceratobranchial.

*Fins*: Pectoral 1, much elongated, about twice length of head, the end expanded and possibly luminous; a rudimentary, subdermal second ray. Dorsal 18 to 20; anal 22 to 24.

### Development.

The Bermuda collection contains 4 transitional adolescents measuring between 49 and 70 mm. in length, with characteristics typical of that growth stage (see p. 79). Their special peculiarities are in the form of the barbel which does not assume a fully adult aspect until the fish has reached a length of more than 100 mm. In the young the bulb is much thicker than the stem, and very noticeably truncate; the prominent terminal appendage of the adult is represented only by a short, unpigmented, unbranched filament arising

from the posterior distal corner of the bulb; at the anterior, distal corner is a cluster of 3 or 4 short filaments which remain in this relative position throughout development. Text-fig. 44 shows the successive steps in the reduction of the bulb, and in the growth of the terminal appendage and its branches. The barbel bulb of the young is bright violet blue to ultramarine, with a small pink spot at posterior distal edge; postorbital organ purple or magenta; serial photophores violet to purple as in adult, but ventral series with broad gold frames.

Specimens of *P. margarita* measuring about 235 or 250 mm. in length may, from the development of their barbels and coelomic organs, be termed adult.

## Behavior.

A female, 273 mm. long was taken alive, enabling the following notes to be made:

"This large melanostomiatid was taken on May 21, 1930, at a depth of 610 fathoms at 12 o'clock. It was alive when brought in at 2 P. M. and put on ice in the refrigerator. At 7 P. M. it was breathing regularly, and when put in the dark room, lay quiet, breathing once every two seconds. The cheek light was almost wide open and motionless. I touched the body of the fish halfway to the tail lightly with my finger and instantly the cheek light revolved downward and closed tightly, held shut a second or two and opened slowly. Again and again this happened with no slackening of response. The fish was then turned upon its ventral side so that we could watch both sides at once. When I pressed gently upon the sides the response came as before and simultaneously to both cheek lights, the closing and opening being absolutely synchronous. This response is apparently a guard against detection from attack, obliterating this light at the hint of outside danger. The fish lived 10 hours, although much of the skin had been scraped away."

## Study Material.

The following list gives the catalogue number, depth in fathoms; date, length and growth stage of each specimen of *Photonectes margarita* taken by the Bermuda Oceanographic Expeditions. All were taken in the cylinder of water off the Bermuda coast described in *Zoologica,* Vol. XVI, No. 1, p. 5 and Vol. XX, No. 1, p. 1.

No. 10,535; Net 181; 1,000 F.; June 17, 1929; 273 mm.; Adult Male.
No. 12,502; Net 388; 900 F.; Aug. 27, 1929; 278 mm.; Adult Male.
No. 13,581; Net 479; 600 F.; Sept. 20, 1929; 250 mm.; Adult Male.
No. 13,842; Net 514; 800 F.; Sept. 27, 1929; 274 mm.; Adult Female.
No. 14,950; Net 577; 800 F.; May 14, 1930; 70 mm.; Trans. Adolescent.
No. 15,253; Net 613; 600 F.; May 21, 1930; 300 mm.; Adult Female.
No. 19,576; Net 967; 500 F.; Sept. 30, 1930; 250 mm.; Adult Male.
No. 20,516; Net 983; 500 F.; June 2, 1931; 55 mm.; Trans. Adolescent.
No. 20,664; Net 1001; 800 F.; June 5, 1931; 49 mm.; Trans. Adolescent.
No. 21,666; Net 1107; 400 F.; July 27, 1931; 57 mm.; Trans. Adolescent.

## Synonymy and References.

*Echiostoma margarita*:

Goode & Bean, 1895, p. 109, fig. 131. (1 specimen, 320 mm.; 420 fath.; Gulf of Mexico; examined by present authors).

*Echiostoma richardi*:

Zugmayer, 1913, p. 4. (1 specimen; 170 mm.; 0-2,000 m. wire; eastern Atlantic).

*Photonectes margarita*:

Parr, 1927, p. 106, fig. 55 B. (Report on reexamination of type of *E. margarita*).

Regan & Trewavas, 1930, p. 126, fig. 121 B. (Recapitulation of preceding reference).

Borodin, 1931, p. 66 (1 specimen; 340 mm.[7]; 1,500 m.; off Bermuda; examined by present authors; a female, in or near breeding condition[8]).

Beebe, 1937, p. 199. (Preliminary list of Bermuda specimens).

*Photonectes flagellatus*:

Parr, 1927, p. 107, fig. 55 A. (1 specimen; 280 mm.; 8,000 ft. wire; off Bahamas; examined by present authors; a male).

Regan & Trewavas, 1930, p. 127, fig. 121 A. (Recapitulation of preceding reference).

*Photonectes intermedius*:

Parr, 1927, p. 109, figs. 57, 58. (3 specimens, 44 to 58 mm.; 5,000 to 10,000 ft. wire; off Bermuda; examined by present authors).

Regan & Trewavas, 1930, p. 126. (22 specimens, 20 to 86 mm.; 150 to 2,000 m. wire; North Atlantic; examined by present authors).

Beebe, 1933.1, p. 180. (Preliminary list of specimens in present Bermuda collection).

Beebe, 1937, p. 199. (Preliminary list of specimens in present Bermuda collection).

*Photonectes richardi*:

Regan & Trewavas, 1930, p. 126, fig. 120 B. (Report on reexamination of type of *E. richardi*).

Roule & Angel, 1931, p. 5. (Report on reexamination of type of *E. richardi*).

Roule & Angel, 1933, p. 17, pl. I, figs. 9, 9a, 9b. (Amplified version of preceding reference).

*Photonectes monodactylus*:

Regan & Trewavas, 1930, p. 127, pl. XII, fig. 3, text-fig. 122. (5 specimens; 180 to 255 mm.; 600 to 4,000 m. wire; North Atlantic, Caribbean Sea).

*Echiostoma barbatum*: (*non* Lowe):

Borodin, 1931, (*part.*) p. 65. (2 specimens, 70, 75 mm.; 600 fathoms; North Atlantic; examined by present authors).

## Genus ***Flagellostomias*** Parr, 1927.

(See also pp. 70, 73, 75, 80, 81, 87, 88, 90, 91, 96, 97, 99, 101, 102, 105-110).

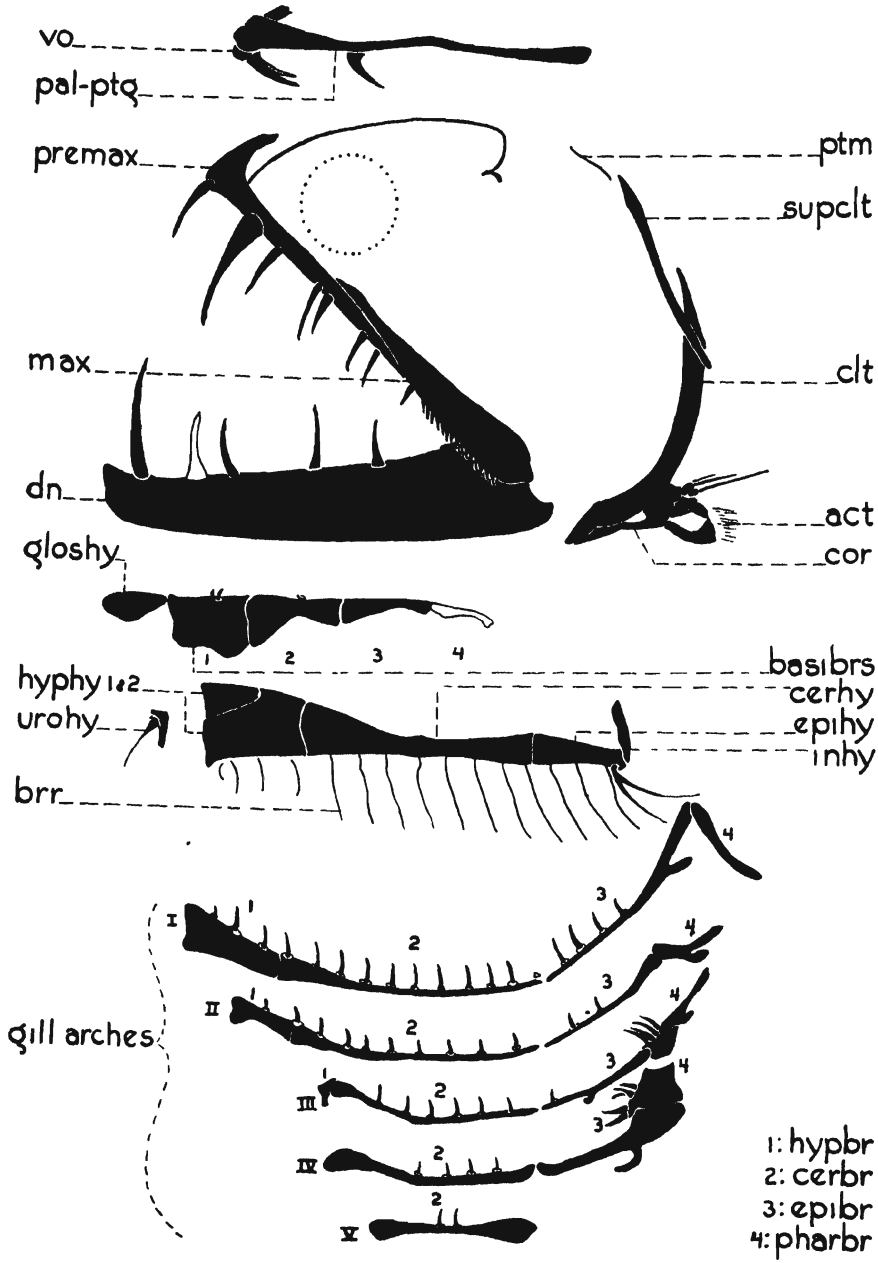
(Text-figs. 2, 11, 12, 45-48 incl.).

### General Discussion.

Two species of *Flagellostomias* have been described, *F. boureei* (Zugmayer, 1913), originally placed in the genus *Eustomias*, and *F. tyrannus* Parr, 1927.

We have examined the type specimens of *F. tyrannus* in the Peabody Museum, New Haven, and agree with Regan & Trewavas (1930, p. 57) that

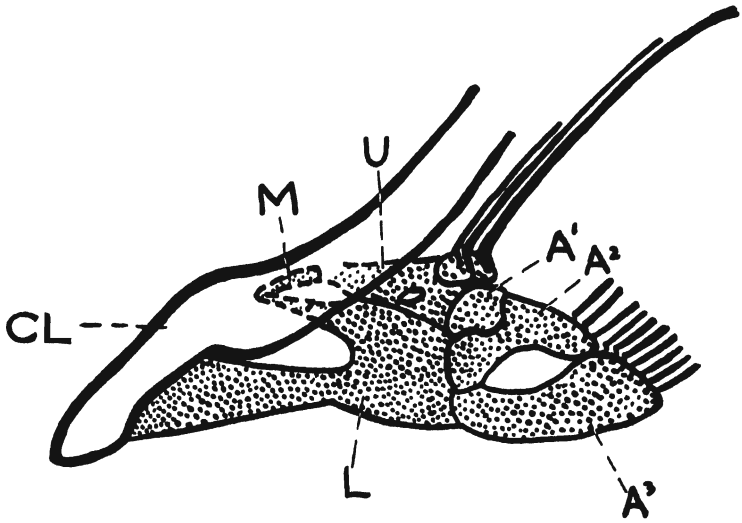
[7] Our measurement. Published measurement of 240 mm. is doubtless a misprint.
[8] Listed under the heading *P. marginata;* obviously a misprint for *margarita*.




Text-figure 45.

*Flagellostomias boureei.* Jaws, hyoid and branchial arches, and pectoral girdle of transitional adolescent, standard length 97 mm. Explanation as in Text-fig. 18.

this species is synonymous with *F. boureei.* Parr's 195 mm. specimen, with the barbel seven-tenths of the length, proves to be a male, while the other, 192 mm. long, with barbel only six-tenths of length, is a female. It is inter-




Text-figure 46.

*Flagellostomias boureei.* Supporting bones of pectoral fin in transitional adolescent, standard length 97 mm. Abbreviations as in Text-fig. 14. The two rays beside the enlarged, isolated ray are not apparent externally.

esting to note that both were taken in the same net, so that it is possible they were swimming together; neither, however, is in breeding condition, the gonads being but slightly developed.

There is considerable variation in the form of the barbel in *F. boureei* (see Regan & Trewavas, *loc. cit.*, fig. 33), which should be borne in mind in relation to other genera, where a number of species have been formed on the basis of relatively slight differences in this same organ. In this case there seems to be no doubt but that individual variation, and perhaps sexual differences as well, are responsible, and that the single species is properly defined.

*Distribution*: *Flagellostomias* is known from the eastern and western North Atlantic, and from the eastern South Atlantic, in tropical and subtropical zones. It has been taken, between, roughly, 100 and 1,000 fathoms. Including the present series, 24 or 25 specimens are known.

## Generic Characters.

Since only one valid species is known in this genus, the following characters are also those of the unique species, *F. boureei* (Zugmayer).

*Color* (from a freshly caught, 97 mm., immature male): General color brownish-black; postorbital silvery white; barbel bulb and swollen tip of first pectoral ray, pale yellow-green; all photophores purple.

*Proportions*: Depth in length 9 to 12 (8.3 to 11.1%); head in length 6.5 to 8.8 (11.4% to 15.4%); eye in head 5 to 6.2 (*ca.* 2.2% to 2.6% of length); snout less than twice length of eye; snout to pelvic in length 1.6 to 1.7 (60% to 62%).

*Barbel*: Barbel about two-thirds length of fish; stem pigmented except distally, spotted with white; bulb ovate or oblong with a much smaller distal bulb; bulb and distal part of stem with many unpigmented filaments, almost always unbranched, varying in number, relative length and arrangement within the single known species.

*Light Organs*: Postorbital almost half size of eye in male, completely atrophied in female. Serial photophores with the following counts: ventral series, I-P 8 to 10, P-V 31 to 33, V-A 14 to 16, the last 1 or 2 above the anal fin, A-C 15 to 18; lateral series, O-V 30 to 32, V-A 13 to 17. First pectoral ray bearing an ovate or elongate luminous bulb near the end terminating in a long filament; a lateral nubbin sometimes present on the bulb.

*Teeth*: Cleft of mouth straight; premaxillary with 4 to 6 rather long, fixed teeth, the second a long fang; maxillary usually with a small erect tooth in addition to a series of 15 or more oblique denticles; mandible with teeth similar to those on premaxillary, except that the first is the long fang, fitting into a groove in the premaxillary, and the second is smaller and depressible; rudimentary barbs present on premaxillary and mandibular teeth; a pair of teeth on the vomer and one or two on each palatine. One pair of small teeth on the basibranchials, sometimes with rudiments of a second; short, slender teeth, not paired or grouped, present on all five gill-arches: on the first and second hypobranchials; on all five ceratobranchials; and on first, second and third epibranchials; 10 to 11 teeth on first ceratobranchial.

*Branchiostegal Rays*: 16 to 17.

*Fins*: Pectoral with 1 + 10 to 11 rays externally, the first isolated, its total length being about 2.5 times as long as head and 3 times as long as other rays, with a luminous, tentacled, terminal bulb. In a cleared and stained specimen there are 2 additional rudimentary rays visible in front of the prolonged first ray; hence the total number is actually 15 or 16. Pelvic 7, inserted well behind middle of length at or near 33rd myomere; dorsal 14 to 17; anal 23 to 26, extending forward well in advance of dorsal origin and ending slightly behind the fin.

*Epidermal Grooves*: There is no provision in the skin for concealment of the luminous pectoral fin or barbel.

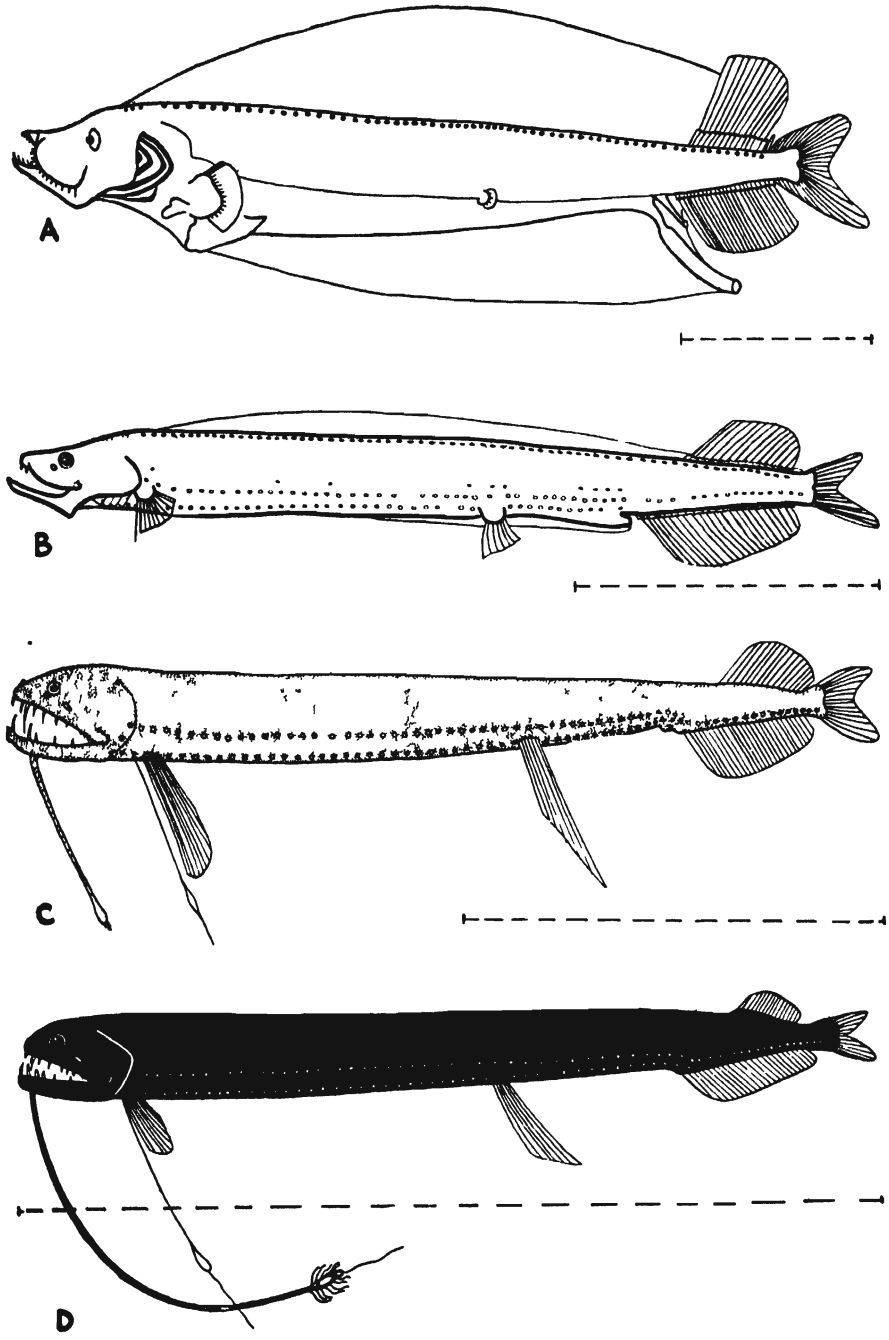
*Osteology*: Parietals present; mesethmoid with lateral processes; posttemporal rudimentary but present and ossified, well separated from skull; supra-cleithrum and cleithrum strong; coracoid elements all of moderate size; actinosts 3; vertebrae about 65 (myomeres to end of anal 67 to 68); first centrum represented only by a fibrous ring as long as centrum, enclosing the notochord, and by a spinal nerve; first neural arch enlarged and directed forward.

*Coelomic Organs*: Stomach 38% of length of fish, barely reaching pelvic origin (in an immature specimen of 97 mm.). This organ is practically unpigmented at this stage, although the lining of the coelom is perfectly black; a similar lack of pigment is indicated by Regan & Trewavas (1930, p. 40, fig. 8D), although the length of the specimen in question is not indicated. Intestine with an anterior pouch but no caecum.

*Sexual Dimorphism*: Postorbital organ well developed in male, atrophied in female. Barbel may prove to be consistently longer in male.

*Size*: The largest known specimen measures 322 mm. in length and was taken by the *Dana* Expedition (Regan & Trewavas, 1930, p. 57).

*Development*: The youngest *Flagellostomias* known are our 2 late larvae, 20 and 21 mm. in length, characterized by the following combination of characters: Myomeres to end of anal 67; from nape to pelvic rudiment 32 or 33; from pelvic rudiment to anal origin 15. Pigment as follows: a single row of chromatophores on each side of dorsal mid-line, one good-sized blotch to a myomere; in post-larva a second row is present immediately above lateral row of photophores, the spots smaller than but equal in number to those of the dorsal row; in each series they extend to end of dorsal; a few flecks of pigment on crown and on ventral finfold near anus. Larval teeth: premaxillary 4; maxillary 14, increasing in size backwards; mandible 5, on outer edge of jaw, directed straight forward. Larval gill-rakers: long spiny rakers present on first 3 arches, and low, spiny mounds present on




Text-figure 47.

*Flagellostomias boureei*. **A**, larva, standard length 21 mm ; **B**, post-larva, 34 mm.; **C**, adolescent, 47 mm.; **D**, transitional adolescent 97 mm See also Text-fig. 2 I.

last 2 arches; 10 rakers on first ceratobranchial. Fins: dorsal and anal of typical numbers, the anal originating slightly in front of dorsal, but not as much as in older fish; finfolds very large. Lengths of Bermuda specimens of succeeding stages post-larvae, 34 and 39 mm.; adolescents, 45 and 47 mm.; transitional adolescent, 97 mm.

As has already been remarked (p. 75), it is likely that the larva described by Roule & Angel as "*Stomiatella D*, phase no. 1," (1930, p. 17, pl. I, fig. 10) belongs to this genus.

### *Flagellostomias boureei* (Zugmayer, 1913).

SPECIMENS TAKEN BY THE BERMUDA OCEANOGRAPHIC EXPEDITIONS.

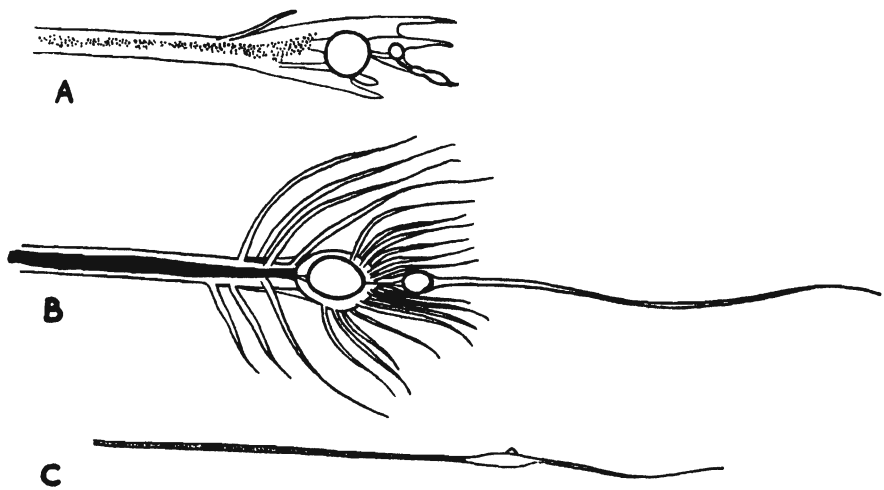
7 specimens; May to September, 1929 to 1931; 500 to 1,000 fathoms; from a cylinder of water 8 miles in diameter (5 to 13 miles south of Nonsuch Island, Bermuda), the center of which is at 32° 12′ N. Lat., 64° 36′ W. Long.; standard lengths from 20 to 97 mm.

SPECIMENS PREVIOUSLY RECORDED.

17 or 18 specimens; *ca.* 182 to 1,067 fathoms; North and South Atlantic, Caribbean; standard lengths from (18?) 39 to 322 mm.

DESCRIPTION OF ADULT.

With the characteristics of the genus.




Text-figure 48.

*Flagellostomias boureei.* **A**, end of barbel in adolescent, standard length 47 mm.; **B**, end of barbel in transitional adolescent, 97 mm.; **C**, end of isolated pectoral ray in same.

DEVELOPMENT.

*Material*: The Bermuda collection of *Flagellostomias* is divided as follows:

2 larvae; 20, 21 mm.; 500, 1,000 fath.; June, Sept.
2 post-larvae; 34, 39 mm.; 800, 900 fath.; June, Sept.

2 adolescents; 45, 47 mm.; 700, 1,000 fath.; July.
1 transitional adolescent; 97 mm.; 900 fath.; May. A male.

All are typical representatives of their respective growth stages (see pp. 76-79). The specific characters of the larvae have already been given on p. 182.

STUDY MATERIAL.

The following list gives the catalogue number, depth in fathoms, date, length and growth stage of each specimen of *Flagellostomias boureei* taken by the Bermuda Oceanographic Expeditions. All were caught in the cylinder of water off the Bermuda coast described in *Zoologica*, Vol. XVI, No. 1, p. 5 and Vol. XX, No. 1, p. 1.

No. 10,249; Net 138; 900 F.; May 30, 1929; 97 mm.; Trans. Adolescent.
No. 10,889; Net 214; 800 F.; June 6, 1929; 39 mm.; Post-larva.
No. 11,181; Net 244; 700 F.; July 1, 1929; 45 mm.; Adolescent.
No. 11,415; Net 277; 1,000 F.; July 9, 1929; 47 mm.; Adolescent.
No. 12,888; Net 407; 900 F.; Sept. 2, 1929; 34 mm.; Post-larva.
No. 16,462; Net 750; 1,000 F.; June 30, 1930; 21 mm.; Larva.
No. 16,642; Net 766; 500 F.; July 3, 1930; 20 mm.; Larva.

SYNONYMY AND REFERENCES.

*Eustomias boureei*:

Zugmayer, 1913, p. 3. (1 specimen; 90 mm.; 3,000 to 0 m.; off western Azores. Type specimen).

*Flagellostomias tyrannus*:

Parr, 1927, p. 50; figs. 29 and 30. (2 specimens; 192 and 195 mm.; 7,000 ft. wire; Bahamas).

*Flagellostomias boureei*:

Regan & Trewavas, 1930, p. 57; pl. II, fig. 3; text-figs. 8D, 9B, 11A, 12A, 33, 34. (10 specimens; 39 to 322 mm.; 200 to 5,000 m. wire; North Atlantic, Gibraltar to West Indies).

Norman, 1930, p. 310. (4 specimens 60 to 85 mm.; 800 (-0) m.; east coast of Africa from Angola to Cape Town).

Roule & Angel, 1933, p. 11; pl. I, fig. 5. (Amplified description of the type).

Beebe, 1937, p. 199. (Preliminary list of Bermuda specimens).

*?Stomiatella D (part.)*

Roule & Angel, 1930, p. 17-18 ("Phase no. 1"); pl. I, fig. 10. (1 larva; 18 mm.; 0-2,000 m.; south-west of Azores).

## Genus ***Grammatostomias*** Goode & Bean, 1895.

(See also pp. 70, 72, 73, 75, 81, 83, 85, 87-91, 96, 97, 102, 105, 108, 110). (Text-figs. 2, 11, 12, 49-54 incl.).

GENERAL DISCUSSION.

An examination of the type and unique specimen of *Grammatostomias dentatus* at the U. S. National Museum (U. S. N. M. No. 37,370) has shown that it is exactly the same species as *Lamprotoxus angulifer* Beebe, 1932, which forms a part of the present Bermuda collection. The luminous body line with the downward curving hook anteriorly, characteristic of *L. angulifer*, is clearly apparent in the *Grammatostomias* type specimen (although faded out of all semblance to the luminous organ which it really is), in exactly the same position as in our Bermuda example: it was, indeed, noted

Text-figure 49.

**Anterior part of lateral luminous pattern in *Grammatostomias*. A, *G. dentatus*, transitional adolescent, standard length 139 mm.; B, *G. flagellibarba*, adult male, 206 mm.; C, same, transitional adolescent female, 106 mm.; D, transitional adolescent, 62 mm.; E, transitional post-larva, 29 mm. (loop incomplete, as shown). C, from specimen in Bingham Oceanographic Collection, Peabody Museum; all others from present collection.**

by Goode & Bean in their type description (1895, p. 110) as "a series of pigment cells along the median line of the body, so arranged as to simulate a lateral line." In reality, however, this streak falls well below the usual position of a true lateral line. It is now, of course, apparent that all species since referred to *Lamprotoxus* should be placed in *Grammatostomias*, the older genus, since the absence of luminous tissue on the side was the only character definitely separating the two genera. The type species, *G. dentatus* (synonym: *L. angulifer*), is the most primitive species known in regard to the form of the lateral luminous organ.

The remaining three species which have been described are *G. flagellibarba* Holt & Byrne, 1910; *G. phanobrochus* (Regan & Trewavas, 1930); and *G. paucifilis* (Regan & Trewavas, 1930). All have a closed luminous loop on the side. *G. paucifilis* is described as being distinctly set off by the small number of rays in the pectoral fin (4 to 6 instead of 10 or 11), and by having 4 instead of only 3 downward angles in the anterior end of the luminous loop. Both of these characters turn out to be valueless: First, the specimen of *L. flagellibarba* recorded by Parr (1927, p. 93) has proved, upon examination at the Peabody Museum, to have 4 loops on the left side and 3½ on the right. Second, an examination of the larger (49 mm.) of the two specimens in the type series shows that the full numbers of rays found in *flagellibarba* are present, instead of only 4 to 6; since the 4 last rays arise in a cluster, their bases in a single sheath of skin, as usual in *flagellibarba*, a superficial appearance of a single split ray is given in this young specimen, but the arrangement of all, under a high power lens, is seen to be exactly as in *flagellibarba*. Therefore, *paucifilis* is a synonym of the latter species.

*G. phanobrochus* is described as differing from *G. flagellibarba* significantly only in minor details of the anterior part of the loop (the zig-zag portion being thicker and with a short hook or projection at its anterior end), and in having only one pectoral ray embedded in luminous tissue. The very minor differences in proportion as well as the feeble development of luminous tissue on the pectoral must be laid to the small size of the four known specimens of *G. phanobrochus* (27 to 43 mm.), one of which we have examined. The Bermuda series of *G. flagellibarba* shows luminous loops both typical of *G. flagellibarba* and intermediate between *G. flagellibarba* and *G. phanobrochus*. This latter intermediate specimen has the 3 slender angles of *G. flagellibarba*, but in addition there is a distinct, anterior hook, exactly as in *G. phanobrochus*. We think, therefore, that there is no doubt as to the synonymy of the two species.

The valid species of *Grammatostomias* may therefore be keyed as follows:

A. Linear luminous matter on side a straight line from opercle to beyond anal origin with a simple, anterior, downward hook; pectoral 5 *G. dentatus* (p. 190).

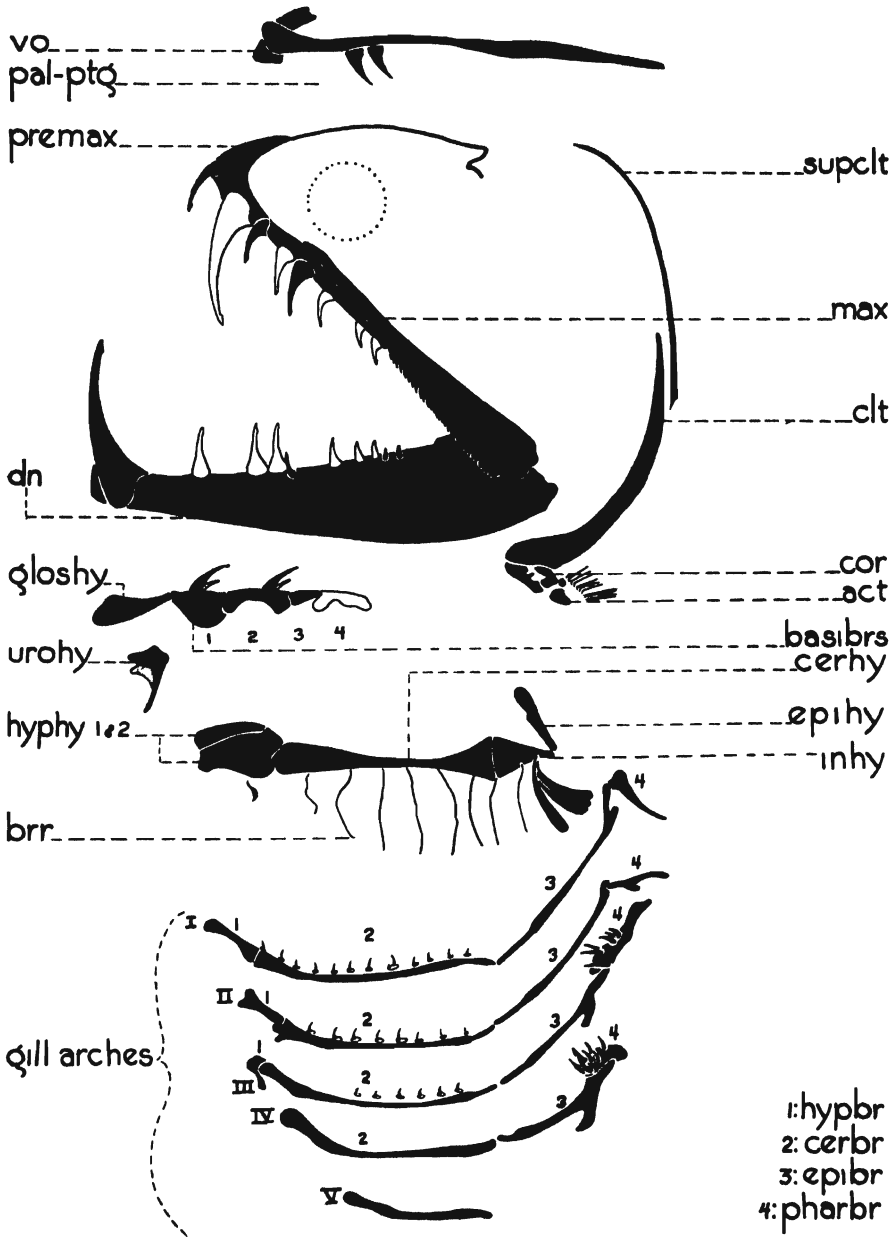
AA. Linear luminous matter on side a closed loop; pectoral 9 to 11 *G. flagellibarba* (p. 192).

*Distribution*: *Grammatostomias* is known only from 17 specimens, including the present series, all taken in the north Atlantic from the West Indies to the coast of Ireland. The depth range is from about 25 to 2,069 fathoms.

## Generic Characters.

*Color* (from freshly caught specimens of *G. dentatus* and *G. flagellibarba*): General color brownish-black; barbel pigmented only basally; postorbital silvery white or yellow; luminous line or loop white or blue-violet; serial photophores violet with gilt caps; non-serial photophores pinkish.

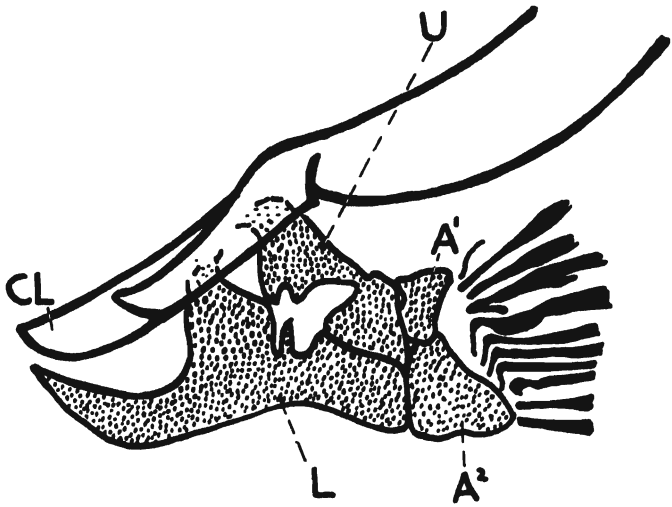
*Proportions*: Moderately elongate melanostomiatids; depth in length 7




Text-figure 50.

*Grammatostomias flagellibarba.* Jaws, hyoid and branchial arches, and pectoral girdle of adult, standard length 206 mm. Explanation as in Text-fig. 18.

to 9 (11.1% to 14.2%); head in length 5 to 6.3 (15.9% to 20%); eye in head 6 to 8 (2.24% to 3.15% of length); snout equal to or a little longer than eye, slightly protractile; snout to pelvic in length 2.3 to 2.4 (42% to 43%).




Text-figure 51.

*Grammatostomias flagellibarba.* Supporting bones of pectoral fin in adult, standard length 206 mm. Abbreviations as in Text-fig. 14. Note laminated rays, which doubtless help support luminous tissue, and rudimentary first ray.

*Barbel*: Simple, very slender, up to 7 times length of fish.

*Light Organs*: Postorbital much smaller than eye in female, larger than eye in male. Serial photophores with the following counts: I-P 6 to 7, P-V 16 to 17, V-A 19 to 22, of which 2 are above the anal fin, A-C 10 to 12; lateral series, O-V 15 to 18, V-A 20 to 22. Non-serial photophores moderately well developed. A line or loop of luminous tissue on each side of body extending from opercle to pelvic origin or beyond; luminous tissue also present in streaks and spots on cheeks, opercles and sides. One or more pectoral rays embedded in luminous tissue.

*Teeth*: Cleft of mouth straight. Premaxillary and mandible with acute teeth of very unequal size, both fixed and depressible, most of them slightly barbed; first maxillary tooth moderate, fixed; second tooth very long, depressible; first mandibular tooth the longest in both jaws, fixed, resting in a groove of the pre-maxillary when mouth is closed; remaining teeth in both jaws relatively small, the majority depressible, numbering from about 6 to 14 behind the above mentioned anterior fangs in each jaw; maxillary teeth all small, oblique denticles numbering between 28 and 35. Vomer toothless; 2 to 4 teeth on each palatine. Two to 3 pairs of teeth on basibranchials. Small, slender teeth, all single except 1 pair on first ceratobranchial, present on first 3 gill-arches, on the ceratobranchials only; 9 to 12 individual teeth set in the first ceratobranchial.

*Branchiostegal Rays*: 11.

*Fins*: Pectoral with 4 to 11 short rays, one or more of them being imbedded in luminous tissue; pelvics 7, inserted a little in advance of middle of length; dorsal 18 to 21; anal 20 to 24, dorsal and anal beginning at same vertical, but anal extending farther back.

*Osteology*: Mesethmoid with lateral processes; parietals absent; posttemporal absent; supra-cleithrum and cleithrum moderately strong; upper and lower coracoids large; mesocoracoid rudimentary; actinosts 8; vertebrae about 50; first centrum represented only by a fibrous ring enclosing notochord, and by a spinal nerve.

*Coelomic Organs*: Stomach 31% to 32.5% of length, ending about midway between pelvic and anal origins; intestine with 2 pyloric caeca.

*Sexual Dimorphism*: Postorbital light organ large in male, almost atrophied in female.

*Size*: The largest known specimen is a male *Grammatostomias flagellibarba*, not very near breeding condition and measuring 206 mm. in length; it was taken by the Bermuda Oceanographic Expeditions. A female 106 mm. long recorded by Parr (1927, p. 93) has the ovaries very slightly developed and is apparently in late transitional adolescence. A female *G. dentatus* in the present collection measuring 139 mm. appears also to be slightly immature.

*Development*: Larva unknown. Very late post-larve and adolescents with traces of subdermal dorsal blotches, and of pigment spots in middle of sides. The anterior portion of the luminous line or loop is apparent in late post-larvae.

### ***Grammatostomias dentatus*** Goode & Bean, 1895.

(See also p. 185).

SPECIMENS TAKEN BY THE BERMUDA OCEANOGRAPHIC EXPEDITIONS.

4 specimens; July to September, 1929 to 1931; 400 to 700 fathoms; from a cylinder of water 8 miles in diameter (5 to 13 miles south of Nonsuch Island, Bermuda), the center of which is 32° 12′ N. Lat., 64° 36′ W. Long.; standard lengths from 34 to 139 mm.

SPECIMEN PREVIOUSLY RECORDED.

1 specimen; 2,069 fathoms; southeast of New York; standard length 145 mm.

DESCRIPTION OF LARGEST KNOWN SPECIMENS.

(From the 145 mm. type and the largest Bermuda specimen, 139 mm. long, formerly described as *Lamprotoxus angulifer* Beebe, 1932).

*Color* (from fresh specimen): Skin blackish-brown with the body segments marked off by lines of black pigment; postorbital light organ silvery; branchiostegal photophores pale violet; serial photophores deeper purple with very large, concave gold caps; non-serial small photophores pale pinkish; all lines and spots of luminous tissue white.

*Proportions*: Depth in length 8 to 8.6 (11.6% to 12.5%); head in length 5.8 (17.2%); eye in head 6.1 to 8 (2.24% to 3.1% of length); snout longer than eye; snout to pelvic in length 2.3 (43%).

*Barbel*: Broken in both specimens. In a 61 mm. Bermuda transitional adolescent it is complete, and reaches to the middle of the anal fin, ending in two short equal filaments.

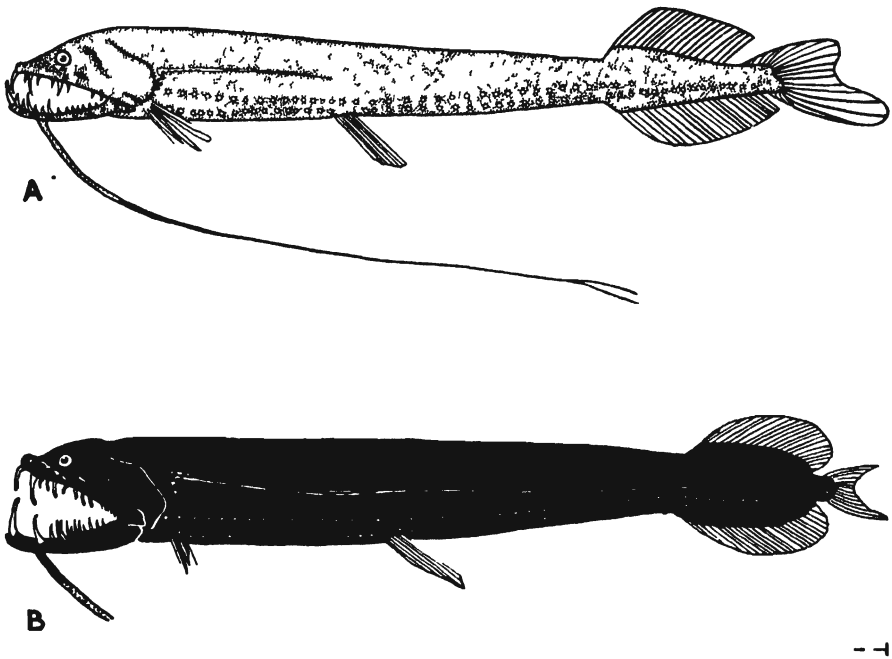
*Light Organs*: Postorbital much smaller than eye, the Bermuda specimen having been sexed and found to be a female; O-V photophores, the only series differing from the other species in the genus, numbering 15 to 16 instead of 16 to 18. Hundreds of minute accessory photophores covering the fish from head to tail, resembling the serial photophores in everything but size and regularity of position. Middle 3 of the 5 pectoral rays imbedded in white, opaque, luminous tissue.

Luminous tissue along the sides of the body in the shape of a long-handled, angled crook, the anterior part of which is formed by a solid line. The crook extends straight downward close to the posterior edge of the gill opening, breaking up into several elongate spots toward the end. The handle extends down the body below the midline and ends above the middle

of the anal fin. It consists of two divisions, a ventral, solid line for much of the distance, and a dorsal line, very close to it, of small, separate spots. The line becomes single at the level of the tenth lateral photophore beyond the ventral fin. Besides this, there is an almost solid line of luminous tissue from the tip of the snout back along the premaxillary to the level of the middle of the eye, and a third, very thin and wavering but solid line arising back of the eye and curving back and down toward the anterior end of the maxillary denticles.

*Teeth*: Anterior fixed and depressible fangs characteristic of the genus. Premaxillary about 11, fixed and depressible teeth irregularly alternating; mandible with about 17 teeth, the majority depressible, after the anterior fang. It is difficult to label the most posterior, small teeth in both jaws as either fixed or depressible, although the fangs, as usual, are clearly referable to one group or the other.

*Fins*: Pectorals short with first, second and fifth rays equal and longest, thread-like and brown; second, third and fourth imbedded in luminous tissue. Dorsal 20 to 21; anal 23 to 24 (not 19, as in type description of *L. angulifer*), both covered thickly with dark body pigment.




Text-figure 52.

*Grammatostomias dentatus*. **A**, adolescent, standard length 34 mm.; **B**, transitional adolescent, standard length 139 mm.

## Development.

Besides the 145 mm. female included in the foregoing description, the Bermuda collection includes 2 adolescents of 34 mm. and a transitional adolescent of 61 mm. All show their immaturity in the fashion typical of their respective growth stages (see p. 77). The luminous tissue on the pectoral fins in a 34 mm. specimen is asymmetrically arranged on the right and left sides of the fish: on the left side there is a relatively small amount surrounding the second ray and partially attaching the first, while the third

and fourth rays are both imbedded in the same, very large mass; on the right side the first ray is free and lacks tissue, the second and third are imbedded in a single mass, and the fourth ray is imbedded by itself. The luminous line is as in large specimens, except that it is not traceable so far back. Traces of dorsal and median subdermal pigment spots are discernible in the small specimens, but are too obscure to furnish any possible identification mark for larvae, which so far have not been caught. However, it is apparent that this genus in its early stages possesses pigment in the general regions characteristic of the family—i.e., along the back and, in a second series, on the sides.

### Ecology.

*Food*: The stomachs of the three smallest specimens all contained remains of small fish; in addition, one of the 34 mm. specimens held a number of ostracods.

### Study Material.

The following list gives the catalogue number, depth in fathoms, date, length and growth stage of each specimen of *Grammatostomias dentatus* taken by the Bermuda Oceanographic Expeditions. All were caught in the cylinder of water off the Bermuda coast described in *Zoologica*, Vol. XVI, No. 1, p. 5 and Vol. XX, No. 1, p. 1.

No. 13,219; Net 439; 700 F.; Sept. 7, 1929; 61 mm.; Trans. Adolescent.
No. 13,313; Net 444; 500 F.; Sept. 9, 1929; 34 mm.; Adolescent.
No. 21,667; Net 1108; 500 F.; July 27, 1931; 139 mm.; Trans. Adolescent. Female.
No. 22,483; Net 1187; 400 F.; Aug. 17, 1931; 34 mm.; Adolescent.

### Synonymy and References.

*Grammatostomias dentatus*:

Goode & Bean, 1895, p. 110; pl. XXXV, fig. 133; (1 specimen; 2,069 fath., east of New Jersey, 145 mm.; examined by present authors).

Parr, 1927, p. 92; figs. 10, 52. (Redescription of type).

Regan & Trewavas, 1930, p. 63. (Record of type; recapitulation of description).

*Lamprotoxus angulifer*:

Beebe, 1932.2, p. 56; fig. 9. (Description of the 139 mm. specimen described in the preceding pages from the Bermuda collection).

Beebe, 1933.1, p. 180. (Preliminary list of Bermuda specimens).

Beebe, 1937, p. 199. (Preliminary list of Bermuda specimens).

## ***Grammatostomias flagellibarba*** Holt & Byrne, 1910.

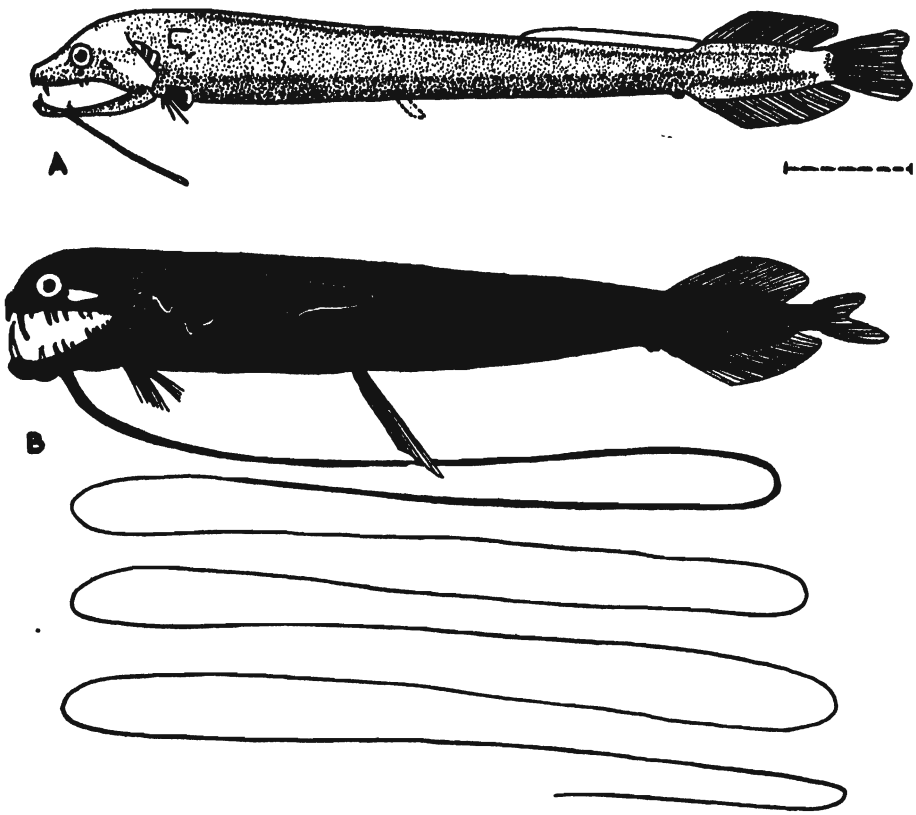
(See also p. 187).

### Specimens Taken by the Bermuda Oceanographic Expeditions.

3 specimens; July to September, 1929 and 1930; 500 to 700 fathoms; from a cylinder of water 8 miles in diameter (5 to 13 miles south of Nonsuch Island, Bermuda), the center of which is at 32° 12′ N. Lat., 64° 36′ W. Long.; standard lengths from 29 to 206 mm.

### Specimens Previously Recorded.

9 specimens; *ca.* 40 to 1100 fathoms; north Atlantic; standard length from 26 to 168 mm.




Text-figure 53.

*Grammatostomias flagellibarba.* **A**, transitional post-larva, standard length 29 mm.; **B**, adult, standard length 206 mm. See also Text-fig. 2 J.

DESCRIPTION OF ADULT.

With the characteristics of the genus.

*Color* (from the Bermuda adult male and a 62 mm. transitional adolescent, both freshly caught): General color, rich brownish-black; barbel white, sprinkled with brown pigment basally, which dies out gradually, disappearing before the middle of the length; postorbital light organ bright yellow in male; serial photophores violet; luminous matter on pectoral fin yellow; luminous loop on side of body rich blue-violet.

*Proportions*: Depth in length 7 to 7.6 (13.1% to 14.3%); head in length 5.7 to 6.3 (15.8% to 17.5%); eye in head 5.5 to 7.5 (*ca.* 3.15% of length); snout longer than eye; snout to pelvic in length 2.4 (42%).

*Barbel*: When complete, at least 7 times as long as fish, as in the Bermuda specimen; it is translucent white, sprinkled with brown pigment basally; distally it has a silvery, corded appearance.

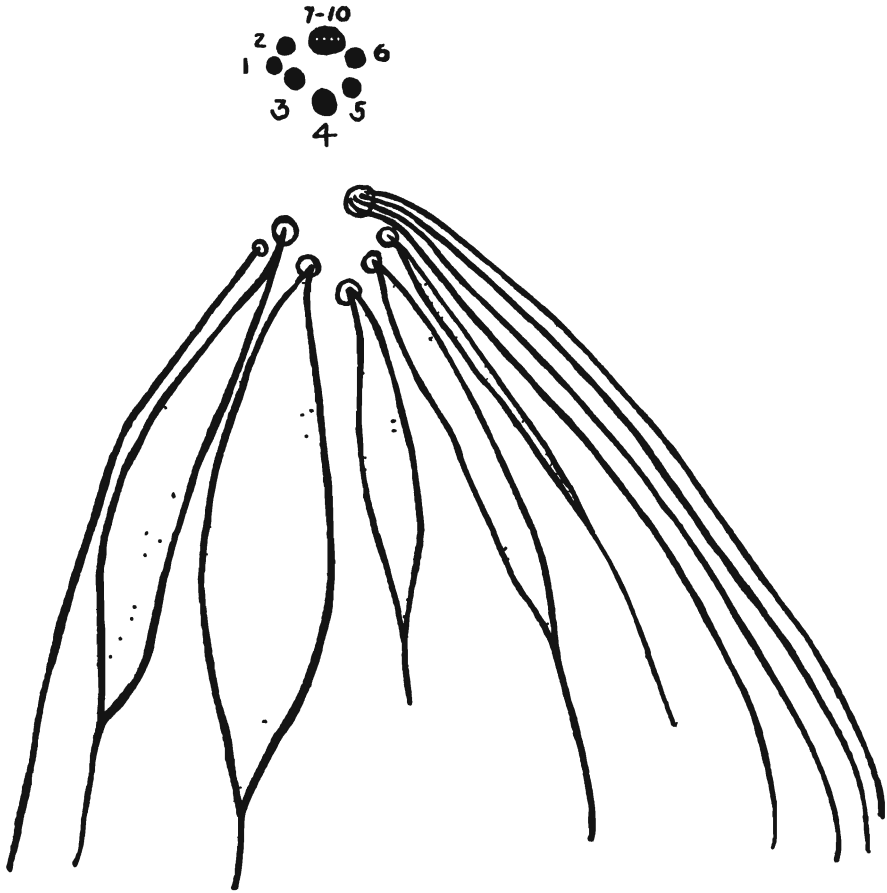
*Light Organs*: Postorbital very large in adult male, almost twice length of eye and contained 4 times in length of head; almost atrophied, apparently non-functional, in adult female. Serial photophore counts typical of the genus. Accessory photophores numerous and conspicuous.

Luminous tissue along sides of body in the shape of a completely closed

loop with 3 or 4 downward angles anteriorly which form a conspicuous zigzag pattern; luminous tissue scattered in dots in the region of the zigzag. The posterior margin of the loop is found at or slightly behind the level of the pelvic base. Pectoral rays more or less imbedded in luminous tissue. Luminous tissue also spattered on the posterior part of the opercles and below the zigzag part of the luminous loop.

*Teeth*: Anterior fixed and depressible fangs characteristic of the genus. In the adult (206 mm.) Bermuda male, there are 7 teeth in the left half of the premaxillary, 8 in the right; about alternately depressible and fixed; in the mandible, after the first enormous fixed fang, comes a series of 9 or 10 teeth, most depressible, one-third (anteriorly) to one-tenth (posteriorly) the size of the fang.

*Fins*: The 9 to 11 pectoral rays are arranged almost in a circle (Text-fig. 54). In the Bermuda specimen, on the left side, the first ray is simple, the third with a large amount of luminous tissue, ending in a short filament, the most in the fin; second, fourth, fifth and sixth rays similar, but with progressively diminishing amounts of luminous matter; seventh through tenth rays arising transversely from a single base. The rays of the right




Text-figure 54.

*Grammatostomias flagellibarba*. Arrangement of pectoral rays of left side of adult, standard length 206 mm. Luminous tissue shown by stippled areas.

side are identically arranged, but the seventh through the tenth rays have traces of luminous matter also.

The pelvics extend more than two-fifths of the distance between their insertion and the anal origin. The membranes of the dorsal and anal fins are thick and blackish, the body skin extending well up beyond their actual bases.

### Development.

The Bermuda collection consists of a transitional post-larva 29 mm. long, a transitional adolescent 62 mm. long, and an adult male 206 mm. long, the largest specimen ever taken. The young specimens are typical of their respective growth stages (see p. 77), the transitional post-larva combining the post-larval characters of finfold remains and partially developed fins, with the adolescent traits of growing teeth, barbel and specialized luminous organs, including a partially developed lateral loop and traces of luminous matter on the anterior pectoral rays; the postorbital organ is very small, less than the diameter of the lens of the eye. In the 62 mm. transitional adolescent the postorbital organ about equals the diameter of the entire eye; sex cannot yet be determined at this stage.

### Study Material.

The following list gives the catalogue number, depth in fathoms, date, length and growth stage of each specimen of *Grammatostomias flagellibarba* taken by the Bermuda Oceanographic Expeditions. All were caught in the cylinder of water off the Bermuda coast described in *Zoologica*, Vol. XVI, No. 1, p. 5 and Vol. XX, No. 1, p. 1.

No. 11,558; Net 297; 500 F.; July 13, 1929; 62 mm.; Trans. Adolescent.
No. 13,876; Net 512; 700 F.; Sept. 25, 1929; 29 mm.; Trans. Post-larva.
No. 17,491; Net 816; 600 F.; Aug. 29, 1930; 206 mm.; Adult Male.

### Synonymy and References.

*Grammatostomias flagellibarba*:

Holt & Byrne, 1910, p. 294. (1 specimen; 168 mm.; *ca.* 700 fathoms; off southwest Ireland).

*Lamprotoxus flagellibarba*:

Holt & Byrne, 1912 (1913), I, p. 8, pl. I. (Further discussion of type specimen).

Boulenger, 1913, p. 1, pl. I. (Histology of luminous organs of type specimen).

Parr, 1927, p. 93. (1 specimen; 106 mm.; 7,000 feet wire; 100 miles south of Nassau). Examined by present authors; a female.

Regan & Trewavas, 1930, p. 63, fig. 13 A, 43, 44 A. (Description from examination of type specimen).

Roule & Angel, 1933, p. 14, pl. I, fig. 7. (1 specimen; 136 mm.; 0 to 4,500 m.; Bay of Biscay).

Beebe, 1937, p. 199. (Preliminary list of Bermuda specimens).

*Lamprotoxus paucifilis*:

Regan & Trewavas, 1930, p. 64, fig. 44B. (2 specimens; 26, 49 mm.; 200 to 300 m. wire; North Atlantic). Larger specimen examined by present authors.

*Lamprotoxus phanobrochus*:

Regan & Trewavas, 1930, p. 64, fig. 44C. (4 specimens, 27 to 43 mm.; 150 to 4,000 m. wire; West of St. Lucia, North of Barbuda, *ca.* 800 to 1,000 miles southeast of Bermuda). 1 specimen examined by present authors.

## Genus **Bathophilus** Giglioli, 1884.

(See also pp. 70, 73-75, 81, 83-85, 87, 90, 91, 95-97, 103, 105, 108, 110).
(Text-figs. 2, 8, 9, 11, 12, 55-63 incl.).

### General Discussion.

Seventeen species referable to *Bathophilus* have been described, including the following three which have appeared since the publication of the monograph by Regan & Trewavas in 1930 (p. 65): *B. irregularis* Norman, 1930; *B. alberti* (Roule & Angel, 1931; amplified in 1933) and *B. altipinnis* Beebe, 1933. *B. alberti* is almost certainly a synonym of *B. metallicus*. *B. irregularis* and *B. altipinnis* will fit into the key given by Regan & Trewavas, as follows:

*B. altipinnis*, in section B of group I:

B. Pelvic fins about equidistant from dorsal and ventral profile (*Bathophilus*).
P. 34 to 47; Pv. 18 to 26; O-V photophores 13.....*nigerrimus*.
P. 24 to 25; Pv. 15; O-V photophores 13.....*altipinnis*.
P. 16 to 19; Pv. 16; O-V photophores 10.....*proximus*.

*B. irregularis* in section A of group II:

A. Pectoral rays in two well-separated groups (*Trichostomias*).
P. 3 to 6+7 to 11; Pv. 7 to 10; no photophores above pelvic base.....*longipes*.
P. 3+7; Pv. 21; photophores above pelvic base.....*irregularis*.
P. 3+4 to 5; Pv. 16 to 20; no photophores above pelvic base.....*schizochirus*.

— etc. —

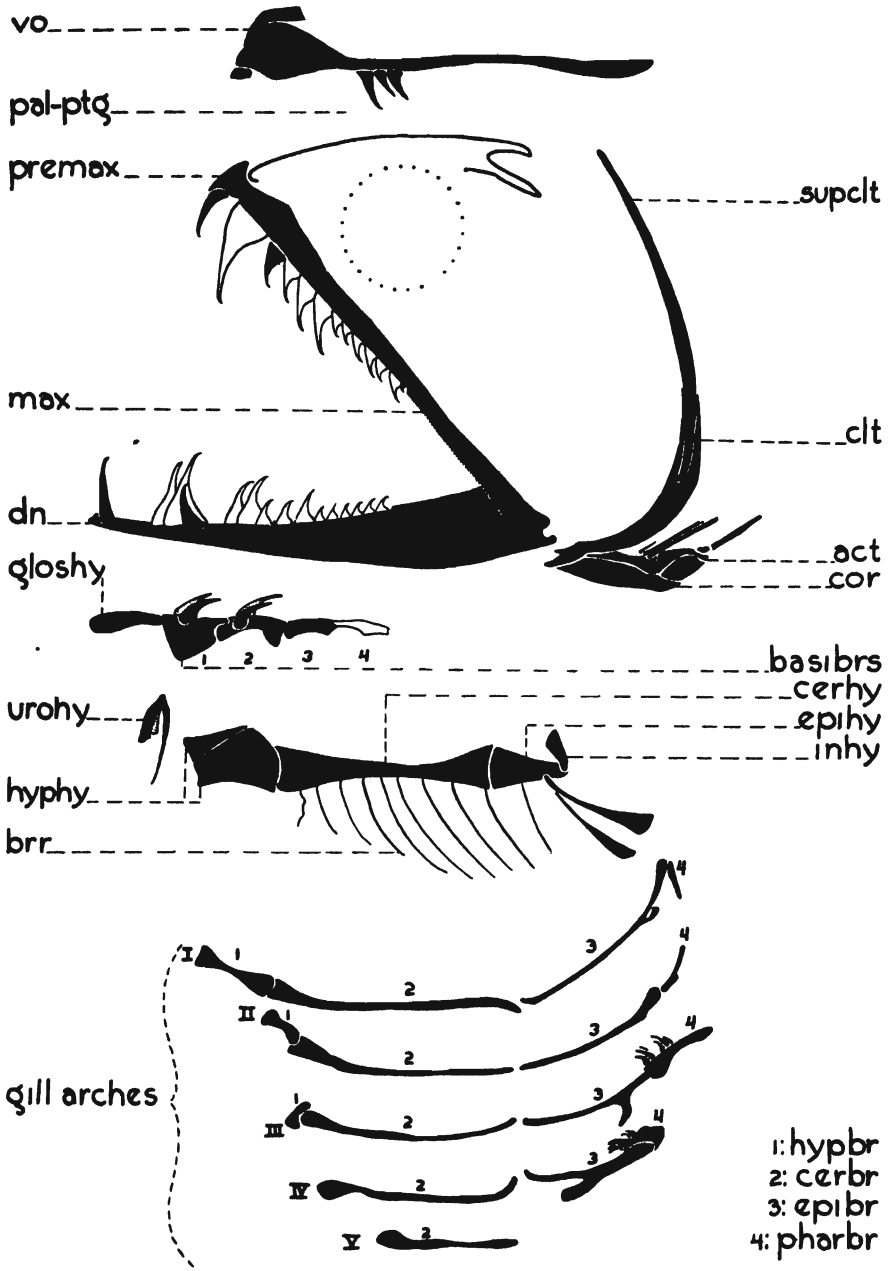
We have considered placing the highly aberrant *B. brevis* in a separate genus, because of its exceedingly great depth, forwardly placed pelvic, and atrophied serial photophores. We have retained it, however, because it is so obviously in the main line of development of *Bathophilus*, because traces of serial photophores were visible in fresh specimens, and because no adult or even large transitional adolescent has ever been taken, so that its mature characteristics are somewhat problematical.

We have examined the type specimen of *B. simplex* Parr, in the Peabody Museum, New Haven, and agree with Regan & Trewavas that it is synonymous with *B. metallicus*, of which we have also examined the type, in the U. S. National Museum. *B. simplex* was separated from *B. metallicus* chiefly because of its lack of lustre; however, it seems likely that preservative may bring out lustre, because at the present time the head and nape of *B. simplex* have considerable gloss. As Regan & Trewavas noted, it is a very variable character. The type of *B. pawneei* Parr, also examined, has a metallic lustre over the entire body.

The following names are synonymous with *Bathophilus*: *Dactylostomias* Garman, 1899; *Trichostomias* Zugmayer, 1911, and *Gnathostomias*, Pappenheim, 1911. *Stomiatella* A. Roule & Angel (1930, p. 14, pl. 1, fig. 6) is probably *Bathophilus brevis* (see p. 75).

Five of the 17 species of *Bathophilus* have been taken by the Bermuda expeditions, namely, *B. brevis*, *B. altipinnis*, *B. metallicus*, *B. longipinnis* and *B. chironema*.

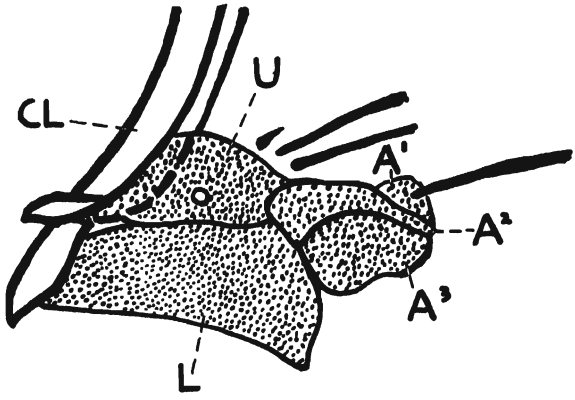
*Distribution*: *Bathophilus* is one of the seven genera of Melanostomiatidae which have been taken outside the Atlantic Ocean, since *B. filifer* (Garman) is known only from the eastern Pacific; the remaining species are all known only from the North and South Atlantic. The depth range appears to




Text-figure 55.

*Bathophilus metallicus.* Jaws, hyoid and branchial arches, and pectoral girdle of transitional adolescent, standard length 105 mm. Explanation as in Text-fig. 18.

be between the surface and about 1,900 fathoms. A total of about 500 specimens has been reported, of which almost 200 are referred to *B. metallicus.*




Text-figure 56.

*Bathophilus metallicus*. Supporting bones of pectoral fin in transitional adolescent, standard length 105 mm. Abbreviations as in Text-fig. 14. Note rudimentary first ray.

## GENERIC CHARACTERS.

With the characteristics of the family.

*Color* (from field observations on 15 immature individuals belonging to four species): General color brownish-black; often with a metallic iridescence; barbel translucent white, sometimes with a few speckles of pigment, especially basally; postorbital green, yellow or reddish; serial photophores golden yellow; luminous patches on head or body white.

*Proportions*[9]: Elongate to very deep melanostomiatids; depth in length 2¼ to 12 (8 1/3% to 44½%); head in length 2 2/5 to 6 2/3 (15% to 42%); eye small, deeply sunken, usually badly preserved; snout considerably longer than eye; snout to pelvic exceedingly variable, since the latter fin is inserted in varying positions from the opercle to behind the middle of the length.

*Barbel*: Always (when complete) much longer than head, often longer than body, slender, simple, unpigmented; bulb absent, the end of the barbel tapering to a point or terminating in two short filaments.

*Light Organs*: Postorbital of varying size, smaller in female than in male, but functional in both sexes; often separated more or less completely into two parts by a vertical black partition; serial photophores usually indistinct, always small, sometimes absent; the rows tend to be highly irregular. Small non-serial organs highly developed. Luminous patches usually present on head or body, their position varying with the species.

*Teeth*: Cleft of mouth straight, each premaxillary with an anterior fixed tooth followed by a series of unequal, depressible fangs, of which the first is longest, fitting down over the mandible; maxillary without erect teeth, but with a series of up to 35 or more oblique denticles; each half of mandible with a moderately strong anterior and a tiny lateral fixed tooth, and an inner series of depressible teeth; teeth all simple, pointed, without barbs; vomer toothless; 1 or 2 teeth (rarely more) on each palatine; 2 pairs on basibranchials; gill-arches entirely toothless.

*Branchiostegal Rays*: *ca.* 8 to 12.

*Fins*: Pectoral and pelvic rays highly variable, sometimes even within the same species, pectoral 1 to 47, long, filamentous; pelvic 4 to 26, usually

[9] Including those of some immature specimens upon which species have been founded.

inserted immediately above the lateral series of photophores, and toward the middle of the length; sometimes, however, they are placed far above the line of photophores and forward on the body, almost on the shoulder; like the pectorals they are long and filamentous; both fins lack webbing entirely. Dorsal and anal subequal, of 9 to 18 rays.

*Superficial Grooves*: The groove for the reception of the barbel is highly developed in this genus, continuing from the isthmus to the anus, and continuing to one side of the anal fin, in the case of long-barbeled species such as *B. metallicus*.

*Osteology*: Mesethmoid with lateral processes; parietals absent; posttemporal absent; supra-cleithrum and cleithrum moderately well developed; upper and lower coracoids large and laminar; mesocoracoid absent; 2 actinosts; 38 to 45 vertebrae; first centrum represented only by a fibrous ring enclosing notochord, and by a spinal nerve.

*Coelomic Organs*: Stomach (in slightly immature specimens; no mature examples available) 25% to 29% of standard length, reaching beyond pelvic origin; two pyloric caeca.

*Sexual Dimorphism*: Postorbital light organ of female smaller than that of male, but functional. The supramaxillary luminous patch is found in both sexes.

*Size*: The largest known *Bathophilus* is a specimen of *B. metallicus*, 140 mm. in length, taken by the *Dana* Expeditions. Judging by the specimens in the present collection, most or all of the known examples in the genus are immature.

*Development*: The larvae of the genus are known from examples of about 5 species and are all easily recognizable by the low total number of myomeres to the end of the anal, (*ca.* 38 to 46), and the small number of prepelvic myomeres (less than 22); external pigment is present only on the back, one large or several small dots occurring on each myomere immediately below the dorsal mid-line. A row of spots along the kidney is also the rule. Short larval gill-rakers are present at least on the first 2 or 3 arches; they are represented by mounds or are absent on the remaining arches; the exception is the 7 mm. larva in Text-fig. 57, which has no trace of rakers, probably because of its youth. For the characteristics of this specimen and of the older larva in Text-fig. 58, see table, p. 81. For characteristics of the growth stages, see p. 76.

## ***Bathophilus brevis*** Regan & Trewavas, 1930.

### Specimens Taken by the Bermuda Oceanographic Expeditions.

4 specimens; May and July, 1929 and 1930; 300 to 900 fathoms; from a cylinder of water 8 miles in diameter (5 to 13 miles south of Nonsuch Island, Bermuda), the center of which is at 32° 12′ N. Lat., 64° 36′ W. Long.; standard lengths from 13 to 26 mm.

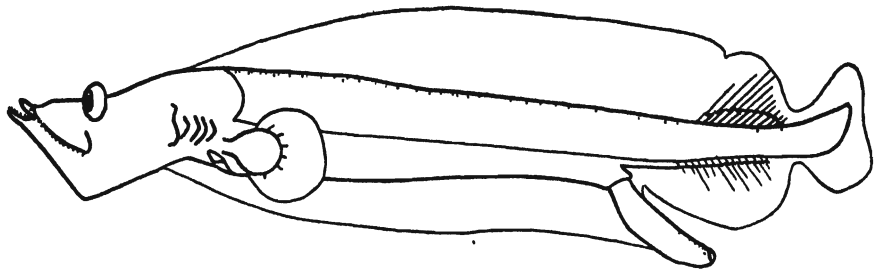
### Specimens Previously Recorded.

6 specimens; approximately between 25 and 175 fathoms; North Atlantic; standard lengths from 15 to 48 mm.

### Description of Transitional Adolescent.

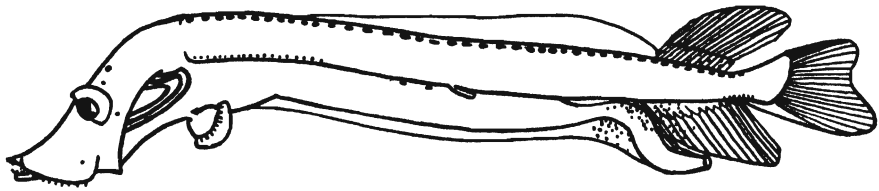
(No adults known).

*Color* (from a single fresh Bermuda specimen frosted with metallic bronze): General color brownish-black; barbel translucent white with a thin thread of red (doubtless blood) down the center; postorbital pale green; non-serial photophores light violet.



Text-figure 57.

*Bathophilus* sp. Larva, standard length 7 mm. See also Text-fig. 2 K.



Text-figure 58.

*Bathophilus* sp., near *longipinnis*. Larva, standard length 11 mm. See also Text-fig. 2 L.

*Proportions*: Depth in length 2.25 to 2.75 (36.5% to 44.5%); head in length 2.4 to 3 (33.3% to 41.5%).

*Barbel*: 1.5 times length of fish, with a tapering end.

*Light Organs*: Postorbital well separated from eye, probably much larger than eye in males; a small luminous patch in front of or below it; another luminous patch on middle of side, between origin of dorsal and anal fins. Serial photophores traceable (but not countable) in fresh specimens only, appearing on lower part of sides in two irregular rows, differentiated from the numerous small non-serial organs by their slightly larger size and brighter violet coloring. All trace of this demarcation, however, is lacking in the same example after preservation; small, non-serial photophores highly developed, distributed all over head and body, (see p. 202).

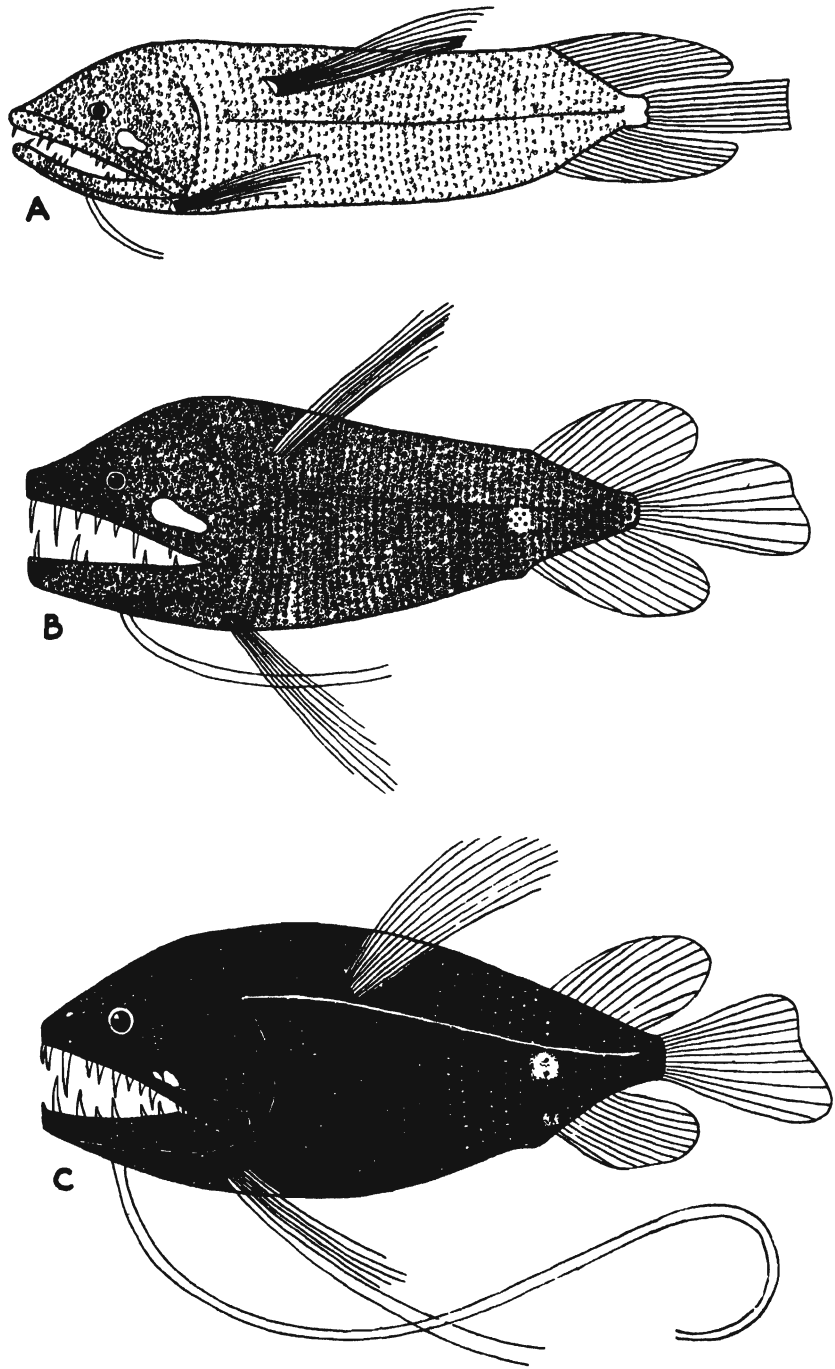
*Teeth*: Relatively larger than in other members of the genus of corresponding stages of development, but in position and character typical of the genus.

*Fins*: Pectoral 2+9 to 11; inserted very low, under opercle; pelvic 11 to 14, inserted much nearer dorsal than ventral profile and about equidistant from end of snout and origin of dorsal; dorsal 10 to 11; anal 9 to 10.

## Development.

*Material*: The Bermuda collection of *Bathophilus brevis* consists of 1 post-larva (13 mm. long), 2 adolescents (13 and 14 mm.) and 1 transitional adolescent (26 mm.). All are typical of their respective growth stages (see p. 77).

There is no trace of serial photophores in the post-larva or adolescent, although the body organs are rudimentary in the former, well developed in the latter. The apparent decrease in the size of the postorbital organ noted by Regan & Trewavas is probably explained by the fact that there was a sexual difference in the specimens examined by these authors; the same is




Text-figure 59.

*Bathophilus brevis.* **A**, post-larva, standard length 13.3 mm.; **B**, adolescent, 13.3 mm.; **C**, transitional adolescent, 26 mm.

true of our own collections, but the examples are too undeveloped internally to determine the sex by genital examination. In the 26 mm. specimen luminous mucous is abundant all over the skin. There is no trace of an antorbital organ in any of the specimens.

*Non-serial Photophores of Head and Trunk*: It seems worth while to describe the non-serial organs of head and trunk, as observed in the Bermuda specimens. As has been said, there are no serial photophores present in this species in the usual sense of branchiostegal, lateral and ventral series. However, the head and body are completely covered with minute organs which are scattered apparently without arrangement over the head, but with the largest of them (Group A below) arranged in more or less regular, single, vertical rows, about 1 to each myomere) on the trunk. The organs may be divided by size into three groups. They appear to be precisely similar all over the fish, both in relative numbers and relative size.

*Group A*: *Large Photophores*: These are the organs referred to above as occurring in vertical rows from gill-opening to caudal base. They are much smaller than regular serial photophores in allied species. All are directed forward, sometimes obliquely upward. In the young adolescent specimen the tips, set in conspicuous black sockets, were pale bluish. In the 25.7 mm. specimen they were mauve. The numbers of this series found on each side of the trunk between gill-opening and caudal base of each of the three specimens is approximately as follows:

| | *Post-larva* | *Adolescent* | *Trans. Adolescent* |
|---|---|---|---|
| Standard length | 13.3 mm. | 13.3 mm. | 25.7 mm. |
| No. vert. rows. | 53 | 56 | 63 |
| Average no. in row at deepest part. | 32 | 45 | 46 |
| Average no. in row at narrowest part. | 6 | 9 | 9 |
| Estimated total. | 850 | 1,400 | 1,500 |

It will be noted that there are approximately the same number of photophores in each of the two older specimens, and more than a third more than in the post-larva. This indicates that new organs are actually developed between the post-larval and early adolescent stages (with no increase in length), but that during the adolescent stage, when the increase in size is great, the number of organs remains constant,—that is, the same number of organs is spread over a much larger expanse of skin.

*Group B*: *Middle-sized Photophores*: Scattered at random between those described above, are at least as many similar lights, varying in size, but on the average less than half the size of the Group A organs. Centers are distinctly visible in the older specimens, but instead of all or even a majority being directed forward, they may be pointed upward, backward, or downward as well. Downward seems to be the least common direction.

*Group C*: *Minute Photophores*: Finally, between these, there are innumerable, minute, slightly elevated pigment spots, at least some of which seem to be luminous organs, since a center is occasionally visible under very high power. It is a question in this fish as to whether there are any epidermal chromatophores which are not luminous organs.

*Development of Head and Trunk Photophores*: In the post-larval specimen the sockets of the Group A organs are developed, as has been stated above, to the number of about two-thirds of those found in the older specimens. No centers, however, are visible, and they are hence probably unfunctional. A comparatively small number of tiny pigment spots scattered among them, some of which are slightly elongate and curved, is the only indication of Groups B and C. The posterior end of the caudal peduncle is entirely destitute of pigment of any kind.

In the early adolescent specimen the centers of all lights of Group A are well-developed, but groups B and C are still almost undifferentiated from each other, with the luminous centers of Group B only rarely developed.

In the largest specimen of 26 mm. all the lights of Groups A and B are fully developed, and, as has been stated, centers are occasionally visible in even the minute organs of Group C.

### Study Material.

The following list gives the catalogue number, depth, date, length and growth stage of each specimen of *Bathophilus brevis* taken by the Bermuda Oceanographic Expeditions. All were caught in the cylinder of water off the Bermuda coast described in *Zoologica*, Vol. XVI, No. 1, p. 5 and Vol. XX, No. 1, p. 1.

No. 9,897; Net 91; 300 F.; May 11, 1929; 14 mm.; Adolescent.
No. 9,930; Net 99; 500 F.; May 14, 1929; 26 mm.; Trans. Adolescent.
No. 11,228; Net 252; 900 F.; July 4, 1929; 13 mm.; Adolescent.
No. 14,993; Net 572; 300 F.; May 12, 1930; 13 mm.; Post-larva.

### References.

*Bathophilus brevis*:

Regan & Trewavas, 1930, p. 66, Pl. III, fig. 1. (6 specimens; 15 to 48 mm.; 150 to 1,000 m. wire; off French Guiana, West of Bermuda, southeast of Bermuda, southwest of Cape Verde Islands and south of Azores).

Beebe, 1933.1, p. 280. (Preliminary list of Bermuda specimens).

Beebe, 1937, p. 199. (Preliminary list of Bermuda specimens).

## ***Bathophilus altipinnis*** Beebe, 1933.

### Type.

(The unique specimen).

Department of Tropical Research No. 10,885; Bermuda Oceanographic Expeditions of the New York Zoological Society; Net 214; June 24, 1929; 8 miles south of Nonsuch Island, Bermuda; 800 fathoms; standard length 63 mm.; a transitional adolescent male.

### Description.

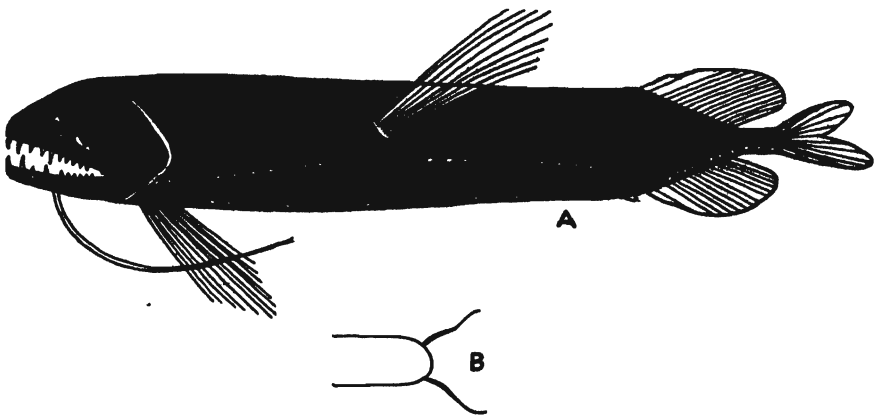
The resemblance of this species to *B. nigerrimus* and *B. proximus* precludes the necessity of a detailed description.

*Measurements*: Total length 70.4 mm.; standard length 63 mm.; depth 10.7 mm. (in length 5.9 or 17%); head 12.6 mm. (in length 5 or 20%); eye 2.4 mm. (in head 5.3 or 3.8% of length; snout 3.3 m. (in head 3.8 or 5.2% of length; pectoral length 14.3 mm.; pelvic length 17.1 mm.; snout to pelvic 29.5 mm.; caudal length 7.4 mm.; suborbital length 2.3 mm. (in head 5.5); barbel length 21.4 mm. (in standard length 2.9 or 34.5%).

*Barbel*: In the freshly caught specimen the barbel, which is undoubtedly complete, was slender and pure white, tapering very gradually and ending in two short, slender filaments.

*Light Organs*: The suborbital photophore is of a flattened, oval shape, and when fully rolled up into view exposes two luminous areas, a small, inferoposterior triangle and a large anterior area, the extreme upper front of which shows in the preserved specimen a white surface, which in the fresh specimen is deep red.

Serial Photophores: lateral series, O-V 13, V-A 11; ventral series, I-P 5, P-V 13, V-A 11, A-C 10.




Text-figure 60.

*Bathophilus altipinnis*. **A**, transitional adolescent, standard length 63 mm.; **B**, same, end of barbel.

*Teeth*: There are 10 premaxillary teeth on the left and 9 on the right side. On each side the second, first and fifth are successively larger, in that order. About 40 small denticles are scattered along the maxillary, the posterior 10 scarcely projecting from the bone. In the mandible, 2 fangs are followed by 8 smaller teeth, the second fang largest, then in succession the first, fourth and third. The vomer is edentulous. There are 2 curved teeth on each palatine, the anterior one the larger. The mandibular symphysis projects as a sharp keel, far ahead of the teeth.

*Fins*: The pectorals have 24 rays in the left and 25 in the right fin. On each side the anterior ray is slightly separated from its fellow, while another slight but bilaterally symmetrical gap occurs between the fifth and sixth rays. Pelvic rays 15; dorsal rays 15; anal rays 15; caudal rays 23.

## Discussion.

This species is closest to *B. nigerrimus* Giglioli and *B. proximus* Regan & Trewavas, having in common with them a moderately deep body (depth 5 to 6 in length), pelvic fins inserted extremely high on the sides of the body, about equidistant from dorsal and ventral profiles, and a large number of rays in the pectoral fins (16 to 50).

From *B. nigerrimus* it differs principally as follows: In the smaller number of rays in the paired fins (pectoral 24 to 25, not 34 to 50, pelvic 15, not 18 to 26) in the shorter barbel, contained nearly 3 times in the length and having 2 short terminal filaments (the most complete barbel of Balducci's[10] series is contained 1.8 times in the length, that in the figure of Regan & Trewavas[11] 1.3, no filaments being mentioned in either case; in Giglioli's[12] type the barbel was entirely missing); in the complete partioning of the suborbital into anterior and posterior luminous triangles and in the absence of a "small, pearl-like protuberance below it;" in the shorter head (contained 5 times in the length, not 4 to 4.5). *B. nigerrimus* is known from about 25 specimens up to 111 mm. in length, taken in the Caribbean Sea, the Gulf of Mexico, the Atlantic and the Mediterranean.

From *B. proximus* the new species differs in the greater number of rays in the pectoral fins (24 to 25, not 16 to 19); in the greater number of photo-

[10] Balducci, 1915: 1-15, pl. 1.
[11] Regan and Trewavas, 1930: 66, pl. 3 fig. 2.
[12] Giglioli, 1884: 261, fig.

phores in the lateral series (O-V 13, not 10; V-A 11, not 10) and in the smaller number in the ventral series (V-A 11, not 13); in the shorter barbel with 2 terminal filaments (contained almost 3 times in the length, not 2.4, as shown in the figure of Regan & Trewavas [13]); in the smaller size and peculiar partition of the suborbital (the figure just mentioned shows a simple oval, larger than the eye; in the present specimen the organ about equals the eye). *B. proximus* is known from a single specimen, 55 mm. in length, from the Atlantic, west of Bermuda.

[13] Regan & Trewavas, *loc. cit.*, 66, pl. 3 fig. 3.

REFERENCES.

*Bathophilus altipinnis*:

Beebe, 1933.2, p. 162. (Preliminary description of specimen described above).

Beebe, 1937, p. 199. (Listing of the same specimen).

## ***Bathophilus metallicus*** (Welsh, 1923).

SPECIMENS TAKEN BY THE BERMUDA OCEANOGRAPHIC EXPEDITIONS.

22 specimens; May to September, 1929 to 1931; 300 to 900 fathoms; from a cylinder of water 8 miles in diameter (5 to 13 miles south of Nonsuch Island, Bermuda), the center of which is at 32° 12′ N. Lat., 64° 36′ W. Long.; standard lengths from 25 to 105 mm.

SPECIMENS PREVIOUSLY RECORDED.

163 specimens; 0 to *ca.* 2,700 fathoms; North Atlantic, between 20° and 43° N. Lat.; standard lengths from 25 to 140 mm.

DESCRIPTION.

(From the largest known specimens, which are probably immature).

*Color* (from field observations upon 5 specimens): General color black, usually with a general greenish or bluish-bronze iridescence and, in addition, with a frosted appearance along the dorsal and ventral profiles, caused by mucous. Barbel translucent white with minute, black framed, pink-centered photophores in distal portion. Postorbital light organ ranging from pale green to lemon yellow. Serial photophores golden yellow. Small, non-serial organs violet.

*Proportions*: Depth in length 7 to 11 (9.2% to 14.3%); head in length 4 to 5.5 (18% to 25%).

*Barbel*: In the largest Bermuda specimen the barbel is slightly longer than the body; the tip is obviously broken; there is a row of tiny photophores in the distal portion.

*Light Organs*: Postorbital at least as large as eye in male, only half as large (though apparently functional) in female. In front of or below this organ an elongate, superficial luminous patch of varying size is usually present; when absent, it has probably been rubbed away accidentally; there seems to be no connection between the size of the patch and the sex of the specimen. Serial photophores with the following counts: ventral series, I-P 5, P-V 13 to 15, including about 2 above the anal fin, V-A 16 to 20, A-C 6 to 7; lateral series, O-V 12 to 14, V-A 14 to 17.

*Fins*: Pectoral 2+1 or 2, the first 2 rays close together, the third isolated, sometimes with a minute fourth ray at its base, which always seems to be present subdermally; pelvic 4 to 6, inserted equidistant from tip of

snout and some part of anal fin; dorsal (11?) 13 to 16; anal (12?) 14 to 17.

*Vertebrae*: 45.

## DEVELOPMENT.

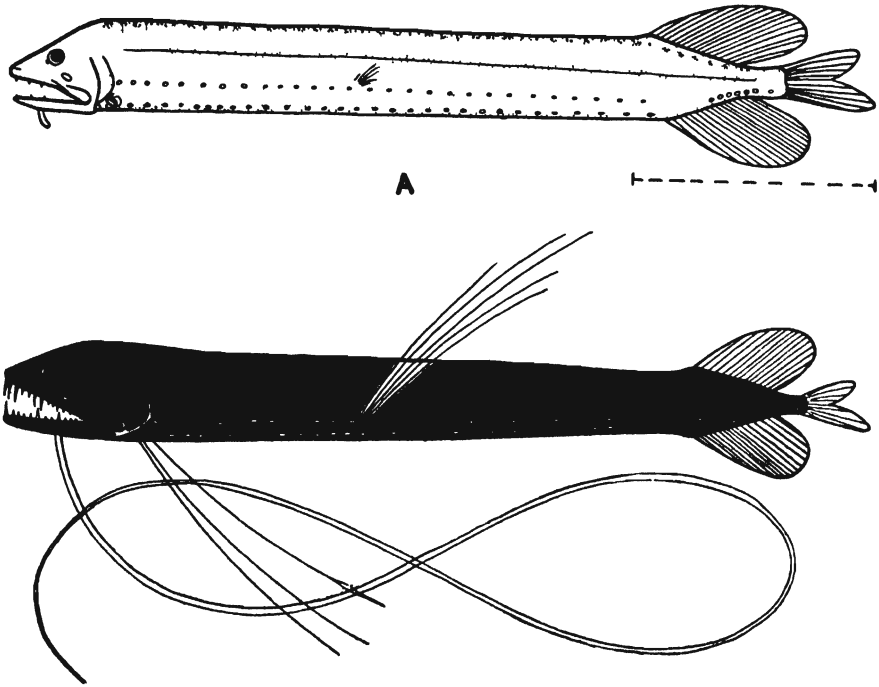
*Material*: The Bermuda specimens are all immature, distributed as follows:

2 post-larvae; 25, 29 mm.; 500, 600 F.; May.
11 adolescents; 30 to 38 mm.; 300 to 900 F.; May to July.
9 transitional adolescents; 44 to 105 mm.; May to September.

They are all typical of their respective growth stages (see p. 77). Their special characteristics are as follows: *Myomeres*: From nape to end of anal, 45; from nape to pelvic insertion, 19; from pelvic insertion to anal origin, 17. *Pigment*: Three or more fine dots on each myomere immediately below dorsal profile. *Gill-rakers*: Moderately long rakers are present in the post larva on the first and second arches; absent on third, fourth and fifth in all specimens. *Sex*: Can be determined in specimens of 68 mm. and over.

## ECOLOGY.

Of the dozen stomachs which were examined (from specimens measuring between 30 and 105 mm.), five contained food—in every case single myctophids, from one-third to one-half the length of the *Bathophilus*. Two




**Text-figure 61.**

***Bathophilus metallicus*. A, post-larva, standard length 29 mm.; B, transitional adolescent, standard length 105 mm. See also Text-fig. 2 M.**

of these ingested fish were species of *Lampanyctus*, one of *Diaphus*, one *Myctophum hygomi* and one unidentifiable. In each one of the 12 *Bathophilus* there was a considerable amount of intestinal material, indicating recent feeding, even when the stomach was empty.

## Study Material.

The following list gives the catalogue number, depth in fathoms, date, length and growth stage of each specimen of *Bathophilus metallicus* taken by the Bermuda Oceanographic Expeditions. All were caught in the cylinder of water off the Bermuda coast described in *Zoologica*, Vol. XVI, No. 1, p. 5 and Vol. XX, No. 1, p. 1.

No. 9,889; Net 94; 600 F.; May 11, 1929; 105 mm.; Trans. Adolescent.
No. 9,997; Net 103; 600 F.; May 15, 1929; 25 mm.; Post-larva.
No. 10,188; Net 130; 500 F.; May 27, 1929; 68 mm.; Trans. Adolescent.
No. 10,203; Net 132; 400 F.; May 28, 1929; 96 mm.; Trans. Adolescent.
No. 10,556; Net 182; 500 F.; June 18, 1929; 30 mm.; Adolescent.
No. 10,557; Net 183; 600 F.; June 18, 1929; 33 mm.; Adolescent.
No. 10,938; Net 211; 500 F.; June 24, 1929; 30, 30 mm.; Adolescents.
No. 11,562; Net 297; 500 F.; July 13, 1929; 34 mm.; Adolescent.
No. 11,575; Net 301; 900 F.; July 13, 1929; 37 mm.; Adolescent.
No. 11,700; Net 311; 600 F.; July 22, 1929; 84 mm.; Trans. Adolescent.
No. 12,545; Net 390; 500 F.; Aug. 8, 1929; 44 mm.; Trans. Adolescent.
No. 12,860; Net 404; 600 F.; Sept. 2, 1929; 95 mm.; Trans. Adolescent.
No. 12,948; Net 409; 500 F.; Sept. 3, 1929; 87 mm.; Trans. Adolescent.
No. 15,353; Net 624; 400 F.; May 23, 1930; 38 mm.; Adolescent.
No. 15,496; Net 645; 600 F.; May 29, 1930; 34 mm.; Adolescent.
No. 15,577; Net 652; 500 F.; May 30, 1930; 29 mm.; Post-larva.
No. 15,738; Net 677; 800 F.; June 5, 1930; 37 mm.; Adolescent.
No. 15,739; Net 679; 400 F.; June 7, 1930; 32 mm.; Adolescent.
No. 16,461; Net 753; 700 F.; July 1, 1930; 105 mm.; Trans. Adolescent.
No. 21,315; Net 1077; 300 F.; July 11, 1931; 35 mm.; Adolescent.
No. 22,199; Net 1158; 600 F.; Aug. 10, 1931; 51 mm.; Trans. Adolescent.

## Synonymy and References.

*?Trichostomias vaillanti*:

Zugmayer, 1911.1, p. 6. (1 specimen; 80 mm.; off southern Portugal; preliminary description).

Zugmayer, 1911.2, p. 78, pl. III, fig. 4. (Full description of the type).

*Trichostomias metallicus*:

Welsh, 1923, p. 10, fig. 10. (9 specimens; 33 to 46 mm.; 50 to 1,000 (-0) M.; between Cape Hatteras and Bermuda; examined by present authors).

*Bathophilus simplex*:

Parr, 1927, p. 87, fig. 9. (1 specimen; 85 mm.; 5,000 ft. wire; off Bermuda; examined by present authors).

*Bathophilus metallicus*:

Regan & Trewavas, 1930, p. 67, pl. IV, fig. 1, text-figs. 1, 13 and 14. (151 specimens; 25 to 140 mm.; 10 to 7,000 m. wire; North Atlantic between 20 and 43 degrees N. Lat.; including the Bermuda region).

Beebe, 1933.1, p. 180. (Preliminary list of Bermuda specimens).

Beebe, 1937, p. 199. (Preliminary list of Bermuda specimens).

*Trichostomias alberti*:

Roule & Angel, 1931, p. 7. (1 specimen; 96 mm.; 0-1000 m.; eastern North Atlantic).

*Bathophilus alberti*:

Roule & Angel, 1933, p. 13. Pl. I, fig. 6.

(Amplified description of preceding specimen).

?*Bathophilus vaillanti*:

Fowler, 1936, p. 204. (Résumé of type description of *T. vaillanti*).

### ***Bathophilus longipinnis*** (Pappenheim, 1914).

SPECIMENS TAKEN BY THE BERMUDA OCEANOGRAPHIC EXPEDITIONS.

2 specimens; May and September, 1929 and 1930; 400 and 900 fathoms; from a cylinder of water 8 miles in diameter (5 to 13 miles south of Nonsuch Island, Bermuda), the center of which is at 32° 12′ N. Lat., 64° 36′ W. Long.; standard lengths 48 and 58 mm.

SPECIMENS PREVIOUSLY RECORDED.

9 specimens; *ca.* 18 to 270 fath.; North and South Atlantic; standard lengths from 26 to 110 mm.

DESCRIPTION.

(All of the recorded specimens are, in all probability, immature).

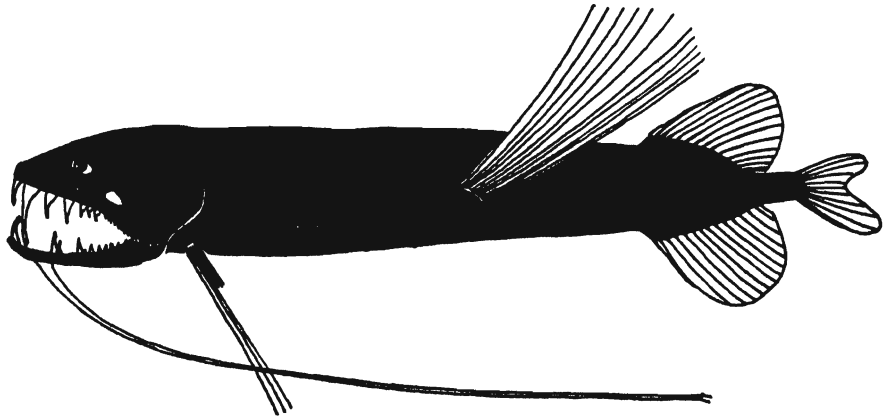
With the characteristics of the genus.

*Color* (from freshly caught Bermuda specimens): General color, pearly gray (probably with mucous); barbel creamy white, with the 2 tiny terminal filaments translucent; postorbital light organ bright yellow in male, pinkish-silver in female, with a silver rim; serial photophores golden yellow; small, non-serial organs pink.

*Proportions*: Depth in length 6.1 to 8 (12.5% to 16.4%); head in length 4 to 5 (20% to 25%).

*Barbel*: About 5/6 as long as fish in a 58 mm. Bermuda specimen, apparently complete, ending in two minute filaments.

*Light Organs*: Postorbital as large as eye in a 58 mm. male, only about half as large in the 48 mm. female. Serial photophores with the following counts: ventral series, I-P 6, P-V 14 to 15, V-A 11 to 13, A-C 5 (starting at



Text-figure 62.

*Bathophilus longipinnis*. Transitional adolescent, standard length 58 mm.

about 8th anal ray; lateral series, O-V 14 to 15, V-A 10 to 11. There are no conspicuous luminous patches, although there are traces of a general covering of probably luminous mucous here and there on the body.

*Fins*: Pectoral 5 to 8, the first 3 rays stronger than the rest; pelvic 11 to 14, inserted slightly behind middle of length; dorsal 14 to 16; anal 15 to 16.

### Development.

The 2 specimens in the present collection are both transitional adolescents, moderately advanced, with characteristics typical of their growth stage (see p. 000).

### Study Material.

The following list gives the catalogue number, depth in fathoms, date, length and growth stage of each specimen of *Bathophilus longipinnis* taken by the Bermuda Oceanographic Expeditions. Both were caught in the cylinder of water off the Bermuda coast described in *Zoologica*, Vol. XVI, No. 1, p. 5 and Vol. XX, No. 1, p. 1.

No. 9,867; Net 87; 400 F.; May 10, 1929; 58 mm.; Trans. Adolescent Male.
No. 19,431; Net 951; 900 F.; Sept. 26, 1930; 48 mm.; Trans. Adolescent Female.

### References and Synonymy.

*Bathophilus longipinnis*:

Regan & Trewavas, 1930, p. 68, Pl. V, fig. 1. (6 specimens; 26 to 110 mm.; 65 to 1,000 m. wire; Florida St., off Leeward Islands and from 700 to 1,300 miles east and southeast of Bermuda).

Norman, 1930, p. 312. (1 specimen, 102 mm.; 650 (-0) M.; 600 miles west of Cape Town).

Beebe, 1933.1, p. 180. (Preliminary list of Bermuda specimens).

Beebe, 1937, p. 199. (Preliminary list of Bermuda specimens).

*Melanostomias longipinnis*:

Pappenheim, 1914, p. 170. (1 specimen, 26 mm.; 20 m.; between Bermuda and Rio d'Oro).

*Gnathostomias longifilis*:

Pappenheim, 1914, p. 172. (1 specimen, 47 mm.; between Bermuda and Rio d'Oro).

*Bathophilus longifilis*:

Fowler, 1936, p. 204. (Résumé of type description of *G. longifilis*).

## ***Bathophilus chironema*** Regan & Trewavas, 1930.

### Specimen Taken by the Bermuda Oceanographic Expeditions.

1 specimen; Department of Tropical Research No. 18,350; Bermuda Oceanographic Expeditions of the New York Zoological Society; Net 869; September 10, 1930; 1,000 fathoms; from a cylinder of water 8 miles in diameter, 5 to 13 miles south of Nonsuch Island, Bermuda, the center of which is at 32° 12′ N. Lat., 64° 36′ W. Long.; standard length 34 mm.

### Specimens Previously Recorded.

5 specimens; *ca.* 41 to 83 fathoms; North Atlantic; standard lengths from 29 to 53 mm.

Text-figure 63.
*Bathophilus chironema*. Transitional adolescent, standard length 34 mm.

DESCRIPTION.

(Doubtless all of the known specimens are immature).

*Proportions*: Depth in length 7 to 9 (11.1% to 14.2%); head in length 5 (20%).

*Barbel*: About half as long as fish in the Bermuda specimen, but end is probably broken off.

*Light Organs*: Postorbital light organ with a round luminous spot in front of it, below eye; usually another small luminous spot behind pelvic fin; serial photophores with the following counts: I-P 5; P-V 15; V-A 12 to 13; A-C 5 to 7; lateral series, O-V 14 to 15; A-C 12 to 13.

*Fins*: Pectoral 2, inserted close together; pelvic 6 to 8, inserted at about the middle of the length; dorsal 14 to 16; anal 15 to 16.

DEVELOPMENT.

The single Bermuda specimen, 34 mm. long, is a young transitional adolescent with characteristics typical of that growth stage (see p. 79). Sex cannot yet be determined.

REFERENCES.

*Bathophilus chironema*:

Regan & Trewavas, 1930, p. 69, Pl. V, fig. 3. (5 specimens, 29 to 53 mm.; 150 to 300 m. wire; Florida Strait and from approximately 300 miles west to 1,300 miles south and east of Bermuda).

Beebe, 1937, p. 199. (Preliminary listing of Bermuda specimens).

## Genus ***Eustomias*** Vaillant, 1888.

(See also pp. 70-75, 79-84, 87-91, 95-97, 99, 102, 103, 105-110).
(Text-figs. 2, 4, 11, 12, 64-77 incl.).

GENERAL DISCUSSION.

The genus *Eustomias* in the broad and usual sense (as understood, for instance, in the monograph by Regan & Trewavas, 1930, p. 71 ff.) is so large and diverse that superficial study indicates that it should be divided into two or more genera. The form varies from moderate to elongate, the teeth from almost all fixed to all depressible, the barbel from long and simple to short and elaborately branched, and the pectoral from having numerous rays to none. Three authors, namely, Gilchrist in 1908 and

Roule & Angel in 1933, felt that these differences were sufficient to divide the genus into two parts, proposing the names *Neostomias* and *Parastomias* respectively for the more specialized species, with the teeth mostly depressible, heads broad, pectorals reduced and barbels elaborate.

A comparative study of the characteristics of all the species, however, shows that they overlap to such an extent that it is impossible to draw a satisfactory generic line between two or more groups of species; also, all of the numerous forms resemble one another in fundamental skeletal characters and general appearance so much more than they do members of other genera that we agree with Regan & Trewavas that it is inadvisable to split the genus, except to the extent of recognizing the subgenera, which the latter authors have proposed.

A total of 52 species is admitted in their monograph[14]. Although the outlines of the main groups (e.g. subgenera) are fairly distinct, neighboring species are often described as differing only in small details of the barbel structure. Both because of lack of adequate new material, and because of our inability to examine the large number of specimens deposited in European museums, we cannot undertake a revision of the genus at the present time. However, from the examples at hand, the need for an extensive reduction in the number of species is clearly apparent, since we have found that, not only the size of the postorbital organ, but the form of the barbel varies extensively with both growth and sex.

Most of the species we have examined belong to the subgenus *Dinematochirus*, characterized chiefly by a barbel having three more or less well developed posterior branches and two pectoral rays. Examination of examples referred to different species, but varying in size and sex, gives the following general results: 1. The final barbel form is assumed only in very late transitional adolescence; specimens which appear adult externally, even to a complicated barbel, actually do not reach their full internal and barbel development until they are much larger. 2. The barbels of adult females differ from those of adult males in having the central branch relatively short—always shorter than the lateral branches, whereas the reverse is true in males; also, this median branch in females has near the tip a well developed bulblet which is small or absent in the male. In the female the major barbel bulb is smaller than in the male, and tends to be oblong rather than round. The postorbital light organ is always very large—as large as or larger than the eye—in the adult male, and atrophied, or at least subdermal, in the corresponding female. In the more primitive subgenera, such as *Nominostomias*, the postorbital is smaller in the male and does not quite atrophy in the female.

We have not seen enough material belonging to other subgenera to generalize on growth and sex characters of the barbels.

Tentative synonymies, some guessed some adequately proven, for the species to which we have had access are as follows:

*E. obscurus* Vaillant, 1888. We have examined the type specimen of *E. proximus* Welsh, 1923, in the U. S. National Museum and agree with Regan & Trewavas (1930, p. 81) that it is identical with *E. obscurus*. Our own Bermuda material is insufficient to determine how much, if any, of the barbel variation shown by the latter authors (text-fig. 58) is sexual.

*E. bibulbosus* Parr, 1927, p. 71; *E. bibulbosus arborifer* (*loc. cit.*); *E. bibulbosus micraster* (*loc. cit.*); *E. bituberatus* Regan & Trewavas, 1930, p. 83; *E. bimargaritatus* Regan & Trewavas, 1930, p. 84. We have examined specimens in our own collection and all of Parr's types, given full specific rank by Regan & Trewavas (1930, pp. 82-85). All specimens with *bibulbosus* forms of barbel are males; those with *arborifer* forms are females. The

[14] Since then the following species have been described: *E. radicifilis* Borodin, 1930; *E. regani* Norman, 1930; *E. trewavasae* Norman, 1930; *E. schiffi* Beebe, 1932; *E. satterleei* Beebe, 1933.

barbel of the type specimen of *arborifer* has characters identical with those shown in the figures of *E. bimargaritatus* Regan & Trewavas, 1930, p. 84, fig. 63. The type of *E. bibulbosus micraster* is a female; judging by analogy with *E. bibulbosus*, *E. bituberatus* Regan & Trewavas, 1930, p. 83, with a simple end to the terminal filament, may turn out to be the male of this long-barbeled form, which certainly requires specific rank. (See p. 219 for description of *E. bibulbosus*).

*E. simplex* Regan & Trewavas, 1930, p. 87. The single Bermuda specimen is a female (p. 221).

*E. polyaster* Parr, 1927, p. 74; *E. dubius* Parr, 1927, p. 66; *E. schiffi* Beebe, 1932. We have examined the types of all of these species, the first two in the Peabody Museum, the last in our own Bermuda collection. It is possible that all are synonymous. The types of *E. dubius* and *E. schiffi* are females, that of *E. polyaster* a male. Parr's figure of the barbel of latter species is somewhat simplified; the figure given by Regan & Trewavas (p. 89, fig. 71, especially the lower cut) from the *Dana* examples represents the type more accurately. It is probable, judging from *E. bibulbosus*, that the lower barbel in the latter figure represents a male, the upper, with branched tip, a female. If this is so, *E. polyaster* and *E. dubius* are distinct; at any rate, they will be so considered in this paper. The specimens referred by Regan & Trewavas (p. 88) to *E. dubius* are probably males, Parr's type of the species, and Beebe's type of *E. schiffi* being females.

The figure given by Parr of the barbel of *E. dubius* is misleading in some respects; his description saying that the barbel is about 3/5 as long as the fish is correct, not the figure, which shows a barbel 1/3 as long as the fish. Also, under fairly high power, the bases of 10 or 11 separate filaments are seen to form the "fan," including two from the anterior and posterior sides of the terminal appendage, respectively, there are, in addition, distinct traces of damage to the organ. Judged in this light, there is not the slightest question but that *E. schiffi* is an undamaged example of the same species (and sex). The difference in barbel lengths between the examples of Parr and of Regan & Trewavas is probably due to different growth rates between barbel and body length, as is known to occur in other genera. (See p. 222).

*E. longibarbus* Parr, 1927, p. 64; *E. microcephalus*, Parr, 1927, p. 75. We have examined the types of these specimens at the Peabody Museum. As Regan & Trewavas (1930, p. 86) suggest, *E. microcephalus* is probably the young of *E. longibarba*, although due to the youth of the latter, an early adolescent, their identity cannot be proved; at least 10 or 11 pairs of larval spots remain on the young example. Both the type specimens of *E. longibarba* are immature females; in both the terminal papilla on the barbel has nodules as in the figure given by Regan & Trewavas (1930, p. 86, fig. 66 A, B); the postorbital is almost atrophied, being minute and barely visible beneath lightly pigmented skin—considerably smaller and less conspicuous than in the figure given by Parr (p. 64, fig. 35).

*E. brevibarbatus* Parr, 1927, p. 68. The type specimen has, as Regan & Trewavas (1930, p. 92) suggest, some pigment on the stem between the bulbs, but not on the bulbs themselves. Also, the fish is definitely juvenile, in the middle of the adolescent stage. *E. micropterygius* is more likely to be the young of this species than of *E. macrophthalmus*.

*E. micropterygius* Parr, 1927, p. 65. We have examined the 57 mm. type, which Regan & Trewavas (1930, p. 93) suggested was the young of *E. macrophthalmus* or an allied species. It proves to be an early adolescent, with the specific characters as yet undeveloped. There is a distinct trace of a smaller bulb anterior to the larger terminal one; to the latter is attached a long, slender, almost filamentous papilla. There are traces of 8 larval pigment spots situated well below the dorsal profile.

*E. macrophthalmus* Parr, 1927, p. 67, figs. 36c, 39. We have examined

the 104 mm. type, which is an immature female. The postorbital organ is minute. The end of the barbel in the type figure is somewhat too thick, the illustration given by Regan & Trewavas (1930, p. 93, fig. 77) being more representative.

*E. lipochirus* Regan & Trewavas, 1930, p. 95. The Bermuda collection contains a single specimen, too young to sex. In all probability this species will prove to be identical with one or more of its neighbors (p. 224).

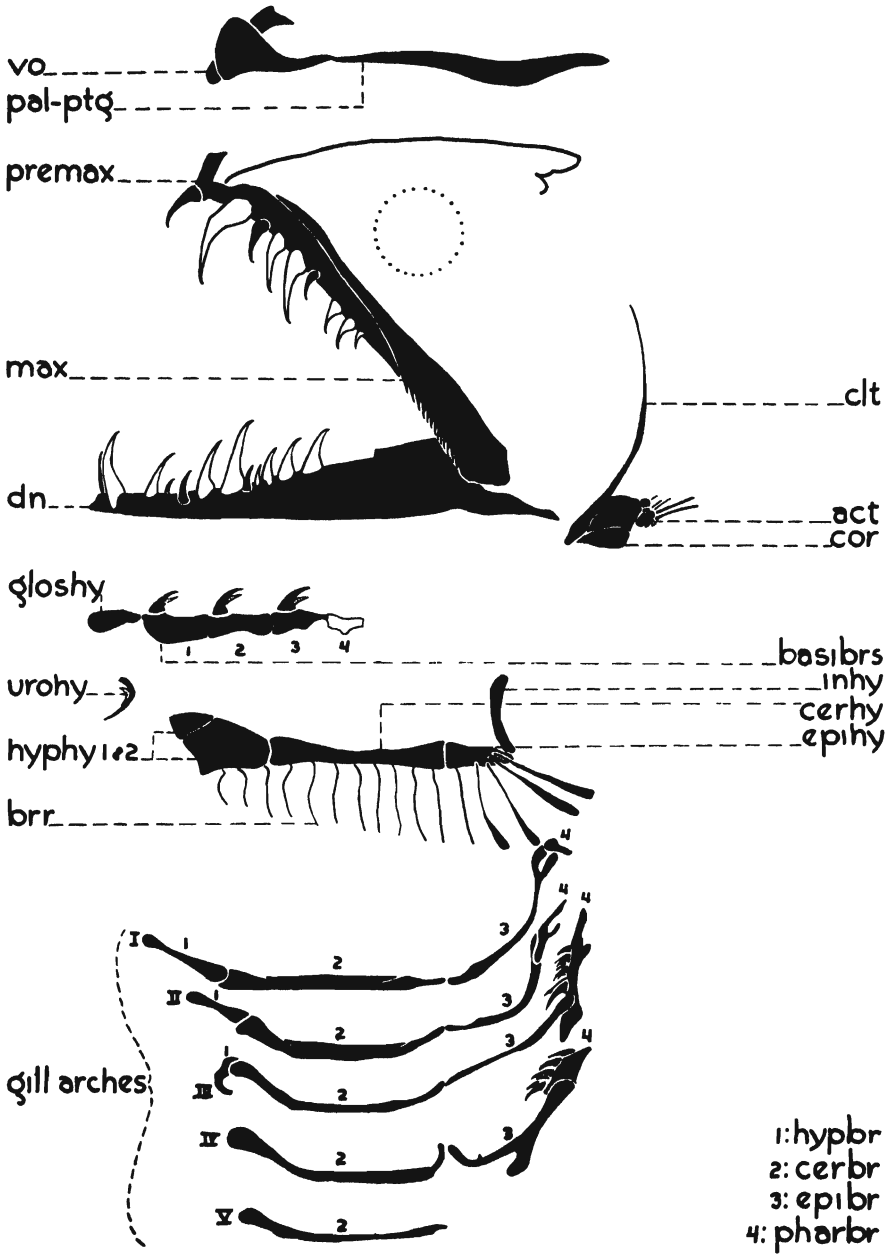
*E. bigelowi* Welsh, 1923, p. 6; *E. bigelowi paucifilis* Parr, 1927, p. 79; *E. bigelowi parvibulbus* Parr, 1927, p. 79; *E. triramis* Regan & Trewavas, 1930, p. 99. We have examined the types of all these species except the last, at the U. S. National and Peabody Museums, and compared them with our own specimens. We are convinced that all are the same species, their differences being due solely to age and sex. *E. bigelowi* and *E. bigelowi parvibulbus* are females, the *parvibulbus* type being the older, near breeding condition. In the latter specimen the terminal ends of the barbel are much more elaborately branched than could be shown in the small figure given by Parr (fig. 46). Also, there is more of a definite bulb, with the transparent outer covering of the bulb continuing farther back than the figure shows. The lateral branchlets have three to five small filaments. The type of *E. bigelowi paucifilis*, on the other hand, is a male, with gonads less than half developed; the figure given with the type description is accurate. *E. triramis* probably represents a growth stage still younger than that of the original *E. bigelowi*. (See p. 225.)

*E. binghami* Parr, 1927, p. 80; *E. frondosus* Regan & Trewavas, 1930, p. 103. We have examined the type of the former in the Peabody Museum, and find that there is a median, short, simple, barbel branch, just as in *frondosus*, the end microscopically swollen. Also, along each branch (except the median one) there are from 2 to more than 6 minute, but perfectly distinct, filaments; of these 1 near the tip of 3 of the 4 branches, has a distinct bulblet, the whole being as in fig. 92 given by Regan & Trewavas. There are traces of even smaller bulbs on several of the filaments. Therefore, *binghami* and *frondosus* are synonymous, *binghami* taking precedence. The type of the latter is a male, the gonads being less than one-half developed. It is probable, judging from analogy in other species, that in the figure given by Regan & Trewavas the upper barbel is of a female, and the two lower ones of males.

*E. silvescens* Regan & Trewavas, 1930 and *E. satterleei* Beebe, 1933. Judging again by analogy of barbel structure, we synonymize *E. satterleei*, a female, with *E. silvescens*, which, from the size of the postorbital organ in the illustration of the type (Regan & Trewavas, 1930, pl. IX, fig 2), is undoubtedly a male. (See p. 228).

*E. fissibarbis* (Pappenheim, 1914, p. 175); *E. nigrifilis* Parr, 1927, p. 81; *E. dendriticus* Regan & Trewavas, 1930, p. 104. We have examined the type of *E. nigrifilis* at the Peabody Museum, and agree with Regan & Trewavas (1930, p. 103) that it is synonymous with *E. fissibarbis*. It is a female with the gonads about one-half developed. The figure of the type does not show the tipped filament on the posterior surface of the bulb, which is in about the same position as one in the Bermuda collection. There are also, in *nigrifilis*, two very slender, simple filaments from the anterior face of each of the two minor branches, just before they divide, this is another characteristic of the Bermuda specimens. We think it likely that *E. dendriticus* will prove to be the male of *E. fissibarbis*. (See p. 232).

*Distribution*: *Eustomias* is known only from the North and South Atlantic, from about 390 specimens. Of the 60-odd species which have been described, probably less than half will prove to be valid, when adequate material has been obtained. The known vertical range of distribution is between the surface (young) and 1,000 fathoms.

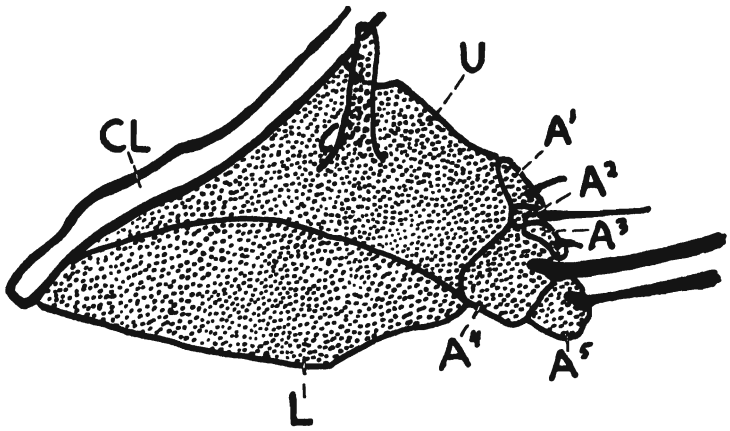



Text-figure 64.

*Eustomias fissibarbis.* Jaws, hyoid and branchial arches, and pectoral girdle of adult, standard length 130 mm. Explanation as in Text-fig. 18.

## Generic Characters.

*Color* (from fresh specimens of 7 species): General color brownish-black; postorbital light organ silvery- or opalescent-white; barbel bulb




Text-figure 65.

*Eustomias fissibarbis*. Supporting bones of pectoral fin in adult, standard length 130 mm. Abbreviations as in Text-fig. 14.

and branches pink, yellow, green or blue; serial photophores violet with gold frames.

*Proportions*: Elongate melanostomiatids with protractile snouts. Depth in length 10 to 15 (6.7% to 10%); head in length 4.5 to 7 (14.3% to 22.2%); eye in head 4.5 to 7; snout when extended much longer than eye; snout to pelvic in length *ca.* 1.8 to 2 (50% to 56%).

*Barbel*: From shorter than head to almost as long as fish; stem with or without branches above the bulb; bulb simple or filamented; a second bulb sometimes present.

*Light Organs*: Postorbital almost or completely atrophied in adult female, moderate to very large in male; serial photophores with the following counts: I-P 7 to 8; P-V and O-V 24 to 31; V-A 12 to 21, A-C 16 to 25. Non-serial light organs usually inconspicuous.

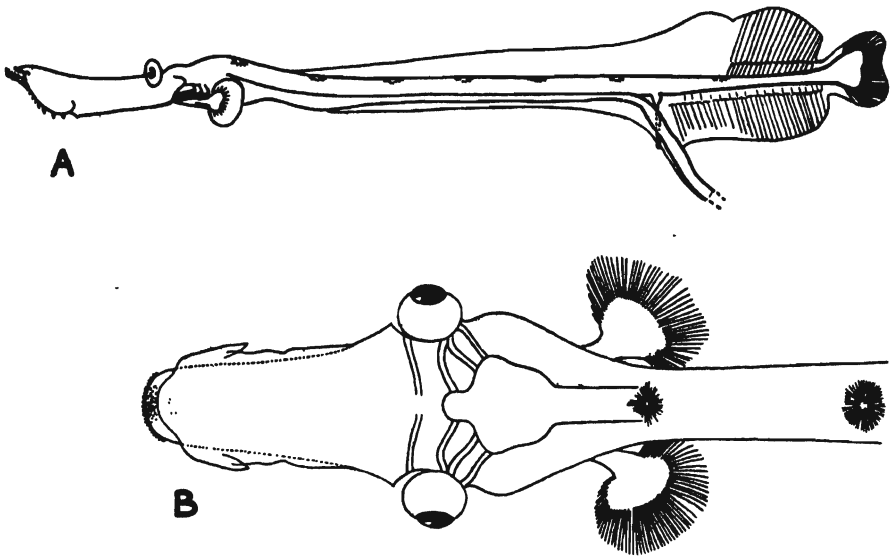
*Teeth*: Cleft of mouth straight; teeth in jaw very variable, ranging from mostly fixed and relatively few to mostly depressible and rather numerous; no teeth on vomer or palatine; three pairs on basibranchials; no teeth on gill-arches.

*Branchiostegal Rays*: About 16.

*Fins*: Pectoral with 0 to 13 rays, short or long; pelvic 7; placed about middle of length or behind it; dorsal 21 to 30; anal 33 to 46, beginning far in front of dorsal and ending slightly behind it.

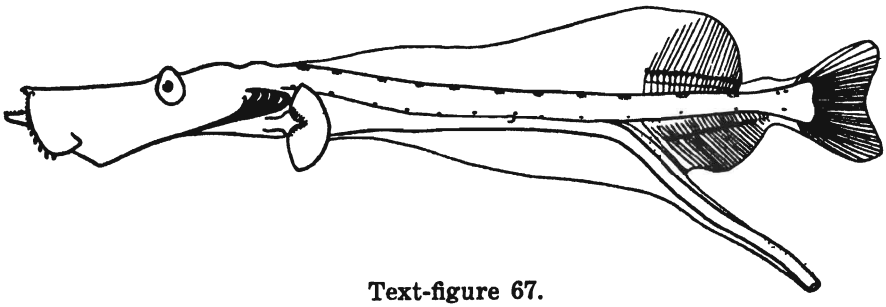
*Epidermal Grooves*: A pronounced groove in the isthmus for grasping the stem of the barbel.

*Osteology*: Mesethmoid with lateral processes; parietals absent; palatine and ectopterygoid loosely attached by ligaments to mesethmoid and quadrate, respectively, but firmly fastened to premaxillary and maxillary; this arrangement permits the forward projection of the jaw; post-temporal absent; supra-cleithrum absent; upper and lower coracoids large and laminar; mesocoracoid absent; actinosts 5 in species with 2 pectoral rays, with rudiments of 3 other rays; vertebrae about 66 to 77; anterior 9 or 10 vertebrae highly modified; centra of all except third vertebra absent; no neurapophyses before the third, which are large and meet above; behind this the notochord bends sharply in a ventrally convex loop which includes the displaced centrum of the third vertebra; four pairs of strong neurapophyses behind the loop, belonging to the sixth to ninth vertebral segments; some-



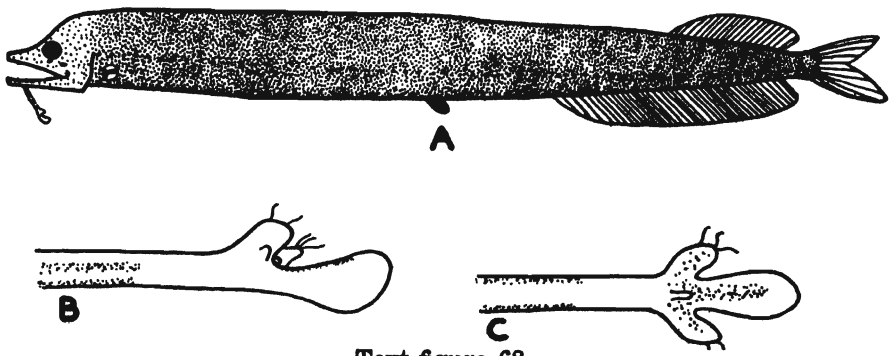

Text-figure 66.

*Eustomias* sp. Larva, standard length 13 mm. **A**, lateral view; **B**, dorsal view of head. See also Text-fig. 2 O.



Text-figure 67.

?*Eustomias* sp. Larva, standard length 12 mm. See also Text-fig. 2 N.




Text-figure 68.

*Eustomias* sp. Subgenus *Dinematochirus*. Transitional post-larva, standard length 43 mm. **A**, lateral view; **B**, barbel, lateral view; **C**, barbel, posterior view.

times a smaller loop behind these, formed by the last 2 modified and first normal vertebrae; no parapophyses before third vertebra; subsequent ones in modified portion small or minute, with or without pleural ribs and epipleurals, sometimes absent posteriorly.

*Coelomic Organs*: Stomach 22% (subgenus *Dinematochirus*) to 38% (subgenus *Nominostomias*) of standard length. Two pyloric caeca.

*Sexual Dimorphism*: Postorbital light organ almost or completely atrophied in adult female. Barbel branches and filaments different in the sexes, the trend of variation depending on the subgenus. (See p. 211).

*Size*: The largest known specimen of *Eustomias* is the type of *E. bigelowi parvibulbus* (adult female *E. bigelowi*), 204 mm. long, taken by the Bingham Oceanographic Expeditions. It is near breeding condition. Sex can be determined in transitional adolescents measuring from around 90 or 100 mm. Two Bermuda males, *E. bigelowi* and *E. fissibarbis*, measuring 138 and 118 mm., are apparently adult, with gonads well, but not fully, developed.

*Development*: The larvae of *Eustomias* are very distinct, bearing a close resemblance to those of *Idiacanthus*, except that the eyes are not stalked and the pigment spots are fewer (no more than 5 to 11 pairs), instead of one to each myomere, and dorsally instead of laterally located. The snout is long and flattened, with a small, terminal mouth; the head is correspondingly large; the finfolds are small, and the gut is longer than usual, extending behind the caudal fin when unbroken; larval gill-rakers are well developed at least on the first arch; on succeeding arches they are in the form of spiny mounds or are rudimentary; they are usually absent on the fifth arch.

The Bermuda Expeditions took 4 larvae and 12 post-larvae, none of which can be specifically identified because of the lack of a barbel. In the future complete life-histories will perhaps be worked out by tabulating the myomeral positions of the pigment spots when adequate material has been obtained. The subgenus of post-larvae can usually be determined through photophore counts; it is certain that the number of pairs of spots is not constant or even similar in each subgenus: in *Nominostomias* we have young with spots ranging from 7 to 10; in *Dinematochirus* from 5 to 10.

It is highly probable that the larva in Text-fig. 66B does not belong to *Eustomias*, since it has only about 55 myomeres to the end of the anal, instead of more than 70; if it is not a *Eustomias*, it may belong to some genus hitherto undiscovered, since its characteristics are otherwise definitely eustomiad. In addition to the usual paired dorsal spots, this specimen has an internal row of dots, along the kidney, as in *Bathophilus*. (See table, p. 81, for other *Eustomias* characters, and p. 76 for characteristics of the growth stages).

## Subgenus ***Eustomias*** Vaillant, 1888.

### ***Eustomias obscurus*** Vaillant, 1888.

SPECIMENS TAKEN BY THE BERMUDA OCEANOGRAPHIC EXPEDITIONS.

5 specimens; May to September, 1929 and 1930; 500 to 700 fathoms; from a cylinder of water 8 miles in diameter (5 to 13 miles south of Nonsuch Island, Bermuda), the center of which is at 32° 12′ N. Lat., 64° 36′ W. Long.; standard lengths from 51 to 98 mm.

SPECIMENS PREVIOUSLY RECORDED.

About 195 specimens; 0 to 2,011 fathoms; North and South Atlantic; standard lengths from 52 to 180? mm.

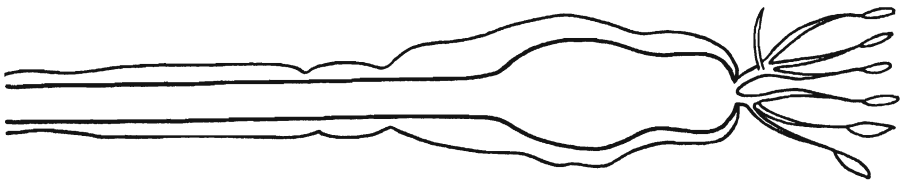
## Description of Adult.

With the characteristics of the genus.

This species is the only known *Eustomias* having some of the photophores of the lateral series in pairs.

*Color* (from a fresh transitional adolescent): Skin dark brownish-black; postorbital light organ brilliant silvery-white; barbel stem, terminal filaments and outer covering of bulb translucent white; core of bulb violet proximally yellowish, green distally.

*Proportions*: Depth in length 12 to 20 (5% to 8.5%); head in length 7.3 to 9.5 (11% to 13.7%); eye in head 4.5 to 7 (14.3% to 22.2%); interorbital in head 8 to 13 (7.7% to 12.5%).



Text-figure 69.

*Eustomias obscurus*. Barbel of transitional adolescent, standard length 98 mm.

*Barbel*: From less than ¼ to more than ½ length of fish; stem unpigmented with a terminal, oval or pear-shaped bulb; the latter is very variable in shape, sometimes having a deep median constriction; there are a number (usually 3 to 8) of distal, translucent filaments with swollen tips, which sometimes arise from a single, distal stalk and sometimes separately, and are often in 2 groups. Sexual dimorphism probably plays a part in the variation.

*Light Organs*: Postorbital apparently small even in males. Serial photophores with the following counts: ventral series, I-P 7, P-V 33 to 35; V-A 15 to 16, A-C 19 to 22; lateral series O-V 30 to 37, V-A 15 to 18. Many of the organs in the lateral series are paired, the arrangement varying in individual fish.

*Teeth*: First tooth in upper jaw and second in lower fixed fangs, directed slightly forward and outward; separated by a gap from second tooth which is about the same size, no larger, and depressible; following are depressible teeth and 1 or 2 outer, fixed teeth.

*Fins*: Pectoral 3; pelvic 7, inserted behind middle of length; dorsal 23 to 30; anal 34 to 36.

## Development.

The five specimens of the Bermuda collection consist of 2 post-larvae (51, 55 mm.), 2 adolescents (55, 57 mm.), and 1 transitional adolescent (98 mm.). All have the characteristics of their respective growth stages (see p. 77). In the post-larvae are at least 9 pairs of pigment spots. The transitional adolescent too young to be sexed.

## Study Material.

The following list gives the catalogue number, depth in fathoms, date, length and growth stages of each specimen of *Eustomias obscurus* taken by the Bermuda Oceanographic Expeditions. All were caught in the cylinder of water off the Bermuda coast described in *Zoologica*, Vol XVI, No. 1, p. 5 and Vol. XX, No. 1, p. 1.

No. 9,951; Net 100; 600 F.; May 14, 1929; 55 mm.; Adolescent.
No. 14,944; Net 574; 500 F.; May 14, 1930; 98 mm.; Trans. Adolescent.
No. 15,006; Net 583; 700 F.; May 15, 1930; 55 mm.; Post-larva.
No. 15,191; Net 606; 500 F.; May 20, 1930; 57 mm.; Adolescent.
No. 19,111; Net 922; 600 F.; Sept. 20, 1930; 51 mm.; Post-larva.

REFERENCES AND SYNONYMY.

*Eustomias obscurus*:

Vaillant, 1888, p. 113; pl. VIII, figs. 3, 3a. (1 specimen; 165 mm.; 2,792 m.; off Azores).

Zugmayer, 1911.2, p. 75. (1 specimen; 180 mm.; 3,660-0 m.; eastern Atlantic).

Parr, 1927, p. 63. (Résumé of type description).

Regan & Trewavas, 1930, p. 81; pl. VII, fig. 4 (191 specimens; 52 to ? mm.; 25 to 5,000 m. wire; North Atlantic).

Norman, 1930, p. 313. (1 specimen; 156 mm.; 250 (-0) m.; tropical South Atlantic).

Roule & Angel, 1933, p. 11 (2 specimens; 150 and 170 mm.; 0-550 m.; off Azores).

Fowler, 1936, p. 208. (Copy of type description).

Beebe, 1937, p. 199. (Preliminary list of Bermuda specimens).

*Eustomias macrorhynchus*:

Pappenheim, 1914, p. 173, figs. 2, 3. (3 specimens; 42 to 105 mm.; 0-20 mm.; eastern Atlantic).

Parr, 1927, p. 62 (Résumé of type description).

Fowler, 1936, p. 207. (Copy of type description).

*Eustomias proximus*:

Welch, 1923, p. 5, figs. 3, 4. (6 specimens; 75 to 132 mm.; 100 to 0 m.; western North Atlantic). Examined by present authors in U. S. National Museum.

Parr, 1927, p. 63. (Résumé of type description).

*Eustomias zugmayeri*:

Parr, 1927, p. 62. (Elevation of Zugmayer's specimen of *E. obscurus* to a new species).

## Subgenus ***Nominostomias*** Regan & Trewavas, 1930.

### ***Eustomias bibulbosus*** Parr, 1927.

(See also p. 211).

SPECIMENS TAKEN BY THE BERMUDA OCEANOGRAPHIC EXPEDITIONS.

8 specimens; April to September; 1929 and 1930; 500 to 900 fathoms; from a cylinder of water 8 miles in diameter (5 to 13 miles south of Nonsuch Island, Bermuda), the center of which is at 32° 12′ N. Lat., 64° 36′ W. Long.; standard lengths from 42 to 123 mm.

SPECIMENS PREVIOUSLY RECORDED.

4 specimens; *ca.* 83 to 550 fathoms; western North Atlantic; standard lengths from 105 to 136 mm.

## Description of Adult.

With the characteristics of the genus.

*Color* (from field notes made on two specimens, of which one was living): General color black with bronze iridescence; distal barbel bulb of male clear pink, but giving off pale green light in dark-room; proximal bulb and stem translucent white without visible luminescence; postorbital of male silver white; serial photophores purple, the ventral series having broad gold frames.

*Proportions*: Depth in length 12 to 13.6 (7.3% to 8.3%); head in length 7.5 to 8 (12.5% to 13.3%); eye in head 4.3 to almost 5 (20% to 23.3%).

*Barbel*: Slightly shorter or longer than fish; stem unbranched; two bulbs and a long tapering terminal appendage, about half length of head; unbranched proximally in both sexes, but with distal filaments in female. Bulbs subequal or the distal larger, separated by a distance 2 or 3 times the diameter of the larger.

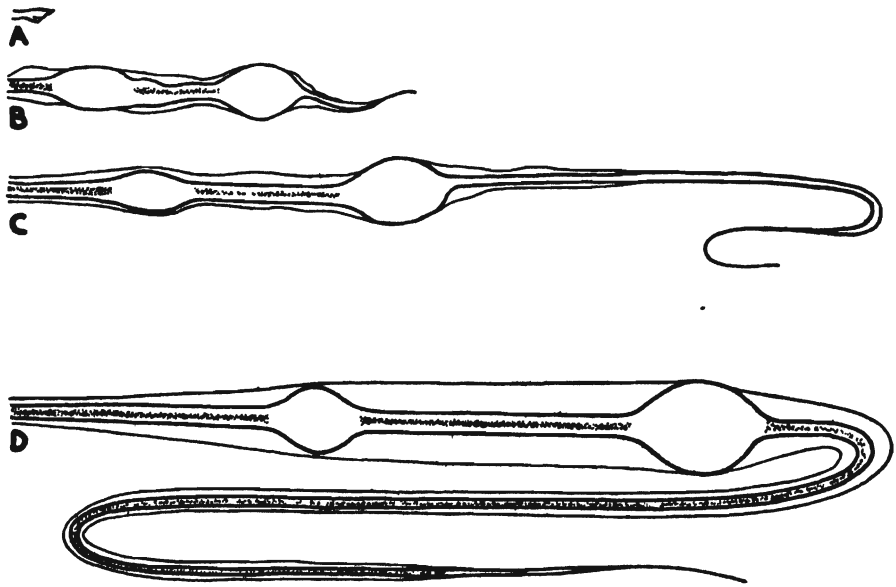
*Light Organs*: Postorbital smaller than eye in both sexes, but apparently functional in both; much smaller in female than in male. Serial photophores with the following counts: ventral series, I-P 7 or 8, P-V 30 to 32, V-A 18, A-C 17 to 19; lateral series, O-V 30 to 33; V-A 17 to 19.

*Teeth*: Anterior fangs (first tooth in upper jaw, second in lower) fixed; second fang in upper jaw fixed or depressible, larger than first; behind these in both jaws a series of depressible teeth and a few small, outer fixed ones.

*Fins*: Pectoral 3; dorsal 23 to 25; anal 38 to 39.

## Development.

The Bermuda collection is composed of 2 post-larvae (42, 52 mm.), 3 adolescents (52 to 58 mm.), 2 transitional adolescents (64 and 95 mm.)




Text-figure 70.

*Eustomias bibulbosus*. **A**, post-larva, standard length 52 mm.; **B**, adolescent, standard length 58 mm.; **C**, transitional adolescent, standard length 64 mm.; **D**, adult male, standard length 123 mm.

and 1 adult male (123 mm.). The post-larvae could be referred to other closely related species (such as *E. bituberatus*), but *E. bibulbosus* is the only one which has been taken by the Bermuda Expeditions, and for the sake of completing the series they are referred to *bibulbosus*. All the young are characteristic of their respective stages (see pp. 76-79). Remains of 8 pairs of larval spots are found, and an additional small pair at base of caudal.

### Study Material.

The following list gives the catalogue number, depth in fathoms, date, length and growth stage of each specimen of *Eustomias bibulbosus* taken by the Bermuda Oceanographic Expeditions. All were caught in the cylinder of water off the Bermuda coast described in *Zoologica*, Vol. XVI, No. 1, p. 5 and Vol. XX, No. 1, p. 1.

No. 8,798; Net 23; 600 F.; April 15, 1929; 95 mm.; Trans. Adolescent.
No. 10,134; Net 122; 700 F.; May 25, 1929; 52 mm.; Post-larva.
No. 10,293; Net 148; 700 F.; June 1, 1929; 123 mm.; Adult Male.
No. 13,131; Net 427; 900 F.; Sept. 5, 1929; 50 mm.; Adolescent.
No. 17,738; Net 828; 500 F.; Sept. 2, 1930; 58 mm.; Adolescent.
No. 17,770; Net 836; 500 F.; Sept. 3, 1930; 64 mm.; Trans. Adolescent.
No. 17,901; Net 841; 500 F.; Sept. 4, 1930; 57 mm.; Adolescent.
No. 18,589; Net 889; 500 F.; Sept. 15, 1930; 42 mm.; Post-larva.

### Synonymy and References.

*Eustomias bibulbosus bibulbosus*:

Parr, 1927, p. 70 (1 specimen; 121 mm.; 7,000 ft. wire; southeast of Nassau). A male; examined by present authors.

*Eustomias bibulbosus*:

Regan & Trewavas, 1930, p. 82, fig. 61A. (2 specimens; 132 and 136 mm.; 300, 1,100 m. wire; northwest and southeast of Bermuda).

Fraser-Brunner, 1931, p. 218. (1 specimen; 54 mm.; tropical South Atlantic).

Beebe, 1937, p. 199. (Preliminary list of Bermuda specimens).

*Eustomias bibulbosus arborifer*:

Parr, 1927, p. 70. (1 specimen, 115 mm.; 6,000 ft. wire; Bahamas). A female; examined by present authors.

*Eustomias arborifer*:

Regan & Trewavas, 130, p. 85. (Résumé of preceding description).

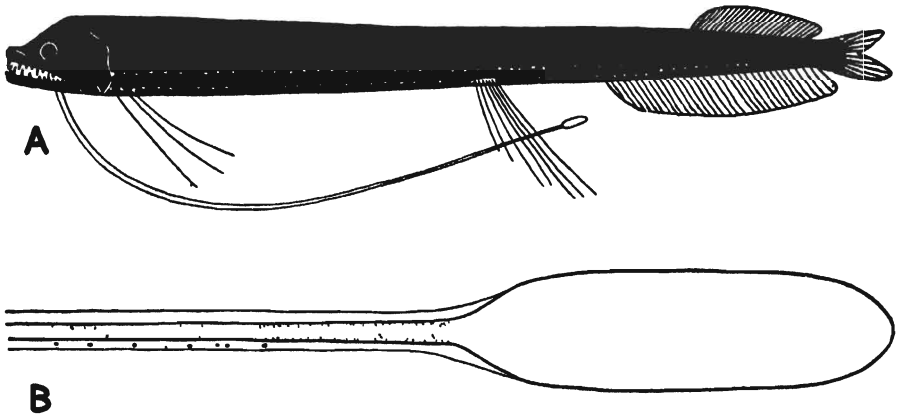
## ***Eustomias simplex*** Regan & Trewavas, 1930.

### Specimen Taken by the Bermuda Oceanographic Expeditions.

1 specimen (Department of Tropical Research No. 9,750; Net 64); May 4, 1929; 600 fathoms; from a cylinder of water 8 miles in diameter (5 to 13 miles south of Nonsuch Island, Bermuda), the center of which is 32° 12′ N. Lat., 64° 36′ W. Long.; standard length 91 mm., a female.

### Specimens Previously Recorded.

3 specimens; *ca.* 22 to 83 fathoms; western North Atlantic; standard lengths from 50 to 75 mm.




Text-figure 71.

*Eustomias simplex*. Transitional adolescent, standard length 91 mm. **A**, lateral view; **B**, end of barbel.

DESCRIPTION OF TRANSITIONAL ADOLESCENT.

(No adults known).

With the characteristics of the genus.

*Proportions*: Depth in length 10 to 12 (8.3% to 10%); head in length 7 to 8 (12.5% to 14.3%); eye in head 5.7 to 6 (16.7% to 17.6%), equal to interorbital width.

*Barbel*: From ½ to ⅔ as long as fish, terminating in a simple, oval bulb without appendages. The stem is translucent with a lightly pigmented, core. In the Bermuda specimen the bulb is an elongate oval, without the slight constriction shown in the illustration of the type specimen (Regan & Trewavas, 1930, fig. 66C).

*Teeth*: The teeth of the Bermuda specimen are very similar in arrangement to that shown in the diagram accompanying the type description (*loc. cit.*, fig. 67B). However, the second premaxillary fang seems to be fixed, not depressible, and there are several more teeth in the posterior part of the mandible. Two pairs of teeth on the palatines.

*Fins*: Pectoral 3, the first and second set close together; dorsal 23 to 26; anal 32 to 36.

The Bermuda female is a typical advanced transitional adolescent (see p. 79).

REFERENCES.

*Eustomias simplex*:

Regan & Trewavas, 1930, p. 87, figs. 66C, 67B. (Type description).

Beebe, 1937, p. 199. (Preliminary listing of Bermuda specimens).

## ***Eustomias dubius*** Parr, 1927.

(See also p. 212).

SPECIMENS TAKEN BY THE BERMUDA OCEANOGRAPHIC EXPEDITIONS.

3 specimens; May to October, 1930 and 1931; 600 fathoms; from a cylinder of water 8 miles in diameter (5 to 13 miles south of Nonsuch Island, Bermuda), the center of which is at 32° 12′ N. Lat., 64° 36′ W. Long.; standard lengths from 43 to 115 mm.

### Specimens Previously Recorded.

4 specimens; *ca.* 250 to 585 fathoms; western Atlantic; standard lengths from 72 to 122 mm.

### Description of Transitional Adolescent.

(No completely mature specimens have been taken, judging by the 115 mm. Bermuda example).

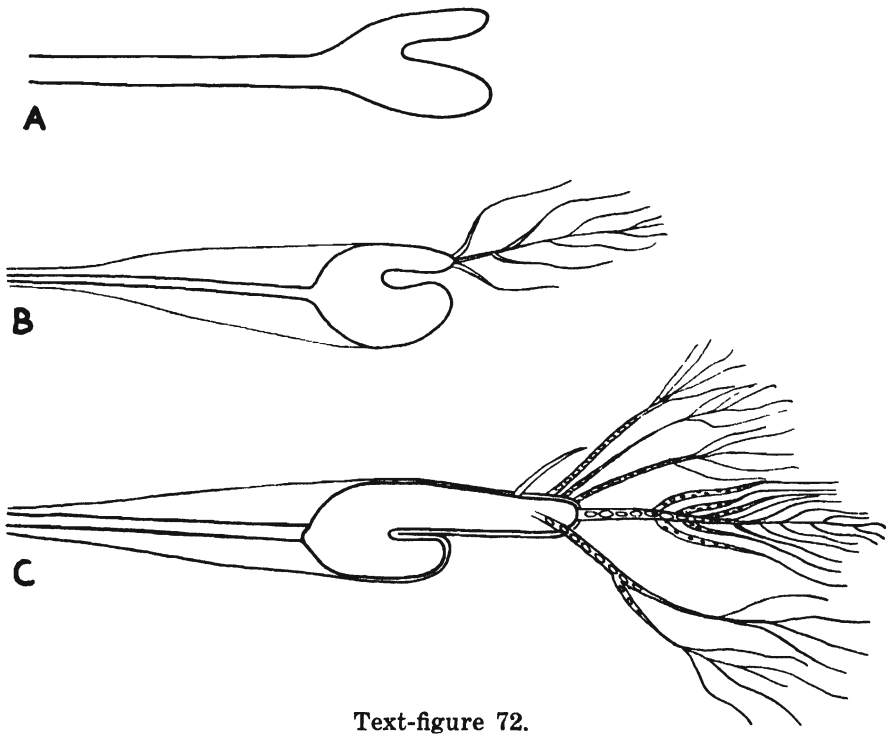
With the characteristics of the genus.

*Color* (from the freshly caught, 115 mm. Bermuda specimen): General color dark brown; barbel bulb with the predominating colors peacock and turquoise blue; postorbital light organ silvery-white; serial photophores reddish-violet.

*Proportions*: Depth in length 11 to 15 (6.7% to 9.1%); head in length 7.5 to 8 (2.5% to 13.3%); eye in head 5 to 6 (16.7% to 20%).

*Barbel*: 1/3 to 3/5 as long as fish; stem translucent with a thin core speckled with dendritic chromatophores; bulb divided by a deep distal notch into an anterior short lobe and a posterior longer lobe, the latter being long, slender, and tipped with two short, simple filaments, or shorter, and tipped with an elaborately branched cluster of filaments. The difference is in all probability sexual, the elaborate form belonging to the female in the specimens we have examined.

*Light Organs*: Postorbital of female much smaller than eye but apparently functional. Serial photophores with the following counts: ventral




Text-figure 72.

*Eustomias dubius*. Barbels, lateral view. **A**, post-larva, standard length 43 mm.; **B**, adolescent, 58 mm.; **C**, transitional adolescent, 115 mm.

series, I-P 7 to 8, P-V 32 to 35; V-A 13 to 16; A-C 18; lateral series, O-V 33 to 35; V-A 15 to 17. Non-serial photophores unusually prominent, in vertical bands.

*Fins*: Pectoral 2; dorsal 23; anal 37.

### Development.

The Bermuda collection consists of a late post-larva (43 mm.), and 2 transitional adolescents (58 and 115 mm.), the larger being a female. Their characteristics are typical of their respective growth stages (see p. 77). On the post-larva are 7 pairs of subdermal larval pigment spots.

### Study Material.

The following list gives the catalogue number, depth in fathoms, date, length and growth stage of each specimen of *Eustomias dubius* taken by the Bermuda Oceanographic Expeditions. All were caught in the cylinder of water off the Bermuda coast described in *Zoologica*, Vol. XVI, No. 1, p. 5 and Vol. XX, No. 1, p. 1.

No. 15,653; Net 646; 600 F.; May 29, 1930; 115 mm.; trans. adolescent; female.
No. 17,419; Net 810; 600 F.; Aug. 28, 1930; 43 mm.; post-larva.
No. 23,942; Net 1336; 600 F.; Oct. 29, 1931; 58 mm.; trans. adolescent.

### Synonymy and References.

*Eustomias dubius*:

Parr, 1927, p. 66, figs. 36D, 38. (1 specimen, 84 mm.; 7,000 ft. wire; Bahamas). A female; examined by present authors.

Regan & Trewavas, 1930, p. 88, fig. 68. (3 specimens, 72 to 122 mm.; 600 to 1,500 m. wire; western Atlantic.)

*Eustomias schiffi*:

Beebe, 1932.2, p. 54. (Description of the largest Bermuda specimen).

Beebe, 1937, p. 199. (Preliminary list of Bermuda specimens).

## Subgenus ***Achirostomias*** Regan & Trewavas, 1930.

## ***Eustomias lipochirus*** Regan & Trewavas, 1930.

### Specimen Taken by the Bermuda Oceanographic Expeditions.

1 specimen (Department of Tropical Research No. 18,597, Net 889); September, 1930; 500 fathoms; from a cylinder of water 800 miles in diameter (5 to 13 miles south of Nonsuch Island, Bermuda), the center of which is at 32° 12′ N. Lat., 64° 36′ W. Long.; standard length 50 mm.

### Specimen Previously Recorded.

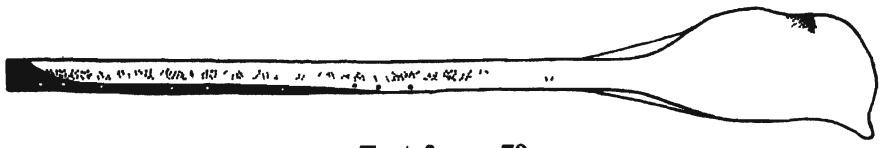
1 specimen; *ca.* 220 fathoms; Caribbean Sea; standard length 88 mm.

### Description.

(From the type, probably immature, and the transitional adolescent Bermuda specimen).

With the characteristics of the genus.

*Proportions*: Depth in length 12 to 12.8 (7.8% to 8.5%); head in length 6.8 to 8 (12.5% to 14.7%); eye in head 5 to 6.2 (16.1% to 20%); interorbital width in head 5.5 (18.2%); snout to pelvic in length 2 (50%).



Text-figure 73.

*Eustomias lipochirus*. Barbel of transitional adolescent, standard length 50 mm.

*Barbel*: Slightly shorter than head, with a rather large bulb having the anterior, distal corner produced as a blunt appendage; stem white, with a series of black dots anteriorly, and, proximally, an anterior blackish streak on axis.

*Light Organs*: Postorbital rudimentary in the Bermuda specimen, which is too young to sex. Serial photophores with the following counts: ventral series, I-V 35, V-A 12, A-C 20; lateral series, O-V 28, V-A 13.

*Teeth*: All depressible, except a few, small, outer, fixed teeth; in the Bermuda specimen there are 8 teeth in the premaxillary, 10 in each half of the mandible.

*Fins*: Pectoral 0 (represented by a fleshy nubbin in the young Bermuda example); pelvic 7, inserted about middle of length; dorsal 23; anal 39.

*Remarks*: The barbel bulb of the Bermuda transitional adolescent differs from that of the type in being comparatively elongate, and in having a transverse, posterior band of pigment in a shallow depression slightly more than half-way to the bulb's tip. There is an irregular double row of about 8 small photophores along the posterior side of the black, proximal portion of the stem. The general characteristics of the specimen are typical of its growth stage (see p. 79).

REFERENCES.

*Eustomias lipochirus*:

Regan & Trewavas, 1930, p. 95, fig. 80A. (Type description).

Beebe, 1937, p. 199. (Preliminary list of Bermuda specimens).

## Subgenus ***Dinematochirus*** Regan & Trewavas, 1930.

### ***Eustomias bigelowi*** Welsh, 1923.

(See also p. 213).

SPECIMENS TAKEN BY THE BERMUDA OCEANOGRAPHIC EXPEDITIONS.

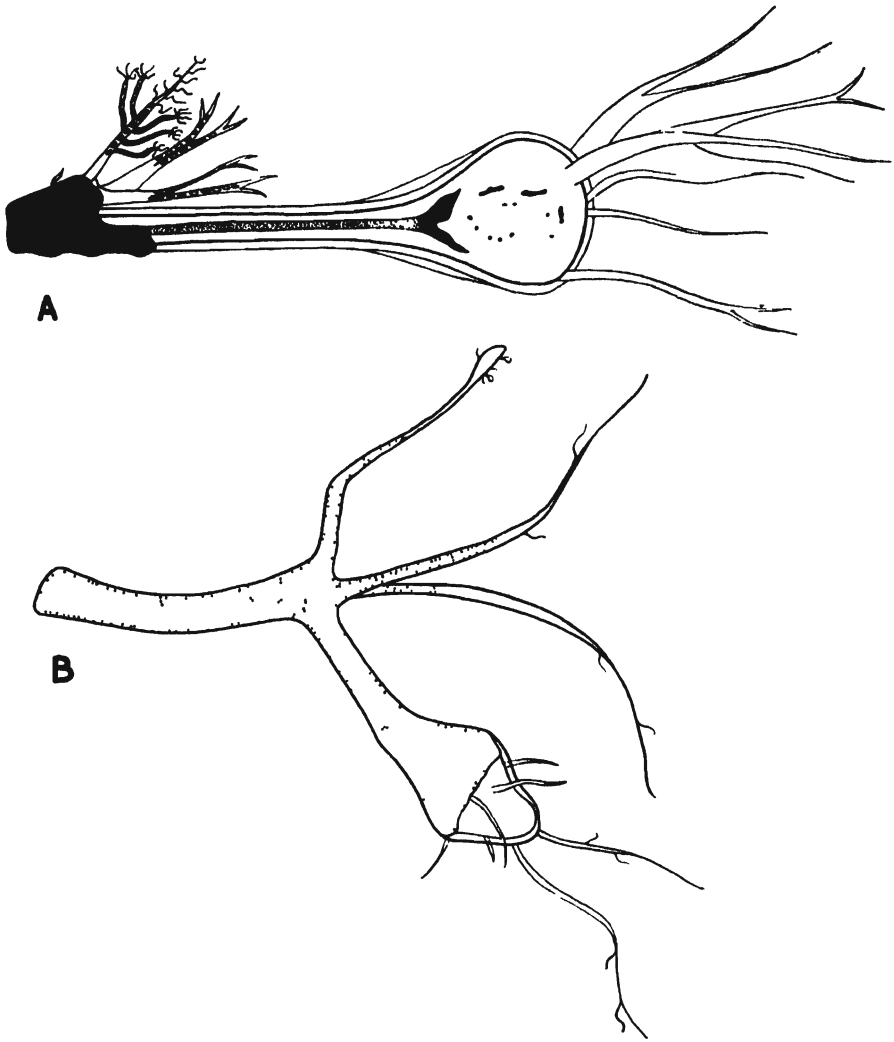
2 specimens; May and August, 1929 and 1930; 700, 800 fathoms; from a cylinder of water 8 miles in diameter (5 to 13 miles south of Nonsuch Island, Bermuda), the center of which is at 32° 12′ N. Lat., 64° 36′ W. Long.; standard lengths 108 and 134 mm. a female and male, respectively.

SPECIMENS PREVIOUSLY RECORDED.

10 specimens; *ca.* 0 to 833 fathoms; North Atlantic; standard lengths from 56 to 204 mm.

DESCRIPTION OF ADULT.

*Color* (from the fresh Bermuda specimens): General color almost jet black; male postorbital silvery-white with green reflections; male antorbital




Text-figure 74.

*Eustomias bigelowi.* Barbels. **A**, adult male, standard length 134 mm ; **B**, transitional adolescent female, standard length 108 mm.

(crescentic, below eye, small) violet blue; male barbel bulb brilliant greenish-yellow, marked externally with flecks of black pigment; two fine, scarlet blood vessels also branched over the bulb, arising from the black core of the stem; the yellow of the bulb extends up into the translucent sheathing of the stem; distal filaments cream-colored, translucent, with numerous coffee-colored granules inside and slender, scarlet cores (doubtless blood vessels); the posterior branches are similar to the distal filaments, except that the median branch is almost as bright yellow as the bulb; the swellings of the fine filaments of the branches are coffee-colored. Female barbel bulb, small bulb on median branch, and swellings on filaments all vivid bluish-green; branches and filaments translucent white.

*Proportions*: Depth in length 10 to 12 (8.5 to 10%); head in length

7.3 to 8.7 (11.5% to 13.3%); eye in head 5 to 7 (14.3% to 20%), less than interorbital width which is contained about 4.5 in head (22.2%).

*Barbel*: About as long as head, with three moderate branches, giving off varying numbers of sub-branches and filaments; bulb large, ovoid or round, giving rise to a varying number of terminal filaments with fine branches. Female characteristics: Median branch shorter than lateral branches and tipped with a small, round bulblet giving rise to a fringe of fine, swollen-tipped filaments; lateral branches without major sub-branches; bulb tiny, oval, proximally covered with black skin of stem. Male characteristics: Median branch longer than lateral branches, without terminal bulblet; lateral branches distinctly bifid; bulb round with a posterior patch of pigment; black skin of stem stopping at base of posterior branches.

*Light Organs*: Postorbital as large as or larger than eye in male, atrophied in female. Serial photophores with the following counts: ventral series, I-P 7, P-V 28 to 30, V-A 13 to 16, A-C 20 to 22; lateral series, O-V 26 to 29, V-A 14 to 16.

*Fins*: Pectoral 2; dorsal 22 to 26; anal 39 to 42.

## Development.

As shown by the barbel of what was formerly distinguished as typical *E. bigelowi*, the barbel bulb in young females is much larger than in adults of the same sex, and the lateral branches are shorter. The Bermuda female is a late transitional adolescent.

## Study Material.

The following list gives the catalogue number, depth in fathoms, date, length and growth stage of each specimen of *Eustomias bigelowi* taken by the Bermuda Oceanographic Expeditions. All were caught in the cylinder of water off the Bermuda coast described in *Zoologica*, Vol. XVI, No. 1, p. 5 and Vol. XX, No. 1, p. 1.

No. 12,602; Net 393; 800 F.; August, 1929; 134 mm.; Adult Male.
No. 15,145; Net 597; 700 F.; May, 1930; 108 mm.; Trans. Adolescent Female.

## Synonymy and References.

*Eustomias bigelowi*:

Welch, 1923, p. 6, figs. 5, 6. (2 specimens; 88 and 102 mm.; 500 to 0 m.; off Cape Hatteras). Examined by the present authors.

Parr, 1927, p. 77, fig. 44. (Résumé of type description).

Regan & Trewavas, 1930, p. 98, fig. 85. (2 specimens; 56 and 95 mm.; 600, 2,000 m. wire; Florida Strait and east of Bermuda).

Beebe, 1937, p. 199. (Preliminary list of Bermuda specimens).

*Eustomias bigelowi paucifilis*:

Parr, 1927, p. 79, fig. 45. (1 specimen; 125 mm.; 7,000 ft. wire; Bahamas). A male; examined by present authors.

*Eustomias bigelowi parvibulbus*:

Parr, 1927, p. 79, fig. 46. (1 specimen; 204 mm.; 10,000 ft. wire; Bahamas). Adult female; examined by present authors.

*Eustomias parvibulbus*:

Regan & Trewavas, 1930, p. 98. (Résumé of description of preceding specimen).

*? Eustomias triramis*:

Regan & Trewavas, 1930, p. 99, fig. 86. (1 specimen; 73 mm.; 110 m. wire; western Atlantic).

*Eustomias pauciflis*:

Regan & Trewavas, 1930, p. 99, fig. 87. (3 specimens, 68 to 70 mm.; 300 to 2,000 m. wire; near Barbuda and near Cape Verde Islands).

Beebe, 1937, p. 199. (Preliminary listing of Bermuda male).

## ***Eustomias silvescens*** Regan & Trewavas, 1930.

(See also p. 213).

### Specimen Taken by the Bermuda Oceanographic Expeditions.

1 specimen (Department of Tropical Research No. 13,457; Net 455); September 10, 1929; 1,000 fathoms; from a cylinder of water 8 miles in diameter (5 to 13 miles south of Nonsuch Island, Bermuda), the center of which is at 32° 12′ N. Lat., 64° 36′ W. Long.; standard length 140 mm.; a female; the type of *E. satterleei* Beebe, 1933.

### Specimen Previously Recorded.

1 specimen; *ca.* 220 fathoms; Caribbean Sea; standard length 111 mm.

### Description of Adult.

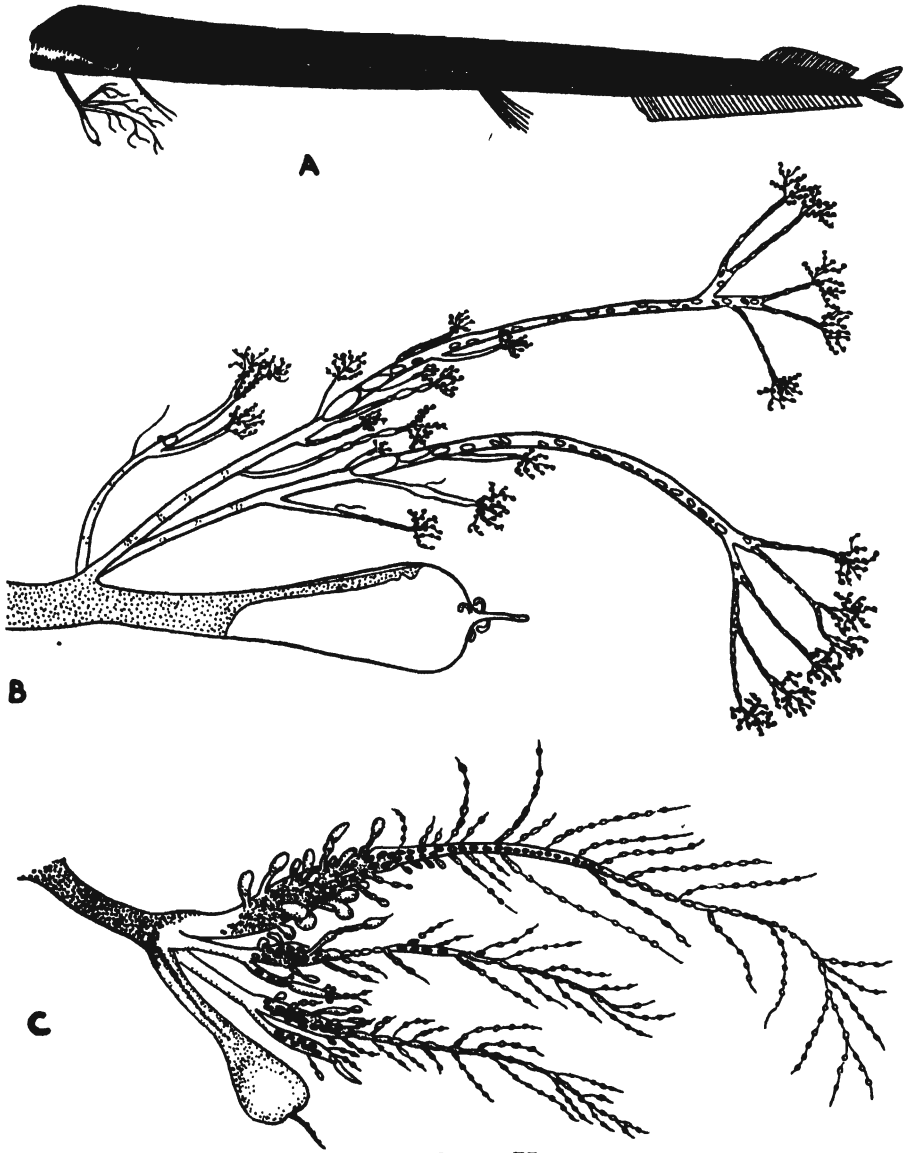
With the characterstics of the genus.

*Color* (from the fresh Bermuda female): General color brownish-black. Postorbital light organ opalescent white. Iris metallic sapphire blue. Barbel bulbs, bulblets and oval bodies in branches brilliant chrome yellow, except posterior part of bulb, which was streaked with apple green; branches translucent white. Serial photophores amethyst violet, those of the ventral series with broad gold frames.

*Proportions*: Depth in length 11.8 to 12 (8.3% to 8.5%); head in length 8 (12.5%); eye in head 4.7 to 5.4 (18.5% to 21.3%); equal to interorbital width; snout to pelvic in length 1.94 (51.5%).

*Barbel*: A little shorter than head to end of bulb, but 3 posterior branches extending far beyond bulb tip; bulb large with a short terminal filament, its base sometimes surrounded by several still shorter ones; all branches elaborately branched, beaded and filamented. Sexual differences: *Male* with the central branch much longer than the lateral branches, very thick proximally with many ovate bodies fastened directly to it, tapering distally, giving off beaded filament, but without a conspicuous terminal bulblet. Lateral branches similar but smaller, each with a stout secondary branch. Barbel stem pigmented only to base of branches; from there to bulb is a dark, median core; bulb expanded distally, rather truncate, with a single median filament. *Female* with central branch much shorter and thinner than lateral branches, simple basally but with a distinct bulblet near the end which gives rise to two subdivded filaments; one or two fine, simple filaments just below bulblet; lateral branches simpler than in male, without secondary branches, except fine, subdivided filaments. Barbel stem entirely pigmented, the pigment extending over three-quarters of the posterior face of the oval bulb in a narrow, forked tongue; four minute filaments clustering around base of the central, short terminal filament.

*Light Organs*: Postorbital apparently well developed in male (in illustration of the type); much smaller than eye, but apparently functional in female; serial photophores with the following counts: ventral series I-P 7,




Text-figure 75.

*Eustomias silvescens.* **A**, adult female, standard length 140 mm. (total number of fine filaments not shown); **B**, barbel of same. **C**, presumably male, standard length 111 mm. **A** and **B**, from specimen in present collection; **C**, after Regan & Trewavas.

P-V 27 to 29, V-A 14 to 16; A-C 20 to 21; lateral series, O-V 27 to 28, V-A 15 to 16.

*Teeth*: Premaxillary with about 11 teeth, maxillary about 12 denticles, minute; each half of mandible with about 18 teeth.

*Fins*: Pectoral 2; the bases of both rays are tightly sheathed in a common covering of skin, making them appear as a single unit proximally; dorsal 22; anal 41.

SYNONYMY AND REFERENCES.

*Eustomias silvescens*:

Regan & Trewavas, 1930, p. 100, fig. 88; pl. IX, fig. 2. (Description of the type).

*Eustomias satterleei*:

Beebe, 1933.2, p. 165, fig. 3. (Description of the Bermuda specimen now referred to *E. silvescens*).

Beebe, 1937, p. 199. (Listing of above specimen).

## ***Eustomias schmidti*** Regan & Trewavas, 1930.

SPECIMENS TAKEN BY THE BERMUDA OCEANOGRAPHIC EXPEDITIONS.

2 specimens; July to September, 1929 and 1930; 700 to 800 fathoms; from a cylinder of water 8 miles in diameter (5 to 13 miles south of Nonsuch Island, Bermuda), the center of which is at 32° 12′ N. Lat., 64° 36′ W. Long.; standard lengths 55 and 118 mm.

SPECIMENS PREVIOUSLY RECORDED.

3 specimens; *ca.* 41 to 220 fathoms; eastern and western tropical North Atlantic; standard lengths 55 to 70 mm.

DESCRIPTION OF ADULT.

With the characteristics of the genus.

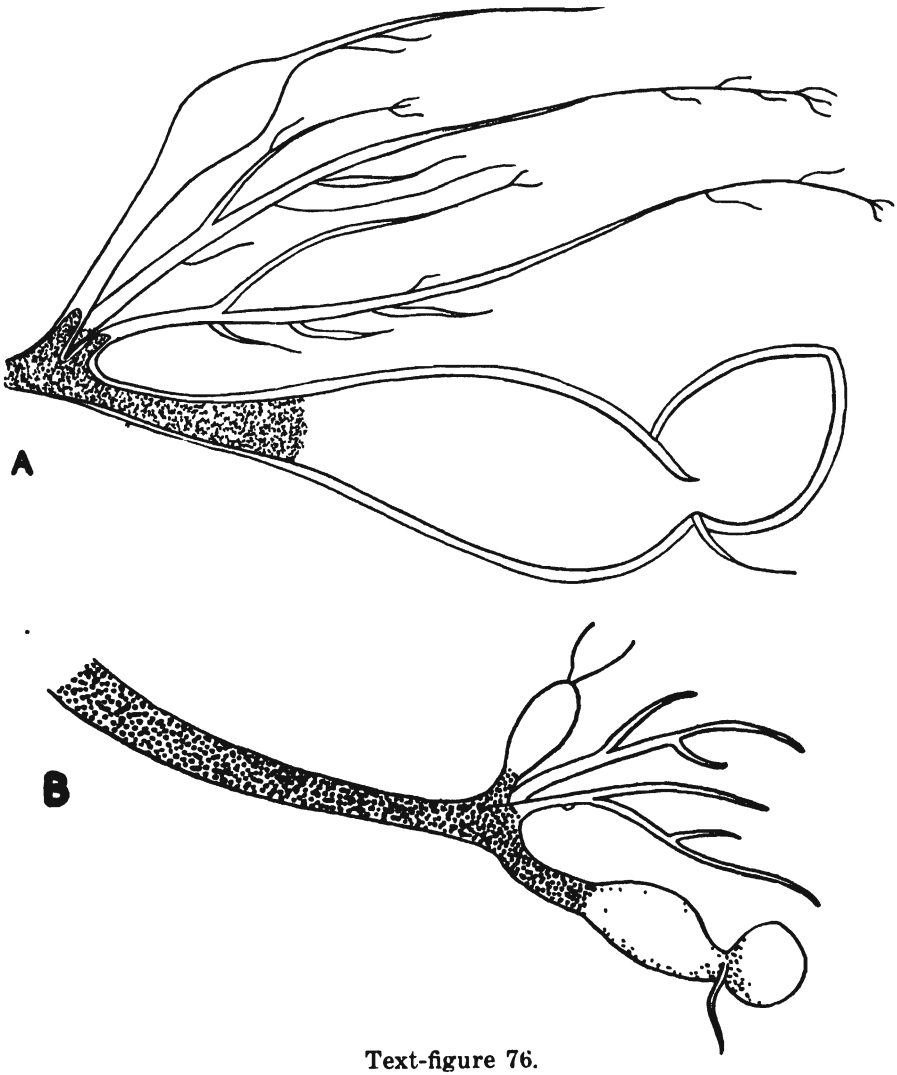
*Color* (from the 118 mm. Bermuda male): General color brownish-black; postorbital light organ silvery-white with golden rim, especially ventrally; main barbel bulb and that of median branch pale rose pink; branches and all filaments translucent, packed with tiny beads of pale ochre; serial photophores phlox purple; non-serial organs very numerous, minute, pale violet blue.

*Proportions* (from the Bermuda adult, the only mature example known): Depth in length 11.8 (8.5%); head in length 7.4 (13.5%); eye in head 4.5 (22.2%); interorbital width about equal to eye; snout to pelvic in length 1.93 (52%).

*Barbel*: As long as head. Bulb large, divided by a constriction into a longer, oval proximal part and a shorter, rounded, distal part; a small filament from the anterior part of the base of the distal portion of the bulb; three posterior branches, the median one largest, without branches but with a prominent elongate or round swelling and one or two distal filaments; lateral branches bifurcate, each main branch having one or more filaments beyond the bifurcation; no bead-like bodies in branches. Sexual Differences: In the Bermuda male the median branch is longer than in the illustration of the type, with only a slight swelling with a long terminal filament, instead of a distinct bulb wth two short terminal filaments; judging by the barbel form in related species, we are fairly certain that the larger type specimen, at least, will prove to be a female.

*Light Organs*: Postorbital well developed in Bermuda male, slightly smaller than eye. Serial organs with the following counts: ventral series, I-P 7 to 8, P-V 27 to 28, V-A 14 to 15, A-C 20 to 23; Lateral series, O-V 27 to 29, V-A 14 to 15.

*Fins*: Pectoral 2; sheathed basally in a common skin; dorsal 22 to 26; anal 40 to 44.




Text-figure 76.

*Eustomias schmidti.* Barbels. **A**, adult male, standard length 118 mm.; **B**, presumably an immature female, standard length 70 mm. A, from specimen in present collection; B, after Regan & Trewavas.

## Development.

Besides the 118 mm. adult male, the Bermuda collection contains an adolescent 55 mm. in length, with characteristics typical of its growth stage. The barbel is similar to that of the 70 mm. young specimen figured by Regan & Trewavas (1930, p. 101, fig. 89).

## Study Material.

The following list gives the catalogue number, net, depth in fathoms, date, length and growth stage of each specimen of *Eustomias schmidti* taken by the Bermuda Oceanographic Expeditions. All were caught in the cylinder

of water off the Bermuda coast described in *Zoologica*, Vol. XVI, No. 1, p. 5 and Vol. XX, No. 1, p. 1.

No. 11,726; Net 312; 700 F.; July 22, 1929; 118 mm.; Adult Male.
No. 13,883; Net 513; 700 F.; Sept. 27, 1929; 55 mm.; Adolescent.

REFERENCES.

*Eustomias schmidti*:

Regan & Trewavas, 1930, p. 100, figs. 89, 90. (Type description).

Beebe, 1937, p. 199. (Preliminary list of Bermuda specimens).

## ***Eustomias fissibarbis*** (Pappenheim, 1914).

(See also p. 213).

SPECIMEN TAKEN BY THE BERMUDA OCEANOGRAPHIC EXPEDITIONS.

1 specimen (Department of Tropical Research No. 13,791, Net 509); September 25, 1929; 800 fathoms; from a cylinder of water 8 miles in diameter (5 to 13 miles south of Nonsuch Island, Bermuda), the center of which is at 32° 12′ N. Lat., 64° 36′ W. Long.; standard length 130 mm.

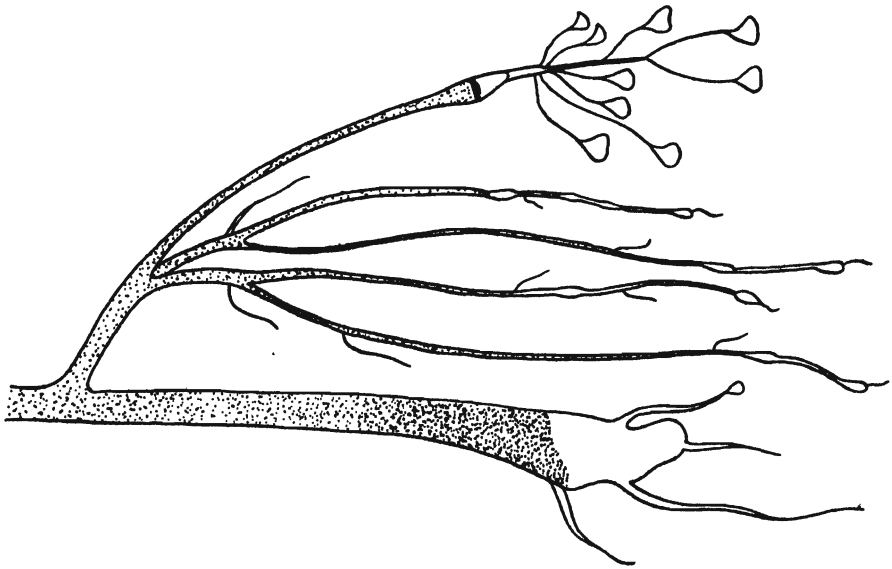
SPECIMENS PREVIOUSLY RECORDED.

11 or 12 specimens; *ca.* 14 to 330 fathoms; North and South Atlantic; standard lengths from 50 to 112 mm.

DESCRIPTION.

With the characteristics of the genus.

*Color* (from the fresh Bermuda female): General color brownish-black; postorbital light organ greenish-silver; serial photophores lavender with narrow gold frames.



Text-figure 77.

*Eustomias fissibarbis.* Barbel of transitional adolescent female, standard length 130 mm.

*Proportions*: Depth in length 10 to 12 (8.3% to 10%); head in length 6 to 8 (12.5% to 16.7%); eye in head 5.5 to 7 (14.3% to 18.2%).

*Barbel*: Barbel 1 to 1⅓ times length of head, stem and proximal half of bulb pigmented; bulb rather elongate, at least in female, with 2 to 4 median and 1 to 3 paired filaments distally; median branch slightly thicker than lateral ones, ending in a small, ovate bulb bearing up to 11 filaments with swollen tips; lateral branches originating from median branch well above main barbel stem; each divides into two unequal branches which may contain oval swellings and a few fine filaments. If, as seems highly probable, *E. dentriticus* Regan & Trewavas is the male of this species, the median barbel branch, as usual in this subgenus, lacks a terminal bulb and is longer than in the females, while the major barbel bulb is rounded rather than oblong.

*Light Organs*: Postorbital much smaller than eye in Bermuda female, but apparently functional; almost atrophied in the type of *E. nigrifilis*, a larger specimen. Serial photophores with the following counts: ventral series, I-P 7, P-V 27 to 28, V-A 13 to 15. A-C 19 to 21; lateral series, O-V 26 to 29, V-A 14 to 16.

*Teeth*: The teeth in the Bermuda specimen are extremely similar in size and arrangement to the diagram given by Regan & Trewavas, 1930, p. 105, fig. 95.

*Fins*: Pectoral 2, in a common sheath of black skin; dorsal 22 to 26, anal 36 to 41.

*Food*: Completely filling the stomach and most of the oesophagus was a 73 mm. specimen of *Luciosudis* sp., a genus represented in the Bermuda collections by only five examples, all considerably smaller.

## Synonymy and References.

*Neostomias fissibarbis*:

Pappenheim, 1914, p. 175, figs. 4, 5. (1 specimen; 86 mm.; 20 m.; eastern North Atlantic).

*Eustomias nigrifilis*:

Parr, 1927, p. 81, figs. 8, 49. (1 specimen; 112 mm.; 8,000 ft. wire; Bahamas). A female; examined by present authors.

*Eustomias fissibarbis*:

Parr, 1927, p. 81. (Résumé of type description of *N. fissibarbis*).

Regan & Trewavas, 1930, p. 103, figs. 94, 95. (8 specimens; 57 to 100 mm.; 50 to 1,200 m. wire; North Atlantic).

Fowler, 1936, p. 209. (Résumé of type description of *N. fissibarbis*).

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?*Eustomias dendriticus*:

Regan & Trewavas, 1930, p. 104, fig. 96. (1 specimen; 64 mm.; 110 m. wire; North Atlantic).

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# 7.

# The Eye Structure of the Four-eyed Blenny, *Dialommus fuscus* Gilbert.

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(Plates I & II; Text-figures 1-3).

Interest in the peculiar horizontally divided eye of *Anableps* led us to search for the possibility of the existence of other species of fishes that might show a similar or analogous condition. Thus far only a single species has been found which on superficial examination reveals a dark division running across the corneal surface. Specimens of this species, *Dialommus fuscus* Gilbert, were kindly supplied to us by Dr. H. Walton Clark of the California Academy of Sciences, and these form the basis of the present report.

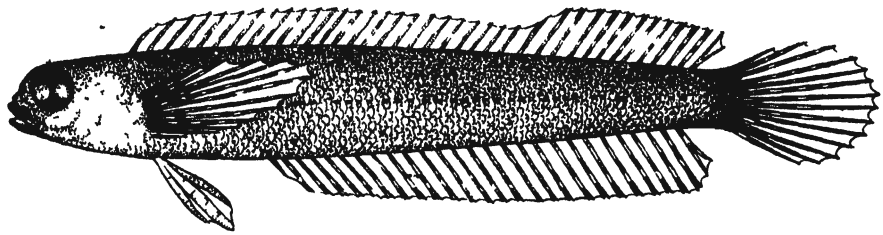
Superficial examination shows what appears to be a dark and nearly *vertical* band reaching across the eye. Closer examination shows that this area of pigment actually is so arranged as to give the impression of an opaque cover through which there are *two* circular openings through which light may pass. This is indicated in Pl. I, Figs. 1-5, and diagrammatically in Text-figs. 1-3. A description of the condition, based chiefly on serial sections, follows.

The eyes are lateral, externally circular and heavily pigmented. The diameter of the cornea is 3 mm. in a specimen of 72 mm. standard length. In each of the lower quadrants a clear corneal area of 1 mm. in diameter is present reaching laterally to the limbus but separated from each other by the aforementioned pigment band. No secondary limbus for the two cornealae are differentiated. The entire cornea is weakly convex in its outer curvature and without local change in the smaller corneal areas or in the pigmented areas; nor are there differences in the corneal thickness in the various areas. The remaining structures of the eye are of normal piscine character.

The corneal pigmentation is of melanophore cells derived from the dermal melanophores by extension into the cornea as a single-layered sheet of cells in the tissue plane between the true and false corneal epithelium. There is a secondary spread into the superficial epithelium especially in the intervening area of the cornealae, in which area pigment cells interweave between the epithelial cells themselves. No melanophores are found in the stroma of the true cornea. The transparent cornealae are sharply demarcated by the pigment cells without the presence of a transition zone comparable to a limbal area.

The anterior chamber is of usual depth throughout; the iris is silver gray in color and of normal structure both as to position and its somewhat horizontally oval pupillary opening. No adhesion between iris and cornea exists as is found in *Anableps anableps*, which aside from the rotation of the ocular "septum" has a quite different structural pattern. Furthermore, in *Dialommus* there is only one pupillary opening present in the iris instead of two as in *Anableps* (see Text-figs. 2 & 3). The crystalline lens is spherical and shows no curvature alterations that might be expected in so odd a corneal optical system—and are, in fact, realized in that of *Anableps*.

No necessity exists to describe the retina, choroid, optic nerve or sclera in detail in this place as these layers are comparable to fish eyes in general.



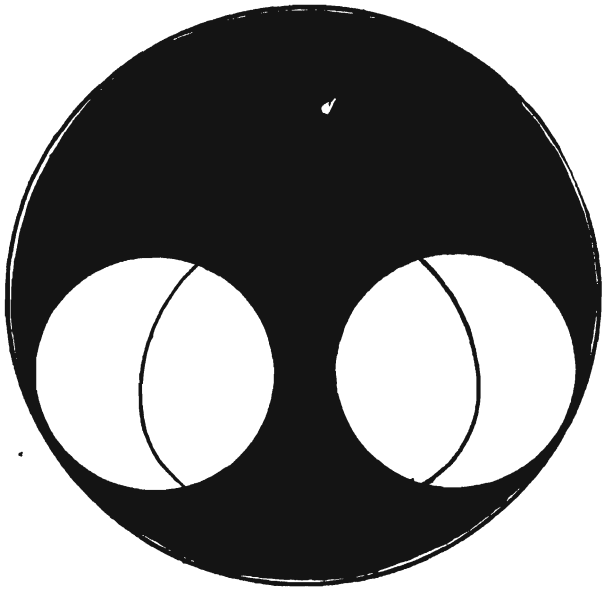
Text-figure 1.

*Dialommus fuscus* Gilbert, 51 mm. in standard length. Drawing by Ralph Graeter.

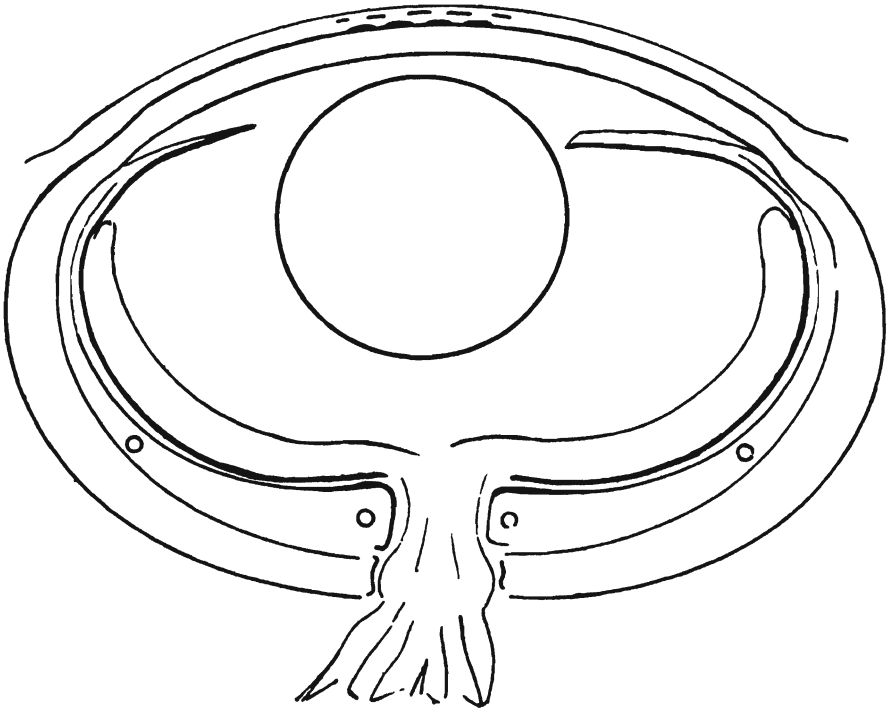
Gilbert (1891) in his diagnosis of the monotypic genus *Dialommus* wrote: "Eyes as in Anableps, the cornea divided by an oblique pigmented band into an anterior lower and a posterior upper half." Unfortunately he gives no figure, but an examination of our illustrations shows that the division, in our material as already noted, is nearly vertical with a slightly backward slant from the top downward. The material on which these notes are based was collected at Academy Bay, Indefatigable Island, Galápagos, on May 9, 1932, by the Templeton Crocker Expedition for the California Academy of Sciences.

Since it is known that *Anableps* swims at the surface with the upper part of its eyes thrust into the air and that the peculiar distortion of the crystalline lens and corneal curvature provides for suitable focus in air and water, respectively, through the upper and lower pupil, it is generally assumed that this condition gives the fish a visual advantage (e.g., Clarke & Mortimer, 1839; Klingelhöffer, 1910). See Plate I, Fig. 6, and Plate II. Observations on both *Anableps anableps* Linnaeus and *Anableps dowei* Gill in aquaria have not served to clarify this contention, although the fishes certainly hold themselves for the major portion of the time in such a position that the surface meniscus rests between the two pupillary openings. While they are clearly alert to conditions above the surface, it would be hard, on a basis of our observations, to demonstrate that they are any more so than many other surface fish, for example, their relatives the Poeciliidae. Like many of the latter, they are omnivorous with a decided predilection for algae-eating, for which their mouths are well suited, although it is not clear what advantage such a four-eyed condition would confer.

Although we have not been able to examine living specimens of *Dialommus*, we have the valuable description given by Dr. Clark (1936) of their field behavior under the name of *Crockeridius odysseus*. Like *Anableps* they live near the water's surface but unlike the latter, instead of swimming in quiet waters for most part, are found on more or less exposed rocky shores where there is a surf. Here they apparently spend as much time out of as in the water. Of this behavior Clark wrote: "The



**Text-figure 2.**
Diagrammatic aspect of lateral view of eye of *Dialommus*.



**Text-figure 3.**
Reconstructed diagrammatic horizontal section of eye showing typically piscine appearance of eye of *Dialommus* except for the vertical band of corneal pigment.

first example seen was noticed on the top of a rock along the shore of Wreck Bay, Chatham Island, April 18. It looked very much like a curled-up salamander, with black, smooth, glistening skin and prominent beady, watchful eyes. Upon approaching with a dipnet, it sprang into the water. From time to time about a dozen more were seen coiled up on rocks, and it was then ascertained that they were fish. They were seen from time to time making quick jumps from and over rocks into deeper water. From their alertness and activity and their unexpected position they were apparently the most elusive of fishes and probably absent from collections. Beebe had apparently caught glimpses of them, for he remarks (Galapagos p. 112): 'Blennies climbed out and flicked here and there upon tide-soaked rocks.'" Clark further states: "They seem to be neither ocean nor tide-pool fishes but rather pot-hole inhabitants, living, along with the suck-fishes (Gobiesocidae), in deep depressions back some distance from all but the highest tides. Unlike the suck-fishes they have no means of attaching themselves firmly to rocks against the dash of surf. They showed great alacrity in climbing out of the steep sided pools and it was only by administering poison and keeping them down in the pools that they could be collected in such situations. They were indeed able to ascend the smooth vertical side of the enameled collecting can."

Since the eye partition is nearly vertical, it is tempting to imagine that these fish spend considerable time clinging to the vertical sides of their pot-holes with only the forepart of the head thrust out of water so that the water's edge passes between their paired cornealae in a manner analogous to that to be seen in *Anableps*. Unfortunately for such an idea, the illustrations here shown give no evidence of structural peculiarities that would suggest an optical advantage for such behavior. Stated rather flatly, the eye seems to be nothing more than that of a typical fish, suitable for underwater vision, with a covering so arranged that vision is possible only through a fore and aft opening. If this confers any optical advantage, it is certainly not evident from present data.

This item cannot be dismissed so simply, however. Since fishes make visual adjustments by moving the lens back and forth, instead of deforming it, there is a possibility of some lateral movement. This is especially noteworthy, as in the normal fish eye there is a slight rearward movement of the lens as it is retracted, due to the structural features of the mechanism involved. Thus it is conceivable that these fishes could so operate their lens movements as to allow the anterior portion to be in focus for aerial vision while the posterior portion was focussed for vision in water. Obviously such minor adjustments if existent could not be detected in the sectioned eye.

Abandoning any attempt to impute any particular advantage to this condition in the sense that it is alleged for *Anableps*, another feature of fish eyes may be considered. Umbulacra of various sizes and shapes are not uncommon in fishes. These are not infrequently associated with environments of very bright light and presumably act as visors. If we may accept the view of Breder (1932) who thought that various belonids which live over very bright and reflecting sand in shallow water may derive some optical advantage from having umbulacra and a horizontally closing pupil, certain hypotheses may be considered. His idea was that the umbulacrum protected permanently from the usual glare from above and the horizontally contracting pupil from the secondary and more variable glare from below. On such a basis the condition in *Dialommus* may be thought of as associated with a life spent largely in an even greater glare and in which extensions of the dorsal and ventral umbulacrum-like protection fused somewhat below the center of the orbit, resulting simply in an accidental condition of two visual openings.

This suggestion, of course, may be countered by citing all manner of

optical peculiarities in one species or another involving variants of off-circular openings which cannot be associated with any environmental features. It might be held, on the other hand, that these structures are sufficiently unimportant to permit their taking nearly any form so long as it is not positively detrimental. Heavy pigmentation and its extension into areas not usually pigmented, in a general way, are frequently associated with environments exposed to large amounts of illumination. In this connection it may be noted that the general dermal pigmentation in our material is extremely heavy.

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## EXPLANATION OF THE PLATES.

### PLATE I.

Sections of the eye of *Dialommus* and *Anableps.*

Fig. 1. *Dialommus.* Preserved head. Shrinkage of the eye somewhat distorts the appearance, but the only non-pigmented areas show cavetation.
Fig. 2. *Dialommus.* Vertical section, anterior to the central pigmented band.
Fig. 3. *Dialommus.* Horizontal section showing median pigment band.
Fig. 4. *Dialommus.* Horizontal section showing the pupil and the two cornealae.
Fig. 5. *Dialommus.* Higher magnification of the median central barrier.
Fig. 6. *Anableps anableps.* Vertical median section showing the two pupillary openings.

### PLATE II.

Fig. 7. Eye of a living *Anableps anableps* (Linnaeus). Photographed under water in an aquarium by S. C. Dunton.

FIG 1

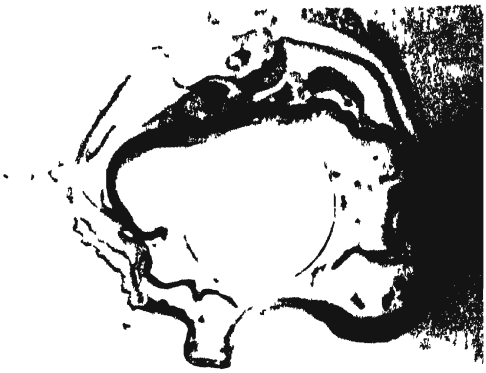

FIG 2.

FIG 3

FIG 4

FIG. 5

FIG 6.

THE EYE STRUCTURE OF THE FOUR EYED BLENNY,
DIALOMMUS FUSCUS GILBERT.

FIG 7

THE EYE STRUCTURE OF THE FOUR EYED BLENNY,
DIALOMMUS FUSCUS GILBERT

# 8.

# Studies on Virus Diseases of Fish. III. Morphological and Experimental Observations on the Lymphocystis Disease of the Pike Perch, *Stizostedion vitreum.*[1]

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*The Wistar Institute of Anatomy and Biology*

(Plate I).

## INTRODUCTION AND REVIEW.

The lymphocystis disease of fish is characterized by the appearence of membrane-enclosed uninucleated cells in the connective tissue, especially of the fins. These cells grow to a gigantic size—in *Pleuronectes flesus* for instance, they reach a diameter of 2 millimeters—and enclose in their cytoplasm peculiar reticular bodies which show a staining reaction like basichromatin. They were first supposed to be eggs of parasites (Sandeman, 1892). In a second period they were interpreted as parasitic protozoa and were described by Woodcock in 1904 in the European plaice and flounder as a new species and a new genus of Sporozoa with the name *Lymphocystis johnstonei.* In 1918, J. W. Mavor found a similar disease on the perch *Stizostedion vitreum* in the United States and described the peculiar cells in this fish as a new species: *Lymphocystis vitrea.* But, in the meantime, the writer succeeded in discovering lymphocystis disease on a Baltic Sea race of the European perch *Acerina cernua* and observed the whole development of the peculiar cells (Weissenberg, 1914). A result entirely different from the interpretation of the predecessors was reached. It was discovered that the so-called lymphocystis cells are connective tissue cells of the fish which hypertrophy and become transformed in a peculiar manner by the formation of a membrane and later by the appearance of the conspicuous inclusion bodies.

The study of the morphology and the development of these cells, as well as infection experiments, led to the conclusion that the disease is produced by a virus localized in the hypertrophying cells which are stimulated to a metamorphosis and to gigantic growth.

For the experimental infections, fish of the same Baltic Sea race of *Acerina cernua* were used, on which the disease had been discovered by Weissenberg in a bay of Rügen Island. When fish of this race were kept under laboratory conditions at the Anatomic-Biological Institute of the University of Berlin, Germany, it was seen that healthy perch developed lymphocystis tumors as a rule when kept together with specimens strongly

[1] From the Department of Cytology, Washington University School of Medicine, Saint Louis, Mo., and from the E. B. Morris Biological Farm of The Wistar Institute, Bristol, Pa.

affected by lymphocystis disease. Likewise, the disease appeared in a high percentage of such perch after addition of an emulsion of lymphocystis tumor material to the aquarium water (Weissenberg, 1914, p. 801-802; 1921, p. 1365). A similar result was observed with European flounders from the river Warne caught at Rostock, when these were kept in an aquarium infected with an emulsion of lymphocystis tissue from flounders caught at Rügen Island (Weissenberg, 1921, p. 1366).

The decisiveness of these experiments was somewhat impaired by the fact that the treated fish came from waters in which lymphocystis disease is endemic (*Acerina cernua* of Rügen Island) or from waters in which the disease may occasionally occur (flounders of Rostock). Therefore, it was of importance when it was found that in an experiment with fresh water *Acerina cernua* from an inland lake of Germany where the disease was entirely unknown, one of 4 fish developed the tumors after being kept with diseased Baltic Sea *Acerina cernua* (Weissenberg, 1914, p. 802).

Considering the small number of fish in this last-mentioned experiment, it was very desirable to carry out further experiments with a greater number of fish procured from waters in which lymphocystis disease does not occur. This opportunity was obtained with material of the American perch *Stizostedion vitreum* in 1937 when the author came as Visiting Professor of Cytology to Washington University, St. Louis, and Dr. E. V. Cowdry, Head of the Department of Cytology, generously placed the facilities of his laboratory at the author's disposal for a series of experimental observations.

## Lymphocystis Disease of *Stizostedion vitreum.*

J. W. Mavor first described in 1918 some cases of lymphocystis disease of the wall-eyed pike perch, *Stizostedion vitreum,* caught at Minocqua, Wisconsin. It is now known that the disease is not rare in this perch caught in Lakes Michigan, Huron and Erie. Roscoe R. Hyde has referred in 1937 in his "Laboratory Outline in Filterable Viruses" (p. 40) to material collected from Lake Erie.

In 1937 the author had the opportunity of seeing fresh material taken from about sixty specimens of *Stizostedion vitreum* caught in Lake Huron and Lake Erie. These were adult fish of a length of 33 to 44 cm. The general aspect of the disease in these fish is very similar to the appearance of the lymphocystis disease of the European perch *Acerina cernua,* described and figured by Weissenberg in 1920. The affected fish show gray transparent tumors, especially on the fins and also often on the trunk and head, forming growths of a diameter of 2 to 3 mm. and sometimes larger cauliflower-like tumors or nodes of the size of a cherry. They are covered by the epithelium and by a connective tissue layer with some pigment cells and contain as the most conspicuous elements the large lymphocystis cells, visible to the naked eye or with the magnifying glass as gray-whitish granules.[2]

## Young *Stizostedion vitreum* for Infection Experiments.

On account of the large size of the adult *Stizostedion,* only young fish seemed suitable for experiments in the laboratory. It was very important to procure for experimental infection young fish from a hatchery in a region where lymphocystis disease does not occur. The author is deeply grateful to Mr. E. B. Speaker, State Superintendent of Fisheries, Iowa State Conservation Commission, Des Moines, Iowa, for supplying him with young

[2] The author is greatly indebted for procuring the *Stizostedion* material to Dr. Carl L. Hubbs and Dr. Hilary J. Deason, Ann Arbor, Michigan; to Dr. Thomas H. Langlois, Put-In-Bay, Ohio; and especially to Mr. Robert E. Ellsworth, Supervisor of Spawn Collection, Bay City, Michigan, and to Captain Clarence Smith, Essexville, Michigan.

pike perch from Spirit Lake, Iowa. This lake is fed through a series of glacial lakes located in southern Minnesota and has no connection with the Great Lakes. The young pike perch were raised at the State Fish Hatchery of Spirit Lake and were of pure native Iowa stock.

The young *Stizostedion* of a length of 10-14 cm. were sent in September and October to St. Louis and were kept alive at the Department of Cytology under laboratory conditions for 8-10 weeks. As they were fish of prey, they had to be fed with living food fish (minnows).

## Treatment of Young *Stizostedion* from Iowa with Lymphocystis Material of Adult *Stizostedion* from the Great Lakes.

An infection experiment was attempted with 10 young pike perch from Spirit Lake, Iowa. Eleven specimens served as control fish. Lymphocystis tumor tissue removed from adult *Stizostedion vitreum* of the Great Lakes was used as the infecting material. The experimental procedure attempted to imitate the conditions in nature when infection of *Stizostedion* occurs, on the supposition that the lymphocystis virus is picked up either with the food or with the water used in respiration. Tumor material was cut in small bits and dispersed in the tanks. Live minnows were first fed with lymphocystis cells or kept in an emulsion of tumor material and then offered as food to the pike perch. The *Stizostedion* were kept for 13 days under these conditions of exposure to infection. In addition, two of the pike perch with a length of 14 cm. received on the 13th day, by means of a pipette, an injection of a dense emulsion of tumor material through the mouth into the pharynx and through the opercular clefts into the gill atria. The other treated *Stizostedion*, with a length of only 10 to 12 cm., were bathed on the same day in a rather dense emulsion of the tumor material for about half an hour.

Two kinds of tumor material were used, first, material from Lake Erie which was sent without ice and, therefore, arrived in a state of decomposition (material I). Six days later additional tumor material was applied which arrived in excellent fresh condition from Lake Huron (material II). In the previous experiments on the European perch *Acerina cernua* done in Germany, an infection was never recognized before the 9th day of the experiment at the earliest. The close resemblance in morphology of the lymphocystis disease of *Acerina* and *Stizostedion* suggested that the incubation period probably would not be very different for the two fishes belonging to the same family.

Four of the treated fish died within the first 15 days after the experiments were begun, without any signs of lymphocystis infection. But the six surviving fishes developed lymphocystis disease without exception as disclosed by an examination of the fins four weeks later.

Probably only material II, which was applied in much fresher condition than material I, had been effective. Concerning the four fish, which died without showing the eruptions of the disease, two died on the first day of the application of material II, one on the 6th day and the last on the 9th day. Therefore, the period during which these four fishes died, based on the application of material II, would not be appreciably longer than the incubation period observed in the experiments with *Acerina*. Considering the fact that all fishes surviving for a longer period proved to be infected, this may mean that all treated fish developed lymphocystis disease after experimental exposure, when they lived long enough to do so.

Two of the 6 surviving perch which developed lymphocystis cells were the above mentioned larger specimens with a length of 14 cm. These two fish showed much more severe lymphocystis reactions than the 4 smaller *Stizostedion*. A cell count estimating the number of lymphocystis cells appearing

on the tail fin, the favorite place for the localization of the lymphocystis cells in the perch, and for the pectoral fins, showed the following: The number of lymphocystis cells on the tail fin was for the first small specimen 27, for the second 39, for the third 83, and for the fourth 400. On the pectoral fins no lymphocystis cells were observed in the first and second fish, 48 lymphocystis cells were found on the two pectoral fins of the third fish and 35 on the pectoral fins of the fourth fish. In contrast, in each of the larger pike perch, more than 1,000 lymphocystis cells developed on the tail fin. The number of the lymphocystis cells found on the pectoral fins was about 4,000 in the one and an estimated 14,000 in the other larger fish.

The conspicuous difference in the number of lymphocystis cells appearing on the fins of the smaller and the larger fishes may be related to the fact that only the two larger fish were treated with tumor emulsion injected into the pharynx and the gill atria. However, it must not be overlooked that these two, being larger fish, swallowed more food fish than did the smaller, and therefore could pick up with the food fish more of the tumor material.

None of the 11 control fish developed lymphocystis disease. In the six experimentally infected specimens, the growth and differentiation of the lymphocystis cells could be studied during the subsequent period of 33 days. Unfortunately, the pike perch employed in the experiment could not be kept alive longer because of an intercurrent disease which they picked up from the food fish. The last of the 6 experimentally infected *Stizostedion* died on the 66th day of the experiment (the 59th day after treatment with material II).

Summarizing, it can be stated that the experimental infection of *Stizostedion* verifies the previous results of the author on European fishes and confirms his opinion that lymphocystis tumor material is to be considered as highly infectious for fish which belong to the same species as the carrier of the tumors. The conclusiveness of the previous experiments on *Acerina* and *Pleuronectes* was somewhat diminished by the fact that the treated fish could not be procured from waters where lymphocystis disease did not occur and that the number of the fish kept under experimental conditions was very small. The experiments on *Stizostedion*, however, clearly indicate the highly infectious nature of the lympocystis disease by an experimental procedure imitating the conditions which may be effective for infection occurring in nature.

## Concerning the Problem of the Control of Lymphocystis Disease.

The lymphocystis disease is not rare in *Stizostedion vitreum* of the Great Lakes. The number of the diseased pike perch caught at Saginaw Bay of Lake Huron was estimated, for instance, in the spring 1937 to be about 5 per cent.

Because severely infected fish have a repulsively diseased appearance and are not saleable, the disease becomes of economic importance.

From a correspondence with Dr. A. S. Hazzard, Director of the Institute for Fisheries Research, Ann Arbor, Michigan, it was gathered that it is a common practice of the commercial fishermen at Saginaw Bay to return to the water any fish, taken in the nets, which are badly affected by lymphocystis disease. The writer had the same experience in Germany with lymphocystis-diseased flounders caught off Rügen Island at the Baltic Sea.

Judging from the present experiments it may be inferred that each lymphocystis-affected perch is highly contagious for other wall-eyed pike perch. It must be strongly emphasized that there is no hope of preventing the spread of this disease except by destroying all affected *Stizostedion* taken in the nets so that no lymphocystis material will return into the lakes.

## Review of the Development of the Lymphocystis Cells of *Acerina* and *Pleuronectes*.

Previous observations about the development of the lymphocystis cells of the perch *Acerina cernua* (Weissenberg, 1914, 1920, 1921), gave the following results: On fish kept under infection conditions, groups of connective tissue cells (fibroblasts and osteoblasts) began to hypertrophy during the second week, especially in the fin membranes. Originally these cells were characterized by only a small amount of cytoplasm and by nuclei containing little fluid. Now they became richer in cytoplasm. Their nuclei swelled and their nucleoli increased in size. About one day later numerous hypertrophying connective tissue cells drew in their amoeboid processes, became round in shape and a transparent membrane appeared on their surface. By the appearance of this membrane the cells were characterized as young lymphocystis cells, which now began to grow continuously.

At first they contained no inclusion body. But, about one week later, an inclusion appeared in their cytoplasm as a tiny point which increased in size to a round compact body resembling very much a Guarnieri body of a corneal epithelium cell of the rabbit after inoculation with vaccine virus. The young lymphocystis cells grew larger and larger and corresponding to their growth the inclusion body increased more and more in size to an oval disc, then to a calotte, which became fenestrated and sprouted into a network of basophilic staining reaction. The network lay at first on one side of the nucleus but surrounded the nucleus with its meshes in the following weeks. In the course of one year the lymphocystis cells reached a gigantic size with a diameter of 700 microns and in their cytoplasm the network was distributed with numerous folds.

It is characteristic for *Acerina* that, as a rule, only one network develops from a single inclusion body and that accessory inclusion bodies, if there should be any present at all, remain rudimentary (Weissenberg, 1921, p. 1372). In contrast to *Acerina*, the lymphocystis cells of the European flounder, *Pleuronectes flesus*, always contain as adult cells very numerous inclusion networks. These inclusions appear in young flounder lymphocystis cells as small bodies, one after another (Weissenberg, 1921, pp. 1371, 1373). Another difference between the lymphocystis cells of *Pleuronectes* and *Acerina* is that the nucleus of the *Acerina* lymphocystis cells contains as a rule only one nucleolus, rarer two nucleoli, whereas numerous nucleoli have always developed in the adult *Pleuronectes* lymphocystis cells.

## Stages of the Development of the *Stizostedion* Lymphocystis Cells.

Hitherto only adult *Stizostedion* lymphocystis cells have been described (Mavor, 1918). They resemble the lymphocystis cells of *Acerina* in the configuration of the membrane, in the formation of one inclusion network and especially in the structure of the nucleus. This striking resemblance is easy to understand since both fishes belong to the same family, the perches. Judging from the resemblance of the adult lymphocystis cells of *Stizostedion* and *Acerina* it might be supposed that the development of the lymphocystis cells of *Stizostedion* would also take a course similar to that seen on *Acerina*. The stages of development observed in the infection experiment, three of which are pictured on the plate, follow indeed very well the course of development observed on *Acerina*.

Fig. 1 shows the youngest stage of lymphocystis cells observed in a piece of a tail fin border excised on the 29th day of the infection experiment (the 23rd day after the start of the treatment with material II). From a total preparation a group of 11 lymphocystis cells, which developed in the periosteum of a fin-ray, is pictured. The cells can be recognized as lymphocystis cells by their round shape, by the contour of the still thin cell-mem-

brane and by their inclusions (*i*). The cytoplasm of each lymphocystis cell contains one inclusion body which is now at the stage of development in which it resembles very much the Guarnieri bodies of cells of mammals infected by vaccine virus. The inclusions are always surrounded by the halo of a fluid vacuole and when they are projecting in the total preparation over the nucleus, as in cell B for instance, they may be easily distinguished from the nucleoli by this halo. The diameter of the lymphocystis cells varies from 13.5 to 27.4 microns because, as usual, some cells are developing faster while others are lagging a little behind. The two largest cells (F and D) contain the largest inclusion bodies, whereas as a rule small inclusion bodies are seen in small lymphocystis cells, for instance in cell J.

Among the young lymphocystis cells lie naked cells (h) of amoeboid forms which have a denser cytoplasm and usually also a larger size than the normal cells of the periosteum. Apparently they represent hypertrophying fibroblasts which were stimulated to the formation of lymphocystis cells but did not accomplish this development, remaining naked cells without inclusions. The stellate cells to the right from the lymphocystis cells A and D evidently represent some of these originally hypertrophying fibroblasts which were secondarily compressed by the quickly increasing lymphocystis cells.

The pseudopodium-like processes of the lymphocystis cells A and D are to be considered as a deviation from the rule that lymphocystis cells usually appear perfectly round. There is no reason to suppose that these cells could be damaged artificially by pressure. The observations on *Acerina* had led to the opinion that the hypertrophied fibroblasts draw in their amoeboid processes and become round cells before the surrounding membrane appears. But the processes observed on these young lymphocystis cells of *Stizostedion* might be interpreted as pointing out that occasionally the membrane formation of the lymphocystis cells may begin before all the amoeboid processes are taken in and that the irregular shape can remain recognizable for some time.

The lymphocystis cells of Fig. 2 are from a total preparation of a fin border excised on the 44th day of the infection experiment (the 38th day after the start of the treatment with material II). Thus the four cells represent 15 days more of development than the lymphocystis cells of Fig. 1. In these two weeks they have considerably increased in size. The dimension of the smallest cell of this group is 45 by 37.4 microns, the size of the largest cell 67.7 by 58.5 microns. A corresponding enlargement can be seen on the nuclei and the nucleoli. The cell-membrane has become thicker and appears as a glassy, double-contoured layer. A remarkable progress of development is seen in the inclusion bodies which have considerably increased in size. They are seen in the three smaller cells as discs of approximately oval form. In the largest cell the inclusion body (*i*) has become fenestrated and shows a basket-like shape. Whereas the inclusions of the stage of Fig. 1 were rather compact bodies, they display now an alveolar or reticular structure, strongly stained with hematoxylin. The meshes or alveoles are filled with a paler staining substance.

Figs. 3 and 4 represent the latest stage of development which could be observed in the infection experiment. The two lymphocystis cells belong to a total preparation of the tail fin border of a young pike perch which lived about two weeks longer than the other five specimens. The cells were preserved on the 61st day of the infection experiment (the 55th day after the start of the treatment with material II). Thus they represent a stage of development which is 17 days older than the lymphocystis cells in Fig. 2. In comparison to these there is again a considerable increase in size to be seen. The membrane has become still thicker. The cell represented in Fig. 3 with two adjustments (A and B), has with the membrane a size of 81 by 72 microns. The cell of Fig. 4, the cytoplasm of which has withdrawn from

the membrane by shrinking, has at the circumference of the membrane reached a size of 113 by 97 microns.

Along with the enlargement of the cell body the nucleus and the nucleolus have also increased in size. The most conspicuous progress in development is seen on the inclusion body which has grown even faster than the other contituents of the cell. The shape of the inclusion body is now a fenestrated calotte which can also be designated as a network of coarse bars. The bars themselves show many larger and smaller vacuoles which give them an alveolar structure.

As is seen in Fig. 3A, which represents the view of the inclusion network from the side ("en profil") in an optical section through the cell, the network has extended through a considerable part of the cell surrounding the nucleus on one side. Fig. 3B shows a higher adjustment of the same cell.

In Fig. 4 the inclusion network is seen "en face" with medium adjustment. Therefore, only the brim of the calotte of the inclusion network is represented surrounding the nucleus. The processes of the network directed toward the center-part of the picture would appear with high adjustment as continuing into the middle curvature of the fenestrated calotte.

In summarizing it may be stated for the three stages of development represented in Fig. 1, in Fig. 2 and in Figs 3 and 4 that in the observed period of 33 days the largest diameters of the largest lymphocystis cells have increased from 27.4 to 113 microns. During the same time the inclusion body has developed from the stage of a small, rather compact body, which looks very similar to the so-called Guarnieri bodies of cells of mammals infected by vaccine virus, to a wide network which surrounds one half of the nucleus.

## Comparison of Young Lymphocystis Cells of *Stizostedion vitreum* and of *Acerina cernua*.

The general aspect of the young lymphocystis cells of *Stizostedion vitreum*, observed in the infection experiment, and of the corresponding stages of *Acerina* lymphocystis cells is very similar. It is easy to understand why the cell-structure is similar since the two fish belong to the same family, the Percidae. As a rule, the lymphocystis cells of both fish contain only one large nucleolus, occasionally two nucleoli. Often binucleated cells are to be found in *Stizostedion* as well as in *Acerina*.

The type of the inclusions, which usually appear as single bodies, occasionally as double and very seldom as multiple bodies, is also similar in both fish. A slight difference is seen in the stage of the sprouting network, in that the bars of the network appear coarser in *Stizostedion* than in *Acerina*.

More conspicuous is the contrast in the size of the cells of corresponding stages. Whereas the youngest lymphocystis cells of both fish seem to be not essentially different in size, in *Stizostedion* the lymphocystis cells as well as their inclusion bodies grow faster than in *Acerina*. Therefore, the lymphocystis cells in stages which are characterized by large oval inclusion bodies or by the beginning of the formation of the network (Fig. 2), are about one-third larger in *Stizostedion* than in *Acerina*. The same fact can be noted in the following stages in which the extending network has surrounded about one-half of the nucleus (Figs. 3 and 4). Consequently, some morphological details can be demonstrated in *Stizostedion* with the high dry objective, whereas in *Acerina* the oil immersion must be employed.

The statement that the growing lymphocystis cells in corresponding stages are about one-third larger in *Stizostedion* than in *Acerina* harmonizes with the fact that the lymphocystis cells apparently reach a larger final size in *Stizostedion* than in *Acerina*. Whereas the *Acerina* lymphocystis

cells, as a rule, reach no more than 700 microns in diameter, lymphocystis cells of 1,200 by 900 microns could be seen in some tumors of the *Stizostedion* material from Lake Huron. It is still to be determined whether this is the maximum size or if full grown lymphocystis cells of *Stizostedion* can attain still larger dimensions.

## SUMMARY.

1. The high infectiousness of lymphocystis-tumor material for fish of the same species was proved in an infection experiment on *Stizostedion vitreum* with the treatment of young fish from a lake where lymphocystis disease is unknown. The experimental procedure attempted to imitate the conditions which may be effective in nature for the infection of *Stizostedion*, on the supposition that the lymphocystis virus is picked up either with the food or with the water used in respiration. The experiment started with 10 treated specimens. Four died early during a period which probably has to be considered as the incubation period. The six surviving perch without exception developed lymphocystis disease.

2. A very severe lymphocystis infection of two of the young pike perch of this experiment may be related to the fact that these fish were of larger size and furthermore were treated with injections of the tumor-emulsion through the mouth into the pharynx and through the opercular clefts into the gill atria.

3. The lymphocystis disease of the American perch *Stizostedion vitreum* shows a great similarity to the lymphocystis disease observed on the European perch *Acerina cernua*. The general aspect of the disease as well as the morphology and the development of the lymphocystis cells which are hypertrophied and metamorphosed fish-connective tissue cells are similar in the two forms. But a difference is seen in the fact that the young lymphocystis cells of *Stizostedion* grow faster than the corresponding stages of *Acerina* and, therefore, are one-third larger. This harmonizes with the fact that the lymphocystis cells of *Stizostedion* can reach 1,200 microns in diameter whereas the final diameter of the lymphocystis cells of *Acerina* is about 700 microns.

4. The growth of the young lymphocystis cells of *Stizostedion* was observed in the infection experiment during a period of 33 days. Within this time the diameter of the largest cells increased from 27.4 to 113 microns and their cytoplasmic inclusions developed from the stage of small, compact bodies, looking very similar to Guarnieri bodies, into wide networks surrounding one-half of the nuclei.

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## EXPLANATION OF THE PLATE.

Figs. 1-4. Lymphocystis cells of different stages which developed on the tail fins of young pike perch treated with lymphocystis material of adult pike perch. Total preparations fixed with absol. alcohol 95 parts, acetic acid 5 parts, stained with Delafield's hematoxylin.

General labels: **i**—inclusion bodies, **m**—cell-membrane. × 580.

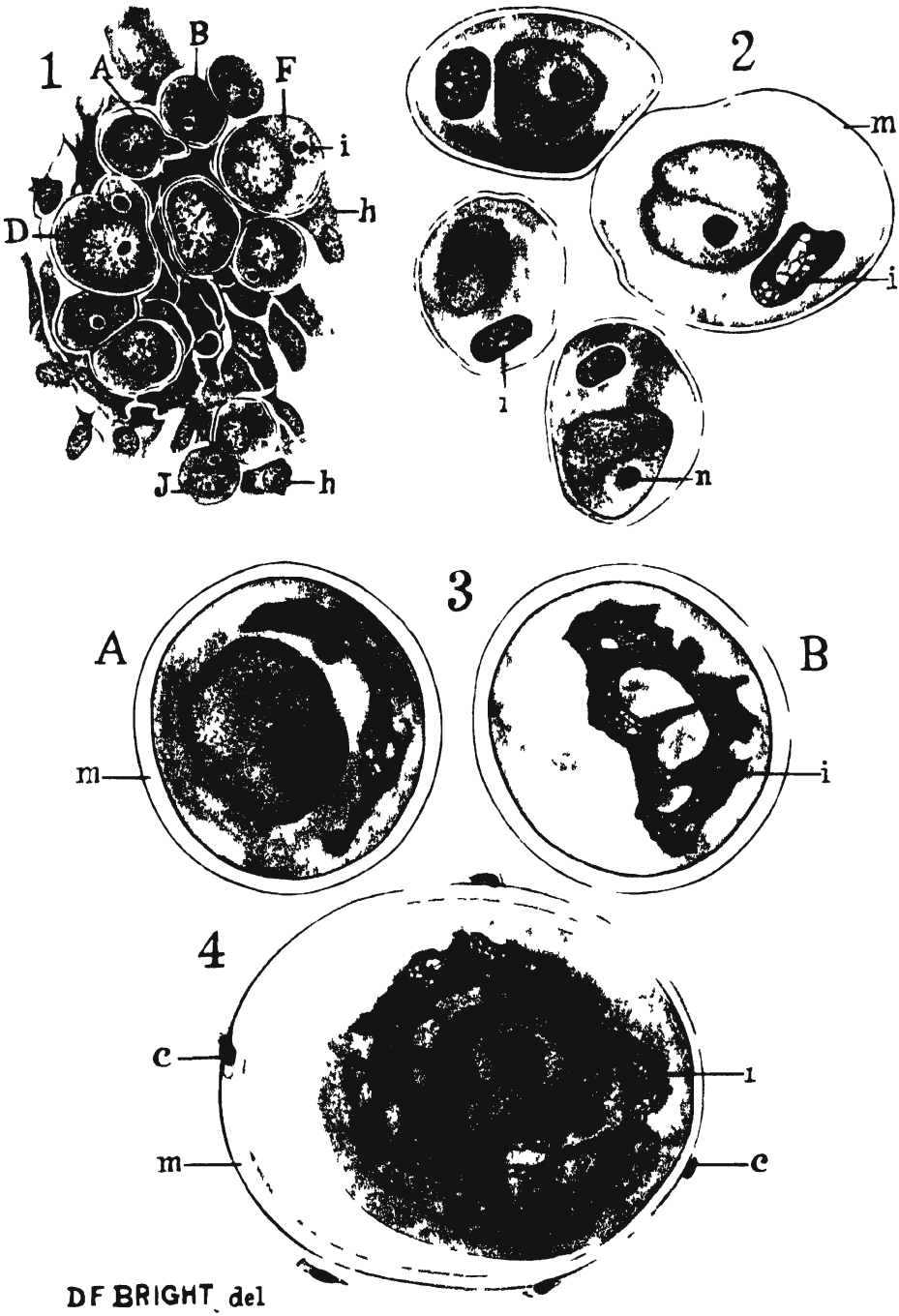
Fig. 1. Stage of the 29th day of the infection experiment. **A, B, D, F, J**—five of the 11 lymphocystis cells of the figured group. **h**—hypertrophied connective tissue cells not transformed into lymphocystis cells.

Fig. 2. Stage of the 44th day of the infection experiment. **n**—nucleolus.

Figs. 3 & 4. Stages of the 61st day of the infection experiment.

Fig. 3. **A**—lymphocystis cell in optical section; **B**—the same cell with higher adjustment.

Fig. 4. Lymphocystis cell with medium adjustment. **c**—small connective tissue cells lying above the membrane.




STUDIES ON VIRUS DISEASES OF FISH MORPHOLOGICAL AND EXPERIMENTAL OBSERVATIONS ON THE LYMPHOCYSTIS DISEASE OF THE PIKE PERCH STIZOSTEDION VITREUM

# 9.

# Studies on Lymphocystis Disease in the Orange Filefish, *Ceratacanthus schoepfii* (Walbaum), from Sandy Hook Bay, N. J.

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(Plates I-VIII).

## INTRODUCTION.

Lymphocystis disease is characterized by the development of small, irregular, solitary or confluent nodules of grayish-white color on the skin and fins of marine and fresh-water fishes. It was first reported as multiple tumors from the European flounders, *Pleuronectes flesus* and *P. platessa*, by Lowe (1874), McIntosh (1884, 1885) and Sandeman (1892). Microscopically, the disease appears as large cells, each surrounded by a thick membrane. The cells contain large nuclei, nucleoli, and cytoplasmic inclusions, the latter appearing either as discrete bodies or in the form of one or more networks. Woodcock (1904) believed these cells to be sporozoa, which he named *Lymphocystis johnstonei*. Since then various discussions have appeared in the literature concerning the true identity of the disease. Johnstone (1905) agreed with Woodcock as to its protozoan nature. A similar interpretation was given by Awerinzew (1907, 1909, 1911). He believed that the enlarged cells were stages in the life-history of a myxosporidian, which he called *Henneguya johnstonei* (Woodcock), disagreeing with Woodcock as to its taxonomic position. According to Awerinzew (1911), the youngest cells are minute in size and have a single nucleus. The cells grow rapidly, and in the process, chromatin passes out from the nucleus to form a chromidial ring in the cytoplasm. From this ring secondary nuclei are formed, around which bits of cytoplasm are cut off to form small cells referred to as "secondary ameboids." These are compared to sporonts of *Glugea*. Further, within the "secondary ameboids," spores are formed, the detailed structures of which were not clearly definable. Minchin (1912), reporting on this subject and on Woodcock's paper, regarded them as doubtful protozoa. Doflein (1928) included *Lymphocystis johnstonei* as one of the neosporidians although he recognized the controversy involved.

Mavor (1918) was the first to report the disease in America, having discovered the condition on the pike-perch, *Stizostedion vitreum*. He also thought that the cells were neosporidians, but considered them sufficiently different from the European *Lymphocystis* to propose the name *Lymphocystis vitrel*.

Zschieche (1910) was first to report the disease in the fresh-water paradise fish, *Macropodus*. However, he failed to recognize the true nature of this condition because he believed that the large cells observed were some form of fish ova.

Other investigators, however, are of the opinion that these cells are not parasites, but consider them as greatly hypertrophied host cells. This view was first formulated by Weissenberg (1914, 1920, 1921 b, c) who produced histological and cytological evidence that these "giant" cells were hypertrophied connective tissue cells. This evidence was deduced partly from periodic examination of experimentally produced tumors, especially those obtained in *Acerina cernua* and *Pleuronectes flesus*.

Similar interpretation was given to the disease found in *Sargus annularis* by Joseph (1917, 1918); for the European flounder, *Pleuronectes flesus*, by Claussen (1917), Plehn (1924), Johnstone (1926) and Raab (1935); for *P. platessa* and the paradise fish, *Macropodus*, by Schäperclaus (1935); for the East Indian coral fishes, *Premnas biaculeatus* and *Amphiprion percula*, by Benisch (1937). Lymphocystiosis was first demonstrated for the American Atlantic seaboard in the West Indian angelfish, *Angelichthys isabelita*, by Smith & Nigrelli (1937); for the hogfish, *Lachnolaimus maximus*, by Weissenberg, Nigrelli & Smith (1937); for the orange filefish, *Aleutera schoepfii*, by Weissenberg (1938); and for the common killifish, *Fundulus heteroclitus*, by Weissenberg (1939).

It is of interest to mention here that the disease described by Gilruth & Bull (1912) as *Lymphocystis macropodus* must not be confused with the condition reported by the above investigators. According to Gilruth & Bull, *L. macropodus* is a sarcosporidian-like parasite found in the intestinal mucosa of the kangaroo (*Macropus* sp.). Wenyon (1926), however, refers this parasite to the genus *Globidium*.

## Nature of Cytoplasmic Inclusions in Lymphocystis Cells.

Although Awerinzew (1911) considered the lymphocystis cells as protozoan, he nevertheless recognized the fact that the inclusion bodies found in the cytoplasm were made up of chromatin material given off by the nucleus. This chromatin material has been referred to as "chromidia," and he further believed that this was a normal nuclear behavior similar to that recognized among certain protozoa preparatory to "spore" formation.

Weissenberg (1914-1939) considers the inclusions as basochromatin and the tremendously developed network found in older hypertrophic cells as the result of growth of a granule of basochromatin which has the appearance of a Guarnieri-like body. In his later papers he reports that the cell hypertrophy is due to an intracellular virus. Joseph (1918) considered the reticulation to be modified and much hypertrophied centrophormium, a point disputed by Weissenberg (1921a). Jirovec (1932), employing a modified Feulgen's technique, concluded that the inclusions in lymphocystis cells were nuclear in origin, giving a positive reaction for thymonucleic acid. Raab (1935) concluded that the cell hypertrophy in lymphocystis was the result of an intracellular protozoan parasite (microsporodian) which he tentatively placed in the genus *Glugea*. Such intracellular organisms also have been known to cause tremendous cell hypertrophy. For example, *Glugea* (*Nosema*) *anomala*, parasitic in wandering connective tissue cells of the stickleback, enlarges from a cell 8 microns in diameter and containing a single organism to one 4,000 microns in diameter and containing thousands of spores (*vide* Weissenberg, 1921d, 1937). Hyde (1937) in his laboratory outline of filterable viruses considers lymphocystis a virus disease, following Weissenberg's opinion.

LYMPHOCYSTIS IN ORANGE FILEFISH FROM SANDY HOOK BAY, N. J.

Four orange filefish caught in the waters of Sandy Hook Bay, New Jersey, in August, 1938, were found heavily infected with lymphocystis; two taken in September of that year showed no external signs of the disease. Although the size and form of the external tumors varied considerably, the gross appearance was typical. These gross lesions are pictured in the photographs in Pl. I, Figs. 1 and 2. The material was freshly fixed in 10% neutral formalin, decalcified and stained with hematoxylin-eosin, Giemsa's or Mallory's triple stain. Some of the material was used in attempting experimental transmission.

Histological observations on the orange filefish material at our disposal indicate that the disease is not limited to a cutaneous manifestation, but that internal organs are involved as well. Material recently studied showed the presence of typical hypertrophic cells in the gastro-intestinal tract, spleen and ovary. These visceral lesions together with the cutaneous ones, will be discussed later in this paper.

Microscopically, the fully developed lymphocystis cells are seen in Pl. I, Fig. 3. In Pl. II, Fig. 4, the tumor has formed a small pedunculated mass attached to the fin by a fibrous stalk. The small tumor is composed entirely of fully developed lymphocystis cells, separated by a meshwork of dense hyalin material usually referred to as the hyalin membrane of the cell. Where the cells form isolated units in adjacent tissues the membrane closely surrounds the cytoplasm of each cell (Pls. V, VI, VII), but in the tumor mass the cell membrane material appears to be a confluent and connecting network (Pl. I, Fig. 3; Pls. II, III, IV). Outstanding as well is the fact that this membrane-like material is laid down early in the development of the hypertrophic mesenchymal cell, the latter eventually growing to typically gigantic size. The cell membrane material appears to be continuous at times with the more delicate reticulum of adjacent normal areas.

Whenever the lymphocystis cells are highly developed and closely packed together to form a tumor, ordinary connective tissue stroma of the tumor proper is very scanty and the blood supply is not a rich one. Epithelium overlying small nodules may either remain unchanged or be somewhat thickened.

The present material has afforded an opportunity to study collections or nests of growing lymphocystis cells, and certain progressive stages from the young fibroblastic phase up to the extremely hypertrophied adult cells. These observations on progressive stages of cell hypertrophy tend to confirm Weissenberg's (1914-1938) interpretation that the disease is primarily a cell hypertrophy affecting host connective tissue cells. It is further demonstrated in this study that the hypertrophic cells can be recognized at a very early stage (cells measuring 8.3 microns or 6 x 21 microns). At this stage, the hyalin membrane already has been developed; the cytoplasmic material is somewhat increased in amount over the normal; and the nucleus decidedly enlarged and deeply pycnotic. The shape of the young lymphocystis cells may be round, oval or fusiform. Certain early stages (9 x 24 microns) show cells in what resembles a binucleate condition (Pls. III, IV). In other cells (20 x 50 microns) the nuclear material appears in two forms (Pl. III, Figs. 6, 7): (a) as a deeply pycnotic primary nucleus which later hypertrophies to remain as the nucleus of the enlarged cell, and (b) a secondary nuclear mass, variable in size, which becomes vacuolated and reticulated. The latter mass of basophilic material represents probably the forerunner of the system of inclusion bodies which eventually become distributed in the cytoplasm of the enlarged older cell (Pl. IV, Fig. 9; Pl. V, Fig. 10). In these fully developed cells (see also Pl. VII, Fig. 14; and Pl. VIII) the chromatin forming the cell inclusion bodies is frequently dispersed in the region of the periphery of the cell and nucleus, either as a reticulum or as isolated chromatin granules. Such an extremely developed cell as

shown in Pl. V, Fig. 10, may measure 456 x 608 microns, the hypertrophied nucleus 54 microns, and the hypertrophied nucleolus 10 microns.

The ultimate fate of the lymphocystis cells is as yet not clearly understood, and has not been the subject of previous reports. In some of the sections of the orange filefish tumors composing our material, numerous cells appeared in various stages of degeneration. Since the material was immediately fixed, post-mortem autolytic changes can be probably excluded. In several preparations made from fishes in various stages of recovery, a healing phase of the lesion was demonstrated. It was noted here that the cell membranes were collapsed, lying in a thick fibrous scar tissue exhibiting no recognizable cell content except for small amounts of degenerated material. These degenerative changes, in conjunction with the collapse of cell membranes, suggest that lymphocystis cells have either died *in situ* or that the membranes have ruptured permitting evacuation of possible viral contents into adjacent tissue or into the surrounding water, depending on the immediate location of the cells. The collapsed membranes assume a bizzare appearance as seen in Pl. V, Fig. 11. The original shape is greatly distorted. The walls become approximated and infolded. The thickness of the membrane may be less than usual or greatly increased. Plate VI, Fig. 13, shows a degenerating lymphocystis cell in the spleen. A distinct break in the continuity of the membrane of the cell can be seen, resulting in an invasion of splenic tissue within the cyst cavity. In some of the collapsed cysts in cutaneous regions, loosely arranged connective tissue was noted within the cavity of the degenerated cells. Collections of lymphoid cells in the firm fibrous tissue surrounding collapsed cell membranes are not uncommon.

That lymphocystis disease is not limited to cutaneous lesions has been indicated by Woodcock (1904) and Awerinzew (1909) who reported having found these enlarged cells in the mesentery, intestine and ovary. However, illustrations do not accompany these observations. The study of the lymphocystis disease in orange filefish from Sandy Hook Bay indicates clearly that the lymphocystis disease cannot be regarded alone as a cutaneous lesion in this fish. In one of the specimens, the spleen showed numerous lymphocystis cells fully developed, usually lying in the substance of the splenic pulp. Plate VI, Fig. 12, shows a lymphocystis cell in the spleen in good condition, stained with hematoxylin-eosin, and measuring 364.8 x 480.4 microns. The splenic tissue surrounding the hypertrophied cell has a somewhat concentric arrangement. The infected spleen in this fish was greatly enlarged and on gross section the isolated lymphocystis cells could be readily distinguished by the naked eye or with a small hand lens.

A few lymphocystis cells were also encountered in the gastro-intestinal tract, as shown in Pl. VII and Pl. VIII, Fig. 16. One hypertrophied cell was found to occupy a position directly below the surface epithelium (Pl. VII, Fig. 14), being separated at the surface by a thin layer of flattened host cells (gastric epithelium). The hypertrophied nucleus in this cell showed fairly dense granular substance containing minute basophilic material. The hypertrophied nucleolus had a thick margin and contained closely packed spherical globules with lighter staining centers. In other areas cells were found lying deeper in the connective tissue fold (Pl. VII, Fig. 15). Here the cell lies almost in the middle of the fold, in close relation doubtless to the blood and lymphatic vessels of the intestinal wall. In Pl. VIII, Fig. 16 the lymphocystis cell lies below the submucosa and within the fold. In the latter two sites, the surrounding connective tissue may show a tendency towards encapsulation of the lymphocystis cell.

Again, typical lymphocystis cells, measuring 281.2 x 395.2 microns, were encountered in the ovary (Pl. VIII, Fig. 17). These were closely surrounded by developing oöcytes. No fibrous responses to the presence of lymphocystis cells were noted in this region.

Cytological details of lymphocystis cells occupying the visceral organs

correspond closely with the fully developed cells of the cutaneous lesions. There is this difference, however, in that there occurs no massing of cells to form tumors. The cells appear as isolated units and in no instances were young, growing cells encountered in these viscera. No lymphocystis cells were found in the liver or kidney. In one of our diseased fish, the liver tissue showed evidence of hyperplasia of biliary ducts, but the cause for these changes at the present time remains uncertain.

## Observations on Lymphocystis in the New York Aquarium.

Observations on lymphocystis disease among marine fishes in the New York Aquarium indicate that the disease appears at the height of the summer and has a tendency to disappear in late autumn and winter. Furthermore, outbreaks among fish showing the disease were invariably successive, *i.e.*, one fish may show the disease first, then another, etc., but not all simultaneously. Generally, there is a definite tendency for the infected fish to recover; the disease was seldom found to be fatal. Fish which showed the external manifestation of the disease have been kept for long periods (one year or more) after the external evidence had disappeared. Such fish seemed normal in all other respects.

It is interesting to point out that other species of fish kept in the same tank with infected specimens never showed signs of lymphocystiosis. Joseph (1918) reported similar findings. For example, such forms as *Mugil, Crenilabrus* and *Blennius* kept in the same tank with infected *Sargus*, the sunbream, showed no evidence of lymphocystis. In our observations, however, fishes kept in the same tank with lymphocystis infected specimens were usually more closely related forms and originally lived in the same region or habitat.

## Attempts at Transmission.

Fifty killifish, *Fundulus heteroclitus*, were used for purposes of experimental transmission. A heavily infected orange filefish was used as the donor. The fishes were kept at 21° C. and in sea-water having a specific gravity of 1.0260. Ten of the fish were scarified and rubbed with lymphocystis material; ten were injected interperitoneally with an emulsion of infected material made up in pure sea-water; ten killifish were fed lymphocystis material; 20 fish were used as controls. The experimental fish were examined at the end of 1, 2, 3, and 4 weeks; 2, 3, and 4 months later. All results were negative. These findings, together with the observational data given above, may indicate that the disease is host-specific.

It is interesting to mention here, that in a recent contribution, Weissenberg (1939) also obtained negative results in attempting to transmit lymphocystis from infected pike-perch (*Stizostedion vitreum*) to both marine and fresh-water killifishes (*Fundulus heteroclitus* and *F. diaphanus*).

## Discussion.

Evidence obtained from studies on lymphocystis disease occurring on the orange filefish from Sandy Hook Bay, N. J., is submitted showing that the lesions are not limited to cutaneous areas but that typical hypertrophied connective tissue cells occur also in the spleen, ovary and gastro-intestinal tract. Fully grown lymphocystis cells were found in these organs as solitary cells and cytologically correspond to similar cells in skin lesions. It will require the study of further material to determine the origin and fate of these enlarged cells involving the structures of the visceral organs. They may represent metastatic cells from cutaneous lesions which have found

their way to these visceral sites by way of vascular or lymphatic vessels, and have continued their development to the mature state in a new environment. Another explanation, of possibly greater significance, is that the agent causing the lymphocystiosis is ingested and gains access to the body and skin of the host through a portal of entry represented by the mucosa of the gastro-intestinal tract. It is interesting in this connection to point out that Weissenberg (1914, 1921) has described the transmission of lymphocystis disease by the feeding method in the European fishes, *Acerina cernua* and *Pleuronectes flesus*. Recently (still unpublished) he was able to transfer the lymphocystis by this method from diseased pike-perch of one locality to non-diseased individuals of the same species from a widely separated locality (see Weissenberg, 1939).

Weissenberg (1938) has presented data on lymphocystis disease in the orange filefish (*Aleutera schoepfii* = *Ceratacanthus schoepfii*) present in the Philadelphia Aquarium. He was able to trace the development of the connective tissue cells from those measuring 25-46 microns, and each containing a reticulated inclusion body on one side of the nucleus, to cells measuring 312-515 microns, containing inclusion bodies in the form of connecting networks arranged at the periphéry and immediately below the thickened membrane. His interpretation concerning the development of the inclusions differs from the one given in the present paper. He states that during cell hypertrophy the inclusions appear "first as very thin points. Then they form small, compact, round bodies. Next they grow to oval discs with reticular or alveolar structure, and to fenestrated calottes. Finally, they spread out into the cytoplasm as fine networks." Weissenberg, however, does not indicate the origin of the original inclusion body, although he recognizes the fact that it is basochromatic in nature. The study of our material suggests that the system of cell inclusions present in the growing lymphocystis cell arises from one of two nuclear-like masses developed in early stages; and that therefore, such inclusions are perhaps of nuclear origin. A similar interpretation of the origin of inclusion bodies in this disease was first indicated by Woodcock (1904) and Awerinzew (1911), both reportng the inclusions as forming a "chromidial ring" derived from the nucleus.

Weissenberg (1914-1939) was first to consider lymphocystis as a cell hypertrophy of the host connective tissue, postulating that the causative agent is an intracellular virus probably liberated by the inclusion bodies. The same author was able to transmit the disease experimentally to normal fish by feeding infected tissue. Critical tests have not been made as yet to prove definitely that a virus is involved as a causative agent.

## SUMMARY.

1. Lymphocystis disease is described in orange filefish (*Ceratacanthus schoepfii*) from Sandy Hook Bay, New Jersey.

2. Histological studies reveal that this disease is not merely a cutaneous one, but that internal organs such as the gastro-intestinal tract, spleen and ovary are involved as well.

3. The present observations on progressive stages of cell hypertrophy support Weissenberg's interpretation that the disease results in a hypertrophy of connective tissue cells of the host.

4. The origin and the development of the cell inclusions from one of two nuclear masses formed in certain early stages of the disease is suggested.

5. Certain stages in the healing process of the disease are described.

6. Observations and attempts at experimental transmission indicate that lymphocystiosis may be species-specific.

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## EXPLANATION OF PLATES.

### PLATE I.

Figs. 1 and 2. Cutaneous tumors caused by lymphocystis infection. These were taken from fins of orange filefish caught at Sandy Hook Bay, N. J.

Fig. 3. Typical nodule of lymphocystis tumor. 40 ×. Stained with Giemsa's. (E) epithelium; (L) lymphocystis cells; (M) meshwork of membrane material surrounding lymphocystis cells.

### PLATE II.

Fig. 4. Microscopic section through lymphocystis disease of the skin. 125 ×. H-E. (N) pedunculated nodule composed of fully developed cells, lying in a meshwork of cell membrane material. Note scanty connective tissue stroma containing lymphocytes. (X) area of growing lymphocystis cells in various stages of hypertrophy.

Fig. 5. Section as in Fig. 4, but at a different level. 125 ×. (E) cutaneous epithelium; (X) nest of growing cells; (Y) fully developed lymphocystis cells. Note the progressive stages of cell hypertrophy.

### PLATE III.

Fig. 6. Young lymphocystis cells. 250 ×. H-E. (A) "Binucleate" stage; (B) one nucleus appears compact; the other show signs of vacuolization.

Fig. 7. Young lymphocystis cells. 500 ×. H-E. Higher magnification of a section like that shown in Fig. 6, but at a different level. Note the two types of nuclear masses.

### PLATE IV.

Fig. 8. Young lymphocystis cells. 300 ×. H-E. Note the various "binucleate" stages.

Fig. 9. Lymphocystis cells slightly older than those shown in preceding photomicrographs. This figure shows the reticulate inclusions beginning to disperse.

### PLATE V.

Fig. 10. Fully matured lymphocystis cell, completely hypertrophied. 200 ×. H-E. (N) nucleus; (NL) nucleolus; (I) peripheral cytoplasmic inclusions; (M) cell membrane; (XI) peri-nuclear inclusion bodies.

Fig. 11. Section of cutaneous region showing healing stages from lymphocystis disease. 100 ×. H-E. (H) collapsed hyalin and greatly distorted lymphocystis cell membrances found in dense fibrous (scar) tissue (S).

### PLATE VI.

Fig. 12. Completely hypertrophied lymphocystis cell in the spleen. 150 ×. H-E. As a result of fixation the cell has shrunken away from the concentrically arranged splenic tissue.

Fig. 13. Degenerated lymphocystis cell in the spleen. 150 ×. H-E. Note rupture of cell membrane between (R) and (S), permitting invasion of splenic tissue (Z).

## PLATE VII.

Fig. 14. Lymphocystis cell at the surface of the mucous membrane of stomach. 125 ×. H-E.

Fig. 15. Lymphocystis cell lying in connective tissue below mucous membrane of stomach. **(N)** nucleus; **(NL)** nucleolus; **(I)** cytoplasmic inclusion bodies; **(G)** gastric mucous membrane; **(V)** blood vessel.

## PLATE VIII.

Fig. 16. Lymphocystis cell in a gastric fold. 60 ×. H-E.

Fig. 17. Lymphocystis cell **(L)** in the ovary. 125 ×. Giemsa's stain. The cells surrounding the lymphocystis cell are oöcytes **(O)**.

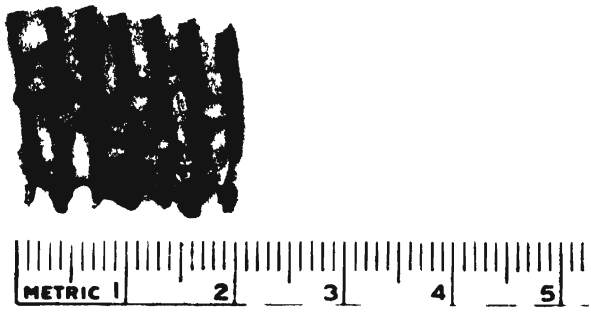


FIG 1

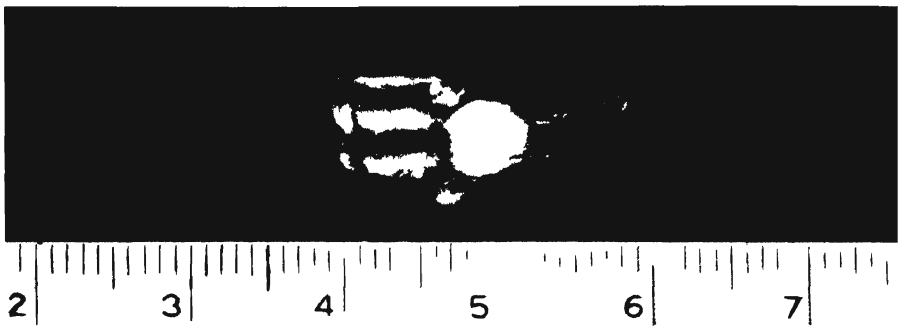


FIG 2.

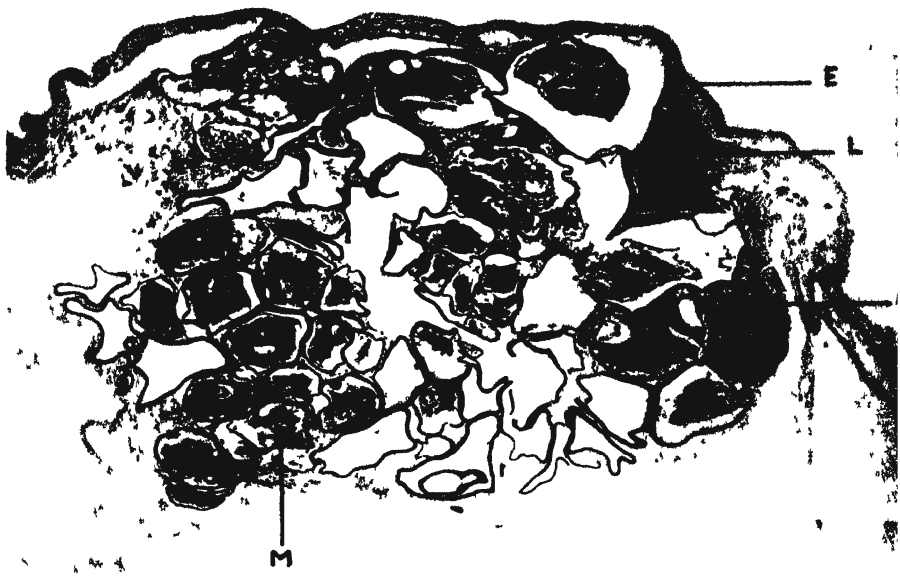


FIG 3

STUDIES ON LYMPHOCYSTIS DISEASE IN THE ORANGE FILEFISH, CERATACANTHUS SCHOEPFII (WALBAUM) FROM SANDY HOOK BAY, N J.

FIG 4

FIG. 5.

STUDIES ON LYMPHOCYSTIS DISEASE IN THE ORANGE FILEFISH, CERATACANTHUS SCHOEPFII (WALBAUM), FROM SANDY HOOK BAY, N. J.

FIG. 6.

FIG. 7.

STUDIES ON LYMPHOCYSTIS DISEASE IN THE ORANGE FILEFISH, CERATACANTHUS SCHOEPFII (WALBAUM), FROM SANDY HOOK BAY, N. J.

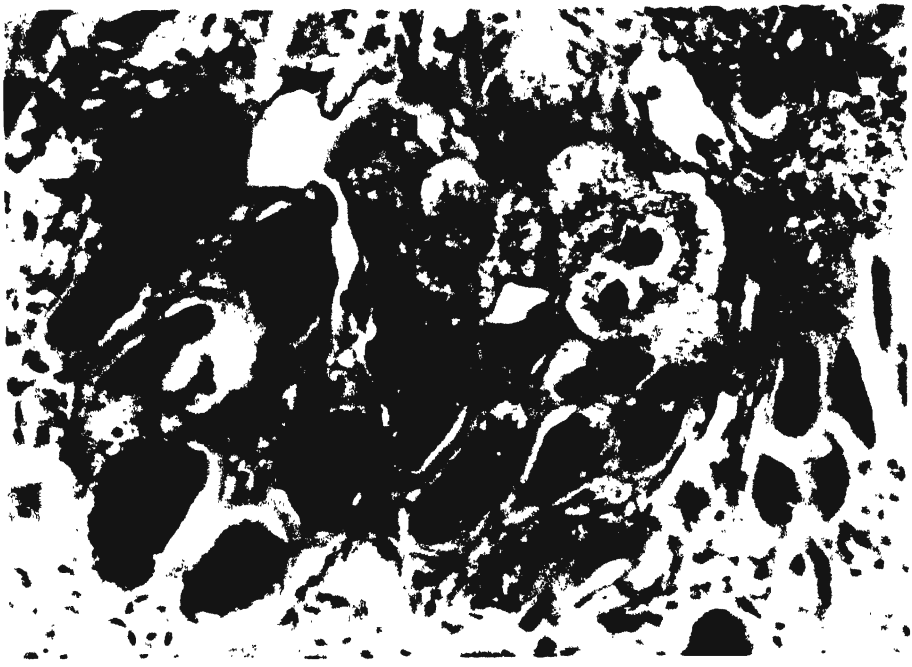

FIG. 8.

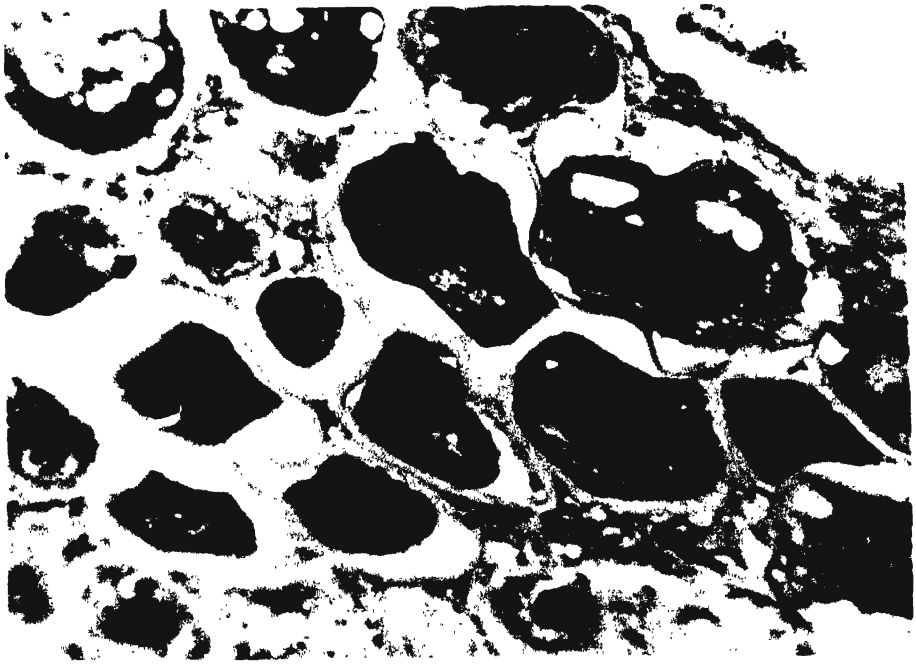

FIG. 9.

STUDIES ON LYMPHOCYSTIS DISEASE IN THE ORANGE FILEFISH, CERATACANTHUS SCHOEPFII (WALBAUM), FROM SANDY HOOK BAY, N. J.

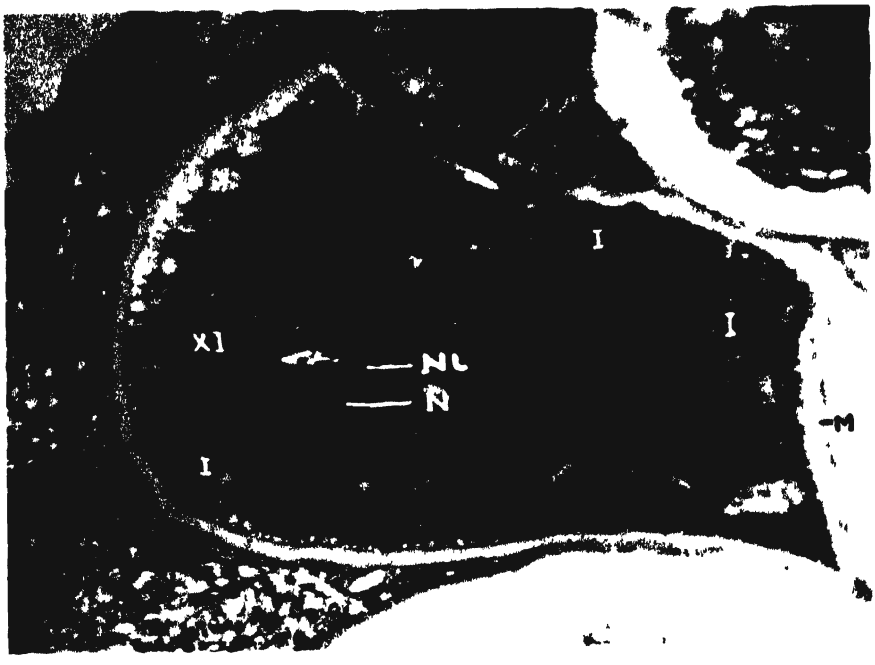


FIG 10

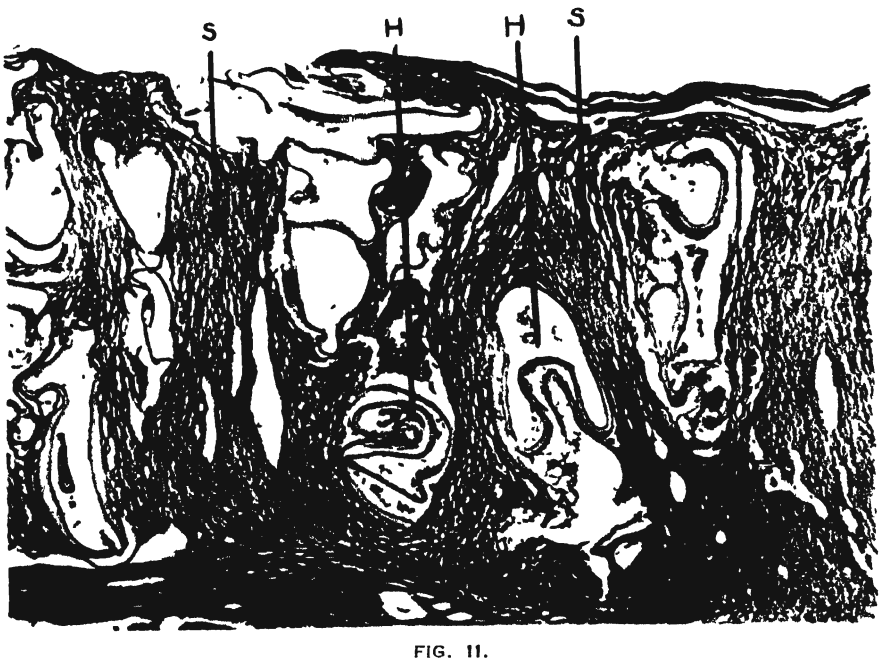


FIG. 11.

STUDIES ON LYMPHOCYSTIS DISEASE IN THE ORANGE FILEFISH, CERATACANTHUS SCHOEPFII (WALBAUM), FROM SANDY HOOK BAY, N. J.

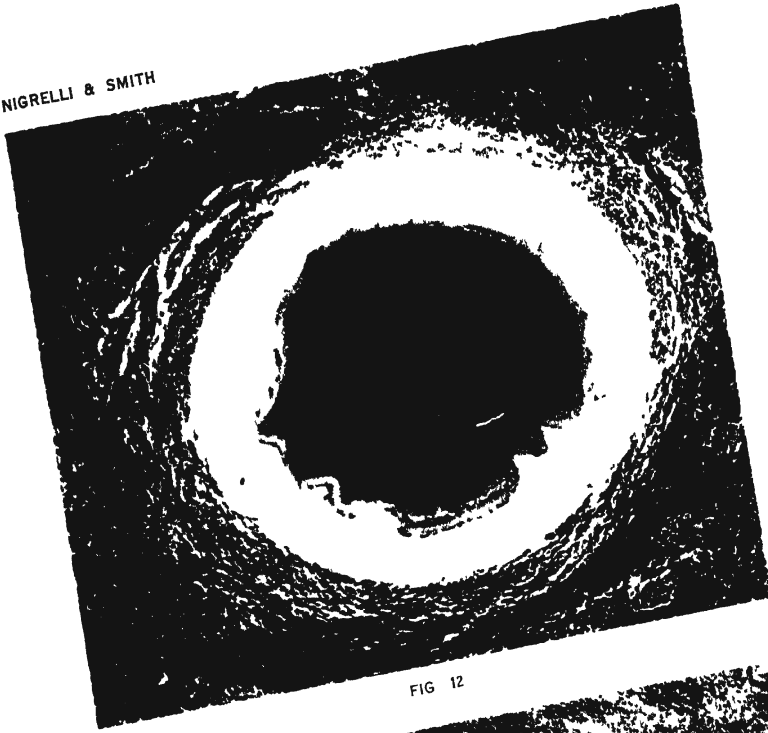

FIG 12

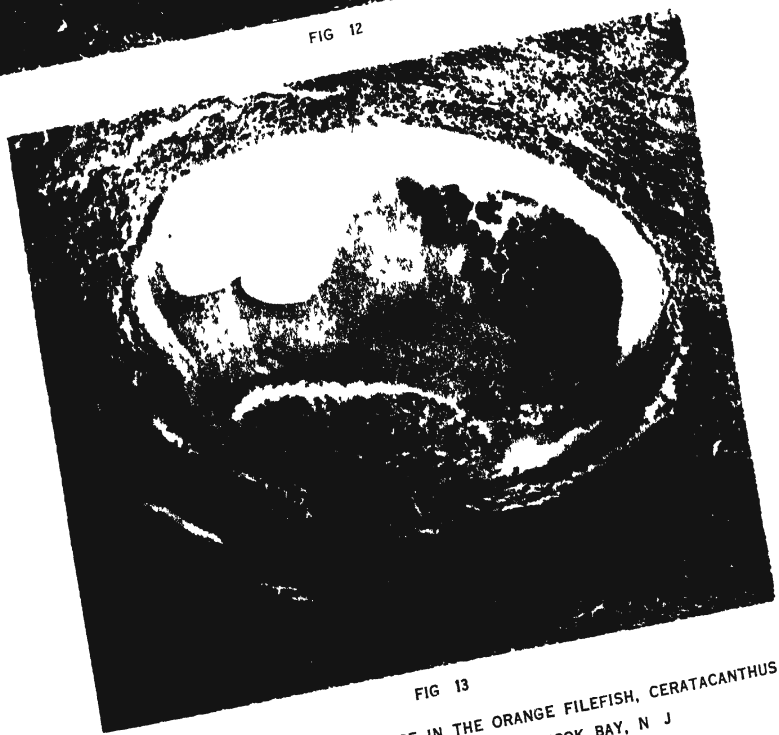

FIG 13

STUDIES ON LYMPHOCYSTIS DISEASE IN THE ORANGE FILEFISH, CERATACANTHUS SCHOEPFII (WALBAUM), FROM SANDY HOOK BAY, N J

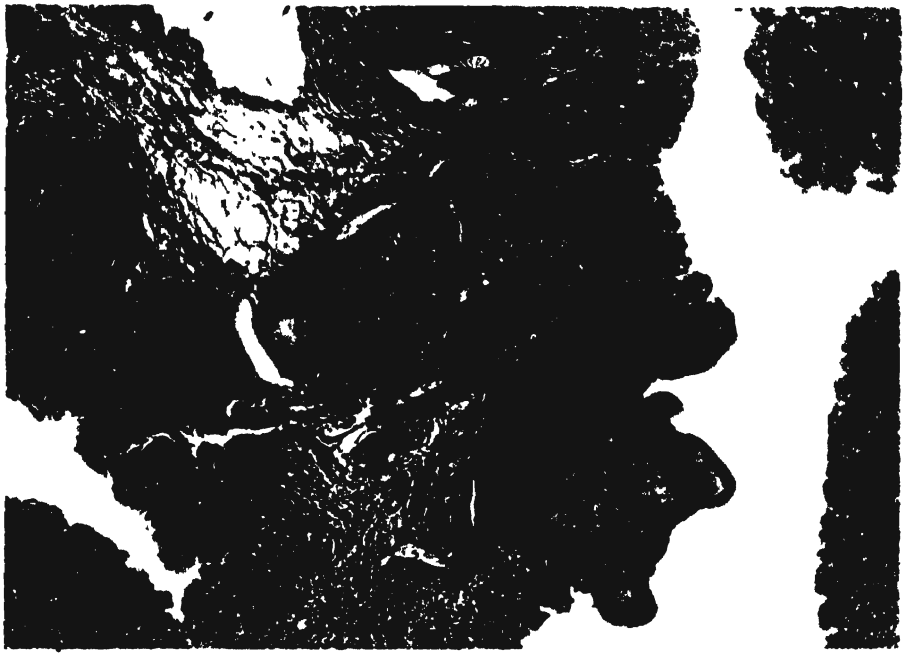

FIG. 14.

FIG. 15.

STUDIES ON LYMPHOCYSTIS DISEASE IN THE ORANGE FILEFISH, CERATACANTHUS SCHOEPFII (WALBAUM), FROM SANDY HOOK BAY, N. J.

FIG 16

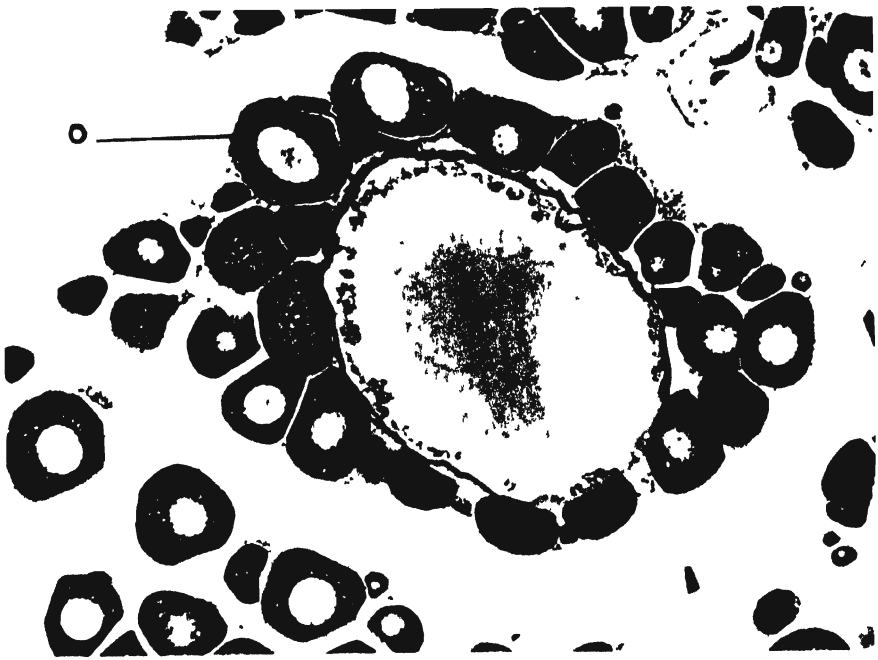

FIG 17

STUDIES ON LYMPHOCYSTIS DISEASE IN THE ORANGE FILEFISH, CERATACANTHUS SCHOEPFII (WALBAUM), FROM SANDY HOOK BAY, N J.

# 10.

## Report of the Hospital and Laboratory of the New York Zoological Park, 1938. Mortality Statistics of the Society's Collection.

C. R. SCHROEDER
*Veterinarian*

This and the following 13 papers, numbers 10 to 23 inclusive, form the bulk of the report of the Hospital and Laboratory of the New York Zoological Park for 1938. A few papers were received too late for inclusion in Part 3 of *Zoologica* and will be published in Part 4.

This particular paper is a résumé of the causes of death in the collection and employs the titles of the International Classification of Causes of Death (human) adopted by an international commission in 1929. Necessarily some of the titles have been modified to include specific animal diseases not encountered in human medicine and to exclude certain diseases of humans to which animal populations have native immunity. It has been suggested that joint causes of death be used, and this practice is attempted here with precedence given to those conditions which we believe were primary.

In the (unfortunately) rare instances in which mortality statistics of zoological gardens have been reported in the past, stress has often been laid upon percentages of mortality. This device has been eliminated from the present report because it is believed that percentages are all too likely to give a false interpretation of the actual state of the collection. Animals in zoological gardens fall into two main groups: the immature (juvenile or pre-adult), and mature (adult). Finer distinctions may sometimes be made, particularly in the Mammalia, but even here accuracy is frequently problematical unless ages are positively known, as when an animal has been born in captivity. Consequently we may find that we have a community populated with individuals the majority of which have reached the upper limit of life expectancy—with the result that in any one year the mortality percentage may rise abruptly with no real cause other than a shift in the average age of the exhibits.

At this stage of zoological knowledge, no reliable criterion is available for age determination in birds and reptiles, and they are therefore listed here simply as immature or adult. Mammals have been classified as immature or pre-adult, adult and post-adult or senile, except where specific ages are known. Longevity records of exhibition life are, of course, available, but the age of newly acquired specimens is seldom accurately known.

To prevent the complication of this table beyond easy interpretation, we have not divided the exhibits into groups below Orders. The table will be found to state the postmortem reference number as carried in the records of the Hospital and Laboratory of the New York Zoological Park. Preceding the table is presented a list of specimens in numerical sequence, grouped by Classes, which will identify each by common and scientific name.

Anyone interested in specific postmortem reports may apply directly to the Hospital and Laboratory, citing the postmortem reference numbers.

For example, the first item in the table lists, under selected causes of death, No. 1, typhoid, one immature member of the Squamata, R-26-38. R refers to reptiles; 26 is the 26th postmortem conducted on a reptile; 38 refers to the year 1938. Our reference list identifies the specimen as a South American boa, *Constrictor c. constrictor*. Our laboratory record cites the organism recovered, together with sugar reactions and final serologic identification, 4 plus agglutination against a specific *Eberthella typhosa* antiserum, in a dilution of 1:640.

To take another example, the adult member of the Carnivora M-155-38, listed under selected causes as 46F, cancer of the pancreas. The reference list preceding the table reports M-155-38 as a Kadiak bear, *Ursus middendorffi*. In this instance a report is currently published, as paper number 11 in this series.

Where especially interesting cases were studied in detail, either by members of the staff or specialists, reports are published in this and other journals. For the greater mass of material, however, it seemed more advantageous to give a titled summary as in the table that follows, with reference numbers that would enable anyone interested to obtain full information by applying to the laboratory of the Zoological Park, rather than to attempt here a detailed report that would necessarily be almost interminable.

It remains only to be noted that many specimens in our permanent records originated outside the Zoological Park and are not, therefore, included in this statistical summary, and that not all specimens, in the collections, that died during the year were sent to the laboratory for examination.

## Specimens from the Collections of the New York Zoological Park Examined by the Laboratory in 1938.

### Reptilia.

| *Laboratory Number* | *Common Name* | *Scientific Name* |
|---|---|---|
| R- 1-38 | Western Diamond-back Rattlesnake | *Crotalus atrox* |
| R- 2-38 | Timber Rattlesnake | *Crotalus h. horridus* |
| R- 3-38 | Indian Cobra | *Naja n. naja* |
| R- 4-38 | Central American Iguana | *Iguana i. rhinolopha* |
| R- 5-38 | Green Tree Boa | *Boa canina* |
| R- 6-38 | Anaconda | *Eunectes murinus* |
| R- 7-38 | Water Snake | *Natrix s. sipedon* |
| R- 8-38 | Green Tree Boa | *Boa canina* |
| R- 9-38 | Western Diamond-back Rattlesnake | *Crotalus atrox* |
| R- 10-38 | Water Moccasin | *Agkistrodon piscivorus* |
| R- 11-38 | Yellow Cobra | *Naja nivea* |
| R- 12-38 | Blood Python | *Python curtus* |
| R- 13-38 | Western Diamond-back Rattlesnake | *Crotalus atrox* |
| R- 14-38 | Green Tree Boa | *Boa canina* |
| R- 15-38 | South American Boa | *Constrictor c. constrictor* |
| R- 16-38 | Anaconda | *Eunectes murinus* |
| R- 17-38 | Gaboon Viper | *Bitis gabonica* |
| R- 19-38 | Central American Iguana | *Iguana i. rhinolopha* |
| R- 20-38 | Green Tree Boa | *Boa canina* |
| R- 21-38 | Puff Adder | *Bitis arietans* |
| R- 22-38 | Gaboon Viper | *Bitis gabonica* |
| R- 23-38 | Indian Python | *Python molurus* |
| R- 24-38 | Gopher Snake (Indigo) | *Drymarchon corais melanurus* |
| R- 25-38 | South American Boa | *Constrictor c. constrictor* |
| R- 26-38 | South American Boa | *Constrictor c. constrictor* |
| R- 27-38 | South American Boa | *Constrictor c. constrictor* |
| R- 28-38 | Anaconda | *Eunectes murinus* |
| R- 29-38 | Green Tree Boa | *Boa canina* |
| R- 30-38 | Bushmaster | *Lachesis muta* |
| R- 31-38 | King Snake | *Lampropeltis getulus floridana* |
| R- 32-38 | Egg-eating Snake | *Dasypeltis scabra* |
| R- 33-38 | Pine Snake | *Pituophis m. melanoleucus* |
| R- 34-38 | Banty Banty (African Coral Snake) | *Homorelaps lacteus* |

| *Laboratory Number* | *Common Name* | *Scientific Name* |
|---|---|---|
| R- 35-38 | South American Boa | *Constrictor c. constrictor* |
| R- 36-38 | European Glass Snake | *Ophisaurus apodus* |
| R- 37-38 | South American Rat Snake | *Spilotes pullatus* |
| R- 38-38 | Water Moccasin | *Agkistrodon piscivorus* |
| R- 39-38 | Ball Python | *Python regius* |
| R- 40-38 | Green Tree Boa | *Boa canina* |
| R- 41-38 | Eastern Diamond-back Rattlesnake | *Crotalus adamanteus* |
| R- 42-38 | Indian Cobra | *Naja n. naja* |
| R- 43-38 | Puff Adder | *Bitis arietans* |
| R- 44-38 | Tegu Lizard | *Tupinambis teguixin* |
| R- 45-38 | Striped Racer | *Masticophis t. taeniatus* |
| R- 46-38 | Western Diamond-back Rattlesnake | *Crotalus atrox* |
| R- 47-38 | Western Diamond-back Rattlesnake | *Crotalus atrox* |
| R- 48-38 | Western Diamond-back Rattlesnake | *Crotalus atrox* |
| R- 49-38 | Green Tree Boa | *Boa canina* |
| R- 50-38 | Yellow Cobra | *Naja nivea* |
| R- 51-38 | Western Diamond-back Rattlesnake | *Crotalus atrox* |
| R- 52-38 | Eastern Diamond-back Rattlesnake | *Crotalus adamanteus* |
| R- 53-38 | Eastern Diamond-back Rattlesnake | *Crotalus adamanteus* |
| R- 54-38 | Eastern Diamond-back Rattlesnake | *Crotalus adamanteus* |
| R- 55-38 | Green Tree Boa | *Boa canina* |
| R- 56-38 | Central American Iguana | *Iguana i. rhinolopha* |
| R- 57-38 | South American Boa | *Constrictor c. constrictor* |
| R- 58-38 | Semi-annulated Snake | *Tarbophis semiannulatus* |
| R- 59-38 | Western Diamond-back Rattlesnake | *Crotalus atrox* |
| R- 60-38 | Tiger Snake | *Notechis scutatus* |
| R- 61-38 | Eastern Diamond-back Rattlesnake | *Crotalus adamanteus* |
| R- 62-38 | Eastern Diamond-back Rattlesnake | *Crotalus adamanteus* |
| R- 63-38 | Tiger Snake | *Notechis scutatus* |
| R- 64-38 | Western Diamond-back Rattlesnake | *Crotalus atrox* |
| R- 65-38 | Eastern Diamond-back Rattlesnake | *Crotalus adamanteus* |
| R- 66-38 | Water Moccasin | *Agkistrodon piscivorus* |
| R- 67-38 | Prairie Rattlesnake | *Crotalus v. viridis* |
| R- 68-38 | Rosy Boa | *Lichanura r. roseofusca* |
| R- 69-38 | Western Diamond-back Rattlesnake | *Crotalus atrox* |
| R- 70-38 | Australian Black Snake | *Pseudechia porphyriacus* |
| R- 71-38 | South American Rat Snake | *Spilotes pullatus* |
| R- 72-38 | South American Blowing Snake | Not identified |
| R- 73-38 | Rhinoceros Viper | *Bitis nasicornis* |
| R- 74-38 | South American Boa | *Constrictor c. constrictor* |
| R- 75-38 | Water Snake | *Natrix sipedon compressicauda* |
| R- 76-38 | Gaboon Viper | *Bitis gabonica* |
| R- 77-38 | Prairie Rattlesnake (Pacific) | *Crotalus viridus oregonus* |
| R- 78-38 | Water Snake | *Natrix s. sipedon* |
| R- 79-38 | Florida Gopher Tortoise | *Testudo polyphemus* |
| R- 80-38 | Large-headed Turtle | *Platysternon megacephalum* |
| R- 81-38 | Mexican King Snake | *Lampropeltis getulus splendida* |
| R- 82-38 | Copperhead | *Agkistrodon m. mokasen* |
| R- 83-38 | Eastern Diamond-back Rattlesnake | *Crotalus adamanteus* |
| R- 84-38 | Ball Python | *Python regius* |
| R- 85-38 | Green Tree Boa | *Boa canina* |
| R- 86-38 | African Monitor | *Varanus niloticus* |
| R- 87-38 | Regal Python | *Python reticulatus* |
| R- 88-38 | Western Diamond-back Rattlesnake | *Crotalus atrox* |
| R- 89-38 | Eastern Diamond-back Rattlesnake | *Crotalus adamanteus* |
| R- 90-38 | Western Diamond-back Rattlesnake | *Crotalus atrox* |
| R- 91-38 | South American Boa | *Constrictor c. constrictor* |
| R- 92-38 | Green Tree Boa | *Boa canina* |
| R- 93-38 | Green Tree Boa | *Boa canina* |
| R- 94-38 | Green Tree Boa | *Boa canina* |
| R- 95-38 | Ringed Boa | *Epicrates cenchris* |
| R- 96-38 | Green Tree Boa | *Boa canina* |
| R- 97-38 | Copperhead | *Agkistrodon m. mokasen* |
| R- 98-38 | Blue-tongued Lizard | *Tiliqua scincoides* |
| R- 99-38 | Anaconda | *Eunectes murinus* |
| R-100-38 | Karung (Indian Water Snake) | *Acrochordus javanicus* |
| R-101-38 | Karung (Indian Water Snake) | *Acrochordus javanicus* |
| R-102-38 | Prairie Rattlesnake | *Crotalus v. viridis* |
| R-103-38 | Ball Python | *Python regius* |
| R-104-38 | South American Boa | *Constrictor c. constrictor* |

## AMPHIBIA.

| | | |
|---|---|---|
| Am- 1-38 | Bullfrog | *Bufo catesbeiana* |

| *Laboratory Number* | *Common Name* | *Scientific Name* |
|---|---|---|
| | **AVES.** | |
| A- 1-38 | Homing Pigeon | *Columba livia* var. |
| A- 2-38 | Australian Broad-billed Roller | *Eurystomus orientalis pacificus* |
| A- 3-38 | California Brown Pelican | *Pelecanus occidentalis californicus* |
| A- 5-38 | Paradise Whydah | *Steganura p. paradisea* |
| A- 6-38 | Paradise Whydah | *Steganura p. paradisea* |
| A- 7-38 | Green-winged Trumpeter | *Psophia v. viridis* |
| A- 8-38 | Hyacinthine Macaw | *Anodorhynchus hyacinthinus* |
| A- 9-38 | Broad-winged Hawk | *Buteo p. platypterus* |
| A- 10-38 | Toco Toucan | *Ramphastos toco* |
| A- 11-38 | Golden Pheasant | *Chrysolophus pictus* |
| A- 12-38 | White Ibis | *Guara alba* |
| A- 13-38 | Japanese Blue Rock Thrush | *Monticola solitaris philippensis* |
| A- 14-38 | Ostrich | *Struthio c. camelus* |
| A- 15-38 | African Silver Bill | *Euodice c. cantans* |
| A- 16-38 | White Pheasant | *Phasianus c. colchicus* × *P. c. torquatus* |
| A- 17-38 | California Brown Pelican | *Pelecanus occidentalis californicus* |
| A- 18-38 | White-shouldered Whydah | *Coliuspasser a. albonotatus* |
| A- 19-38 | Brazilian Silver-beak Tanager | *Ramphocelus b. brasilius* |
| A- 20-38 | Cuban Barn Owl | *Tyto alba furcata* |
| A- 21-38 | Gray-chested Bird of Paradise | *Paradisaea decora* |
| A- 22-38 | European Raven | *Corvus corax corax* |
| A- 24-38 | Great Horned Owl | *Bubo v. virginianus* |
| A- 25-38 | Cayenne Wood Rail | *Aramides c. cajanea* |
| A- 26-38 | Orinoco Goose | *Neochen jubata* |
| A- 27-38 | Yellowhammer | *Emberiza c. citrinella* |
| A- 28-38 | Curaçao Crested Quail | *Colinus cristatus cristatus* |
| A- 29-38 | Costa Rican Green Tanager | *Chlorophonia callophrys* |
| A- 30-38 | European Curlew | *Numenius a. arquata* |
| A- 31-38 | Blue-backed Manakin | *Chiroxiphia p. pareola* |
| A- 32-38 | Pileated Jay | *Cyanocorax chrysops chrysops* |
| A- 33-38 | Cereopsis Goose | *Cereopsis novae-hollandiae* |
| A- 34-38 | Canada Goose | *Branta c. canadensis* |
| A- 35-38 | Black Duck | *Anas rubripes tristis* |
| A- 36-38 | Count Salvadori's Bird of Paradise | *Paradisaea s. salvadorii* |
| A- 37-38 | Black Duck | *Anas rubripes tristis* |
| A- 39-38 | Wattled Ibis | *Bostrychia carunculata* |
| A- 40-38 | California Brown Pelican | *Pelecanus occidentalis californicus* |
| A- 41-38 | Japanese Gray Thrush | *Turdus cardis* |
| A- 42-38 | Eastern Cardinal | *Richmondena c. cardinalis* |
| A- 43-38 | Citron-crested Cockatoo | *Kakatoe citronocristata* |
| A- 44-38 | Purple Caribbean Hummingbird | *Eulampis jugularis* |
| A- 46-38 | Violaceus Jay | *Cyanocorax violaceus* |
| A- 48-38 | Sydney Waxbill | *Aegintha t. temporalis* |
| A- 49-38 | Philippine White-eye | *Zosterops meyeni* |
| A- 50-38 | American Egret | *Casmerodius albus egretta* |
| A- 51-38 | Superb Bird of Paradise | *Lophorina superba latipennis* |
| A- 53-38 | Bourke Parrakeet | *Neopsephotus b. bourkii* |
| A- 54-38 | Gould's Yellow-rumped Manakin | *Munia flaviprymna* |
| A- 55-38 | Hutchins's Goose | *Branta canadensis hutchinsii* |
| A- 56-38 | American Brant | *Branta bernicla hrota* |
| A- 57-38 | Yellow-naped Amazon | *Amazona ochrocephala auro-palliata* |
| A- 58-38 | Pied Myna | *Sturnopastor c. contra* |
| A- 59-38 | Gould's Yellow-rumped Manakin | *Munia flaviprymna* |
| A- 60-38 | Golden-breasted Cotinga | *Euchlornis a. aureopectus* |
| A- 61-38 | Iceland Gull | *Larus leucopterus* |
| A- 62-38 | Blue-bearded Jay | *Cyanocorax cyanopogon* |
| A- 63-38 | Red-faced Gouldian Finch | *Poephila gouldiae* var. |
| A- 64-38 | Black-faced Gouldian Finch | *Poephila gouldiae* |
| A- 65-38 | Cherry Finch | *Aidemosyne m. modesta* |
| A- 66-38 | Gray-headed Amazon | *Amazona farinosa inornata* |
| A- 67-38 | Manchurian Crane | *Grus japonensis* |
| A- 68-38 | West African Crowned Crane | *Balearica p. pavonina* |
| A- 69-38 | Brush Turkey | *Alectura l. lathami* |
| A- 70-38 | Orange-cheek Waxbill | *Estrilda m. melpoda* |
| A- 71-38 | Black-faced Gouldian Finch | *Poephila gouldiae* |
| A- 72-38 | Short-eared Owl | *Asio f. flammeus* |
| A- 73-38 | South African Ostrich | *Struthio camelus australis* |
| A- 74-38 | Red-tailed Finch | *Bathilda r. ruficauda* |
| A- 75-38. | Black-headed Waxbill | *Estrilda a. atricapilla* |
| A- 76-38 | Edward's Pheasant | *Hierophasis edwardsi* |
| A- 77-38 | Guiana Chachalaca | *Ortalis m. motmot* |

| *Laboratory Number* | *Common Name* | *Scientific Name* |
|---|---|---|
| A- 78-38 | Fire-tufted Barbet | *Psilopogon pyrolophus* |
| A- 79-38 | Indian Peafowl | *Pavo cristatus* |
| A- 80-38 | Scarlet Ibis | *Guara rubra* |
| A- 81-38 | Quetzal | *Pharomachrus m. mocinno* |
| A- 82-38 | Jackdaw | *Corvus m. monedula* |
| A- 87-38 | Blue-naped Pitta | *Pitta nepalensis* |
| A- 88-38 | European Kestrel | *Falco t. tinnunculus* |
| A- 89-38 | Gray Pileated Finch | *Coryphospingus pileatus brevicaudus* |
| A- 90-38 | Black-tailed Japanese Hawfinch | *Eophona migratoria* |
| A- 91-38 | Razor-billed Curassow | *Mitu mitu* |
| A- 92-38 | Swinhoe's Pheasant | *Hierophasis swinhoii* |
| A- 93-38 | South African Cuckoo Falcon | *Aviceda cuculoides verrauxii* |
| A- 98-38 | Northern Chachalaca | *Ortalis v. vetula* |
| A- 99-38 | Ochraceous Woodpecker | *Celeus flavescens ochraceus* |
| A-101-38 | European Quail | *Coturnix c. coturnix* |
| A-103-38 | Northern Flicker | *Colaptes auratus luteus* |
| A-108-38 | Red-faced Gouldian Finch | *Poephila gouldiae* var. |
| A-109-38 | Cockateel | *Nymphicus hollandicus* |
| A-110-38 | White-crowned Glossy Starling | *Spreo albicapillus* |
| A-111-38 | Magellan Robin | *Turdus m. magellanicus* |
| A-115-38 | Common Saffron Finch | *Sycalis f. flaveola* |
| A-116-38 | Java Sparrow | *Padda oryzivora* |
| A-117-38 | Canada Goose | *Branta c. canadensis* |
| A-118-38 | Sumatran Ruby-throated Bulbul | *Rubigula dispar* |
| A-121-38 | European White Stork | *Ciconia c. ciconia* |
| A-124-38 | Golden-fronted Bulbul | *Chloropsis a. aurifrons* |
| A-125-38 | California Quail | *Lophortyx c. californica* |
| A-126-38 | European Starling | *Sturnus v. vulgaris* |
| A-127-38 | Mourning Dove | *Zenaidura macroura carolinensis* |
| A-128-38 | Lettered Aracari Toucan | *Pteroglossus i. inscriptus* |
| A-131-38 | King Bird of Paradise | *Cicinnurus r. regius* |
| A-133-38 | Belted Kingfisher | *Megaceryle a. alcyon* |
| A-134-38 | Eastern Screech Owl | *Otus asio naevius* |
| A-136-38 | Brazilian Troupial | *Icterus j. jamacaii* |
| A-137-38 | Panama Wagler's Woodpecker | *Centurus rubricapillus wagleri* |
| A-138-38 | Galeated Curassow | *Pauxi pauxi* |
| A-140-38 | European White Stork | *Ciconia c. ciconia* |
| A-141-38 | Indian Peacock | *Pavo cristatus* |
| A-142-38 | Luzon Hornbill | *Penelopides manillae* |
| A-143-38 | South African Gray Hornbill | *Lophoceros nasutus epirhinus* |
| A-144-38 | Blue and Yellow Macaw | *Ara ararauna* |
| A-145-38 | Cordon Bleu | *Uraeginthus b. bengalus* |
| A-147-38 | Wilson's Thrush | *Hylocichla f. fuscescens* |
| A-149-38 | California Brown Pelican | *Pelecanus occidentalis californicus* |
| A-150-38 | European Curlew | *Numenius a. arquata* |
| A-153-38 | Grass Parrakeet | *Melopsittacus undulatus* |
| A-154-38 | Formosan Pheasant | *Phasianus colchicus formosanus* |
| A-156-38 | Eastern Robin | *Turdus m. migratorius* |
| A-157-38 | Abyssinian Barbet | *Trachyphonus m. margaritatus* |
| A-158-38 | Double-crested Cormorant | *Phalacrocorax a. auritus* |
| A-159-38 | Demoiselle Crane | *Anthropoides virgo* |
| A-167-38 | Mikado Pheasant | *Syrmaticus mikado* |
| A-168-38 | Gray-winged Trumpeter | *Psophia c. crepitans* |
| A-169-38 | Blue-fronted Amazon | *Amazona a. aestiva* |
| A-170-38 | European Partridge | *Perdix p. perdix* |
| A-171-38 | White-headed Sea Eagle | *Haliaetus v. vocifer* |
| A-172-38 | White-naped Sparrow | *Atlapetes albinucha* |
| A-173-38 | Striated Bulbul | *Pycnonotus f. finlaysoni* |
| A-174-38 | Siskin × Canary | *Spinus spinus* × *Serinus canarius* |
| A-175-38 | White Ibis | *Guara alba* |
| A-176-38 | Wattled Ibis | *Bostrychia carunculata* |
| A-178-38 | Eastern Crow | *Corvus b. brachyrhynchos* |
| A-179-38 | Germain Peacock Pheasant | *Polyplectron germaini* |
| A-180-38 | Mikado Pheasant | *Syrmaticus mikado* |
| A-181-38 | Gray-backed Bald Myna | *Sarcops calvus* |
| A-185-38 | Twelve-wired Bird of Paradise | *Seleucides m. melanoleucus* |
| A-188-38 | Shell Parrakeet | *Melopsittacus undulatus* |
| A-189-38 | American Osprey | *Pandion haliaetus carolinensis* |
| A-190-38 | West African Crowned Crane | *Balearica p. pavonina* |
| A-194-38 | South African Sheldrake | *Casarca cara* |
| A-196-38 | Red-shouldered Hawk | *Buteo l. lineatus* |
| A-199-38 | Kenya Scaly Francolin | *Francolinus squamatus maranensis* |
| A-200-38 | Australian Maned Goose | *Chenonetta jubata* |

| *Laboratory Number* | *Common Name* | *Scientific Name* |
|---|---|---|
| A-201-38 | Carrion Crow | *Corvus corone corone* |
| A-203-38 | Andean Goose | *Chloëphaga melanoptera* |
| A-206-38 | Masai Ostrich | *Struthio camelus massaicus* |
| A-210-38 | Lady Amherst Pheasant × Golden | *Chrysolophus amherstiae* × *C. pictus* |
| A-211-38 | Princess Stephanie's Bird of Paradise | *Astrapia s. stephaniae* |
| A-214-38 | Senegal Touraco | *Turacus p. persa* |
| A-215-38 | Lesser Superb Bird of Paradise | *Lophorina superba minor* |
| A-218-38 | Herring Gull | *Larus argentatus smithsonianus* |
| A-219-38 | Salvin Amazon Parrot | *Amazona autumnalis salvini* |
| A-221-38 | Blyth's Wreath-billed Hornbill | *Rhyticeros subruficollis* |
| A-222-38 | Byth's Wreath-billed Hornbill | *Rhyticeros subruficollis* |
| A-223-38 | Silver-throated Calliste | *Calospiza icterocephala* |

## MAMMALIA.

| | | |
|---|---|---|
| M- 1-38 | Polar Bear | *Thalarctos maritimus* |
| M- 2-38 | African Ground Squirrel | *Geosciurus capensis* |
| M- 3-38 | Sea Lion | *Zalophus californianus* |
| M- 4-38 | Beaver | *Castor canadensis canadensis* |
| M- 5-38 | Opossum | *Didelphis v. virginiana* |
| M- 6-38 | Nine-banded Armadillo | *Dasypus novemcinctus texanus* |
| M- 7-38 | Nine-banded Armadillo | *Dasypus novemcinctus texanus* |
| M- 8-38 | Fallow Deer | *Dama dama* |
| M- 10-38 | Sooty Mangabey | *Cercocebus fuliginosus* |
| M- 11-38 | Woodward's Kangaroo | *Macropus robustus woodwardi* |
| M- 13-38 | Llama | *Lama glama* |
| M- 14-38 | Mandrill | *Mandrillus sphinx* |
| M- 16-38 | Bighorn Sheep | *Ovis c. canadensis* |
| M- 17-38 | Raccoon | *Procyon l. lotor* |
| M- 18-38 | Coyote | *Canis latrans* |
| M- 20-38 | Puma | *Felis cougar* |
| M- 21-38 | Mona Monkey | *Cercopithecus mona* |
| M- 22-38 | Wallaroo | *Macropus r. robustus* |
| M- 25-38 | Mouflon | *Ovis musimon* |
| M- 26-38 | Gray Gibbon | *Hylobates lar agilis* |
| M- 27-38 | Black Gibbon | *Hylobates l. lar* |
| M- 28-38 | Dromedary | *Camelus dromedarius* |
| M- 29-38 | Raccoon | *Procyon l. lotor* |
| M- 33-38 | Elk | *Cervus canadensis canadensis* |
| M- 34-38 | Woodchuck | *Marmota monax monax* |
| M- 36-38 | Kob Antelope | *Kobus kob leucotis* |
| M- 37-38 | Woodchuck (Albino) | *Marmota monax monax* |
| M- 38-38 | Woodchuck | *Marmota monax monax* |
| M- 40-38 | Gray Fox | *Urocyon c. cinereoargenteus* |
| M- 41-38 | Chacma Baboon | *Papio porcarius* |
| M- 42-38 | Aoudad | *Amnotragus lervia* |
| M- 43-38 | Aoudad | *Amnotragus lervia* |
| M- 44-38 | Opossum | *Didelphis v. virginiana* |
| M- 46-38 | Aoudad | *Amnotragus lervia* |
| M- 47-38 | Aoudad | *Amnotragus lervia* |
| M- 48-38 | Murine Opossum | *Marmosa murina* |
| M- 49-38 | Dingo | *Canis dingo* |
| M- 52-38 | Genet | *Genetta tigrina* |
| M- 55-38 | Woolly Monkey | *Lagothrix humboldtii* |
| M- 56-38 | Coyote | *Canis latrans* |
| M- 59-38 | Raccoon | *Procyon l. lotor* |
| M- 61-38 | Wolf | *Canis nubilus* |
| M- 62-38 | Java Macaque | *Macaca irus* |
| M- 64-38 | Gray Fox | *Urocyon c. cinereoargenteus* |
| M- 66-38 | European Wolf | *Canis lupus* |
| M- 67-38 | African Civet | *Civettictis civetta* |
| M- 68-38 | Axis Deer | *Axis axis* |
| M- 69-38 | Black Buck | *Antilope cervicapra* |
| M- 70-38 | Dybowski Deer | *Cervus (Sika) hortulorum* |
| M- 73-38 | Striped-tailed Dog | *Cerdocyon t. thous* |
| M- 74-38 | Hyrax | *Procavia capensis* |
| M- 76-38 | Opossum | *Didelphis v. virginiana* |
| M- 77-38 | White-tailed Paradoxure | *Paradoxurus jerdoni* |
| M- 78-38 | Sable Antelope | *Hippotragus niger* |
| M- 79-38 | Sooty Mangabey | *Cercocebus fuliginosus* |
| M- 80-38 | Cotton-Top Marmoset | *Oedipomidas geoffroyi* |
| M- 81-38 | Japanese Sika Deer | *Cervus (Sika) n. nippon* |
| M- 83-18 | Himalayan Tahr | *Hemitragus jemlahicus* |

| *Laboratory Number* | *Common Name* | *Scientific Name* |
|---|---|---|
| M- 84-38 | Fallow Deer | *Dama dama* |
| M- 85-38 | Elk | *Cervus canadensis canadensis* |
| M- 86-38 | Olive (Rhodesian) Baboon | *Papio anubis* |
| M- 87-38 | Opossum | *Didelphis v. virginiana* |
| M- 88-38 | Cotton-Top Marmoset | *Oedipomidas geoffroyi* |
| M- 90-38 | Woodward's Kangaroo | *Macropus robustus woodwardi* |
| M- 92-38 | Nine-banded Armadillo | *Dasypus novemcinctus texanus* |
| M- 93-38 | American Black Bear | *Euarctos americanus* |
| M- 95-38 | Woodchuck | *Marmota monax monax* |
| M- 96-38 | Raccoon | *Procyon l. lotor* |
| M- 97-38 | Great Gray Kangaroo | *Macropus g. giganteus* |
| M- 98-38 | Rock Wallaby | *Macropus brunii* |
| M- 99-38 | Mandrill | *Mandrillus sphinx* |
| M-100-38 | Rock Wallaby | *Macropus brunii* |
| M-101-38 | Red Fox | *Vulpes fulva* |
| M-102-38 | Red Fox | *Vulpes fulva* |
| M-112-38 | Two-Spotted Palm Cat | *Nandinia binotata* |
| M-113-38 | Kadiak Bear | *Ursus middendorffi* |
| M-114-38 | Chimpanzee | *Pan satyrus* |
| M-116-38 | Bay Lynx | *Lynx r. rufus* |
| M-117-38 | Tayra | *Tayra barbara* |
| M-118-38 | Golden Agouti | *Dasyprocta aguti* |
| M-120-38 | Nyala or Harnessed Antelope | *Tragelaphus angasi* |
| M-125-38 | Himalayan Tahr | *Hemitragus jemlahicus* |
| M-126-38 | Fallow Deer | *Dama dama* |
| M-127-38 | Sumichrast's Night-mouse | *Nyctomys sumichrasti* |
| M-130-38 | Opossum | *Didelphis v. virginiana* |
| M-132-38 | Opossum | *Didelphis v. virginiana* |
| M-135-38 | Bushy-tailed Galago | *Galago crassicaudatus* |
| M-136-38 | Vampire Bat | *Desmodus rotundus murinus* |
| M-137-38 | Ocelot | *Felis pardalis* |
| M-138-38 | Hyrax | *Procavia capensis* |
| M-143-38 | Central American Gray Squirrel | Unidentified |
| M-144-38 | Ocelot | *Felis pardalis* |
| M-146-38 | Giant Anteater | *Myrmecophaga tridactyla* |
| M-150-38 | Drill | *Mandrillus leucophaeus* |
| M-151-38 | Dybowski Deer | *Cervus (Sika) hortulorum* |
| M-155-38 | Kadiak Bear | *Ursus middendorffi* |
| M-167-38 | Rhesus Monkey | *Macaca mulatta* |
| M-168-38 | Barasingha Deer | *Cervus (Rucervus) duvauceli* |
| M-169-38 | Red Deer | *Cervus elaphus* |
| M-170-38 | White-handed Gibbon | *Hylobates lar leuciscus* |
| M-171-38 | Rock Wallaby | *Macropus brunii* |
| M-180-38 | Japanese Sika Deer | *Cervus (Sika) n. nippon* |
| M-181-38 | Raccoon | *Procyon l. lotor* |
| M-183-38 | Chacma Baboon | *Papio porcarius* |
| M-184-38 | Pigmy Hippopotamus | *Choeropsis liberiensis* |
| M-188-38 | Lion | *Felis leo* |
| M-189-38 | Tanganyika Giraffe | *Giraffa camelopardalis tippelskirchi* |
| M-190-38 | Canadian Porcupine (Albino) | *Erethizon d. dorsatum* |
| M-195-38 | Prehensile-tailed Porcupine | *Coendou prehensilis* |
| M-196-38 | Duiker | *Sylvicapra grimmi* |
| M-197-38 | Hyrax | *Procavia capensis* |
| M-201-38 | Porcupine | *Erethizon d. dorsatum* |
| M-202-38 | Bison | *Bison b. bison* |
| M-203-38 | Opossum | *Didelphis v. virginiana* |
| M-204-38 | Mouflon | *Ovis musimon* |
| M-208-38 | Hyrax | *Procavia capensis* |
| M-219-38 | Dingo | *Canis dingo* |
| M-220-38 | Two-spotted Palm Cat | *Nandinia binotata* |
| M-221-38 | Axis Deer | *Axis axis* |
| M-233-38 | Raccoon | *Procyon l. lotor* |
| M-234-38 | Hussar Monkey | *Erythrocebus patas* |
| M-239-38 | Spider Monkey | *Ateles cucullatus* |
| M-247-38 | Opossum | *Didelphis v. virginiana* |
| M-249-38 | Ocelot | *Felis pardalis* |
| M-250-38 | Prehensile-tailed Porcupine | *Coendou prehensilis* |
| M-264-38 | Woolly Monkey | *Lagothrix infumatus* |
| M-265-38 | Eland | *Taurotragus o. oryx* |
| M-266-38 | Dingo | *Canis dingo* |
| M-267-38 | Barasingha Deer | *Cervus (Rucervus) duvauceli* |
| M-268-38 | Himalayan Tahr | *Hemitragus jemlahicus* |

## MORTALITY STATISTICS, 1938.

Deaths by Orders and age groups, with causes
(For identification of postmortem numbers, see list preceding table).

| Class | | Reptilia[1] | | | Aves | | | Mammalia | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Total Deaths[2] | | 550 | | 43.2% | 301 | | 15.4% | 128 | | | 25.3% |
| International List Number | Selected Causes[3] | Imm. | Adult | Orders and Postmortem Reference Number | Imm. | Adult | Orders and Postmortem Reference Number | Pre-adult | Adult | Post-adult | Orders and Postmortem Reference Number |
| **I** | **Infectious and parasitic diseases** | **5** | **15** | | **4** | **23** | | **4** | **15** | | **Total: 66** |
| 1 | Typhoid | 1 | | Squamata R-26-38 | | | | | | | |
| 2 | Diseases due to *Salmonella* sp. | 1 | | Squamata R-27-38 | | 1 | Pelecaniformes A-17-38 | | | | |
| 13a | Amebic dysentery | | 1 | Squamata R-52-38 (Helminthiasis) | | | | | | | |
| 23 | Tuberculosis of respiratory system | | 1 | Squamata R-44-38 | | | | | | | |
| 32 | Disseminated tuberculosis | | 1 | Squamata R-64-38 | | 1 | Galliformes A-69-38 | | 1 | | Rodentia M-34-38 |
| | | | | | | | Gruiformes | | 1 | | M-37-38 |
| | | | | | | 1 | A-7-38 | | 1 | | M-38-38 (Scabies) |
| | | | | | | 1 | A-168-38 | | | | |
| | | | | | | | Psittaciformes | | | | |
| | | | | | | 1 | A-66-38 | | | | |
| 36 | Septicemia—purulent infection | | 1 | Squamata R-19-38 (Trauma) | 1 | | Pelecaniformes A-3-38 | 1 | | | Marsupialia M-5-38 |
| | | 1 | | R-22-38 (Drowning) | | | Falconiformes | | 1 | | M-130-38 |
| | | | | | | 1 | A-196-38 | | | | Primates |
| | | | | | | | Galliformes | 1 | | | M-41-38 |
| | | | | | | 1 | A-79-38 | | | | (Brain abcess) |
| | | | | | | | Piciformes | | 1 | | M-80-38 |
| | | | | | | 1 | A-99-38 | | | | |
| | | | | | 1 | | A-103-38 | | | | |
| | | | | | | 1 | A-157-38 | | | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | R-29-38 (Acariasis) | | 1 | Passeriformes A-5-38 | | 1 | | Carnivora M-52-38 |
| | | | 1 | R-60-38 (Acariasis) | | 1 | A-6-38 | | 1 | | M-233-38 (Icterus) |
| | | | 1 | R-63-38 | | 1 | A-63-38 | | | | Edentata |
| | | | 1 | R-67-38 | | 1 | A-64-38 | | | | M-7-38 (Broncho-pneumonia) |
| | | | 1 | R-70-38 (Acariasis) | | 1 | A-65-38 | | 1 | | Hyracoidea |
| | | | | R-88-38 | | 1 | A-89-38 | | | | M-74-38 (Enteritis) |
| | | | 1 | (Stomatitis) | | 1 | A-124-38 | | 1 | | |
| | | | | | | | A-126-38 | | | | |
| 38 | Malaria | | | Squamata | | | | | | | |
| | | | 1 | R-66-38 | | | | | | | |
| 39 | Sarcosporidia | | | | | | | 1 | | | Artiodactyla M-169-38 |
| 41 | Hydatid cysts | | | | | | | 1 | | | Rodentia M-201-38 |
| 42 | Diseases caused by helminths | 1 | | Squamata R-35-38 | | | | | 1 | | Primates M-88-38 (Microfilaria) |
| | | | 1 | R-39-38 | | | | | | | Carnivora |
| | | | 1 | R-74-38 | | | | | 1 | | M-112-38 |
| | | | | | | | | | 1 | | M-116-38 |
| | | | | | | | | | | | Rodentia |
| | | | | | | | | | 1 | | M-127-38 |
| 43 | Mycoses | | | | | | Struthioniformes | | | | Marsupialia |
| | | | | | | 1 | A-73-38 | | 1 | | M-11-38 (Septicemia) |
| | | | | | | | Gruiformes | | | | M-22-38 (Trauma) |
| | | | | | | 1 | A-68-38 (Tracheal obstruction) | | 1 | | |
| 44 | Other infectious and parasitic diseases | 1 | | Squamata R-28-38 | | 1 | Anseriformes A-194-38 (Botulism) | | | | |
| | | | 1 | R-37-38 (Ixodiasis) | | | Galliformes | | | | |
| | | | 1 | R-95-38 (Acariasis) | | 1 | A-199-38 (Pox) | | | | |
| | | | | | | | Columbiformes | | | | |
| | | | | | 1 | | A-127-38 (Pigeon pox) | | | | |

[1] Including Amphibia

[2] From records of Departments of Reptiles, Birds and Mammals, including many specimens not sent to the Laboratory, or not autopsied, and consequently not incorporated in this table. Percentages in Total Deaths column refer to losses based on total number of specimens in each Department during the year

[3] Based on international list for human deaths and joint causes, with modifications

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | R-60-38 | | 1 | A-6-38 | | 1 | | M-253-38 |
| | | | | (Acariasis) | | 1 | A-63-38 | | | | (Icterus) |
| | | | 1 | R-63-38 | | 1 | A-64-38 | | | | Edentata |
| | | | 1 | R-67-38 | | 1 | A-65-38 | | 1 | | M-7-38 |
| | | | 1 | R-70-38 | | 1 | A-89-38 | | | | (Broncho-pneumonia) |
| | | | | (Acariasis) | | 1 | A-124-38 | | | | Hyracoidea |
| | | | | R-88-38 | | 1 | A-126-38 | | | | M-74-38 |
| | | | 1 | (Stomatitis) | | | | | 1 | | (Enteritis) |
| 38 | Malaria | | | Squamata | | | | | | | |
| | | | 1 | R-66-38 | | | | | | | |
| 39 | Sarcosporidia | | | | | | | | | | Artiodactyla |
| | | | | | | | | 1 | | | M-169-38 |
| 41 | Hydatid cysts | | | | | | | | | | Rodentia |
| | | | | | | | | 1 | | | M-201-38 |
| 42 | Diseases caused by helminths | 1 | | Squamata | | | | | | | Primates |
| | | | | R-35-38 | | | | | 1 | | M-88-38 |
| | | | 1 | R-39-38 | | | | | | | (Microfilaria) |
| | | | 1 | R-74-38 | | | | | | | Carnivora |
| | | | | | | | | | 1 | | M-112-38 |
| | | | | | | | | | 1 | | M-116-38 |
| | | | | | | | | | | | Rodentia |
| | | | | | | | | | 1 | | M-127-38 |
| 43 | Mycoses | | | | | | Struthioniformes | | | | Marsupialia |
| | | | | | | 1 | A-73-38 | | 1 | | M-11-38 |
| | | | | | | | Gruiformes | | | | (Septicemia) |
| | | | | | | 1 | A-68-38 | | 1 | | M-22-38 |
| | | | | | | | (Tracheal obstruction) | | | | (Trauma) |
| 44 | Other infectious and parasitic diseases | 1 | | Squamata | | | Anseriformes | | | | |
| | | | | R-28-38 | | 1 | A-194-38 | | | | |
| | | | 1 | R-37-38 | | | (Botulism) | | | | |
| | | | | (Ixodiasis) | | | Galliformes | | | | |
| | | | 1 | R-95-38 | | 1 | A-199-38 | | | | |
| | | | | (Acariasis) | | | (Pox) | | | | |
| | | | | | | | Columbiformes | | | | |
| | | | | | 1 | | A-127-38 | | | | |
| | | | | | | | (Pigeon pox) | | | | |

[1] Including Amphibia.

[2] From records of Departments of Reptiles, Birds and Mammals, including many specimens not sent to the Laboratory, or not autopsied, and consequently not incorporated in this table. Percentages in Total Deaths column refer to losses based on total number of specimens in each Department during the year.

[3] Based on international list for human deaths and joint causes, with modifications

| International List Number | Class / Selected Causes | Reptilia Imm. | Reptilia Adult | Reptilia Orders and Postmortem Reference Number | Aves Imm. | Aves Adult | Aves Orders and Postmortem Reference Number | Mammalia Pre-adult | Mammalia Adult | Mammalia Post-adult | Mammalia Orders and Postmortem Reference Number |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 44 | Other infectious and parasitic diseases (*continued*) | | | | 1 | | Passeriformes A-13-38 (Tropical fowl mite) | | | | |
| | | | | | | 1 | A-46-38 (Pediculosis) | | | | |
| | | | | | | 1 | A-185-38 (Teniasis) | | | | |
| **II** | **Cancers and other tumors** | | | | | **4** | | | | **3** | **Total: 7** |
| 46 | Cancer and other malignant tumors of digestive tract | | | | | | | | | 1 | Carnivora M-155-38 |
| 46f | Pancreas | | | | | | | | | | |
| 48 | Cancer of the uterus | | | | | | | | | 1 | Artiodactyla M-78-38 |
| 49 | Cancer of genital organs | | | | | | Galliformes | | | | |
| 49a | Ovary | | | | | 1 | A-11-38 | | | | |
| | | | | | | 1 | A-154-38 | | | | |
| 53 | Cancer of unspecified organs | | | | | | Galliformes | | | | Carnivora |
| | | | | | | 1 | A-16-38 (Melanoma) | | | 1 | M-61-38 (Thyroid) |
| 53e | ——— | | | | | | | | | | |
| 54 | Nonmalignant tumors | | | | | | Charadriiformes | | | | |
| 54e | ——— | | | | | 1 | A-30-38 | | | | |
| **III** | **Rheumatic, nutritional, endocrines, general** | | | | | **2** | | | **1** | | **Total: 3** |
| 58 | Gout | | | | | | Anseriformes | | | | |
| | | | | | | 1 | A-34-38 (Visceral) | | | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 60 | Scurvy | | | | 1 | Ciconiiformes A-80-38 (Intramuscular hemorrhage) | | 1 | | Edentata M-146-38 |
| **IV** | **Diseases of blood and blood-making organs** | | | | **2** | | | **1** | **1** | **Total: 4** |
| 71 | Anemias | | | | 1 | Anseriformes A-37-38 | | 1 | | Artiodactyla M-189-38 (Nutritional) |
| 71b | Others | | | | 1 | Galliformes A-170-38 (Nutritional) | | | 1 | M-265-38 (Nutritional) |
| **VI** | **Diseases of the nervous system** | | | | **1** | | **1** | | | **Total: 2** |
| 78 | Encephalitis | | | | 1 | Anseriformes A-33-38 | 1 | | | Primates M-239-38 |
| **VII** | **Diseases of the circulatory system** | **3** | | | **6** | | **1** | **3** | **2** | **Total: 15** |
| 90 | Pericarditis | | | | | | | 1 | | Artiodactyla M-196-38 |
| 91 | Acute endocarditis | | | | 1 | Ciconiiformes A-50-38 | | 1 | | Marsupialia M-203-38 (*Salmonella* enteriditis) |
| | | | | | | | | | 1 | Artiodactyla M-202-38 |
| 93 | Diseases of myocardium | 1 | Squamata R-86-38 (Parasitic) | | 1 | Anseriformes A-26-38 (Aneurism) | | | | |
| | | | | | 1 | Psittaciformes A-8-38 | | | | |
| 95 | Other diseases of heart | 1 | Squamata R-50-38 | | 1 | Passeriformes A-131-38 | | | | Primates M-150-38 |
| | | 1 | R-56-38 | | | | 1 | | 1 | Pinnipedia M-3-38 |
| 97 | Arteriosclerosis (Atheromatosis) | | | | 1 | Ciconiiformes A-140-38 | | 1 | | Carnivora M-56-38 |
| | | | | | 1 | Galliformes A-167-38 | | | | |

| International List Number | Class / Selected Causes | Reptilia Imm. | Reptilia Adult | Reptilia Orders and Postmortem Reference Number | Aves Imm. | Aves Adult | Aves Orders and Postmortem Reference Number | Mammalia Pre-adult | Mammalia Adult | Mammalia Post-adult | Mammalia Orders and Postmortem Reference Number |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **VIII** | **Diseases of respiratory system** | | **16** | | **1** | **28** | | **7** | **8** | | **Total: 60** |
| 107 | Bronchopneumonia | | | | | 1 | Psittaciformes<br>A-219-38 | 1 | | | Primates<br>M-55-38<br>(Septicemia) |
| | | | | | | | | 1 | | | M-114-38<br>Carnivora |
| | | | | | | | | 1 | | | M-113-38<br>Rodentia |
| | | | | | | | | 1 | | | M-4-38 |
| 108 | Lobar pneumonia | | | | | | | 1 | | | Primates<br>M-27-38 |
| 109 | Pneumonia (All unspecified) | | | Squamata | | | Ciconiiformes | | | | Marsupialia |
| | | | 1 | R-2-38 | | 1 | A-12-38 | | 1 | | M-44-38 |
| | | | 1 | R-13-38 | | | Passeriformes | 1 | | | M-87-38 |
| | | | 1 | R-34-38 | | 1 | A-70-38 | | | | Carnivora |
| | | | 1 | R-45-38 | | 1 | A-172-38 | 1 | | | M-144-38 |
| | | | 1 | R-46-38 | | 1 | A-181-38 | | | | |
| | | | 1 | R-47-38 | | | | | | | |
| | | | 1 | R-76-38 | | | | | | | |
| | | | 1 | R-90-38 | | | | | | | |
| 111 | Congestion, edema, embolism, hemorrhagic infarct, thrombosis | | | Squamata | | | Pelecaniformes | | | | Marsupialia |
| | | | 1 | R-6-38 | | 1 | A-40-38 | | 1 | | M-97-38 |
| | | | 1 | R-9-38 | | | Ciconiiformes | | | | (Trichomoniasis) |
| | | | 1 | R-23-38 | | 1 | A-176-38 | | | | Carnivora |
| | | | | (Septicemia) | | | Anseriformes | | | | M-117-38 |
| | | | 1 | R-25-38 | | 1 | A-55-38 | | 1 | | Rodentia |
| | | | | (Helminthiasis) | | 1 | A-203-38 | | | | M-118-38 |
| | | | 1 | R-51-38 | | | (Proventricilitis) | | 1 | | M-190-38 |
| | | | 1 | R-84-38 | | | Falconiformes | | 1 | | M-195-38 |
| | | | 1 | R-87-38 | | 1 | A-9-38 | | 1 | | Hyracoidea |
| | | | | (Pericarditis) | | | Galliformes | | | | M-138-38 |
| | | | 1 | R-100-38 | | 1 | A-28-38 | | 1 | | |
| | | | | | | 1 | A-91-38 | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 1 | A-179-38 (Laryngo-tracheitis) | | | | | |
| | | | | | | 1 | A-180-38 | | | | | |
| | | | | | | | Gruiformes | | | | | |
| | | | | | | 1 | A-159-38 (Compound fracture) | | | | | |
| | | | | | | | Psittaciformes | | | | | |
| | | | | | | 1 | A-43-38 | | | | | |
| | | | | | | 1 | A-53-38 | | | | | |
| | | | | | | 1 | A-144-38 (Trauma) | | | | | |
| | | | | | | | Passeriformes | | | | | |
| | | | | | | 1 | A-19-38 | | | | | |
| | | | | | | 1 | A-22-38 | | | | | |
| | | | | | | 1 | A-27-38 | | | | | |
| | | | | | | 1 | A-29-38 | | | | | |
| | | | | | | 1 | A-36-38 | | | | | |
| | | | | | 1 | | A-51-38 | | | | | |
| | | | | | | 1 | A-58-38 | | | | | |
| | | | | | | 1 | A-62-38 | | | | | |
| | | | | | | 1 | A-75-38 | | | | | |
| | | | | | | 1 | A-87-38 | | | | | |
| | | | | | | 1 | A-115-38 | | | | | |
| 114 | Other respiratory diseases | | | | | | | | 1 | | Artiodactyla M-16-38 (Aspiration pn.) | |
| **IX** | **Diseases of the digestive system** | **4** | **34** | | **2** | **22** | | **2** | **7** | **1** | **Total: 72** | |
| 115 | Diseases of buccal cavity and annexa | | 1 | Squamata R-40-38 | | 1 | Strigiformes A-24-38 (Pox) | | | | | |
| | | | 1 | R-42-38 | | | | | | | | |
| | | | 1 | R-43-38 | | | | | | | | |
| | | | 1 | R-55-38 | | | | | | | | |
| | | | 1 | R-59-38 | | | | | | | | |
| | | | 1 | R-62-38 | | | | | | | | |
| | | | 1 | R-102-38 | | | | | | | | |
| 117 | Ulcer of stomach and duodenum | | | | | | | | 1 | | Hyracoidea M-197-38 | |
| | | | | | | | | | 1 | | M-208-38 | |
| 118 | Other diseases of stomach | | | | 1 | | Falconiformes A-171-38 | | | | | |
| | | | | | | 1 | Passeriformes A-211-38 | | | | | |

| International List Number | Class / Selected Causes | Reptilia: Imm. | Reptilia: Adult | Reptilia: Orders and Postmortem Reference Number | Aves: Imm. | Aves: Adult | Aves: Orders and Postmortem Reference Number | Mammalia: Pre-adult | Mammalia: Adult | Mammalia: Post-adult | Mammalia: Orders and Postmortem Reference Number |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 122 | Diseases of | | | Squamata | | | Ciconiiformes | | | | Marsupialia |
| 123 | the intestine | | 1 | R-1-38 | | 1 | A-121-38 | | 1 | | M-90-38 (Trichomoniasis) |
| | | | 1 | R-12-38 | | | Falconiformes | | | | |
| | | | 1 | R-17-38 | | 1 | A-88-38 | | | | |
| | | | 1 | R-20-38 | | | Galliformes | | 1 | | M-98-38 (Trichomoniasis) |
| | | | 1 | R-21-38 | | 1 | A-98-38 | | | | |
| | | | 1 | R-30-38 | | 1 | A-138-38 | | | | M-171-38 |
| | | | 1 | R-31-38 | | 1 | A-210-38 | 1 | | | Primates |
| | | | 1 | R-33-38 | | | Gruiformes | | | | M-26-38 (Ulcerative colitis) |
| | | | 1 | R-38-38 | | 1 | A-67-38 | 1 | | | |
| | | | 1 | R-41-38 | | | Trogoniformes | | | | Artiodactyla |
| | | | 1 | R-53-38 | 1 | | A-81-38 | | | | M-25-38 (Pneumonia) |
| | | 1 | | R-54-38 | | | Coraciiformes | | 1 | | |
| | | | 1 | R-61-38 | | 1 | A-142-38 | | | | |
| | | | 1 | R-69-38 | | 1 | A-143-38 | | | | |
| | | | 1 | R-71-38 | | 1 | A-222-38 | | | | |
| | | | 1 | R-85-38 | | | Piciformes | | | | |
| | | | 1 | R-89-38 | | 1 | A-10-38 | | | | |
| | | 1 | | R-91-38 | | 1 | A-78-38 | | | | |
| | | | 1 | R-92-38 | | | Passeriformes | | | | |
| | | | 1 | R-93-38 | | 1 | A-21-38 | | | | |
| | | | 1 | R-94-38 | | 1 | A-178-38 | | | | |
| | | 1 | | R-96-38 | | | | | | | |
| | | | 1 | R-97-38 | | | | | | | |
| | | | 1 | R-98-38 | | | | | | | |
| 124 | Diseases of | | | Squamata | | | Columbiformes | | | | Carnivora |
| 125 | the liver | 1 | | R-14-38 | | 1 | A-1-38 | | 1 | | M-181-38 |
| | | | 1 | R-16-38 | | | Psittaciformes | | | 1 | M-188-38 |
| | | | 1 | R-32-38 | | 1 | A-188-38 | | | | Rodentia |
| | | | 1 | R-48-38 | | | Passeriformes | | 1 | | M-2-38 |
| | | | 1 | R-68-38 | | 1 | A-41-38 | | | | |
| | | | 1 | R-99-38 | | 1 | A-116-38 | | | | |
| | | | | Amphibia | | 1 | A-136-38 | | | | |
| | | | 1 | Am-1-38 | | 1 | A-145-38 | | | | |
| | | | | | | 1 | A-174-38 | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| X | **Diseases of the genito-urinary system** | | | 3 | | 2 | **Total: 5** | | |
| 130 | Nephritis | | | | Struthioniformes | | Marsupialia | | |
| 131 | | | | 1 | A-14-38 | 1 | M-247-38 | | |
| 132 | | | | | Cuculiformes | | Carnivora | | |
| 133 | | | | 1 | A-214-38 | 1 | M-102-38 | | |
| | | | | | Strigiformes | | | | |
| | | | | 1 | A-20-38 | | | | |
| XI | **Disease of pregnancy (Obstetrical diseases)** | | | 1 | | 1 | **Total: 2** | | |
| 143 | | | | | Passeriformes | | Artiodactyla | | |
| 145 | | | | 1 | A-215-38 | 1 | M-85-38 | | |
| 147 | | | | | | | | | |
| 149 | | | | | | | | | |
| XII | **Diseases of skin and cellular tissue** | 2 | | | | 2 | **Total. 4** | | |
| 151 | Miscellaneous | | Squamata | | | | Carnivora | | |
| 152 | | 1 | R-78-38 | | | 1 | M-29-38 | | |
| 153 | | 1 | R 103-38 | | | | Edentata | | |
| | | | | | | 1 | M-6-38 | | |
| XIII | **Diseases of bones and organs of locomotion** | | | | | | | | |
| | | | | 2 | | 1 2 | **Total: 5** | | |
| 154 | Osteomyelitis | | | | Anseriformes | | Primates | | |
| 155 | and other | | | 1 | A-56-38 | 1 | M-234-38 | | |
| 156 | diseases of bone | | | | Falconiformes | 1 | M-264-38 | | |
| | | | | 1 | A-189-38 | | Artiodactyla | | |
| | | | | | | 1 | M-221-38 | | |
| XIV | **Congenital malformations** | | | 1 | | | **Total: 1** | | |
| 157 | Congenital malformations | | | | Gruiformes | | | | |
| | | | | 1 | A-190-38 | | | | |
| XV | **Diseases of new-born** | | | | | 9 | **Total: 9** | | |
| 159 | Premature birth, | | | | | | Primates | | |
| 160 | injury at birth, | | | | | 1 | M-21-38 | | |
| 161a | atelectasis | | | | | 1 | M-167-38 | | |
| | | | | | | | Carnivora | | |
| | | | | | | | M-1-38 | | |

| International List Number | Class / Selected Causes | Reptilia Imm. | Reptilia Adult | Reptilia Orders and Postmortem Reference Number | Aves Imm. | Aves Adult | Aves Orders and Postmortem Reference Number | Mammalia Pre-adult | Mammalia Adult | Mammalia Post-adult | Mammalia Orders and Postmortem Reference Number |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 159<br>160<br>161a | Premature birth, injury at birth, atelectasis (*continued*) | | | | | | | | | | Artiodactyla<br>M-13-38<br>M-28-38<br>M-42-38<br>M-43-38<br>M-46-38<br>M-184-38 |
| | | | | | | | | 1<br>1<br>1<br>1<br>1<br>1 | | | |
| **XVII** | **Violent and accidental deaths** | **1** | **3** | | **1** | **15** | | **13** | **22** | **2** | **Total: 57** |
| 175 | Homicide | | 1<br>1 | Squamata<br>R-11-38<br>R-57-38 | | | | | 1<br>1<br>1 | | Carnivora<br>M-17-38<br>M-18-38<br>M-20-38 |
| | | | | | | | | 1 | | | M-67-38 |
| 176 | Attack by venomous animal | | 1 | Squamata<br>R-15-38<br>(Parasitism) | | | | | | | |
| 179x | Other poisons | 1 | | Squamata<br>R-24-38 | | 1 | Psittaciformes<br>A-169-38 | | | | |
| 186 | Accidental traumatism | | | | | 1 | Pelecaniformes<br>A-149-38 | 1 | | | Primates<br>M-14-38 |
| | | | | | | 1 | Ciconiiformes<br>A-175-38 | 1 | | | Rodentia<br>M-143-38 |
| | | | | | | 1 | Galliformes<br>A-77-38 | | 1 | | Artiodactyla<br>M-8-38 |
| | | | | | | 1 | A-101-38<br>Psittaciformes | 1 | 1 | | M-81-38 |
| | | | | | | 1 | A-153-38<br>Passeriformes | | 1 | | M-83-38 |
| | | | | | | 1 | A-54-38 | | | | |
| | | | | | | 1 | A-82-38 | | | | |
| | | | | | | 1 | A-90-38 | | | | |
| | | | | | 1 | | A-147-38 | | | | |

| | | |

| International List Number | Class / Selected Causes | Reptilia Imm | Reptilia Adult | Reptilia Orders and Postmortem Reference Number | Aves Imm | Aves Adult | Aves Orders and Postmortem Reference Number | Mammalia Pre-adult | Mammalia Adult | Mammalia Post-adult | Mammalia Orders and Postmortem Reference Number |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 198 | Destroyed (*continued*) | | | | | | | | 1 | | M-68-38 |
| | | | | | | | | | 1 | | M-69-38 |
| | | | | | | | | | 1 | | M-70-38 |
| | | | | | | | | | 1 | | M 84-38 |
| | | | | | | | | | 1 | | M 126-38 |
| **XVIII** | **Ill-defined causes of death** | | **21** | | | **38** | | **9** | **10** | | **Total: 78** |
| 199 | Sudden death | | | | | | Pelecaniformes | | | | |
| | | | | | | 1 | A-158-38 | | | | |
| | | | | | | | (Choke) | | | | |
| | | | | | | | Anseriformes | | | | |
| | | | | | | 1 | A-35-38 | | | | |
| | | | | | | | (Exhaustion) | | | | |
| | | | | | | | Galliformes | | | | |
| | | | | | | 1 | A-92-38 | | | | |
| | | | | | | | (Shock) | | | | |
| 200 | Cause of death unknown, or sent to Museum without autopsy | | | Squamata | | | Ciconiiformes | | | | Marsupialia |
| | | | 1 | R-3-38 | | 1 | A-39-38 | | 1 | | M-48-38 |
| | | | 1 | R-4-38 | | | Anseriformes | 1 | | | M-100-38 |
| | | | 1 | R-5-38 | | 1 | A-117-38 | | 1 | | M-132-38 |
| | | | 1 | R-7-38 | | 1 | A-200-38 | | | | Chiroptera |
| | | | | | | | | | 1 | | M-136-38 |
| | | | 1 | R-8-38 | | | Falconiformes | | | | Primates |
| | | | 1 | R-10-38 | | 1 | A-93-38 | 1 | | | M-10-38 |
| | | | 1 | R-36-38 | | | Galliformes | 1 | | | M-62-38 |
| | | | 1 | R-49-38 | | 1 | A-76-38 | 1 | | | M-86-38 |
| | | | 1 | R-58-38 | | 1 | A-125-38 | 1 | | | M-99-38 |
| | | | 1 | R-65-38 | | 1 | A-141-38 | | 1 | | M-135-38 |
| | | | 1 | R-72-38 | | | Charadriiformes | 1 | | | M-183-38 |
| | | | 1 | R-73-38 | | 1 | A-61-38 | | | | Carnivora |
| | * | | 1 | R-75-38 | | 1 | A-150-38 | | 1 | | M-64-38 |

| | | |
|---|---|---|
| R-77-38 | A-218-38 | M-73-38 |
| R-80-38 | Psittaciformes | M-93-38 |
| R-81-38 | A-109-38 | M-137-38 |
| R-82-38 | Strigiformes | Edentata |
| R-83-38 | A-72-38 | M-92-38 |
| R-101-38 | A-134-38 | Artiodactyla |
| R-104-38 | Micropodiformes | M-47-38 |
| Testudinata | A-44-38 | M-125-38 |
| R-79-38 | Coraciiformes | M-267-38 |
| | A-2-38 | M-268-38 |
| | A-133-38 | |
| | A-221-38 | |
| | Piciformes | |
| | A-128-38 | |
| | A-137-38 | |
| | Passeriformes | |
| | A-18-38 | |
| | A-31-38 | |
| | A-32-38 | |
| | A-42-38 | |
| | A-48-38 | |
| | A-49-38 | |
| | A-59-38 | |
| | A-60-38 | |
| | A-71-38 | |
| | A-74-38 | |
| | A-108-38 | |
| | A-110-38 | |
| | A-111-38 | |
| | A-118-38 | |
| | A-156-38 | |
| | A-223-38 | |

available data. The only case in which jaundice was seen during life, was reported by Scott & Moore (4). This was a cat with a scirrhous carcinoma involving the head and body of the pancreas and constricting the common bile duct.

Our case is the first in which a carcinoma of the pancreas was found in a bear. Ratcliffe's (6) series included sixty bears on which autopsies were performed. He found four instances of carcinoma; these included a medullary carcinoma of the mammary gland, a basal cell carcinoma of the tongue, an adenocarcinoma of the adrenals, and hypernephroma of the kidney. The only other reported instance of a malignant tumor in a bear was reported by Perry (8). This was a 34-year-old animal with an adenocarcinoma of the kidney.

## Case Report.

The large Kadiak bear, whose case is reported here, was captured as a cub in 1907 on Kadiak Island, Alaska, and presented to the New York Zoological Park. He grew and developed normally, reaching a weight of approximately 450 kilograms. He was well until February, 1938, when loss of appetite and weight were noticed. His course was steadily downhill until in August, 1938, he was too weak to stand. At no time was icterus or any other localizing sign or symptom noted. His weight had dropped to approximately 160 kilograms when he was destroyed on August 4, 1938, at the estimated age of 31 years.

## Post Mortem Examination.

The Mount Sinai Hospital Autopsy No. Z-300; New York Zoological Park No. m-155-38.

*Gross*: The specimen was an emaciated, adult, male Kadiak bear, *Ursus middendorffi* Merriam, about eight feet total length and weighing approximately 160 kilograms. His fur was lustreless, sparse, brittle and pulled out easily. Over the upper inner aspect of each buttock was a small shallow decubitus ulcer. A firm pedunculated tumor, about the size of a plum, hung from the outer aspect of the upper one-third of his right thigh. This had a narrow stalk and was covered by skin.

The superficial fat was almost lacking. The heart and lungs were not unusual, except for the pale, gelatinous appearance of the epicardial fat. There was no ascites. In the head of the pancreas, behind the descending portion of the duodenum, was a large, elliptical, stony hard tumor, measuring 8 by 6 by 3 cm. (Pl. I, Fig. 1). The common bile duct passed over the anterior aspect of the tumor, but was neither narrowed nor infiltrated. On cut section, the tumor was salmon-colored and the surface was traversed by interlacing bands of glistening white fibrous tissue. Many soft cystic areas, containing semi-liquified tissue, were found in the tumor. The body of the pancreas appeared normally lobulated. The pancreatic duct could not be found. The retroperitoneal lymph nodes, posterior to the tumor, were as large as hazel nuts, firm, and on section contained gray-white areas. The liver was huge, weighing 5,560 grams (Pl. I, Fig. 2). The surface was studded with large round pink-white metastatic nodules, some umbilicated and ranging from one to eleven cm. in diameter. On section, much of the liver parenchyma was replaced by pink-white circumscribed round foci similar to those seen on the surface. Many of these metastatic nodules contained areas of necrosis and hemorrhage. No other tumor metastases were found. An incidental finding was the presence of numerous, large, facetted stones in the gall bladder, whose wall was somewhat thickened. The large biliary radicles were all patent. No unusual changes were noted in the remaining viscera.

*Microscopic*: The tumor in the pancreas, liver and lymph nodes had essentially the same histologic appearance. There were two types of cell patterns. In one the cells were arranged in definite pseudo-acinar groupings (Pl. II, Figs. 3A and 4A) or in thick, tortuous cords having papillary projections. The cells had large vesicular hyperchromatic nuclei with prominent deep-staining nucleoli. Mitotic figures were infrequent. The cytoplasm was abundant and contained innumerable eosinophilic zymogen granules (Pl. II, Fig. 3B). The zymogen granules in the pseudo-acinar structures were situated on the side of the cells next to the lumen, and pushed the nuclei to the base of the cell. The other predominating cell pattern consisted of epithelioid cords of small cells, many with dark pyknotic nuclei. (Pl. II, Fig. 4B). The cytoplasm was scant and filled with vacuoles which took the Sudan III stain for neutral fat. Some of the cells in these cords contained zymogen granules. The stroma of the tumor consisted of a loose, delicate, highly vascular connective tissue framework. No portion of the carcinoma resembled the Islands of Langerhans. Sections of the pancreas immediately adjacent to the primary tumor showed atrophy of the parenchyma and dense interstitial fibrosis. Histologic study of the rest of the pancreas revealed slight lipomatosis.

## COMMENT.

Ordinarily pancreatic tumors arise from either the ducts or the Islands of Langerhans. Histologic examination proved our tumor to be a parenchymal cell carcinoma, having its origin in the acinar tissue of the pancreas. The most unusual feature was the presence of zymogen granules in the cells. This is a definite indication that active secretion and elaboration of pancreatic enzymes was occurring, and on this basis the origin of the tumor in pancreatic acinar cells can be postulated. In some of the other glandular organs, carcinomas producing secretion are well-known. Hepatomas of the liver produce bile and have the same metabolic functions as normal liver cells. Symptoms of Grave's disease may be associated with adenocarcinomas of the thyroid gland. However, in only one pancreatic carcinoma in the literature was acinar origin proved by the presence of secretion. This was the case of Sugiura, Pack & Stewart (9) who proved the presence of active enzymes in a human pancreatic adenocarcinoma. Their tumor was considered histologically characteristic of an acinar adenocarcinoma, but no mention of the presence of zymogen granules was made. They found that the tumor contained as much protease and lipase and more amylase than normal human pancreas.

## SUMMARY.

A case of primary parenchymal cell carcinoma of the pancreas with extensive liver metastases is reported. The significance of zymogen granules pointing to acinar cell origin is discussed.

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## EXPLANATION OF THE PLATES.

### PLATE I.

Fig. 1. Primary carcinoma of pancreas. **D**—Duodenum. **S**—Stomach. **T**—Tumor.
Fig. 2. Liver with metastases.

### PLATE II.

Fig. 3A. Pseudo-acinar structure.
Fig. 3B. Higher magnification, showing zymogen granules.
Fig. 4A. More anaplastic area.
Fig. 4B. Small-cell area, same magnification as 4A.

FIG. 1.

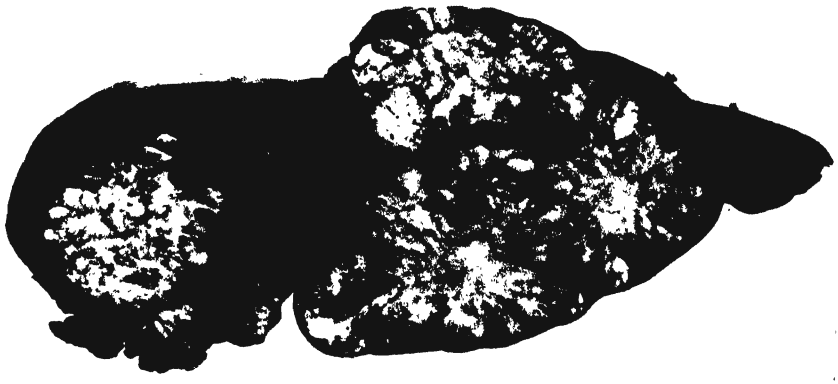

FIG. 2.

CARCINOMA OF THE PANCREAS OF ACINAR ORIGIN IN A BEAR.

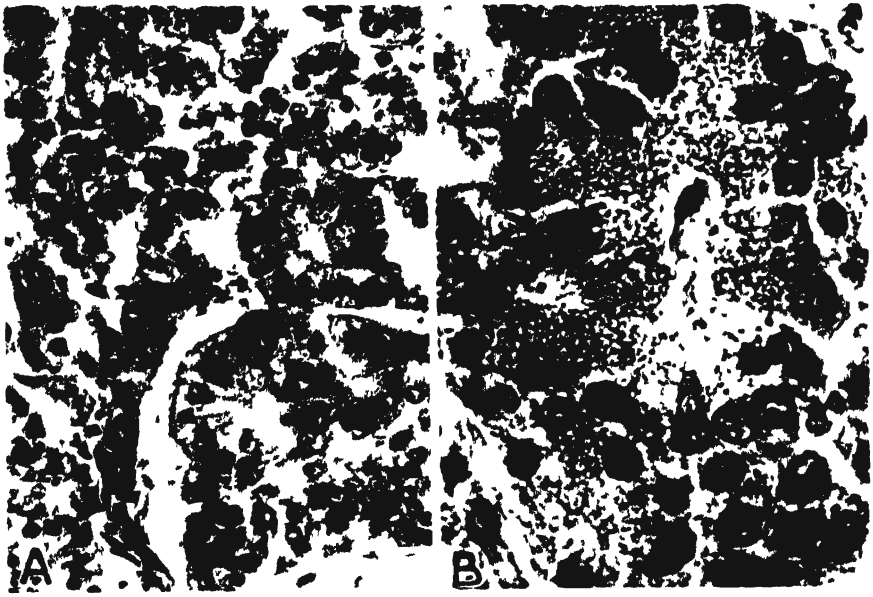


FIG 3A FIG 3B

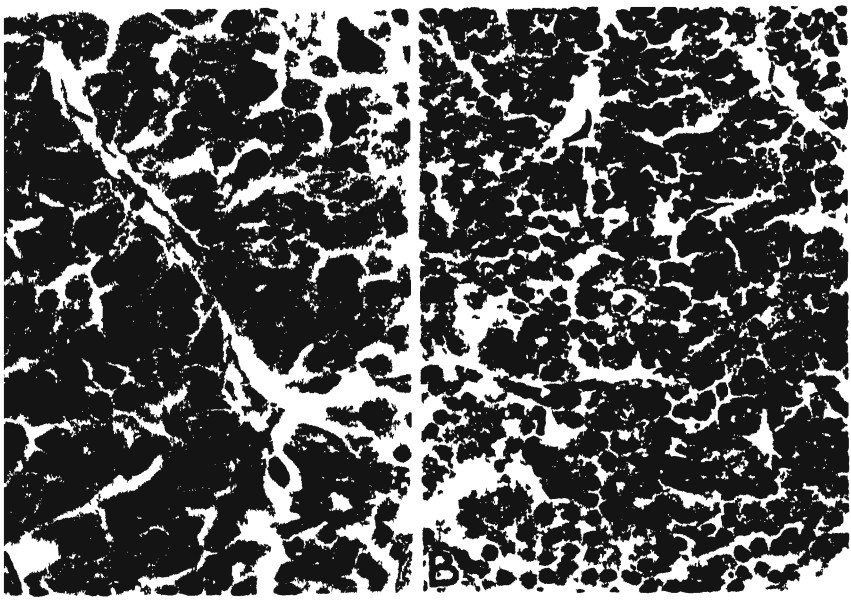


FIG 4A FIG 4B

CARCINOMA OF THE PANCREAS OF ACINAR ORIGIN IN A BEAR

# 12.

## Congenital Macrofollicular Cystic Colloid Goiter in a Dromedary.

LEONARD E. FINKELSTEIN, M.D.[1]

(Plate I).

Congenital colloid goiter, especially with cystic change, is a rarity not only among the lower animals but in the human species as well (4,12). More infrequently is it a cause of intrauterine fetal death and of dystocia, as occurred in the following case at the Zoological Park.

### CASE.

An adult female dromedary, multiparous although without any record of previous pregnancies at the Zoological Park, went into labor following an uneventful full-term period of gestation. Parturition failed to proceed normally. A vaginal examination by Dr. Schroeder, Veterinarian of the New York Zoological Park, revealed that the fetus was in a dorso-sacral position with the hind legs retracted, so that the tarsi presented. In addition, early maceration was evident, indicating that the fetus was dead. A very large cystic mass was palpated on the neck of the fetus. This, together with the head and forelegs, was too large to pass through the birth canal. Embryotomy was performed.

### PATHOLOGICAL EXAMINATION.

The head of the fetus was shortened in the antero-posterior diameter, being a so-called "bull-dog head." Except for this and the tumor of the neck there were no other congenital malformations.

The tumor consists of two equal and similar masses which occupy the normal positions of the thyroid lobes, and is, in fact, a markedly enlarged thyroid gland. Each lobe measures 25 centimeters in length, 15 centimeters in width, and 8 centimeters in thickness. (The length of a normal thyroid in an adult dromedary is 3-4 inches (7-10 centimeters) according to Leese (5)). The enlargement appears diffuse and uniform. A dense gray fibrous capsule to which is adherent several strands of muscle surrounds each lobe. The gland is soft in consistency and feels cystic on palpation.

The cut surface of the gland is moist, glistening, pale brownish in color, and gelatinous in appearance. It possesses a coarsely honeycombed structure, being composed of numerous bulging, round and angulated, very thin walled cysts. (Pl. I). These vary in size from about 0.5 to 2 centimeters in diameter, most of them being about 1 centimeter. The cystic spaces are all filled with translucent, pale brown colloid. In some areas extending in from the capsule there are broad gray fibrous septa. No normal thyroid structure is grossly observed.

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On microscopic examination moderate autolysis is noted. The capsule is seen to be composed of a broad band of dense connective tissue on the external surface of which several striated muscle fibers are intimately attached. The glandular follicles are enormously dilated and cystic, being distended by eosinophilic homogeneous colloid. Some follicles beneath the capsule appear compressed and distorted. The lining epithelium is everywhere compressed, the cells being very much flattened, so that it appears as a thin line between distended follicles. There are no papillomatous spurs, and no distinct evidence of parenchymal proliferation. The cell nuclei are small and very basophilic. Except for occasional thick connective tissue septa, no interfollicular substance is noted. A few small compressed blood vessels are present in the capsule and some of the septa.

The anatomic diagnosis of the specimen is *congenital colloid goiter with macrofollicular cystic degeneration.* The intrauterine death of the fetus was probably due to compression of the carotid arteries by the huge thyroid lobes (12).

## Autopsy on the Dam.

About 16 months after this pregnancy the dam became blind and weak and was destroyed. At necropsy extensive acute and chronic infection of the pulmonary and intestinal tracts and of the meninges and uterus was found. The thyroid gland was moderately enlarged, the right lobe measuring 15× 7×2.5 centimeters, and the left lobe 11×1.5×2.5 centimeters. Upon examination the gland is uniformly brownish-red in color, and on section it appears fleshy. There are no adenomatous nodules. Histologically striking hyperplasia of the parenchymal element is observed. The epithelial cells are large, being high cuboidal in shape. The nuclei, too, are large and vesicular. The colloid content is considerably less than normal.

## Discussion.

Simple, non-toxic goiter is found in a variety of animals, not only in adults, but in the newborn as well (2, 3, 4, 6, 7, 13). In fact, according to Marine (8), goiter may occur in any land or fresh water animal. It is said that wild animals never develop goiter even in regions where endemic goiter is prevalent (14). However, Fox (3) has noted the affliction in captive wild animals at the Philadelphia Zoological Garden.

In acquired goiter, human as well as animal, a definite goiter cycle has been established wherein the hyperactive phase is associated with glandular hyperplasia. Colloid goiter represents a resting state in the cycle, a physiologic return to normal which is expressed anatomically by an accumulation of colloid (7, 8). Joest (4) cites a case described by Johne, of a colloid struma in an adult dromedary.

In congenital goiter, which per se is not infrequent, by far the usual pathologic picture is one of hyperactivity—parenchymal hyperplasia with very little colloid (2, 4, 7, 10, 12, 13, 14). Marine (8) explains this as a physiologic reaction in the fetal gland compensating for the increased demands on the maternal thyroid that often obtain during pregnancy. This causal relationship is well demonstrated in the experimental production of congenital goiter by almost completely extirpating the maternal thyroid (2, 9). Abbott & Ball (1) in a study of 100 fetal and newborn thyroid glands state that it is reasonable to assume that the pathologic changes in the fetal thyroid are induced by the same type of stimulus that exists in the adult.

If the etiology of hyperplastic parenchymatous struma in the newborn is reasonably clear, the pathogenesis of a congenital colloid goiter is equally unclear. The latter is uncommon, the cystic form being extremely rare (4, 10, 12). In most cases of the colloid type there is a coexisting

hyperplasia. This, however, may be obscured by the colloid, so that one may be unable to affirm or deny its presence (11, 12). Since a paucity of colloid is a striking feature of the normal thyroid in the newborn, the association of hyperplasia with colloid is significant. It lends color to the concept that congenital colloid goiter originates in a hyperplastic thyroid rather than that it develops de novo.

In the case presented here, the enormous cystic dilatation of the follicles would readily obfuscate histologic evidence of preceding hyperplasia. It appears likely that the maternal thyroid was already in the hyperactive phase during the period of pregnancy, and initiated the fetal changes which went on to regression. One cannot say from this case alone whether a dysontogenetic hypersecretion of colloid ensued or whether some other factors came into play to produce the final picture.

Congenital goiter in the one-humped camel is not unknown. Leese (5) in a treatise on this species writes that the thyroid glands may be enormously enlarged at birth, and that death from suffocation may occur shortly after delivery.. At times the goiter may persist without change throughout life, or may even become larger, reaching the size of a man's head and interfere with grazing from the ground. While Leese does not describe the anatomic type of goiter, such large masses would seem to be similar to the cystic colloid struma of this fetus.

Leese emphasizes the occurence of congenital goiter among camels out of dams confined to zoos or to ships during long sea-voyages, and suggests that insufficient exercise of the pregnant dam may be a predisposing factor. However, we now know that goiter is due to a relative or absolute lack of iodine which leads to a work hypertrophy of the thyroid (Marine (8) ). The mediate factors involved include various dietary faults and the increased metabolic requirements in pregnancy and febrile, toxic states, any or all of which may be present in captive animals.

## SUMMARY.

1. A case is reported of a congenital macrofollicular cystic colloid goiter occurring in a full-term, still-born dromedary. The goiter resulted in dystocia.

2. Such a struma is rare not only in the lower animals but in humans as well.

3. An autopsy performed on the dam 16 months after delivery disclosed marked parenchymal hyperplasia of the thyroid together with severe acute and chronic infection of the pulmonary and intestinal tracts, meninges and uterus.

4. It is likely that the maternal thyroid was already hyperplastic during pregnancy, and initiated the fetal pathology. The cystic changes in the fetal gland would readily obscure evidence of parenchymatous hyperplasia—the usual picture in congenital goiter.

The author is indebted to Dr. Charles R. Schroeder, Dr. Paul Klemperer and Dr. Sadao Otani for their aid in the preparation of this report.

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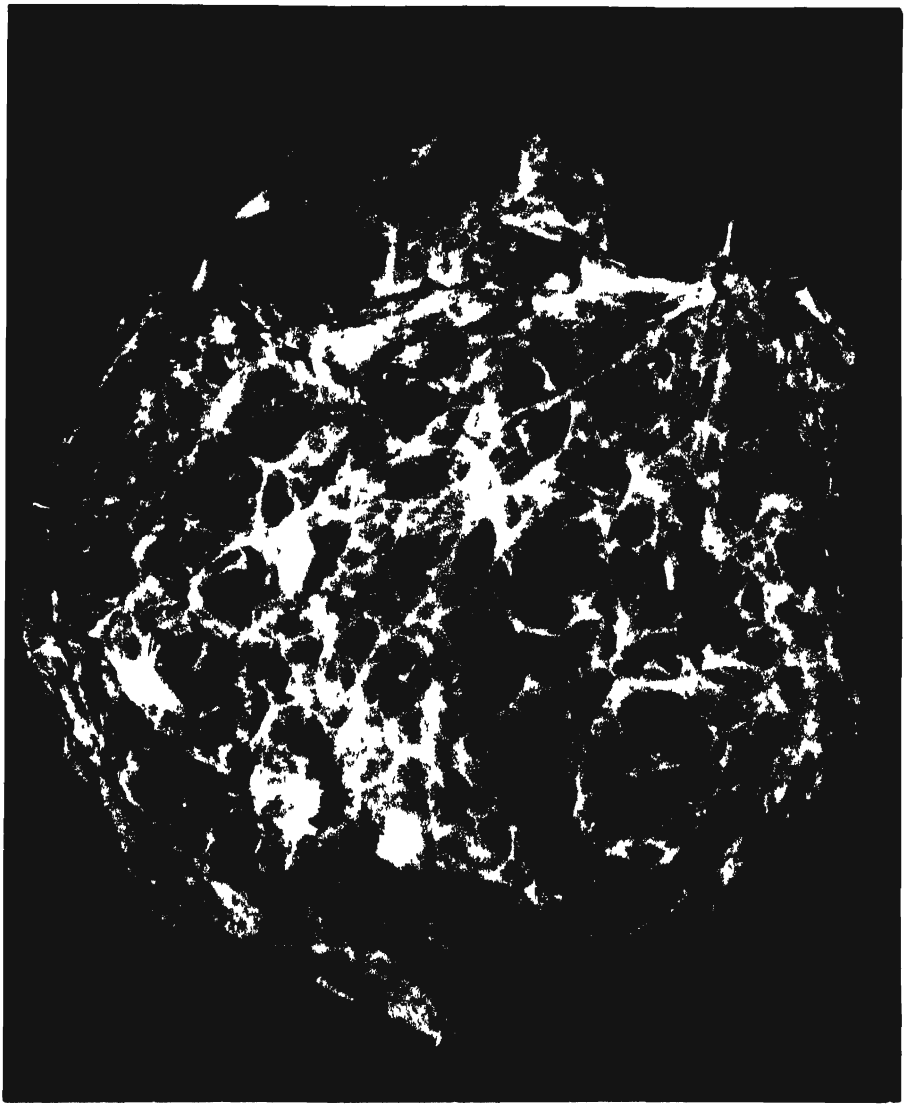
## EXPLANATION OF THE PLATE.

### PLATE I.

Cut surface of the fetal thyroid gland in a case of congenital macrofollicular cystic colloid goiter. Note the uniform enlargement, the glistening, translucent appearance, and the coarsely honeycombed structure. No normal thyroid tissue present. Each lobe measures 25 × 15 × 8 centimeters. (Photographed under water).



CONGENITAL MACROFOLLICULAR CYSTIC COLLOID GOITER IN A DROMEDARY.

# 13.

## *Pentatrichomonas macropi* Tanabe from Kangaroos.

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(Text-figure 1).

A Woodward's wallaroo, *Macropus robustus woodwardi,* in the collection of the New York Zoological Park, died on July 5, 1938. It was autopsied at the Hospital and Laboratory of the Zoological Park within an hour after death. A microscopical examination of material obtained from the enlarged and distended caecum revealed a flagellated protozoan organism of the *Trichomonas* type. Subsequently this parasite was obtained from the caecal contents or feces from a total of five species of kangaroos living at the New York Zoological Park.

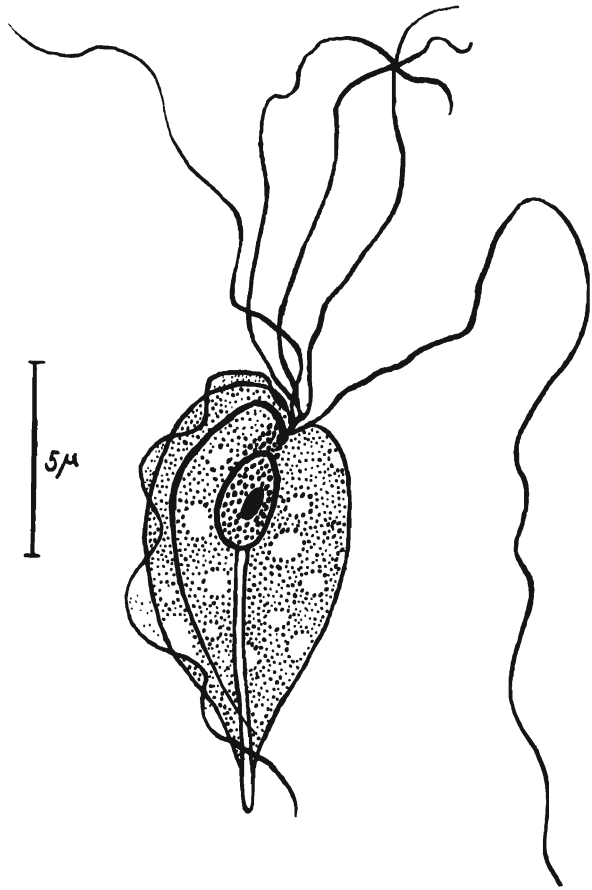
The original material collected from the caecum of the wallaroo was taken to the laboratory of the Mt. Sinai Hospital by Dr. L. Finkelstein and successfully grown on blood agar slants. It was maintained further, by transfers on this media, at the Laboratory of the Zoological Park.

Observations were made from living specimens—both fresh and cultured material—and from fixed preparations. The fixatives employed in this study were Schaudinn's fluid (plus 5% glacial acetic acid), osmic acid vapor and methyl alcohol. Organisms killed with either of the first two fixatives were stained with Heidenhain's iron-alum haematoxylin. Organisms fixed in methyl alcohol were stained with Giemsa's stain. The Giemsa method was found to be best for diagnostic purposes. The stain was used in the same concentration and for the same length of time as employed for blood smears.

The morphology of this parasite agrees with the description of *Pentatrichomonas macropi* Tanabe (1926). Tanabe's description of this parasite from a kangaroo (genus and species not given) was made entirely from cultured material. In the present study there seemed to be a much greater diversity in size in the fresh material and a greater variation of shapes in the cultured forms. The length of specimens from fresh material varied between 4.5 $\mu$ and 15 $\mu$ while in the cultured forms the size tended toward an average between 7 and 10 $\mu$ as reported by Tanabe. A diagrammatic sketch of *Pentatrichomonas macropi* made from observations on both fresh and cultured forms is included in this paper as a text-figure.

The following hosts in the collection of the New York Zoological Park have been found to be infected with this parasite:

3 rock kangaroos, *Macropus brunii.*
2 Woodward's wallaroos, *Macropus robustus woodwardi.*
3 black-faced kangaroos, *Macropus melanops.*
3 great gray kangaroos, *Macropus g. giganticus.*
3 black tree kangaroos, *Dendrolagus ursinus.*




Text-figure 1.
*Pentatrichomonas macropi* Tanabe. From kangaroos (diagrammatic sketch).

*Pentatrichomonas macropi* grows quite readily on a variety of culture media at 37° C. The greatest abundance of organisms can be found in original cultures between 48 and 72 hours after inoculation with fecal material. Subcultures were successfully made through seven transfers. The parasites tend to die out after 72 hours (becoming overwhelmed with bacteria) and even in subcultures the organisms never achieved the great numbers seen in the first tubes inoculated.

A number of culture media were tested as to their ability to support a growth of *Pentatrichomonas macropi*. Fair growth was obtained with the following: undiluted blood serum, diluted blood serum (1 part serum plus 1 part dist. aqua), Loeffler's serum-saline (0.5% Loeffler's plus 0.75% serum), and Hogue's ovo-mucoid (100 cc. physiological saline plus white of one egg). Good results were obtained with blood agar slants. The water of condensation did not prove sufficient to support a growth of the trichomonads but good results were obtained when the various liquid media listed above were added in small quantities. Distilled water or saline on blood agar slants also supported a good growth. Charcoal agar with these various fluids did not support as abundant a growth as the blood agar media. Horse blood was used throughout in the preparation of the culture tubes. The organisms seem to

require a liquid medium but prefer a solid base such as a blood agar slant. The best medium obtained in these experiments was a fecal infusion on blood agar slants. Both rat feces and kangaroo feces were tried with equal success and were used for routine diagnosis of *Trichomonas* in most of the kangaroos studied antemortem.

Of five of the kangaroos that came to autopsy during this study, three had ulcers in the digestive tract. A careful examination of microscopic sections of these ulcers in each case did not reveal any trichomonads associated with the necrosis. Whether or not there is any correlation with the presence of *Pentatrichomonas macropi* and the occurrence of ulcers in kangaroos it would be impossible to state from our present knowledge. Only one of these animals exhibited a diarrhea.

Samples of intestinal contents from various areas seem to indicate that *Pentatrichomonas macropi* is primarily a parasite of the caecum. However, positive evidence of their presence in other portions of the large intestine and the posterior region of the small intestine was obtained both by direct smear and by the culture method.

## SUMMARY.

1. A trichomonad parasite, *Pentatrichomonas macropi* Tanabe, is reported from five species of kangaroos in the collection of the New York Zoological Park.

2. The parasites can be grown readily in vitro. The best culture media found was fecal infusion on a blood agar slant at 37° C.

3. Although three of the kangaroos infected with trichomonads were found to have intestinal ulcers, no parasites could be found in the tissues and it is doubtful if there is any correlative significance to this finding.

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# 14.

# A Report on the Dental Pathology Found in Animals that Died in the New York Zoological Park in 1938.

THEODORE KAZIMIROFF

(Plates I-IX).

## INTRODUCTION.

It is very seldom that one finds a description of oral pathology in autopsy reports of animals in captivity. This is due to several factors; primarily inability to recognize or interpret lesions either in the living state or on the autopsy table, and secondly, the masking of these hard tissue lesions by apparently normal-appearing soft tissues, which effectively cover and hide any lesions present. It is not a widely known fact that the majority of oral lesions invariably affect the hard structures around the mouth—the teeth, which may present lesions of the enamel, dentine or cementum, and the surrounding bone, which indelibly bears the lesions of various oral diseases.

It is apparent that the study of oral lesions in the morbid state would materially augment autopsy reports. In addition this valuable information that would otherwise go unknown and undetected, may help solve some of the mysterious conditions often encountered.

As far as preparation of the material is concerned, the best means is maceration, preferably at body temperature, although room temperature, while slower, is suitable. If rapidity of preparation is desired, the specimens may be cooked down in soap solutions. Neither way will affect the hard tissues, or produce unrecognizable artifacts.

This paper covers the range of pathology found in the specimens collected at the New York Zoological Park Hospital during 1938. This includes dental caries, injuries of the teeth, mal-positioning of the teeth, dento-alveolar abscess, periodontal pathology, impacted teeth and other conditions.

The photography is the work of E. R. Osterndorff. The radiographs were taken by the author.

## 1. DENTAL CARIES.

Dental caries occurs in both wild and captive animals. Sir Frank Colyer has shown that the disease is more prevalent in captive animals than in wild animals. The term caries denotes a pathologic condition which results in the destruction of either enamel, dentine or cementum through the agency of specific, pathogenic micro-organisms. This condition is to be differentiated from loss of tooth structure by attrition or trauma. Although the cause of dental caries is still disputed, several important factors are to be considered: a, the action of micro-organisms; b, structural defects of

the teeth; c, traumatic fractures of teeth; d, mal-positioning of the teeth with resultant food impaction areas; e, a faulty diet, usually found to be rich in carbohydrate intake, and many other factors disputed or accepted by authorities. The following specimens illustrate some of these conditions.

*Primates.*

a. *Macacus rhesus* (immature).

This specimen presents a condition of incipient caries of the enamel on the distal surface of the maxillary right central incisor. The caries occurs at the point of contact between this tooth and the lateral incisor. The mesio-incisal corner of the lateral had been chipped, creating a wedge-shaped food impaction area which undoubtedly contributed to the carious process.

b. Hussar Monkey, *Erythrocebus patas*, M-234-38.[1]

This specimen shows caries that had occurred on the site of an old fracture of the maxillary left canine tooth. The carious process has hollowed out the crown of the canine. (Plate I, Fig. 1).

The exposed pulp present may have been due either to the original fracture or to caries following the fracture. Alveolo-dental abscess of long standing is present, with fistulation through the buccal plate of bone in the apical region.

*Rodentia.*

a. Woodchuck, *Marmota monax*, M-37-38. Plate I, Fig. 2b.

This specimen exhibits caries of the premolar and of the first and second molars. The disto-buccal cusp of the mandibular left premolar is completely destroyed, the carious process having extended below the cemento-enamel junction onto the disto-buccal root which has become exposed through alveoloclasia. The mandibular left first molar presents mesio-occlusal and disto-occlusal caries of the crown, and buccal caries at the cemento-enamel stagnation area. The mandibular left second molar likewise presents caries at the cemento-enamel junction. The carious process starts at the mesial surface and ends on the mesio-buccal apect. In addition there is deep and extensive pocket formation with much evidence of suppuration. (Plate I, Fig. 2).

b. Woodchuck, *Marmota monax*, M-38-38.

This specimen presents occlusal caries of the mesio-lingual cusp of the mandibular left first molar. The carious process is of the typical pit caries type, wherein the caries has penetrated and undermined the mesio-lingual cusp for a distance of two-thirds the length of the crown. The caries has not broken through the mesial plate of enamel, although a discoloration is seen through the enamel.

*Carnivora.*

In the wild state the Carnivora are relatively free from caries. However the Ursidae and Procyonidae show an increased caries susceptibility in captivity.

Raccoon, *Procyon lotor*, M-59-38.

This specimen shows interproximal caries involving the distal surface of the mandibular left first molar, resulting from a food impaction area. The second molar is tilted at an angle of approximately 30° with the horizontal plane of occlusion, and is situated on the ascending anterior curve of the coronoid process. This created a wide, wedge-shaped, food impaction area between the distal of the first molar and the mesial of the second molar. Food, wedged into this interproximal space, and acted upon by the lactic acid-producing organisms, undoubtedly caused the caries.

[1] This and subsequent numbers refers to the case history in the records of the Hospital and Laboratory, New York Zoological Park.

(Plate I, Fig. 2a). In addition bone resorbtion and pocket formation resulted from this food impaction area.

*Hyracoidea.*

Hyrax, *Procavia capensis,* M-138-38. Plate II, Fig. 3.

Heretofore, the Hyracoidea have been regarded as a caries-resistant type. Sir Frank Colyer records 300 specimens examined with none showing caries. Hence I believe that this specimen of hyrax presenting caries is the first to be described in the literature. This animal exhibits a very extensive and destructive type of caries, simulating the condition known as "rampant caries" in the human.

All the maxillary premolars and molars are involved, producing a continuous trough-like carious gutter running from the first premolar to the last molar. (Plate II, Fig. 3). The carious process has hollowed out the crowns, removing most of the coronal dentine, but has left the undermined buccal plate of enamel intact on each tooth. The lingual plate of enamel is missing from some of the teeth, but this appears to be due to the undermined, weakened, enamel plates having chipped off. The carious process has attacked the interproximal areas and the transverse occlusal fissures as well. The mandibular teeth show seven of the twelve posterior teeth involved. The mandibular incisor teeth show incipient caries in the form of interproximal discoloration and etching of the enamel below the contact points. The two central incisors show caries of the enamel at the contact point.

## 2. Injuries of the Teeth.

Plate II, Fig. 4.

*Carnivora.*

Coyote, *Canis latrans,* M-18-38.

The left maxillary fourth premolar of this specimen was injured in some manner during the formative stage, producing several interesting sequellae. The injury affected the mesial portion of the tooth, resulting in a haphazard calcification of dentine and enamel. The crown appears to be completely denuded of enamel in some parts, and composed entirely of enamel in other parts. The dentine and enamel calcification had become indiscriminately intermingled. It appears that the power of growth of both ameloblasts and ondoblasts is not affected by traumatic injury as in this instance.

The root portion was also affected: a gnarled, shortened, misshapen root resulted, with several "rootlets" having been created, particularly one rootlike spur on the buccal aspect which is 1 mm. wide and 2 mm. long. There was a definite ankylosis of root to alveolar bone. The apex of the mesial root had fused to the alveolar bone, and the mesio-buccal margin had fused to the buccal plate of bone. The X-ray indicates that a pulp was present in the distal portion of the tooth, both root and coronal pulp being present.

The effect on the maxillary and mandibular dental arch is interesting. The side opposite that of the injury shows the more severe mal-positioning of the teeth. The mandibular right canine protrudes horizontally at right angles to the long axis of the other mandibular teeth. The left mandibular canine tooth is likewise misplaced but not as severely as the right canine. The maxillary right canine has changed its axial inclination; the crown has been pushed anteriorly, and the root displaced posteriorly.

In spite of all this, the animal showed very little, if any, evidence of suppuration, and only slight alveoloclasia.

### 3. Dento-alveolar Abscess.

Dento-alveolar abscess is frequently found in wild animals kept in captivity. The usual causes are exposure of the pulp by means either of fracture of a tooth or severe attrition. Not all such cases result in abscess formation, however. Another cause of abscess formation, though relatively infrequent, is the result of infection of the peri-dental membrane progressing so far as to produce an abscess.

*Carnivora.*

Gray Wolf, *Canis nubilus*, M-61-38. Plate III, Fig. 5.

This specimen shows abscess formation following a fracture of the upper right central incisor, exposing the pulp chamber. The resultant pulp infection was followed by apical involvement indicated by fistulation and rarefaction of bone. The extreme of alveoloclasia is shown in this case with complete destruction of all alveolar bone, as is seen in the illustration. The pocket formation encircles the root completely. An unusual situation resulted from this condition, hypercementosis and root resorbtion occurring simultaneously.

*Marsupialia.*

Kangaroo, *Macropus robustus.*

This specimen exhibits abscess formation as a result of a fracture of the upper left second incisor. Fistulation took place with the pus pointing into the left nasal aperture. The fistulation resulted in extensive bone destruction with much evidence of suppuration.

*Primates.*

Hussar Monkey, *Erythrocebus patas*, M-234-38.

This specimen presents in addition to abscess formation a very unusual condition which will be fully described in the section dealing with periodontal pathology. The abscess formation followed as a result of exposure of the pulp of the maxillary left canine tooth. An old fracture of the crown was followed by caries. Whether the pulp exposure resulted from the fracture or from the caries is hard to say. However the pulp infection was followed by apical involvement and abscess formation. The resultant fistulous opening is in the bone of the maxilla at the apex of the canine. (Plate III, Fig. 7). Drainage was evidently by means of the soft tissues between the periosteum and the skin, into the oral cavity.

*Artiodactyla.*

Axis deer, *Axis axis*, M-221-38.

This specimen presents one of the rare cases of abscess formation following periodontal membrane infection. The entire condition will be discussed under the section dealing with periodontal pathology.

A severe food impaction area resulted in deep pocket formation between the distal root of the left mandibular second molar and the mesial root of the third molar. Even after maceration, fodder fragments are present interproximally and in the pockets. Suppuration hollowed out the lingual bone and left a definite lateral sinus. (Plate IV, Fig. 9). Fistulation is on the lingual surface of the mandible and is accompanied by a peculiar, raised osteoporosis surrounding the fistulous opening. Drainage was probably through the soft tissues of the floor of the mouth.

### 4. Periodontal Pathology and the Resultant Bone Lesions.

The majority of the specimens skeletonized exhibit evidences of periodontal disturbances.

*Carnivora.*

Gray Wolf, *Canis nubilus*, M-61-38. Plate III, Figs. 5, 6.

This specimen shows a fairly well developed periodontal disturbance. Alveolar bone destruction is marked throughout, slightly more severe in the upper jaw. The bone shows the characteristic signs of suppuration, rarefying osteitis pronounced throughout. Abscess and pocket formation around the upper right central incisor have been described in a preceding section. There is a deep food pocket present between the distal of the maxillary right fourth premolar and the first molar. The maxillary fourth premolar has a large deposit of salivary calculus (visible in the illustration as the projecting white mass under the zygomer, posterior to the canine. Plate III, Fig. 5).

There is also a severe food impaction area between the left mandibular first and second molars. The talonid or distal cusp of the mandibular left first molar has been broken off. The space created acted as a food impaction area, and the wedging of the food caused deep interproximal and lateral pocket formation. (Plate III, Fig. 6). There is much evidence of marginal suppuration in the form of a rarefying osteitis.

Paradoxure, *Paradoxurus jerdoni*, M-77-38.

Sir Frank Colyer reports a case of periodontal disease in *Paradoxurus larvatus* (masked paradoxure) which is similar to the condition found in M-77-38. The alveolar bone destruction around the maxillary teeth is highly advanced, more than one-half of the root surface being exposed. There is much evidence of a rarefying osteitis. The mandibular teeth, however, show a heavy marginal proliferation of bone instead of an alveoloclasia. This appears to be a slow response to a condition of long standing. (Plate V, Fig. 10).

*Artiodactyla.*

Axis Deer, *Axis axis*, M-221-38.

This specimen presents the last stages of periodontal disease, the stage preceding loss of teeth. There is a complete destruction of almost all alveolar bone, lateral as well as interproximal bone. The only means of retention of the teeth is by extreme hypercementosis. This is a response to the destruction of the alveolar bone and is retentive in function. The hypercementosis is so severe that the distal roots of the maxillary first premolars have fused with the mesial roots of the second premolars. (Plate V, Fig. 11b). The incisor teeth likewise exhibit this extreme deposition of cementum. The apical enlargements are thus two or three times the dimensions of the crowns of the teeth. (Plate V, Fig. 11a).

The alveoli show signs of extensive suppuration, a complete rarefying osteitis being present. Fistulation into the maxillary sinus has taken place. (Plate VI, Fig. 12). An unusual condition has resulted from the drainage into the left antrum. The best description seems to be a "suppurative blow-out" of the posterior wall of the left antrum. This is well seen in the inferior view of the skull, marked by the arrows. (Plate IV, Fig. 8). The discharge of pus was into the inferior orbital and infra-temporal region. The pus had distended the posterior wall of the sinus, resulting in a paper-thin, globular, bony swelling that ultimately "blew out." The degree of attrition and the amount of alveoloclasia is well depicted in the accompanying illustrations. (Plate VI, Figs. 12, 13).

*Primates.*

Hussar Monkey, *Erythrocebus patas*, M-234-38.

This specimen presents a very unusual condition: a severe unilateral alveoloclasia. For some reason this animal developed a unilateral mastication, the left side being used almost exclusively for chewing. As a conse-

quence, the degree of attrition is greater on the left side than on the right side. The left was in a fairly normal state, very slight alveolar bone destruction present. (Plate VII, Fig. 14). However, the right or atrophic side shows the extreme effect of alveoloclasia. As the illustrations show, there is complete destruction of all alveolar bone. (Plate VII, Fig. 15). The entire right side, maxillary and mandibular, exhibits a severe, progressive osteitis. The comparison of the photographs of the right and left sides presents the case graphically.

The premolars and molars of the right side have their root apices protruding into the maxillary sinus. See illustration—the arrows point to the sinus openings. (Plate VII, Fig. 15).

Plate I, Fig. 2, shows, beside the raccoon mandible with a carious molar, two examples of periodontal disease in the rodents.

*Rodentia.*

Woodchuck, *Marmota monax*, M-37-38.

In addition to caries this specimen exhibits a lateral pocket or suppurative sinus extending from the mesial of the left mandibular premolar to the distal of the second molar. There is a space of 3 mm. between the root surfaces and the buccal plate of bone. (Plate I, Fig. 2b).

African Ground Squirrel, *Geosciurus capensis.*

This specimen exhibits the end stages of periodontal disease. Only two of the teeth remain, the position of the lost teeth being indicated by the presence of an edentulous trough. (Plate I, Fig. 2c).

## 5. Impactions and Mal-positioning of Teeth.

Occasionally teeth are mal-occluded, mal-positioned or impacted. The cause of these conditions is still obscure, and many factors may be involved. The specimen included in this section is one of unusual interest. A very brief case history and autopsy report may be of value.

*Primates.*

Woolly Monkey, *Lagothrix humboldtii*, M-216-38. Young adult, male.

Partial right facial hemiplegia, cheek and lip principally—blindness—bilateral exopthalmia—weakness—unsteady gait—tarsi and carpi flexed—physically unable to extend limbs—oedema of extremities—eyes had much retro-bulbar fat surrounding optic nerve. The description of the specimen is augmented by photographs and radiographs.

The alveolar process and ridge is about three times that of normal, presenting a swollen, hypertrophic, maxillary alveolar process. The molars were the only teeth in functional occlusion. There are several visible impactions: two maxillary right premolar impactions, and one left maxillary premolar impaction. The maxillary deciduous canines were retained, while the permanent canines remained impacted. (See X-rays, Plate IX, Fig. 18). The maxillary third molars are seemingly horizontally impacted.

The mandible presents a somewhat similar picture. The permanent canines are impacted, but there are no retained deciduous canines. (Plate IX, Fig. 18a). The left mandibular second premolar is likewise impacted. The third molars are impacted horizontally, under the ascending portion of the coronoid process. (Plate IX, Fig. 18 b, c). Unfortunately, the calvarium and some of the teeth were lost in the preparation of the specimen. However, an examination of the long bones ruled out what appeared at first to be a case of Paget's disease. It would appear that this condition resulted from some complex glandular disturbance.

SUMMARY.

This paper is a report on the oral pathology observed in specimens received from the New York Zoological Park hospital for the year 1938. The specimens were skeletonized, and all observations were made from lesions as seen in the morbid state. This means of studying dental pathology should be invaluable in augmenting the autopsy reports of zoological collections. The pathology found includes dental caries, injuries of the teeth, mal-positioning of the teeth, dento-alveolar abscess, periodontal disease, osteitis and impacted teeth.

The following are the orders represented: Carnivora, Marsupialia, Rodentia, Artiodactyla, Hyracoidea and Primates.

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## EXPLANATION OF THE PLATES.

### PLATE I.

Fig. 1. Occlusal view of skull and mandible of *Erythrocebus patas*. The left canine shows caries of the previously fractured crown. The right maxillary and left mandibular lateral incisor teeth are missing. The left maxillary premolars and first molar, and the left mandibular first molar, are missing.

Fig. 2. a. *Procyon lotor*, showing interproximal caries involving the distal surface of the mandibular left first molar.

b. *Marmota monax;* caries of the mandibular left premolar and first and second molars. Buccal to these teeth there is an extensive suppurative sinus.

c. Mandible of *Geosciurus capensis* with two teeth remaining. The rest have been lost through periodontal disease.

### PLATE II.

Fig. 3. Skull and mandible of *Procavia capensis*, showing extensive caries of the teeth.

Fig. 4. Mal-positioning of the teeth of *Canis latrans* as a result of an early injury to the left maxillary fourth premolar. Note the shifting of the teeth in both arches, and the misshapen mandible.

### PLATE III.

Fig. 5. Anterior view of the skull of *Canis nubilus*. The crown of the right maxillary central incisor had been fractured, exposing the pulp chamber. Fistulation and apical bone rarefaction followed the pulp infection. The infection likewise destroyed the periodontal tissues. The dark areas on the tooth indicate a resorbtion of the root.

Fig. 6. Lateral view of the left half of the mandible of the same specimen, *Canis nubilus*. The distal cusp of the first molar had been fractured, creating a food impaction area that resulted in deep pocket formation. The extracted tooth is the fractured incisor seen in Fig. 5.

Fig. 7. Abscess formation and fistulation at the apex of the maxillary left canine tooth in *Erythrocebus patas*.

## PLATE IV.

Fig. 8. Inferior view of skull of *Axis axis*, showing the extent of alveoloclasia. Abscess formation and fistulation into the sinus resulted in a distension of the posterior wall of the left sinus (arrows).

Fig. 9. Abscess formation and fistulation on the lingual surface of the mandible of *Axis axis*, following infection of the periodontal tissues around the roots of the lower left second and third molars. The degree of alveoloclasia and attrition is well shown.

## PLATE V.

Fig. 10. Periodontal disease in *Paradoxurus jerdoni*. The mandible shows a marginal proliferation of bone as a response to a periodontal disturbance of long standing.

Fig. 11. **a**. Extracted incisors of *Axis axis*, showing apical hypercementosis. **b**. Fusion of the distal roots of the maxillary first premolars with the mesial roots of the second premolars, through an increased deposition of cementum. This indicates the loss of the interproximal plates of bone. **c**. Hypercementosis of molar roots.

## PLATE VI.

Fig. 12. Inferior view of the skull of *Axis axis*, showing the degree of attrition, alveoloclasia, evidences of suppuration and fistulation into the antrum.

Fig. 13. Left lateral view of the skull of *Axis axis*, showing the degree of attrition and the alveolar bone destruction.

## PLATE VII.

Fig. 14. Left lateral view of *Erythrocebus patas*, showing the slight degree of alveolar bone destruction. The arrow indicates fistulation.

Fig. 15. Right lateral view of the same specimen. Compare this with Fig. 14. There is complete alveolar bone destruction, loss of teeth and fistulation into the antrum.

## PLATE VIII.

Fig. 16. Left lateral view of *Lagothrix humboldtii*, showing impacted maxillary and mandibular premolars. The only functional occlusion appeared to be between the molars. None of the other teeth exhibit wear facets.

Fig. 17. Occlusal view of *Lagothrix humboldtii*. Note the hypertrophic maxillary and mandibular processes. The missing teeth were lost in the maceration of the specimen.

## PLATE IX.

Fig. 18. Radiographs of *Lagothrix humboldtii*.

**a**. X-ray of mandible. Note impacted canines, premolar and molars.
**b**, **c**. Lateral X-rays of mandible, showing impactions.
**d**. X-ray of skull. Note impacted canines, premolars and molars.

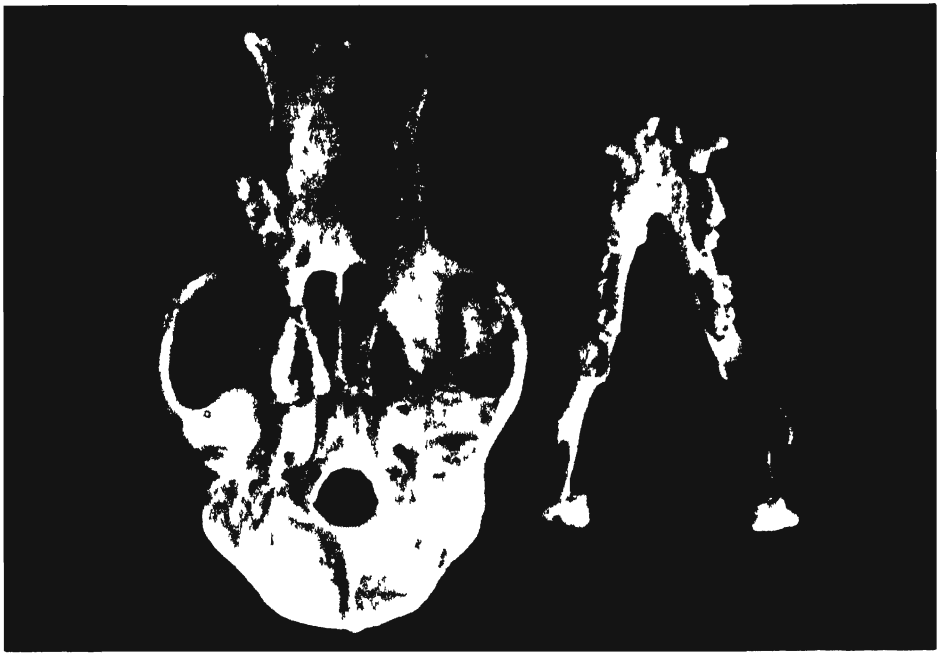


FIG 1

FIG 2

A REPORT ON THE DENTAL PATHOLOGY FOUND IN ANIMALS THAT DIED IN THE NEW YORK ZOOLOGICAL PARK IN 1938

FIG 3

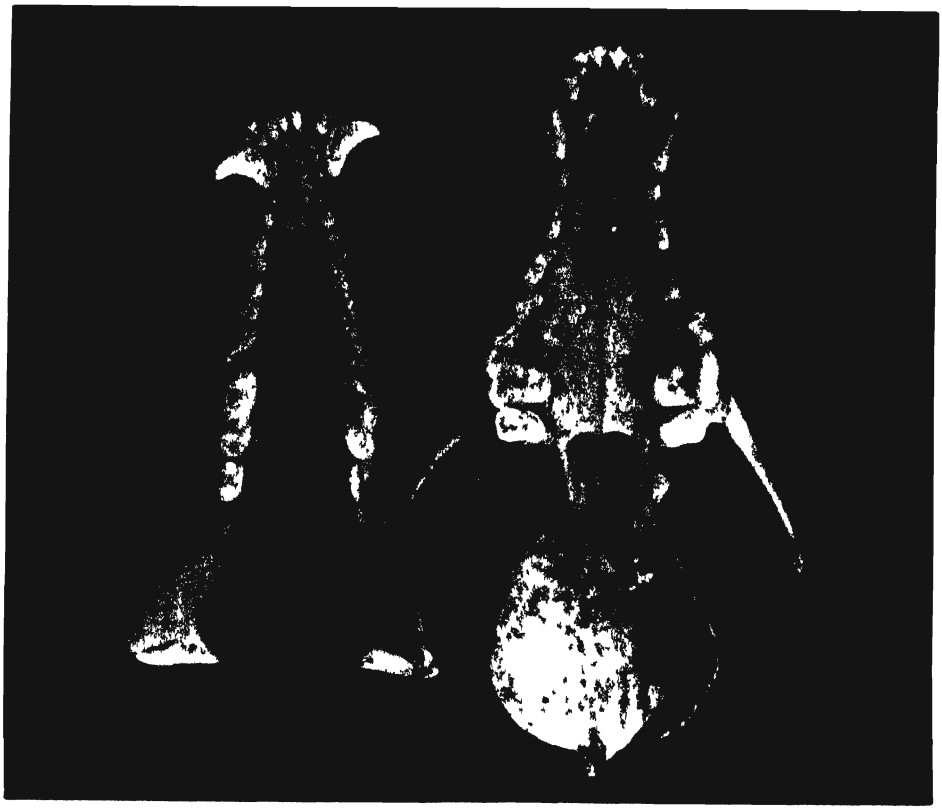


FIG 4

A REPORT ON THE DENTAL PATHOLOGY FOUND IN ANIMALS THAT DIED IN THE NEW YORK ZOOLOGICAL PARK IN 1938

FIG 5

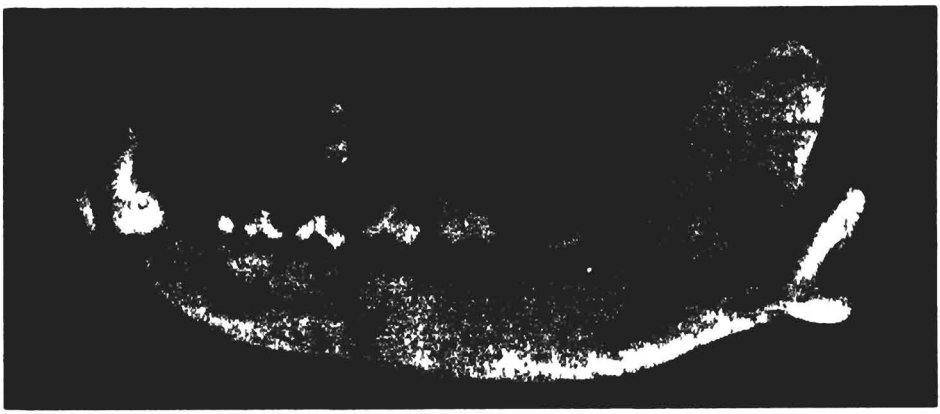


FIG 6

FIG 7

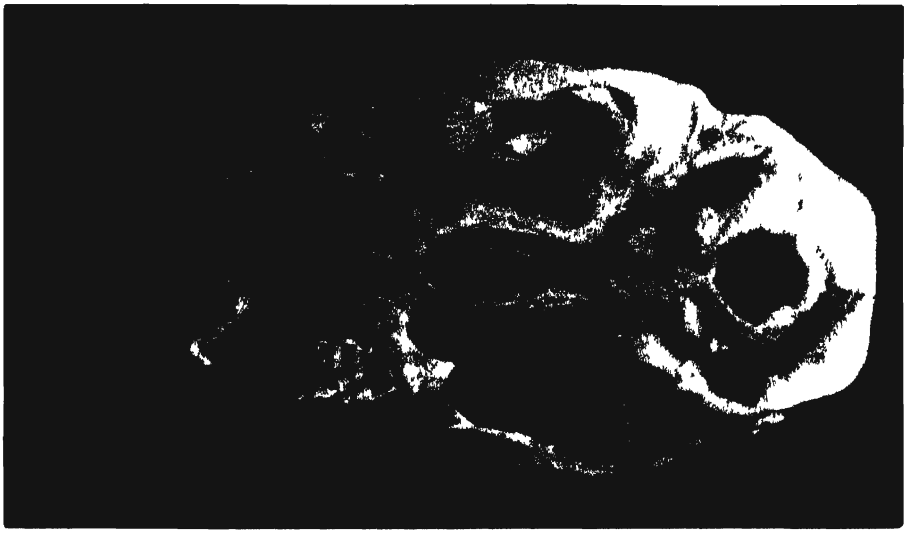


FIG 8

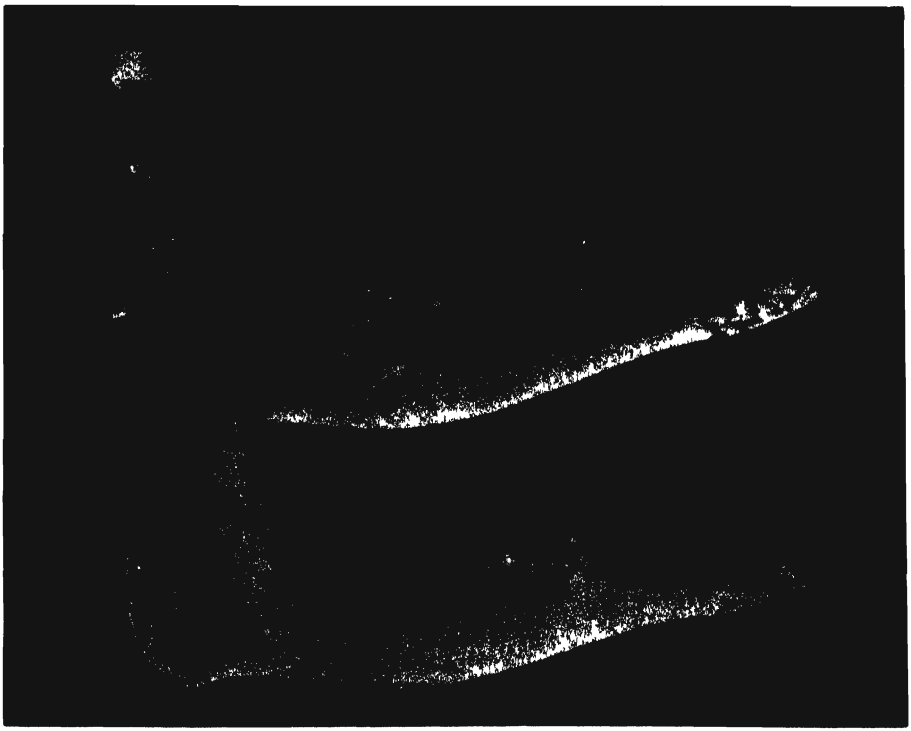


FIG 9

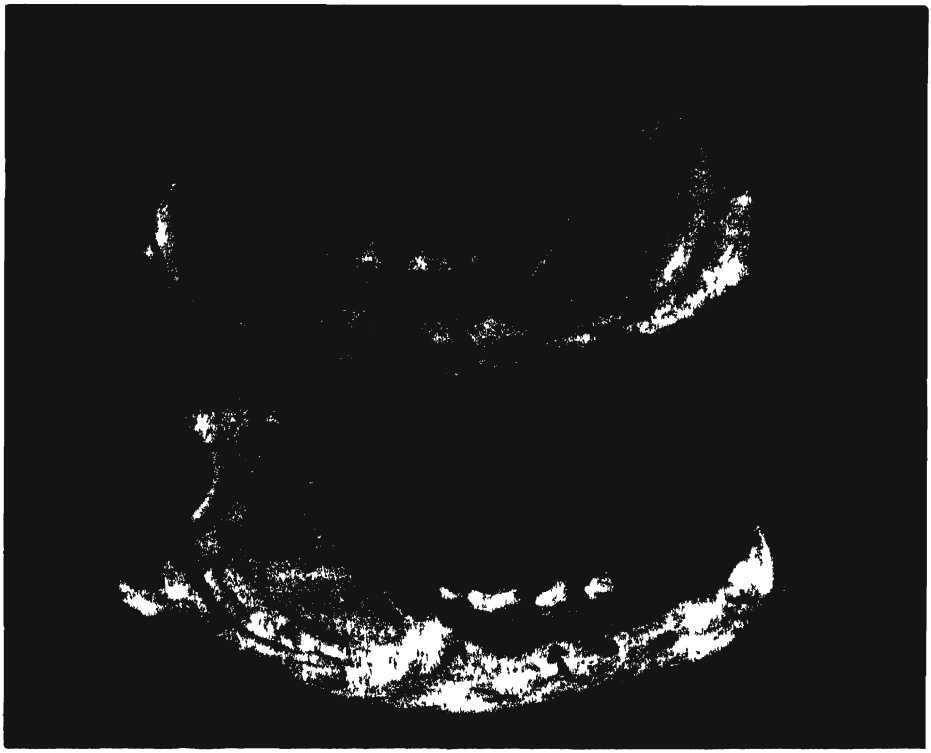


FIG 10

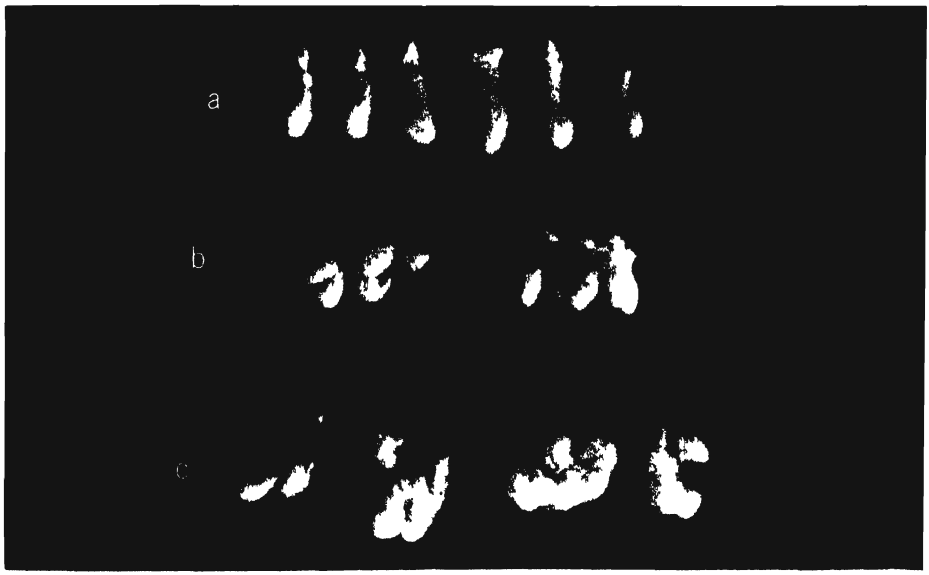



FIG 11

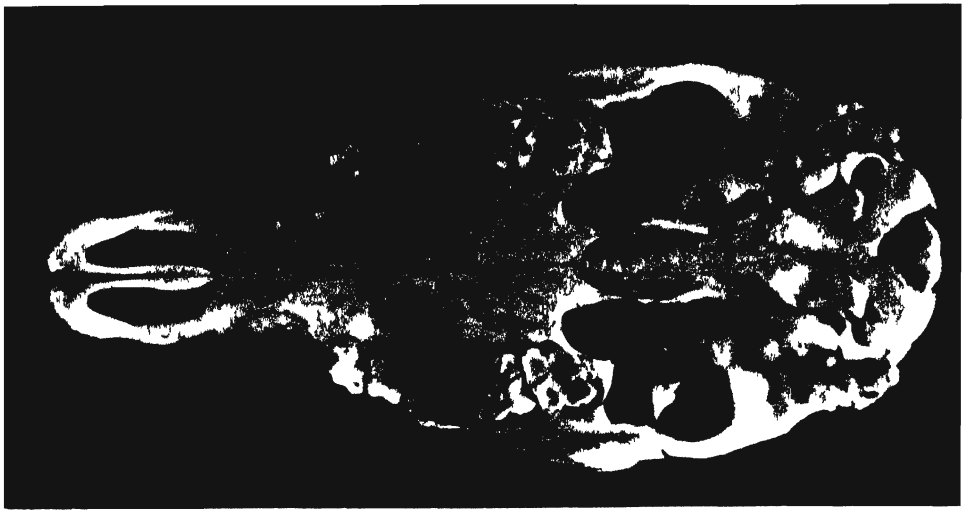


FIG 12

FIG 13

A REPORT ON THE DENTAL PATHOLOGY FOUND IN ANIMALS THAT DIED IN THE NEW YORK ZOOLOGICAL PARK IN 1938

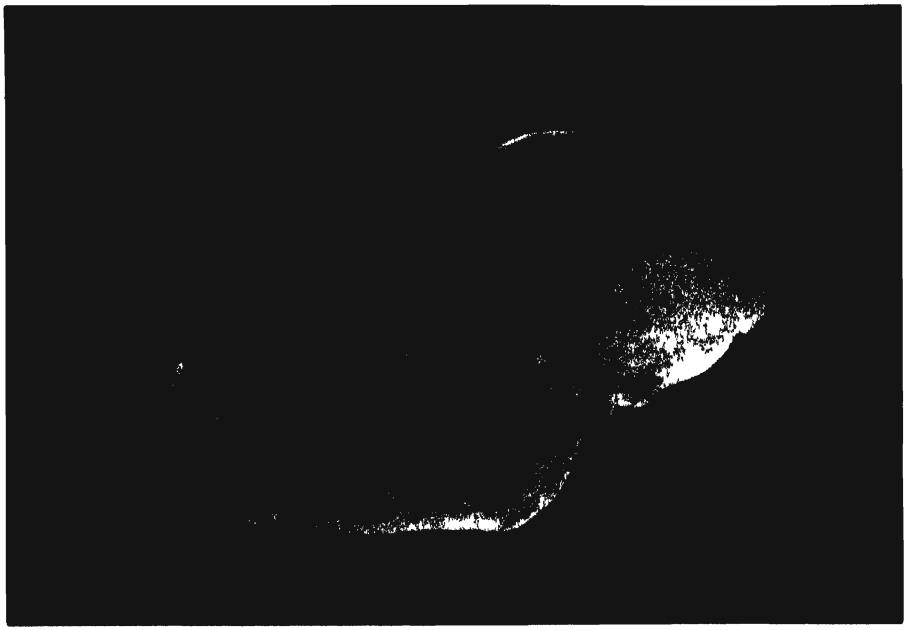


FIG. 14.

FIG 15.

A REPORT ON THE DENTAL PATHOLOGY FOUND IN ANIMALS THAT DIED IN THE NEW YORK ZOOLOGICAL PARK IN 1938.

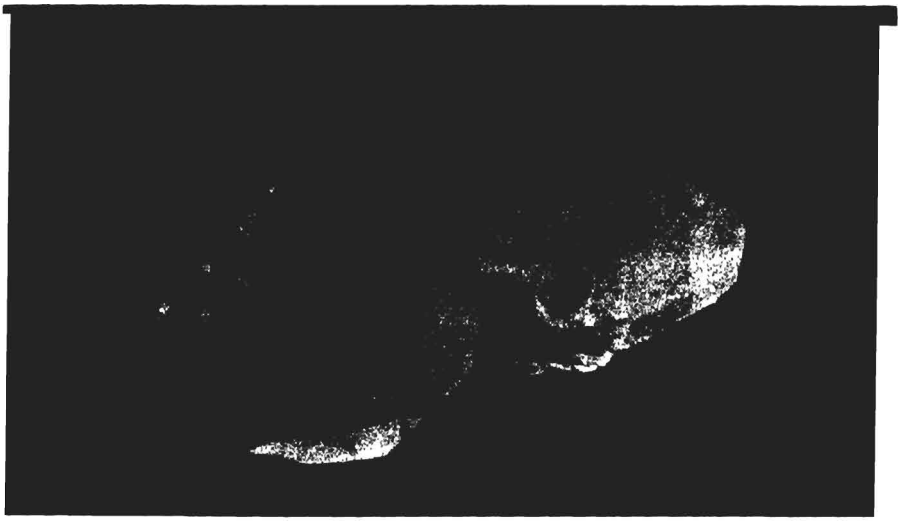


FIG. 16.

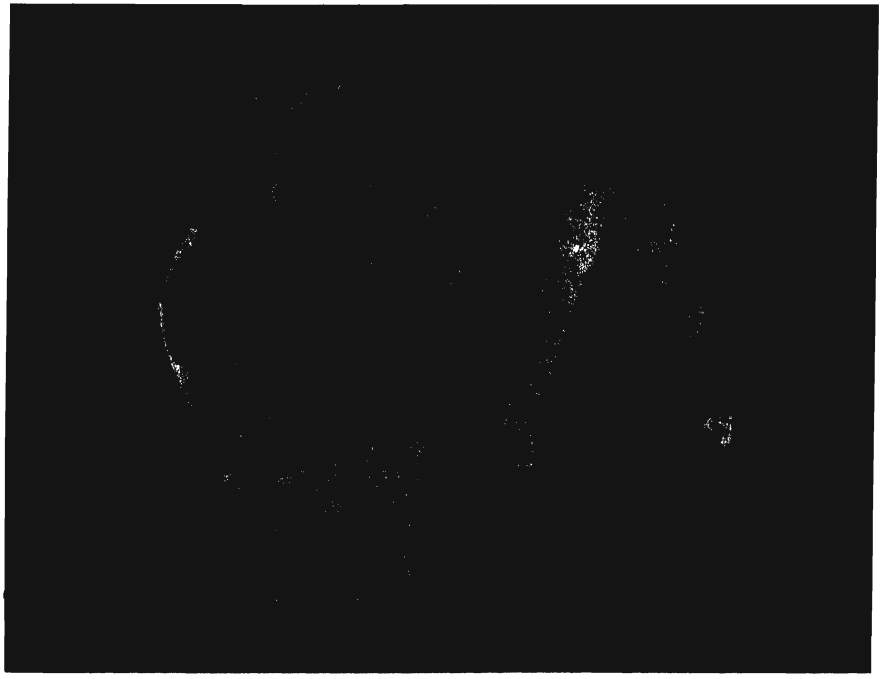
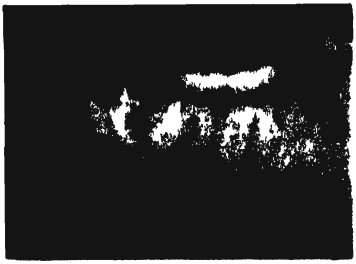


FIG. 17.

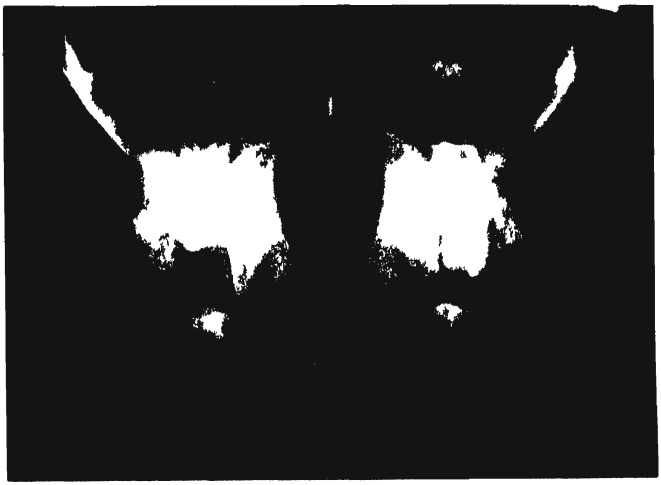
A REPORT ON THE DENTAL PATHOLOGY FOUND IN ANIMALS THAT DIED IN THE NEW YORK ZOOLOGICAL PARK IN 1938.

a



b

c



d

FIG 18

A REPORT ON THE DENTAL PATHOLOGY FOUND IN ANIMALS THAT DIED IN THE NEW YORK ZOOLOGICAL PARK IN 1938

# 15.

## A Parasitological Survey of Wild Rats in the New York Zoological Park.

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*Hospital and Laboratory, New York Zoological Park*

The control of wild rat populations in zoological parks throughout the world apparently is a universal problem. At times large scale poisoning and trapping become necessary to curb this pest which is attracted by the scattered food in the animal pens and the more or less rugged and natural wild surroundings in zoological parks within an otherwise urban community. Several of the keepers at the New York Zoological Park from time to time shoot rats which become a nuisance in the runs of the animals under their care. Many of these rats have been brought to the laboratory for postmortem examination. The author is particularly indebted to Mr. J. Gerben for his cooperation in this survey.

Parasites have been shown by many workers in the past to be very common in rats. Surveys of parasitism in rats killed within the Philadelphia Zoological Garden have been pursued for a number of years. In their annual Report of the Laboratory and Museum of Comparative Pathology for 1926 the question was raised of the importance of rats as transmitters of parasites within the collection. In 1929 Dr. Henry Winsor began to examine rats and mice killed in the Garden and his findings have been tabulated annually since that date. His reports are very general and brief and he records a much lower prevalence of parasites than most other workers have observed. According to his reports one would conclude that intestinal cestodes are rare in the rats in the Philadelphia Zoological Garden. *Capillaria hepatica* was the most common but apparently had never been observed in more than 30% of the rats examined in any one year. No blood parasites are included in Dr. Winsor's reports. More than 300 rats were examined for several of these reports.

In an examination of 2,500 adult *Rattus norvegicus* in Baltimore, Maryland, Luttermoser (1936) reported more than 97% infected with helminths. Andrews & White (1936), in an examination of the same group of 2,500 rats reported by Luttermoser, found 33.3% infected with protozoon parasites. Their investigation included an intensive search for protozoa in the intestine as well as blood smears. They reported 7.4% positive for *Trypanosoma lewisi* but only one rat with *Hepatozoon muris* in a blood smear. Price & Chitwood (1931) examined 100 rats caught in Washington, D. C., and found *H. muris* in 17%.

Rodents in a zoological collection are susceptible to some of these parasites. There is also the chance that other groups of animals may become infected with the rat parasites. *Cysticercus fasciolaris* occurs in the liver of rats as a developmental form of *Taenia taeniaeformis* which reaches maturity in the intestine of cats. Blood parasites of rats may also be transmitted to other animals. *Hepatozoon muris* has been reported from several species of

rodents. While *Trypanosoma lewisi* has been reported only from rats there has been very little investigation to test its host-specificity. A great many species of trypanosomes have been reported from a large variety of rodents; the parasites have the same morphology as *T. lewisi* but have not been as extensively studied. To what extent wild rats in a zoological park may be a menace as a source of parasitic infestation of the animals in the collection is not known. It was with the hope of shedding some light on this question that the present survey was begun. As yet no conclusions can be drawn since this survey can only give us an inkling of a part of one side of the picture. More data must first be obtained from examination of the animals in the collection. It is hoped that this investigation will be continued and extended in the future and perhaps aid in an evaluation of the status of the wild rat as a disseminator of parasites to confined animals in exhibit parks.

## Methods of Examination.

The dead rats were brought to the laboratory and placed in the refrigerator until examination was made of the liver and the intestinal contents. Only parasites which could be seen on gross examination were collected. No smears were made from the intestinal contents and a microscope was not used when the parasites were collected. Thus, small parasites which could not be seen with the unaided eye have been overlooked.

The tapeworms and nematodes collected from the intestine were preserved for species identification. Blood smears were made from all the rats examined, stained with Giemsa's stain and then examined under the oil immersion objective of a compound microscope with a 5× ocular for at least five minutes to each smear. Fleas and mites were observed from time to time and a few of these were collected but the findings were not tabulated. Intensive collections in the past have been made of ectoparasites in connection with epidemiological investigations of typhus fever, plague and other diseases.

## Results.

The occurrence of parasites in the 200 rats (*Rattus norvegicus*) examined in this survey between July 20, 1938, and July 20, 1939, is tabulated in the accompanying table. The bottom column, "total number parasitized," represents the number of rats in which at least one of the parasites occurred. All of the species found, which included two nematodes, three cestodes and two protozoa, have been previously reported from rats in other surveys.

Of the forms found, *Capillaria hepatica* was the most common in both the adults and the young. The intensity of the infection with this parasite varied greatly in the group of rats examined. In most of the younger rats only a very small portion of the liver was involved, but in a few of the adults the characteristic yellowish masses of nematode eggs involved almost the entire area of the liver. In one such heavy case the examination of histological sections revealed a wide-spread regeneration of liver cells in the damaged areas. In the 129 *Capillaria* infections in the adult rats 14% could be termed heavy infections since they involved more than one-half of the liver's surface. None of the livers of the young rats were so extensively implicated.

From one to six cysts were observed in the *Cysticercus*-infected livers but the usual number was only one or two. *Hymenolepis diminuta* was much more frequent in its occurrence in the intestines than was *Hymenolepis nana*. The number of these worms present in each infection was not tabulated. Only one nematode species was seen in the intestine. In one rat 17 specimens of *Heterakis spumosa* were collected. *Trypanosoma lewisi* occurred much more frequently in the blood smears than did *Hepatozoon muris*.

Fifty-nine of the 200 rats examined were considered, on the basis of

TABLE I.

**Incidence of Parasites in Wild Rats, *Rattus norvegicus*.**

| Taxonomic Group | Name of parasite | 59 young rats | | 141 adult rats | | 200 total | |
|---|---|---|---|---|---|---|---|
| | | Positives | Per cent. infected | Positives | Per cent infected | Positives | Per cent. infected |
| Protozoa | *Trypanosoma lewisi* | 9 | 15.2 | 12 | 8.5 | 21 | 10.5 |
| | *Hepatozoon muris* | 0 | 0 | 4 | 2.8 | 4 | 2.0 |
| Nematoda | *Capillaria hepatica* | 18 | 30.5 | 129 | 91.5 | 147 | 73.5 |
| | *Heterakis spumosa* | 0 | 0 | 1 | 0.7 | 1 | 0.5 |
| Cestoda | *Cysticercus fasciolaris* | 5 | 8.4 | 30 | 21.2 | 35 | 17.5 |
| | *Hymenolepis diminuta* | 5 | 8.4 | 28 | 19.8 | 33 | 16.5 |
| | *Hymenolepis nana* | 3 | 5.0 | 6 | 4.2 | 9 | 4.5 |
| Total number parasitized | | 28 | 47.4 | 133 | 94.3 | 161 | 80.5 |

their size, to be young animals. No parasites were found in 52.5% of the young rats, while only 5.6% of the adults were free of the forms observed in this study. The accompanying table shows the variations in the percentage of infection for each of the parasites in both adults and young. For the most part, there was a much higher prevalence of infection in the adults, due possibly to the longer period of susceptibility. The one exception to this was found in the prevalence of trypanosomes. In all other cases the present observations probably represent the complete prevalence of the parasites, while for *Trypanosoma lewisi* (and possibly *Hepatozoon* as well) the findings no doubt must be interpreted as the incidence, or recently infected animals. Animals once infected with *T. lewisi* develop an immunity to reinfection and, after the initial course of infection, trypanosomes may never be observed in a blood smear again. This would explain the higher apparent occurrence in the younger rats.

Careful record of the source of the rats within the park has been kept but as yet the number of rats is too small to show any significant variations of parasite infection in the rats from different areas. There is possibly a seasonal variation in the incidence of trypanosomes since most of the infections with this parasite were in the late summer months. However, this may be only apparent variation and could be more correctly explained by the fact that most of the younger rats were examined during this period Andrews & White (1936) report the same seasonal and age variation with *T. lewisi* as found in the present survey. In regard to this finding they make the following statement: "This may be due directly to seasonal differences in transmission potential, indirectly to the inclusion of more young and susceptible rats as 'adults' in those seasons following the reproductive peak, or to both of these factors."

## SUMMARY.

1. The occurrence of parasites in 200 rats (*Rattus norvegicus*) killed in the New York Zoological Park is tabulated.

2. *Capillaria hepatica* was the most frequently observed and occurred in 91.5% of the adults. The other parasites collected included *Trypanosoma lewisi, Hepatozoon muris, Heterakis spumosa, Cysticercus fasciolaris, Hymenolepis diminuta* and *Hymenolepis nana*.

3. Parasites were seen in adults much more frequently than in young rats. No parasites were found in 52.5% of the young rats, while only 5.6% of the adults were free from infection. There was a seasonal variation in the occurrence of *T. lewisi* and these parasites were more prevalent in the younger rats. No significant variation in the prevalence of parasites was recognized in rats from different areas within the park because of the small number examined thus far.

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# 16.

## Serologic Relationships among Bovidae and Cervidae.

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### INTRODUCTION.

A difficulty which confronts the serologist in studies of animal relationships is lack of blood specimens of the uncommon animals. Most mammalian serological studies have been made on the bloods of the smaller animals and common domesticated forms. The author has been fortunate in securing the sera of some uncommon animals among which were several species of the order Artiodactyla. These bloods were obtained through the efforts and kindness of Dr. C. R. Schroeder of the New York Zoological Park. The present report emphasizes the relationships among eleven species belonging to the families Bovidae and Cervidae and includes data of cross reactions with other Artiodactyla and two Perissodactyla.

Ehrhardt (1929) gave a complete review of the research done to 1927 on the serological relationships of animals by means of the serum precipitin test. The first report on Artiodactyla blood was that of Myers (1900) who described reactions of antisera produced by injections of the globulin fraction of ox and sheep bloods. Uhlenhuth (1901) injected rabbits intraperitoneally with defibrinated ox blood and reacted the antiserum with the blood of fifteen different species of mammals. Nuttall & Dinkelspiel (1901) noted that anti-ox serum gave weaker reactions with the blood of sheep than with ox. Nuttall (1904) in his monograph "Blood Immunity and Blood Relationships," described many qualitative and quantitative tests, the latter being done in cooperation with Strangeway. These tests included bloods from many species of Bovidae and Cervidae. A number of other workers since Nuttall's report have used the bloods of the more common domesticated Bovidae but very little data has been accumulated with the blood of Cervidae. A general conclusion that could be arrived at from all the work done is that the Bovidae and Cervidae show a close serological affinity to each other though the animals of these two families often could be distinguished from each other. Moreover, at times, within the family Bovidae, the ox could be distinguished from the sheep or goat. The results have not been sufficiently consistent and these discrepancies have prevented the serological method from being considered as useful as morphological or other criteria in taxonomic and phylogenetic studies.

Factors that modify the serum precipitin reaction in regard to relationship studies and methods which yield more consistent results were not formulated until recent years. Boyden (1926) stressed the importance of controlling physical and chemical factors in the *in vitro* tests. He devised the principle of "reciprocal relationships." Wolfe (1933) further elaborated on this and showed that greater specificity (1935, 1936) could be secured by regulating the amount of antigen injected into the antibody producer, namely, the rabbit. Wolfe (1939) found that injecting minimum quantities of antigen necessary for antibody production would yield, with a fair consistency,

antisera that could be used in distinguishing very closely related forms. It was emphasized in this report that there was a necessity for uniformity and standardization of the known factors by serological workers. It was also shown that discrepancies of relationship values within his own data and probably the data of other workers was often not due to the technique but due to the variance in antibody productivity of the rabbit. Thus it was necessary to secure as many antisera as possible to insure reliable results.

## Methods and Materials.

Nineteen healthy adult rabbits were injected with the blood serum of eight different species of animals of the order Artiodactyla. Fifteen of the animals were given a series of 3 injections with a standardized antigen solution containing 2 mg. protein per cubic centimeter. The injections were made on alternate days and were given in increasing dosages. The total quantity injected varied from 0.75 to 1.5 mg. per kilo body weight. If this did not result in antisera of sufficient potency the rabbits were given 2 additional injections with a quantity equal to one-half the amount given in the first series. It was necessary to give one of the rabbits a third series of injections in order to secure a high titered antiserum. Several rabbits failed to produce

Table 1.
Antiserum production data.

| *Rabbit No.* | *Antigen injected* | *Series of injections* | *Amount injected mg. per kilo body weight* | *Bled — days after last injection* | *Titer* |
|---|---|---|---|---|---|
| A2 | Sheep | 1 | 1. cc. undiluted | | not used |
| | | 1* | .5 | 8 | 512,000 |
| 71 | | 1 | 1.5 | 10 | not good |
| | | | .75 | 9 | 512,000 |
| 41 | Tahr | 1 | 1.5 | 10 | 512,000 |
| 42 | | 1 | 1.5 | 10 | 256,000 |
| 50 | Goat | 1 | 25. | 9 | 512,000 |
| 51 | | 1 | 25. | 9 | 256,000 |
| 45 | Black buck | 1 | .75 | 10 | 512,000 |
| 49 | antelope | 1 | .75 | 14 | 256,000 |
| 72 | | 1 | 1.5 | 11 | 256,000 |
| 73 | | 1 | 1.5 | 11 | 256,000 |
| 55 | Eland | 1 | 1.5 | 10 | 512,000 |
| 64 | | 1 | 1.5 | 9 | 384,000 |
| A12 | Axis deer | 1 | 1.5 | 9 | 512,000 |
| 61 | | 1 | 1.5 | 9 | 512,000 |
| 35 | | 1 | 1 | 10 | not good |
| | | 1 | .5 | 10 | not good |
| | | 1 | .5 | 9 | 1,024,000 |
| 46 | Elk | 1 | 1.5 | 10 | 1,024,000 |
| 48 | | 1 | 1.5 | 10 | 1,024,000 |
| 57 | | 1 | 1.5 | 10 | not good |
| | | 1 | .75 | 10 | 256,000 |
| 62 | Virginia deer | 1 | 25. | 10 | 512,000 |

* 2 injections given 10 months after 1st series.

antisera of the desired titer (1:128,000 after 1 hour of incubation). Four rabbits were injected with larger quantities of antigen. These animals (except A2) were to be reinjected for another type of experiment but the quantity injected in the first series was small enough to give a fairly specific antiserum (Wolfe, 1935). Table 1 records the antiserum production data.

The test antigens used for relationship studies were the blood sera of 15 species of Artiodactyla and Perissodactyla and these are listed in Table 2. Since the amount of antisera and antigens on hand was not always sufficient, each antiserum was not tested with each antigen. Moreover, some of the antigens were received after the *in vitro* tests were made. One-half cubic centimeter of a standard antigen solution containing 2 mg. (1:500 dilution) of protein (based on total nitrogen) was serially diluted in serological test tubes. Layered beneath the antigen was 0.1 cc. of the antiserum which was used either undiluted or diluted. The degree of dilution for the different antisera was not constant but the dilution listed in the relationship tables was that one which gave the greatest differentiation of the heterologous reactions without affecting the clearness of the end point. At times slightly higher dilutions than those recorded so altered both the homologous and heterologous titers that the readings and results were not trustworthy.

The tests were made in duplicate and were incubated in a water bath at a temperature of 37.5° C. ± 1° C. Readings were taken at 1, 5, 10, 20, 30 and 60 minutes. The titer of the reaction was the highest dilution of the antigen at each interval of time that gave a "ring" at the region of contact of antigen and antiserum. In relationship studies the cross-reactions were calculated in per cent. of the homologous titer. When the homologous titers were 1:64,000 or less the results are unsatisfactory for then low heterologous titers resulted in high percentage values. The error in reading the end point was plus or minus one tube or a possible error of 100%, which is not great for such a sensitive reaction.

The degree of relationship among the animals could be determined at times by the 60 minute readings with undiluted sera. It was often necessary to use either the time factor (readings at intervals up to an hour) or various

TABLE 2.
Source of test antigens.

| *Family* | *Scientific name* | *Common name* | *Source of material* |
|---|---|---|---|
| Bovidae | *Bos taurus* | Ox | Local Packing Co |
| | *Bison bison* | American buffalo | Yellowstone Park |
| | *Taurotragus oryx* | Eland | N. Y. Zoo. |
| | *Antilope cervicapra* | Black buck antelope | N. Y. Zoo |
| | *Hippotragus niger* | Sable antelope | N. Y. Zoo |
| | *Ovis aries* | Domestic sheep | Local Packing Co |
| | *Capra hircus* | Domestic goat | University Farm |
| | *Hemitragus jemlahicus* | Tahr | N. Y. Zoo |
| Cervidae | *Axis axis* | Axis deer | N. Y. Zoo |
| | *Cervus canadensis* | American elk | N. Y. Zoo |
| | *Odocoileus virginianus* | Virginia deer | Madison Zoo |
| Suidae | *Sus scrofa* | Domestic pig | Local Packing Co |
| Hippopotamidae | *Choeropsis liberiensis* | Pigmy hippopotamus | N. Y. Zoo |
| Camelidae | *Llama huanacos* | Llama | Madison Zoo |
| Equidae | *Equus caballus* | Horse | University Farm |
| | *Equus caballus (mulus)* | Mule | Fur Farm |

dilutions of antiserum or both factors in order to differentiate the bloods. Control of these factors, it is known, increases the specificity of the reaction (Nuttall, 1904, p. 142; Wolfe, 1939).

## Experimental Data.

Table 3 records the reactions of 2 anti-tahr sera. Serum No. 41 was less specific than No. 42. Two series of tests were made with the former. In one

**Table 3.**

**Reactions (titers*) of 2 anti-tahr sera.**

| *Antigen* | *Serum No. 41* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *5 min.* | | *10 min.* | | *20 min.* | | *30 min.* | | *60 min.* | |
| | *Antiserum dilution* | | | | | | | | | |
| | *1:1* | *1:3* | *1:1* | *1:3* | *1:1* | *1:3* | *1:1* | *1:3* | *1:1* | *1:3* |
| Tahr | 32 | 12 | 54 | 64 | 128 | 128 | 256 | 128 | 512 | 256 |
| Goat | 8 | 2 | 32 | 2 | 128 | 64 | 256 | 64 | 256 | 128 |
| Sheep | 16 | 1 | 64 | 3 | 128 | 64 | 256 | 128 | 256 | 128 |
| Sable Antelope | 4 | 4 | 16 | 16 | 64 | 16 | 128 | 16 | 128 | 48 |
| Black Buck Antelope | 2 | 0 | 6 | 2 | 16 | 8 | 128 | 16 | 256 | 16 |
| Ox | 1 | 1 | 8 | 4 | 8 | 8 | 96 | 16 | 256 | 16 |
| Buffalo | 3 | 1 | 6 | 4 | 6 | 8 | 64 | 8 | 256 | 8 |
| Eland | 2 | 0 | 4 | 0 | 6 | 2 | 64 | 4 | 128 | 4 |
| Virginia Deer | 1 | 0 | 1.5 | 0 | 1.5 | 0 | 1.5 | 0 | 3 | 0 |
| Axis Deer | 1.5 | | 3 | | 4 | | 6 | | 6 | |
| Elk | 3 | 0 | 8 | 0 | 8 | 0 | 12 | 0 | 12 | 2 |
| Pigmy Hippopotamus | 0 | | 0 | | 0 | | 0 | | 0 | |
| Pig | 0 | | 0 | | 0 | | 0 | | 0 | |
| Horse | 0 | | 0 | | 0 | | 0 | | 0 | |

*Serum No. 42*
*Antiserum dilution = 1:0.5*

| | | | | | |
|---|---|---|---|---|---|
| Tahr | 8 | 32 | 128 | 128 | 256 |
| Goat | 0 | 0 | 4 | 16 | 64 |
| Sheep | 0 | 0 | 4 | 16 | 96 |
| All other tests were negative | | | | | |

* All titers are in thousands.

series the antiserum was diluted with an equal volume of saline (1:1 dilution) and in the other series it was diluted with three volumes of saline (1:3 dilution). The higher dilution resulted in much weaker reactions at the 5 and 10 minute readings for all the heterologous antigens. With this same dilution the titers at 20, 30 and 60 minutes remained weak for the heterologous tests, with the exception of the sheep, goat and sable antelope. Thus the titers of the tahr, sheep and goat antigens were relatively of the same order at the 5 or 10 minute reading when the antiserum was of a 1:1 dilution but

TABLE 4.

Relationship values (in per cent.) of 2 anti-tahr sera.

| *Antigen* | *Serum No. 41* | | | | | |
|---|---|---|---|---|---|---|
| | *10 min.* | | *30 min.* | | *60 min.* | |
| | | | *Antiserum dilution* | | | |
| | 1:1 | 1:3 | 1:1 | 1:3 | 1:1 | 1:3 |
| Tahr | 100. | 100. | 100. | 100. | 100. | 100. |
| Sheep | 50. | 3.12 | 100. | 50. | 50. | 50. |
| Goat | 100. | 4.68 | 100. | 100. | 50. | 50. |
| Sable Antelope | 25. | 6.25 | 50. | 12.5 | 25. | 18.75 |
| Black Buck Antelope | 9.37 | 3.12 | 50. | 12.5 | 50. | 6.25 |
| Ox | 12.5 | 6.25 | 37.5 | 12.5 | 50. | 6.25 |
| Buffalo | 9.37 | 6.25 | 25. | 6.25 | 50 | 3.12 |
| Eland | 6.25 | 0 | 25. | 3.12 | 25. | 1.56 |
| Elk | 12.5 | 0 | 2.34 | 0 | 2.34 | .39 |
| Axis Deer | 4.67 | —— | 3.12 | —— | 1.17 | —— |
| Virginia Deer | 2.34 | 0 | .58 | 0 | .58 | 0 |
| Pigmy Hippopotamus | 0 | | 0 | | 0 | |
| Pig | 0 | | 0 | | 0 | |
| Horse | 0 | | 0 | | 0 | |
| Llama | 0 | | 0 | | 0 | |

*Serum No. 42*
*Antiserum dilution = 1:0.5*

| | | | |
|---|---|---|---|
| Tahr | 100. | 100. | 100. |
| Sheep | 0 | 12.5 | 25. |
| Goat | 0 | 12.5 | 37.5 |
| All other tests were negative. | | | |

with the higher dilution the latter two were easily distinguished from the tahr blood. The reactions of all the other Bovidae were high at the 30 and 60 minute intervals when the more concentrated antiserum was used, but upon a higher dilution the reactions of all, with the exception of the sable antelope, decreased considerably. The reactions with the Cervidae blood were generally much weaker than those of the Bovidae at both dilutions and at all time intervals.

Serum No. 42 was exceedingly specific. It gave reactions only with the sheep and goat, these reactions being weak except at the 60 minute reading.

Table 4 shows the degree of relationships of the 2 anti-tahr sera based on the data of Table 3. The values for 10, 30 and 60 minutes were picked arbitrarily for they illustrate best the effect of both the dilution and the time factors. Serum No. 41 shows that tahr, sheep and goat are very closely related. This follows their accepted classification for they are members of the same subfamily Caprinae. The data also indicate that the sable antelope is more closely related to the tahr than are the other members of the Bovidae

TABLE 5.

**Relationship values** (in per cent.) of 2 anti-sheep and 2 anti-goat sera.

| *Antigen* | *Anti-sheep A2 diluted 1:4 Anti-sheep 71 undiluted* | | | *Anti-goat 50 diluted 1:0.5 Anti-goat 51 diluted 1:0.5* | | |
|---|---|---|---|---|---|---|
| | | *30 min.* | *60 min.* | | *30 min.* | *60 min.* |
| Sheep | A2* | 100. (256) | 100. (512) | 50 | 100 | 100. |
| | 71* | 100. (256) | 100. (512) | 51 | 100. | 100. |
| Goat | A2 | 100. | 50. | 50* | 100. (256) | 100. (512) |
| | 71 | 12.5 | 25. | 51* | 100. (128) | 100. (256) |
| Tahr | A2 | 100. | 100. | 50 | 100. | 100. |
| | 71 | 12.5 | 25. | 51 | 100 | 100. |
| Sable Antelope | A2 | 50. | 25. | 50 | 50. | 25. |
| | 71 | 6.25 | 25. | 51 | 100. | 50. |
| Black Buck Antelope | A2 | 25. | 25. | 50 | 12.5 | 12.5 |
| | 71 | 1.56 | 1.56 | 51 | 12.5 | 12.5 |
| Ox | A2 | 12.5 | 37.5 | 50 | 6.25 | 6.25 |
| | 71 | 1.56 | 1.56 | 51 | 12.5 | 18.75 |
| Buffalo | A2 | 18.75 | 50. | 50 | 6.25 | 12.5 |
| | 71 | 1.56 | 1.56 | 51 | 12.5 | 25. |
| Eland | A2 | —— | —— | 50 | 3.12 | 6.25 |
| | 71 | 3.12 | 3.12 | 51 | 4.68 | 6.25 |
| Elk | A2 | —— | —— | 50 | 3.12 | 6.25 |
| | 71 | .78 | .78 | 51 | 3.12 | 6.25 |
| Axis Deer | A2 | 6.25 | 12.5 | 50 | 3.12 | 6.25 |
| | 71 | 1.56 | .78 | 51 | 6.25 | 3.12 |
| Virginia Deer | A2 | 6.25 | 25. | 50 | 6.25 | 6.25 |
| | 71 | 1.19 | .58 | 51 | 2.34 | 6.25 |

* The number in parenthesis is the titer in thousands. Heterologous titers may be calculated from the per cent. of relationship.

with the exception of the goat and sheep. The bloods of the Cervidae showed a definite but a more distant affinity to the tahr. The negative results with pig, pigmy hippopotamus and horse do not indicate a lack of relationship but emphasize that specific antisera can be produced that will give only "group" or "subgroup" reactions (Wolfe, 1935, 1936).

The relationship values with serum No. 42 were limited to the most closely related forms because of the great specificity of the serum. The closeness of the goat and sheep to the tahr, demonstrated by serum No. 41, was verified by the reactions of this second serum.

The reactions of two anti-sheep and two anti-goat sera are recorded to-

TABLE 6.

Relationship values (in per cent.) of 2 anti-eland sera.

| Antigen | | *No 55 diluted 1 0 75, No 64 diluted 1 3* | | | | | |
|---|---|---|---|---|---|---|---|
| | | *1 min* | *5 min* | *10 min* | *20 min* | *30 min* | *60 min* |
| Eland | 55* | 0 (0) | 100 (32) | 100 (128) | 100 (256) | 100 (512) | 100 (512) |
| | 64* | 100 (12) | 100 (128) | 100 (128) | 100 (192) | 100 (384) | 100 (384) |
| Ox | 55 | 0 | 3 12 | 3 12 | 1 56 | 12 5 | 25 |
| | 64 | 0 | 25 | 50 | 75 | 37 5 | 75 |
| Buffalo | 55 | 0 | 3 12 | 1 56 | 1 56 | 12 5 | 50 |
| | 64 | 0 | 50 | 100 | 100 | 75 | 75 |
| Black Buck Antelope | 55 | 0 | 0 | 78 | 58 | 78 | 2 34 |
| | 64 | 0 | 0 | 25 | 75 | 37 5 | 75 |
| Sable Antelope | 55 | 0 | 0 | 0 | 1 56 | 1 56 | 3 12 |
| | 64 | no tests | made | | | | |
| Sheep | 55 | 0 | 0 | 0 | 39 | 39 | 78 |
| | 64 | 0 | 0 | 0 | 18 75 | 37 5 | 37 5 |
| Goat | 55 | 0 | 0 | 0 | 39 | 39 | 39 |
| | 64 | 0 | 0 | 0 | 37 5 | 37 5 | 75 |
| Tahr | 55 | 0 | 0 | 78 | 58 | 39 | 58 |
| | 64 | 0 | 0 | 0 | 18 75 | 18 75 | 37 5 |
| Elk | 55 | 0 | 0 | 0 | 39 | 39 | 78 |
| | 64 | 0 | 0 | 25 | 75 | 75 | 75 |
| Axis Deer | 55 | 0 | 0 | 78 | 78 | 39 | 39 |
| | 64 | 0 | 0 | 25 | 37 5 | 37 5 | 75 |
| Virginia Deer | 55 | 0 | 0 | 78 | 78 | 39 | 78 |
| | 64 | 0 | 0 | 25 | 37 5 | 37 5 | 37 5 |
| Mule | 55 | all tests | negative | | | | |
| | 64 | no tests | made | | | | |
| Pigmy Hippopotamus | 55 | all tests | negative | | | | |
| | 64 | no tests | made | | | | |
| Pig | 55 | all tests | negative | | | | |
| | 64 | no tests | made | | | | |

* The number in parenthesis is the titer in thousands. Heterologous titers may be calculated from the per cent of relationship

gether in Table 5. Serological tests have shown that the bloods of these two animals are very closely related and usually indistinguishable by the precipitin method. Wolfe (1933) emphasized that when the bloods of two or more animals are very closely related their heterologous reactions should be similar. The data further verify this principle. The antisera of the two different species gave reactions that indicated the very close affinity of the tahr to them and also showed that the sable antelope, though not as closely related to the goat and sheep as is the tahr, has a closer affinity to them than do the other Bovidae or the Cervidae. The anti-sheep sera brought out this fact more clearly than did the anti-goat sera; this may be due to the fact that the former antisera were produced by the injection of a smaller quantity of antigen, which often results in more specific antisera. The anti-sheep sera also gave definite Bovidae-group reactions but the less specific anti-goat sera did not.

Two anti-eland sera (55 and 64) of different specificity were produced by injections of minute quantities of antigen. The relationship values of these two antisera are recorded in Table 6 and they indicate that the ox and buffalo are more closely related to the eland than are some other members of the Bovidae. Serum 55 was the more specific antiserum and its reactions at the intervals of time at which the titers were read were greater with the ox and buffalo antigens than they were with other Bovidae or with the Cervidae. On the other hand, serum 64 showed a closer kinship of the ox and buffalo to the eland only at the 5, 10 and 20 minute titers while the 30 and 60 minute readings were not significantly different from those of other Bovidae or the Cervidae.

Serum 55 gave weak reactions but of similar magnitude with the three species of Cervidae and the Bovidae except the ox and buffalo. On the other

TABLE 7.

Relationship values (in per cent.) of anti-black buck antelope antisera*.

| *Antigen* | *No. 45 Diluted 1:0.5* | *No. 49 Undiluted* | *No. 72 Undiluted* | *No. 73 Undiluted* |
|---|---|---|---|---|
| Black Buck Antelope | 100.(516)† | 100.(256) | 100.(256) | 100.(256) |
| Sable Antelope | 6.25 | 0 | 12.5 | 6.25 |
| Sheep | 6.25 | 0 | 12.5 | 3.12 |
| Goat | 3.12 | 0 | 12.5 | 1.56 |
| Tahr | 3.12 | 0 | 6.25 | 1.56 |
| Ox | 3.12 | 0 | 3.12 | 3.12 |
| Buffalo | .78 | 0 | 3.12 | 1.56 |
| Eland | 1.56 | 0 | 3.12 | .78 |
| Elk | .78 | 0 | .78 | .78 |
| Axis Deer | .39 | 0 | 1.56 | .78 |
| Virginia Deer | .78 | 0 | .39 | .39 |

† The number in parenthesis is the titer in thousands. Heterologous titers may be calculated from the per cent. of relationship.

* All are 60 minute values.

hand, with serum 64 the Cervidae reactions were very definite at 10 minutes, but the sheep, goat, tahr and black buck antelope reactions were not noticed until the 20 minute period. This difference in reaction was evident when one volume of the antiserum was diluted with three volumes of buffered saline but not if it were used undiluted or diluted with one volume of saline. These results may indicate that the bloods of the Cervidae used are more closely related to the eland than certain members of the family to which the eland belongs according to its present classification. Since only one of 2 antisera gave these results it is, of course, necessary to secure additional data.

TABLE 8.

Relationship values (in per cent.) of 3 species of Cervidae.

| *Antiserum* | *Antiserum No.* | *Antiserum dilution* | *Time of reading (min.)* | *Axis Deer* | *Elk* | *Virginia Deer* |
|---|---|---|---|---|---|---|
| Axis Deer | A12 | 1:1 | 5 | 100. (16) | 100. | 0 |
| | | | 10 | 100. (64) | 75. | 50. |
| | | | 20 | 100. (192) | 100. | 75. |
| | | | 30 | 100. (256) | 100. | 75. |
| | | | 60 | 100. (512) | 75. | 75. |
| | | 1:4 | 20 | 100. (8) | 50. | 50. |
| | | | 30 | 100. (128) | 100. | 3.12 |
| | | | 60 | 100. (128) | 100. | 100. |
| | 35 | 1:2 | 5 | 100. (2) | 25. | 0 |
| | | | 10 | 100. (128) | 50. | 1.56 |
| | | | 20 | 100. (384) | 75. | 37.5 |
| | | | 30 | 100. (1024) | 25. | 12.5 |
| | | | 60 | 100. (1024) | 25. | 12.5 |
| | 61 | 1:3 | 5 | 100. (64) | 100. | 50. |
| | | | 60 | 100. (512) | 100. | 25. |
| Elk | 46 | 1:3 | 5 | 100. | 100. (256) | 25. |
| | | | 60 | 50. | 100. (1024) | 25. |
| | 48 | 1:3 | 5 | 50. | 100. (128) | 25. |
| | | | 60 | 100. | 100. (1024) | 25. |
| | | 1:5 | 5 | (1) | (2) | (0) |
| | | | 60 | 50. | 100. (128) | 3.12 |
| | 57 | 1:0.5 | 5 | 37.5 | 100. (128) | 3.12 |
| | | | 10 | 50. | 100. (256) | 25. |
| | | | 60 | 100. | 100. (256) | 75. |
| | | 1:2 | 60 | 50. | 100. (128) | 12.5 |
| Virginia Deer | 62 | 1:1 | 5 | 50. | 50. | 100. (128) |
| | | | 60 | 75. | 75. | 100. (512) |
| | | 1:3 | 10 | 0 | 0 | 100. (64) |
| | | | 20 | 50 | 50. | 100. (128) |
| | | | 60 | 50. | 50. | 100. (256) |
| | | 1:4 | 10 | 0 | 0 | 100. (16) |
| | | | 20 | 0 | 0 | 100. (64) |
| | | | 60 | 50. | 50. | 100. (256) |

* The number in parenthesis is the titer in thousands.

Four antisera were produced by injections of minimum quantities of black buck antelope serum; these were all very specific. The cross reactions with Bovidae and Cervidae were much weaker than the homologous tests. Antiserum 49, though showing a high homologous titer, failed to give reactions with any of the heterologous antigens. Further results indicate that the sable antelope, sheep, goat, and tahr were more closely related to the black buck antelope than were the other Bovidae or Cervidae. Beddard (1920) states, "It is exceedingly difficult to separate antelopes from the sheep, oxen and goats. Their inclusion along with these creatures in one family, Bovidae, shows that no differences of an important character exist. . . . It is perhaps with the goats that the antelopes have their nearest affinities." The correlation of present serological findings with the statements of Beddard based on morphological data is highly significant.

The reactions of black buck antelope with the ox, buffalo and eland, though slightly greater, were not significantly higher than those with the Cervidae. It is possible that the less specific antisera might have demonstrated the relationships better than the antisera that were used. The high degree of specificity of the reactions has somewhat obscured the kinship involved and attempts should be made to further verify the present findings by the use of slightly less specific antisera.

The Cervidae antisera reactions furnished the interesting results shown in Table 8. The only reactions listed are the homologous ones and the cross reactions with the bloods of the other two deer, although tests were also made with eight species of Bovidae. The three axis deer and three elk antisera yielded reactions that usually failed to distinguish these two species. The greater number of relationship values for the cross tests with the elk or axis deer were 50 to 100 per cent., only a few being 25 and 37.5 per cent., which is just outside the limits of error of the tests. On the other hand, the titers of certain of the antisera of these two species with the Virginia deer serum were often so much lower than the homologous titers that the latter could easily be distinguished from either the axis or elk. This fact is especially well shown with the anti-axis deer serum A12 diluted 1:4, anti-axis deer serum 35 diluted 1:2, anti-elk serum 57 diluted 1:5 and anti-elk serum 48 diluted 1:2.

Only one anti-Virginia deer serum was produced. This serum when diluted with 3 volumes of saline could differentiate the Virginia deer serum from that of either the elk or axis deer at the 10 minute reading. A 1:4 dilution of the antiserum retarded the positive reaction with the two heterologous bloods to the 60 minute reading, while with the homologous antigen the reactions were positive though of low titer at 10 and 20 minutes.

These results, which show an exceedingly close similarity of the blood of elk to that of the axis deer and a distinction of both of these from the Virginia deer, are very significant, for they can be correlated with the origin of these animals. According to Scott (1937, p. 322), the American elk (also called wapiti) and the Virginia deer are North American forms that have had a different origin. Scott states that, ". . . North American deer form two strongly contrasted groups, the northern and southern. In the northern group the deer are like those of the Old World—these include the Wapiti." The southern group, which includes the Virginia deer, seems to have had a different ancestry and, according to Scott, probably originated from a "long line of American ancestry."

The per cent. values of the anti-deer reaction with the Bovidae were usually much lower than that with the homologous blood. In a small number of tests the titers were high enough so that a distinction was not possible, but most often the percentage of reaction was 12.5 per cent. or lower. The indications were that the ox and buffalo were more closely related to the deer group than were the other Bovidae.

## DISCUSSION.

The precipitin test, a serological method, was used by the author to determine the relationships among eight Bovidae and three Cervidae. The value of the serological method in taxonomic studies is controversial. Zuckerman & Sudermann (1935) believe "the serum precipitin test is of limited value in tracing phylogenetic relationship." Boyden, on the other hand, in his publications states that he considers the method an important and reliable tool for phylogenetic studies.

The data presented here offered evidence in support of the idea that the precipitin test can, at times, be of use in the corroboration of morphological facts. Secondly, it seems that it may be a better method for determination of the degree of interrelationships among animals in the smaller taxonomic group, such as an order or family. Especially is this true when certain factors, such as protein concentration of the antigen solutions, are determined and the specificity of the antisera is controlled by injection methods and *in vitro* factors.

Of the eight species of Bovidae whose bloods were tested it was shown that the sheep, goat and tahr were very closely related. Their classification into the subfamily Caprinae would be justified by the serological reactions. The bloods of three antelopes, the eland, black buck and sable (each of which is placed in a separate subfamily) did not give similar reactions with sheep, goat or tahr antisera, the sable antelope reactions being definitely higher, indicating its closer kinship to the sheep, goat and tahr. The degree of this relationship was less than that of the sheep, goat and tahr to each other.

The reactions of the anti-eland sera made possible a distinction of the eland blood from that of all other Bovidae and of the Cervidae. Its relationship values were by far the highest with the ox and buffalo bloods, indicating a closer affinity of the eland to these two animals than to the other animals studied. Beddard states (1920, p. 308), "Such an antelope, however, as the eland, is very ox-like in habit." This similarity is, of course, based on a very superficial characteristic, and the addition of the similar serologic qualities of the animals is important. There was some indication that the eland may be more closely related serologically to the three Cervidae than to the Bovidae, with the exception of the ox and buffalo. This would be contrary to their present taxonomic position.

Several antisera were produced against ox and buffalo blood sera. The results were conflicting, however, and it was believed advisable to postpone a report of the data until further research could ascertain the cause of the discrepancies. The ox and buffalo antisera reactions always showed the very close affinity of the ox to the buffalo, and the value of the cross reaction was almost always 50 to 100 per cent. On the other hand, the titers with the eland, other Bovidae, and the Cervidae were dissimilar and inconsistent. In most instances the eland and Cervidae showed a closer relationship to the ox and buffalo than did the other Bovidae; less often the opposite results were secured.

The antisera produced against the black buck antelope resulted in reactions that easily distinguished it from the other bloods tested. The degree of the heterologous tests suggests that this animal was sufficiently different from the other Bovidae tested to warrant its being classified as a definitive group within the family Bovidae.

The results of the reactions of the anti-Cervidae sera were elaborated upon in the presentation of the data. It was conclusively shown that the American elk and axis deer, an old world deer, were very closely related to each other. The degree of this relationship was of the same order that was found among sheep, goat and tahr, or between ox and buffalo.

In conclusion a brief serologic classification, based upon the values of the Bovidae and Cervidae antisera reactions, is presented. The homologous

serum is considered to belong to Group I and it may be subdivided into subgroups A and B. This group includes, in addition to the homologous blood, those heterologous bloods that consistently gave the highest cross values. The bloods which were usually indistinguishable with the less specific antisera would belong in subgroup A (refer to cross reactions of serum 41 with sheep, goat and tahr). Group II would contain the species whose reactions are consistently lower than those of Group I, and Group III would include the lowest titered reactions. Table 9 presents the provisional serologic classification of the eight Bovidae and three Cervidae.

TABLE 9.

A provisional serologic classification of eight Bovidae and three Cervidae.

*Classification based on antisera against sheep, goat and tahr bloods*:

Group I
- Subgroup A. Sheep, goat, tahr.
- Subgroup B. Sable antelope.

Group II—Other Bovidae tested.

Group III—Cervidae.

*Classification based on anti-eland sera*:

Group I
- Subgroup A—Eland.
- Subgroup B—Ox and buffalo.

Group II—Other Bovidae tested and Cervidae.

*Classification based on anti-black buck antelope sera*:

Group I—Black buck antelope.

Group II—Sheep, goat, tahr, sable antelope.

Group III—Other Bovidae tested and Cervidae.

*Classification based on anti-ox and anti-buffalo sera*:

Group I—Ox and buffalo.
Others doubtful.

*Classification based on anti-deer sera*:

Group I
- Subgroup A—Axis deer and elk.
- Subgroup B—Virginia deer.

Group II—Ox and buffalo.

Group III—Other Bovidae tested.

## SUMMARY.

1. Nineteen antisera against five species of Bovidae and three species of Cervidae were produced in rabbits.

2. The antigens of fifteen species of Artiodactyla and Perissodactyla were used as test antigens.

3. Many of the antisera which were produced by injections of minute quantities of antigen resulted in very specific antisera.

4. The advantage of the serologic method is that a quantitative relationship could be determined for closely related bloods.

5. The serologic relationships usually agreed with the accepted morphological classification.

6. There were indications that the ox and buffalo were more closely related to the Cervidae than were the other Bovidae tested.

7. The tahr and sable antelope gave higher relationship values with the goat and sheep antisera than did the other Bovidae and Cervidae.

8. The ox and buffalo showed the closest affinity to the eland.

9. The axis deer and elk sera were found to be indistinguishable from each other but distinguishable from the Virginia deer.

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# 17.

## *Multiceps serialis* Infestation in a Baboon[1]. Report of a Case Exhibiting Multiple Connective Tissue Cystic Masses.

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(Plates I & II).

### INTRODUCTION.

Sporadic reports have appeared in the literature concerning the occurrence of the coenurus, *Multiceps serialis*, in human and sub-human primates. Infestation with related members of the family *Taeniidae*, the genera *Taenia* and *Echinococcus*, is fairly well known. Accordingly, a pathological analysis of a case in a monkey is of interest not only because of its "considerable potential significance in human medicine" (10), but also because of a dearth of detailed post-mortem study of the disease.

This paper is a report of a coenurus, which produced a large intra-abdominal mass together with numerous connective tissue and intermuscular cystic tumor masses in a baboon, *Theropithecus gelada*.

### CASE REPORT.

The animal was a young unexhibited baboon about 4 years of age. It was born in captivity in Hanover, Germany, and was brought to this country about two to three months before death. For a few months the animal appeared to be ailing, lost weight, was noticeably weak, and had developed several small ulcerations on the dorsum of the right foot. A large mass was palpable in the abdomen. A short time before death spastic paralysis of the right lower extremity was noticed, the leg being kept flexed against the body. The animal was destroyed by its owner and the necropsy performed by us on April 27, 1939, about twenty-four hours after death.

### POST-MORTEM EXAMINATION.

The body is that of a well developed, cachectic baboon (*Theropithecus gelada*) about four years of age. Moderate post-mortem rigidity is present. In each pectoral region there is a subcutaneous cystic mass, which is approximately the size and shape of a hen's egg. The one on the left is slightly larger. The overlying skin is freely movable. Similar, but smaller cystic masses are palpable in the right mastoid region, in the left axilla and over-

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lying the upper border of the left scapula. An incision over the mass in the left pectoral region reveals a well encapsulated, soft, multiloculated cystic structure lying within the subcutaneous tissues. The capsule is fairly thin and gray. Upon section, numerous small round clear cysts (bladder worms) are extruded together with some clear colorless fluid. These bladder worms measure from 0.5 to 1 centimeter in diameter. The other above-mentioned cystic masses are morphologically identical.

The lower portion of the abdomen, especially on the right side, bulges distinctly and on palpation a large mass can be felt. The right lower extremity is partially flexed at the hip and completely flexed at the knee. On the dorsum of the right foot, overlying the metatarso-phalangeal joints and also over the tarsal bones, there are several shallow ulcers with even, regular edges. The majority of these are approximately 1 centimeter in diameter and about 0.4 centimeter in depth. A similar but larger lesion is present over the medial aspect of the hallux, measuring about 4 by 1 centimeter in diameter. The bases of the ulcers are grayish and have a dry slough.

*Thorax.* Neither free fluid nor adhesions are present in either pleural cavity. In the left paravertebral region, just above the dome of the diaphragm, and extending over the lower four ribs, there is a firmly adherent multilocular cystic mass which measures approximately 6 by 5 centimeters in diameter. This rests upon the costovertebral junctions and portions of the adjacent ribs. At its infero-lateral margin it lies anterior and internal to another cystic mass, which is situated within the lowermost intercostal space, bulging externally, and which measures about 5 by 6 centimeters. This tumor is 2 centimeters in thickness and is located within the intercostal muscle at this site The intra-pleural cystic mass penetrates the pleura to communicate with this intermuscular cystic mass. At no place do the cysts invade the ribs, vertebral column or spinal cord. The heart, mediastinum and diaphragm are grossly uninvolved.

*Abdomen.* Upon opening the peritoneum a large cystic mass presents, occupying the entire right lower quadrant, its upper pole being at the liver edge and its lower pole being at the brim of the true pelvis. It is covered anteriorly by the posterior parietal peritoneum, and is entirely encompassed by a well defined translucent capsule. Posteriorly it is firmly adherent to the muscle and connective tissue overlying the right wing of the ilium and the lower portion of the spine. The peritoneal surfaces, elsewhere, are smooth and glistening and there is no free fluid in the peritoneal cavity. The viscera have their usual position and relationships except that the right kidney and ureter and the ascending colon are displaced to the left by the cystic mass. The mesenteric nodes are similar to the pulmonary nodes described below.

*Lungs.* The lungs weigh 190 grams, have a smooth and glistening pleura, and retain their shape fairly well upon the table. The upper lobes are light pink in color, while the lower lobes are dark purple. Crepitancy is normal throughout. The entire surface is studded by discrete, pin-head sized, pale gray, slightly elevated nodules, which on section extend into the depth of the lung for a distance of about 1 millimeter. The largest of these occurs in the right middle lobe, measures 5 millimeters in diameter and feels firm and calcified; on section, it has a caseous core. The cut surface of the lung is grossly negative, except for the presence of small gray pinhead sized nodules which are distinctly visible throughout. The hilar and tracheo-bronchial nodes are slightly enlarged, firm and adherent to each other. On section, each presents a peripheral grayish-white thick zone, which in some is calcified, and a central cheesy-like yellowish mass.

*Liver.* The liver surface contains a few pin-point to pin-head sized flat grayish nodules identical with those seen in the lung. A small firm nodule, 2 millimeters in size, is likewise present. It is translucent and contains within

it two pin-point opaque yellow dots. On cut surface the hepatic architecture is regular and distinct.

The remaining abdominal viscera and the genitalia are grossly not remarkable.

*Abdominal Tumor.* This large oblong cystic mass measures 21 centimeters in length, 12 centimeters in width, 7 centimeters in depth and weighs 815 grams (Pl. I, Fig 1). The anterior surface is smooth and presents several well demarcated lobulations, which contain clear colorless fluid and bladder worms (larval tapeworms). On opening into the mass, it is found to be multiloculated and honeycombed due to the presence of numerous closed and intercommunicating chambers, which also contain many small and large bladder worms. The cystic mass infiltrates the underlying muscle, but does not invade the bone.

*Bladder Worms.* The bladder worms vary in shape, most of them being elliptical, while others are sperical or entirely irregular and branching. Many of them occur in grape-like clusters; some are pedunculated. These bladder worms possess a pale, milky-white, transparent, delicate wall, and contain clear, colorless fluid together with multiple heads, both invaginated and evaginated (Pl. II, Fig. 4A). A fully detailed description of this coenurus has been given by Schwartz (10).

*Extremities: Upper.* Both upper extremities show similar changes. On the medial and volar aspect of each there is a large multiloculated, well encapsulated, cystic mass, measuring approximately 12 centimeters in length and 5 centimeters in width, which extends along the entire length of the forearm, its upper pole being about 3 centimeters distal to the olecranon. It is adherent to the muscles and tendons of the forearm, and compresses and flattens them. Numerous bladder worms are visible in the loculations.

*Lower: Left.* Between the larger muscle groups of the posterior aspect of the thigh there is an oval, translucent, well encapsulated cystic structure, approximately 8 by 4 by 3 centimeters, which compresses, flattens, and is bound to the muscles of the adjacent region. A cyst, 3 centimeters in diameter, is present in the connective tissue of the popliteal space. A similar mass is present in the lower leg and is adherent to the muscles and tendons immediately posterior to the tibia. It displaces the gastrocnemius posteriorly, which has become a thin compressed band of muscle (Pl. I, Fig. 2, and Pl. II, Fig 3). *Right.* Cystic masses, similar in all respects to those described in the lower extremity, diffusely infiltrate the subcutaneous connective tissue and the inter-muscular fascia, producing pressure atrophy of the muscles.

The tail, on section, contains many very small cysts within the connective tissue.

The brain and spinal cord are grossly uninvolved.

## Microscopic Examination.

Typical fresh miliary tubercles are found in the liver, lung and spleen. A fibro-calcific area containing lymphocytes and giant cells is present in the liver just beneath the capsule. Smaller collections of large mononuclear cells are scattered in the sinusoids; a moderate number of lymphocytes and plasma cells are found in the portal fields. In the spleen there were many plasma cells in the pulp and moderate erythro- and sidero-phagocytosis. The tracheo-bronchial and mesenteric lymph nodes show evidence of old and recent tuberculosis with calcification. The left axillary node shows caseation. Ziehl-Neelsen stain failed to reveal any acid-fast organisms. The connective tissue adjacent to the right wing of the ilium and located just beneath the lower pole of the abdominal mass shows acute and chronic non-specific inflammation with focal necrosis.

The muscle immediately adjacent to the cystic mass in the extremities reveals marked degeneration and atrophy, some edema, mild replacement fibrosis and focal collections of lymphocytes together with evidences of repair as indicated by the presence of many muscle buds.

Section of the bone (right wing of the ilium) is entirely normal. The contiguous muscle shows the changes described above. The bases of the ulcers of the right foot are formed by non-specific granulation tissue.

## COMMENT.

It is to be noted that *M. serialis* infestation evokes no characteristic or specific inflammatory reaction in its sites of localization, and, indeed, very little inflammatory reaction altogether. The changes in the muscles resulting from the presence of the interfascicular cystic masses are those due to pressure.

In passing, it may be stated that calcification of tuberculous foci, as found in our case, is uncommon in monkeys.

## LABORATORY DATA.

The fluid within the cysts gave a strongly positive (four plus) complement fixation reaction for *Echinococcus*. X-ray of the extremities showed cystic masses, with streaks of calcification, not invading the bone. X-ray of the abdominal mass revealed only a multicystic tumor without calcification. Post-mortem roentgenogram of the lung showed numerous calcified para-tracheal nodes. Guinea pig innoculation for tubercle bacilli was unsatisfactory. A fresh preparation of a coenurus revealed the presence of many hooklets (Pl. II, Fig. 4B).

*Pathologic Diagnosis*: Widespread infestation by a coenurus (*M. serialis*) resulting in multiple connective tissue and inter-muscular cystic masses located in all extremities, retroperitoneally, intra-pleurally, in the anterior and posterior chest wall, right mastoid region, and the tail. Generalized miliary tuberculosis of the lung, liver, spleen and old and recent tuberculosis of the axillary, hilar, tracheo-bronchial and mesenteric lymph nodes are present, with calcification of the latter two. Degeneration, atrophy and fibrosis of the involved muscles of the extremities. Trophic ulcers of the right foot.

## DISCUSSION.

The larval cestode described above was sent to the Bureau of Animal Industry[3], U. S. Department of Agriculture, where it was identified by Mr. Allen McIntosh as *Multiceps serialis theropitheci* (Schwartz, 1927).

*M. serialis* infestation in primates is rare. The literature on this subject has been recently reviewed by Sandground (9), who listed five cases in primates and two instances in humans. The usual intermediate host is the rabbit. References to other intermediate hosts can be found in Meggitt (6) and Hall (5). The common definitive host is the dog. Schwartz (10) described a case of *M. serialis* infestation occurring in a baboon (*T. obscurus*) with a large cystic subcutaneous tumor in the right thoracic region similar to that found in our case, and gave a careful morphologic description of the larval and adult tapeworm. Schwartz adopted the name *M. serialis* var. *theropitheci* because, although the morphology of the cestode and of the tapeworm reared from a dog was similar to, if not identical with *M. serialis*, nevertheless there was a biological difference in that he was unable to obtain

[3] We are greatly indebted to Mr. Allen McIntosh for kindly identifying the bladder worm for us and to Dr. E. W. Price, Acting Chief, Zoological Division, Bureau of Animal Industry, U. S. Department of Agriculture, Washington, D. C., for his cooperation.

this cestode after feeding the adult worm to rabbits. In Scott's (11) two cases, both occurring in *Theropithecus gelada,* one animal had cystic masses in the right upper arm, submental region, pericardium, mediastinum and right perirenal tissue, while in the other, a mass in the left pleural cavity had invaded and compressed the lower dorsal spinal cord. Sandground's (9) case was atypical in location, the cyst being in the brain of a monkey (*Cercopithecus nictitans*).[4] Railliet & Marullaz (8) reported cystic masses in the perineum of a monkey (*Macacus sinicus*) due to *M. ramosus.* Sandground (9), however, believes this is really *M. serialis.* In the two reported human cases (1, 2), one showed multiple subcutaneous tumors and the other a solitary cyst in the right buttock. In these cases, the coenurus was identified by morphological study.

According to Dévé and the Registry of the Royal Australasian College of Surgeons (both cited by Godfrey (4), the incidence in humans of *Echinococcus* infestation involving muscle and fascia is about 5%. Generally the diagnosis of *Echinococcus* disease is made by the mere finding of cysts without a detailed morphologic study of them and by various laboratory tests, including the complement fixation, intradermal and precipitin tests. These tests, however, are now recognized to be specific for related groups rather than for individual species (3, 7). Since in our case of *M. serialis* we obtained a positive complement fixation for *Echinococcus,* we are led to consider the possibility that infestation by *M. serialis* in man may be more frequent than commonly noted. This view gains credence since as Schwartz (10) has stated: "The question of the specific identity of the coenurus stage of the tapeworm genus Multiceps involves primarily the number, size and shape of the hooks and incidentally the other head structures, notably the suckers and rostellum." Such an analysis is not a routine procedure in most hospital laboratories.

## SUMMARY.

1. A case is reported of infestation in a baboon (*Theropithecus gelada*) by a cestode identified as *Multiceps serialis.*

2. There were numerous cystic masses in the subcutaneous and intermuscular connective tissues and a large intra-abdominal, retro-peritoneal cystic tumor.

3. This type of cestode infestation is rare in primates. So far as could be determined, this is the sixth such case to be reported in a primate. Two instances have been described in humans.

4. *M. serialis* infestation produced no specific or characteristic inflammatory response in our case.

5. An incidental finding was a fibro-caseo-calcific tuberculosis with miliary dissemination.

6. Fluid obtained from the coenurus gave a strongly positive complement fixation test for *Echinococcus.* It is suggested, therefore, that some cases thought to be *"Echinococcus"* infestation in humans, with cystic masses in connective tissue and in muscle, may actually be due to *M. serialis.*

The authors are indebted to Dr. Charles R. Schroeder for his kind cooperation; and Drs. Paul Klemperer and Sadao Otani for their valuable criticism and helpful aid in the preparation of this report.

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[4] It may be mentioned here that some authors, notably Southwell (10), believe that no sharp distinction can be made morphologically between *M. serialis* and *M. multiceps.*

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## EXPLANATION OF THE PLATES.

### PLATE I.

Fig. 1. Large intra-abdominal cystic mass, which measures 21 by 12 by 7 centimeters. Weight 815 grams. Anterior surface covered by peritoneum.

Fig. 2. Left lower limb showing cystic masses displacing muscle in thigh and leg.

### PLATE II.

Fig. 3. Left leg, higher power view, showing encapsulated cystic mass with muscular atrophy. Arrow points to muscle.

Fig. 4A. Right forearm. Cystic masses displacing muscle and showing extruded bladder worms.

Fig. 4B. Photomicrograph of bladder warm showing hooklets (fresh preparation).

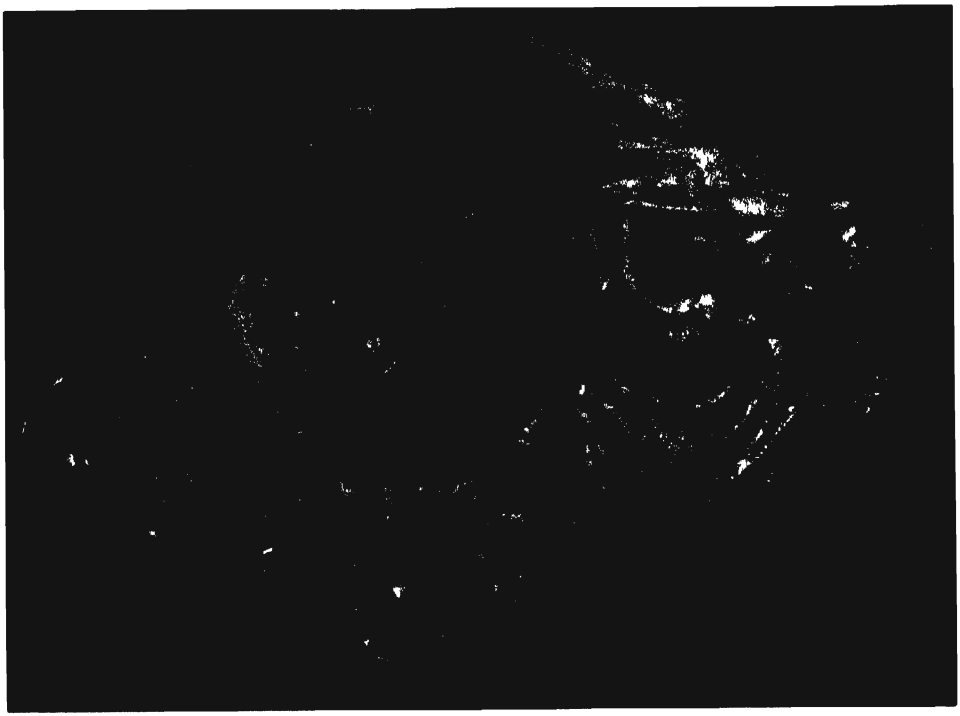

FIG 1

FIG 2

MULTICEPS SERIALIS INFESTATION IN A BABOON

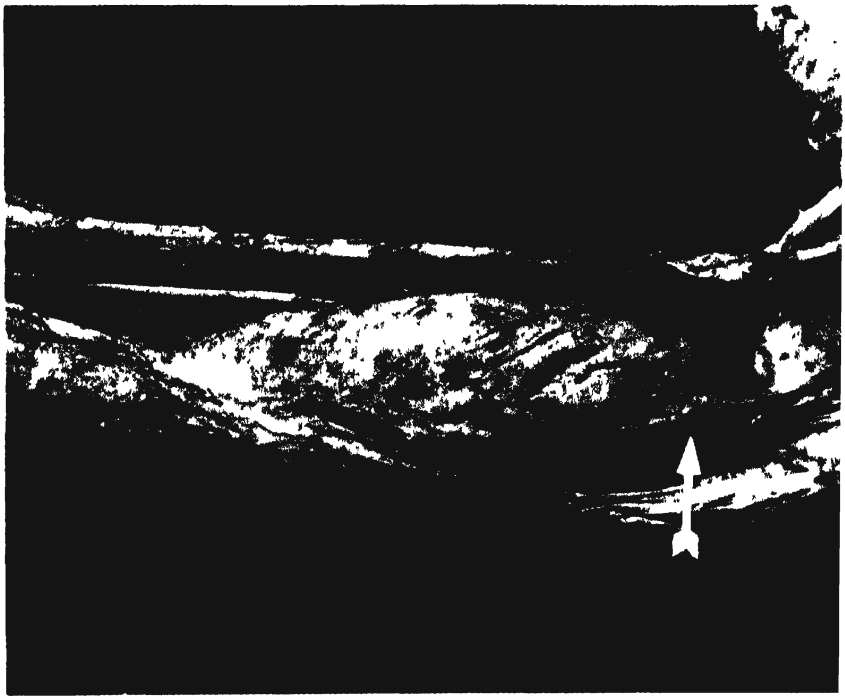

FIG 3

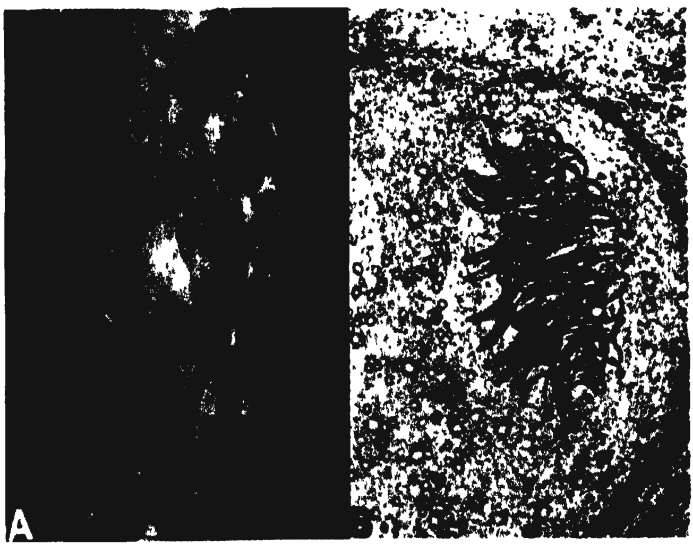


FIG 4A. FIG 4B

MULTICEPS SERIALIS INFESTATION IN A BABOON

# 18.

## A Quantitative Study of the Testes of Certain Mammals.

THOMAS H. KNEPP.

(Text-figures 1 & 2).

A quantitative histological study of the testes of six mammals, four domestic and two wild, was undertaken in 1935, and the research problem initiated at that time has been continued through the cooperation of the Laboratory and Hospital of the New York Zoological Park in supplying me with testes of mammals which died in the Zoological Park.

The testes were fixed in 10% formalin, except those of the gray squirrel and cottontail rabbit which were fixed in Bouin's picro-formol. Each testis was weighed after fixation and hardening. Material was sectioned in paraffin, then stained with Heidenhain's iron-hematoxylin.

Microscopic measurements were made with an ocular micrometer. In finding the percentage of interstitial tissue and seminiferous tubules the paper method employed by Bascom (1925) was used. This method does not take into account the thickness of the tunica albuginea and mediastium in calculating the amount of seminiferous tubules and interstitial tissue.

The average of 20 measurements was used in computing the diameter of the seminiferous tubules and the thickness of the tunica albuginea. In finding the average size of the sperms 25 measurements were taken.

Testes from the polar bear, Punjab wild sheep, mouflon and wallaroo were from the Zoological Park; testes from the Virginia deer, gray squirrel and cottontail rabbit were from the fauna of Pennsylvania.

In the table below, the date the specimen was secured is given. It remains to be proved whether the season of the year has anything to do with spermatogenesis and quantitative measurements.

It is evident that the testicular weight bears no ratio to the gross weight of the animal. Tubular diameter is not as great in the carnivore (polar bear) as in the six herbivores; likewise the cross-section area of the tubules is smaller in the carnivore. The polar bear and gray squirrel are at the extremes in thickness of tunica albuginea and connective tissue. The smallest testis in weight has the thinnest tunica albuginea and connective tissue, but the greatest thickness is not found in the heaviest testis.

The percentage of interstitial tissue is greatest in the polar bear, but relatively constant in the herbivores; the inverse is true of the seminiferous tubules. The length of the seminiferous tubules is greater in the largest testes, the weight of the testis being due to the increased length of the tubules.

In meters of tubules per gram of testicular weight, and in meters of tubules per gram of tubules, the carnivore is the extreme. Sperm sizes vary from the smallest in the Virginia deer to the largest in the wallaroo, the intermediate ones being fairly constant. The heads of the sperms of all the animals except the wallaroo are somewhat oval; those of the wallaroo appear

to be pointed and thin, with the end of the head somewhat curved. In the wallaroo no loose sperms are seen in the lumen of the tubules; the tails are in large masses, making the individual study of a sperm difficult. This may be due to the fact that the animal was immature.

| | Polar Bear | Punjab Wild Sheep | Mouflon | Virginia Deer | Wallaroo | Gray Squirrel | Cottontail Rabbit |
|---|---|---|---|---|---|---|---|
| Date secured | 11/2/37 | 1/6/38 | 1/6/38 | 12/4/37 | 2/17/38 | 11/25/33 | 5/22/35 |
| Weight of the testis without epididymus, grams | 31.7 | 70.2 | 41.05 | 36.2 | 5.8 | 1.97 | 9.6 |
| Mean tubule diameter, microns | 105.8 | 176.4 | 149.5 | 139.4 | 141.1 | 169.68 | 173.88 |
| Mean cross-section area of tubules, square millimeters | 0.008 | 0.024 | 0.017 | 0.014 | 0.015 | 0.022 | 0.023 |
| Mean thickness of tunica albuginea and connective tissue, microns | 708.3 | 555.2 | 473.7 | 168.0 | 164.6 | 99.9 | 374.64 |
| Interstitial tissue, percent. | 33.5 | 15.86 | 15.45 | 17.94 | 21.96 | 18.44 | 18.69 |
| Seminiferous tubules, percent. | 66.5 | 84.14 | 84.55 | 83.06 | 78.04 | 81.55 | 81.30 |
| Length of seminiferous tubules, meters | 2635 | 2461 | 2041 | 2121 | 301 | 73 | 339 |
| Meters of tubules per gram of testicular weight | 83.1 | 31.5 | 49.7 | 58.5 | 52.0 | 37.1 | 35.3 |
| Meters of tubules per gram of tubules | 125.5 | 41.7 | 58.8 | 71.4 | 67.1 | 45.6 | 43.5 |
| Length of average sperm, microns | 36.3 | 24.3 | 26.6 | 18.9 | 49.4 | 27.47 | 29.57 |

Text-figures 1 & 2 (gray squirrel and cottontail rabbit) illustrate the structural make-up of the respective testes. Definite pyramidal arrangement is evident in the rabbit testis, the base of the pyramid resting on the tunica albuginea, the apex pointing toward the center. (This arrangement is also evident in the common dog).

From the Zoological Park's Laboratory and Hospital there have been sent to me testes from the collared peccary, mouflon, white-tailed paradoxure, Hussar monkey, woolly monkey, tahr, pigmy hippopotamus, Kadiak bear, axis deer, black buck antelope and North and South African ostrich. Since this group includes carnivores, herbivores and omnivores, the data when prepared may show some interesting facts.

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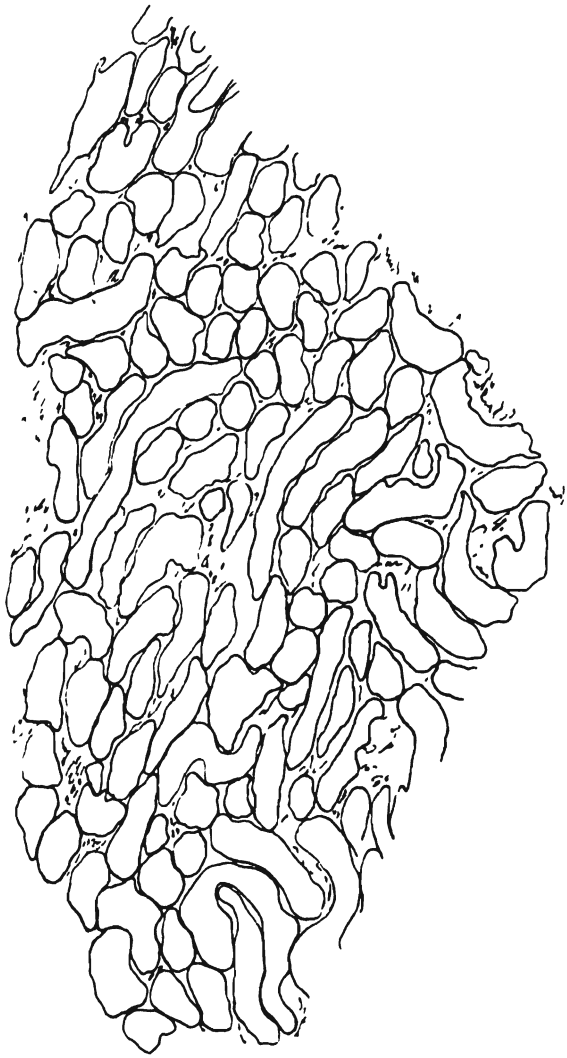

**Text-figure 1.**

Section of Gray Squirrel testis. Tubules not in any definite arrangement.

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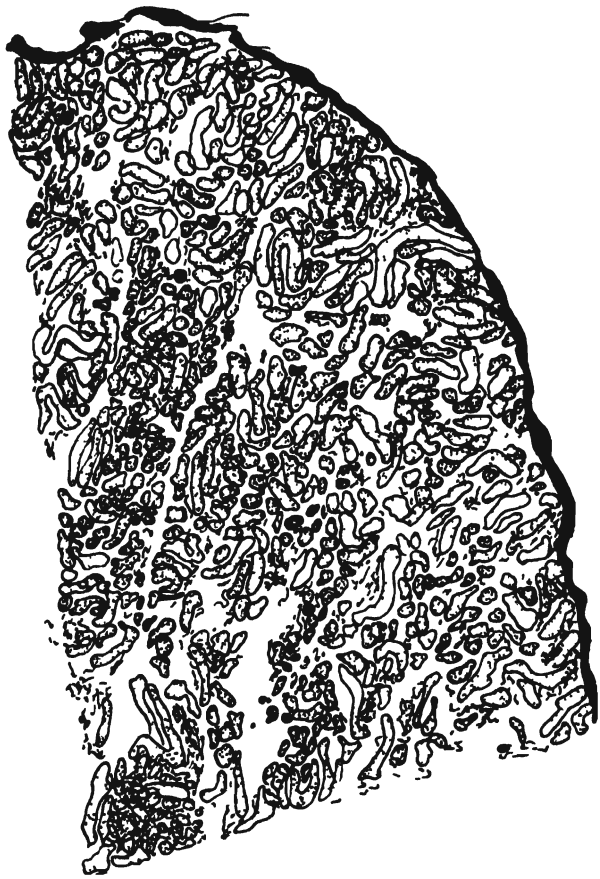

Text-figure 2.

Section of Cottontail Rabbit testis. Tubules in pyramidal arrangement, with bases of pyramids resting on tunica albuginea.

# 19.

## A Preliminary Report on the Os Opticus of the Bird's Eye.

OTTO W. TIEMEIER

*University of Kansas Museum of Birds and Mammals, Lawrence, Kansas.*

(Text-figures 1-24).

In the eyes of many birds there is a small U- or horseshoe-shaped bone, located in the rear portion of the cartilaginous sclerotic coat of the eye. The open part of the U is toward the upper part of the eye, and through this the optic nerve passes. In some instances the bone may be more or less circular in form and thus completely surround the optic nerve.

Upon the suggestion of Mr. C. D. Bunker of the University of Kansas Museum of Birds and Mammals, an investigation of this bone was made. The purpose of the investigation was to consider its possible taxonomic value, the forms in which it was present, the extent of variation and its probable function.

An examination of the literature revealed that the bone was first described by Gemminger (1853). He noticed that it was present in the eyes of woodpeckers. In his list of 20 forms of European birds he describes and illustrates it in a number that were not woodpeckers. Leydig (1855) adds 13 forms to this list. Later investigators have added a few more forms.

Concerning the function of this element, Gemminger, whose work was mostly with the woodpeckers, writes that this bone is for protection of the optic nerve at its entrance into the eyeball. I am sure that the shock which the eyeball receives as these birds hammer holes in trees must indeed be considerable, but it appears to me that this does not completely answer its purpose.

Gemminger failed to find the bone present in the nocturnal and diurnal birds of prey, in the gallinaceous birds, and what he calls the swamp and swimming birds.

The fine collection of skeletons in the University of Kansas Museum of Birds and Mammals furnished most of the material. I have examined 6,500 skeletons in the above collection. Other material was obtained through the courtesy of Dr. C. R. Schroeder of the New York Zoological Park and from Mr. C. C. Sperry and Mr. Ralph H. Imler of the Food Habits Research Laboratory at Denver.

The method used to secure this very small bone was the dermestid beetle process. Specimens of birds were skinned and drawn, thoroughly dried and then left in the "bug room" to become infested. Within several months the skeletons were entirely cleaned by the beetles and the bones could be picked out of the débris. If, in particular forms, I was certain that the bone was present but I could not find it in the collection of skeletons, the eyes of fresh specimens coming into the museum were saved and dried, and then placed in small glass containers with a number of small

beetle larvae. A week later the inconspicuous bone could be separated from the débris of cast-off beetle remains, if it had ever been present in the sclera of the eye.

Former investigators have described this bone under the misleading name of "the rear sclerotic ring," which would seem to indicate an association with or a relation to the sclerotic ring. In reality there is very little relation between the two, except that they are both located in the sclerotic coat of the eye. I wish to propose the name "*os opticus*" which, I believe, will help to clarify and differentiate the two.

Microscopic sections of the os opticus show that it can be differentiated from the sclerotic ring in that it has a marrow cavity which contains fat and marrow cells and blood vessels. In the sections that I have made of the bone I have always found the cells and vessels. Franz (1934) did not find them in *Motacilla*. The os opticus does not consist of plates like that of the sclerotic ring, although in some instances it has been described as consisting of two or three separate bony elements.

Leydig writes that the origin of the two bony elements of the eye are different. The sclerotic ring, he states, is formed by calcification of the connective tissue, while that of the os opticus is formed by calcification of the hyaline cartilage of the sclera. I have not been able to verify this statement.

There is a great variation in the size, shape and development of the os opticus. In general it is U-shaped or horseshoe-shaped with variations as to the development of the two heels. One heel may be long and well developed and the other one short. There is often very little symmetry and by a comparison of the bone in the right and left eye, Text-figs. 8 and 9, it would often be difficult to conceive of them as coming from the same bird, except for the ground pattern of the U that is easily identifiable. In others they may be exact mirror images and may be definitely designated as left and right.

By securing the eyes of fifty game cocks and using the dermestid method on them, I have been able to obtain a very interesting series of bones from the eyes of this species, although Gemminger and Leydig stated that it was not present in the domestic fowl. In Text-figs. 1 to 6 I have drawn a series of these bones. Text-figs. 1 and 2 show the basal plate which is apparently the first portion to develop. As the series progresses the heels of the horseshoe develop until finally they are in their mature forms.

The bone was apparently not present in all of the eyes, although the birds were mature enough to have been entered in cock fights. This seems to indicate that the development of the os opticus is an age character, and may be formed after the birds are mature. Gemminger and Leydig report that they have found the bone in nestling woodpeckers that they examined. Possibly in forms like the woodpeckers the bone develops early in the life of the bird, and in those forms in which it is not so well developed it appears later in life.

By comparing the different families of birds it appears that the os opticus is best developed in the Picidae, although it is also prominent in the Corvidae and the Fringillidae. In the birds which I have examined, the bone is largest in the Pileated Woodpeckers where the measurement is 1 cm. in the longitudinal axis and .73 cm. in the vertical axis. The measurement of the bone in the fully mature Brown Creeper is .16 cm. by .15 cm. and is the smallest of any of the species represented in my list.

In many instances the bone forms a complete ring around the optic foramen. The optic foramen is a slit whose vertical distance is about twice that of the horizontal distance. This accounts for the U-shape of the os opticus. In those species in which the bone is well developed it is curved to correspond to the curvature of the eyeball.

In woodpeckers, especially, there is quite frequently an enlarged development of bone at the upper portion of the heel. Text-figs. 7 and 9. I have not

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

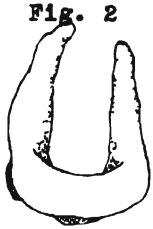

Fig. 6

Fig. 7

Fig. 8

Fig. 9

Fig. 10

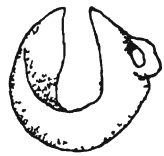

Fig. 11

Fig. 12

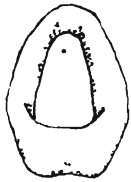

Fig. 13

Fig. 14

Fig. 15

Fig. 16

Fig. 17

Fig. 18

Fig. 19

Fig. 20

Fig. 21

Fig. 22

Fig. 23

Fig. 24

TEXT-FIGURES 1-24.

**1** to **6.** *Gallus* sp., × 5.5; **7.** *Ceophloeus pileatus pileatus*, × 3; **8.** *Corvus brachyrhynchos brachyrhynchos*, × 5; **9.** *Dryobates villosus villosus*, × 4; **10.** *Buteo borealis calurus*, × 4; **11.** *Colaptes auratus luteus*, × 5; **12 & 13.** *Melanerpes erythrocephalus*, × 5; **14.** *Falco sparverius sparverius*, × 4; **15.** *Sturnella magna magna*, × 5; **16.** *Hedymeles melanocephalus papago*, × 6; **17.** *Tyrannus tyrannus*, × 5; **18.** *Butorides virescens virescens*, × 8; **19.** *Phasianus colchicus torquatus*, × 6; **20.** *Piranga ludoviciana*, × 6; **21.** *Toxostoma rufum*, × 5; **22.** *Dumatella carolinensis*, × 6; **23.** *Sturnus vulgaris*, × 5; **24.** *Dendroica fusca*, × 7.

been able to determine whether this development is separate from that of the bone proper or whether it is only a lobular development of the bone itself. I am rather inclined to think that it is the latter because it is not uniform in position. Sometimes the lobe may be attached to the basal portion of one of the heels or in any position between these two extremes. In any event it does not seem to be a constant development.

Gemminger reports the presence of this element in 20 forms of European birds. Leydig later adds 13 forms to the list. In my material I find it to be present in 152 different forms of North American birds. I feel certain that it is also present in a large number of species belonging to orders represented in my list but which are absent because of lack of material. I have included a list of the forms in which Gemminger and Leydig have reported the bone, and a list of forms that I wish to report.

| REPORTED BY GEMMINGER | REPORTED BY LEYDIG |
|---|---|
| *Drycopus martinus* | *Falco tinnunculus* |
| *Gecinus viridis* | *Muscipeta satelles* |
| *Gecinus canus* | *Motacilla alba* |
| *Picus minor* | *Turdus merula* |
| *Picus medius* | *Sylvia phoenicurus* |
| *Picus major* | *Troglodytes gigas* |
| *Apternus tridactylus* | *Passer domesticus* |
| *Corvus corax* | *Fringilla carduelis* |
| *Corvus cornix* | *Fringilla caelebs* |
| *Corvus corone* | *Sturnus vulgaris* |
| *Corvus frugilegus* | *Cassicus phoeniceus* |
| *Corvus monedula* | *Trochilus* |
| *Pica caudata* | *Hirundo urbica* |
| *Garrulus glandaris* | |
| *Silla europaea* | |
| *Certhia familiaris* | |
| *Tichdroma muraria* | |
| *Parus ater* | |
| *Pyrrhula rubicilla* | |

Following is a list of forms in which I have secured specimens of the os opticus.

| | |
|---|---|
| *Butorides virescens virescens* | *Tyrannus vociferans* |
| *Accipiter velox velox* | *Muscivora forficata* |
| *Buteo borealis borealis* | *Myiarchus crinitus boreus* |
| *Buteo borealis calurus* | *Sayornis phoebe* |
| *Falco sparverius sparverius* | *Sayornis nigricans nigricans* |
| *Falco sparverius phalaena* | *Empidonax minimus* |
| *Gallus* sp. | *Empidonax difficilis difficilis* |
| *Phasianus colchicus torquatus* | *Myiochanes virens* |
| *Syrmaticus reevesi* | *Nuttallornis mesoleucus* |
| *Zenaidura macroura carolinensis* | *Otocoris alpestris leucolaema* |
| *Columbigallina passerina pallescens* | *Otocoris alpestris praticola* |
| *Megaceryle alcyon alcyon* | *Hirundo erythrogaster* |
| *Colaptes auratus luteus* | *Progne subis subis* |
| *Colaptes cafer collaris* | *Perisoreus canadensis capitalis* |
| *Colaptes chrysoides mearnsi* | *Cyanocitta cristata cristata* |
| *Ceophloeus pileatus pileatus* | *Cyanocitta stelleri diademata* |
| *Centurus carolinus* | *Pica pica hudsonia* |
| *Centurus aurifrons* | *Corvus corax sinuatus* |
| *Melanerpes erythrocephalus* | *Corvus cryptoleucus* |
| *Sphyrapicus varius nuchalis* | *Corvus brachyrhynchos brachyrhynchos* |
| *Sphyrapicus thyroideus nataliae* | *Cyanocephalus cyanocephalus* |
| *Dryobates villosus villosus* | *Penthestes atricapillus atricapillus* |
| *Dryobates villosus monticola* | *Penthestes atricapillus septentrionalis* |
| *Dryobates pubescens medianus* | *Penthestes gambeli gambeli* |
| *Dryobates pubescens pubescens* | *Baeolophus bicolor* |
| *Dryobates scalaris symplectus* | *Sitta carolinensis carolinensis* |

*Dryobates arizonae arizonae*
*Tyrannus tyrannus*
*Tyrannus verticalis*
*Salpinctes obsoletus obsoletus*
*Mimus polyglottos polyglottos*
*Mimus polyglottos leucopterus*
*Dumatella carolinensis*
*Toxostoma rufum*
*Toxostoma curvirostre curvirostre*
*Oreoscoptes montanus*
*Turdus migratorius migratorius*
*Turdus migratorius propinquus*
*Hylocichla mustelina*
*Hylocichla guttata faxoni*
*Hylocichla ustulata swainsoni*
*Hylocichla minima aliciae*
*Sialia sialis sialis*
*Polioptila caerulea caerulea*
*Regulus satrapa satrapa*
*Corthylio calendula calendula*
*Anthus spinoletta rubescens*
*Bombycilla cedrorum*
*Phainopepla nitens lepida*
*Lanius ludovicianus migrans*
*Lanius ludovicianus excubitorides*
*Sturnus vulgaris vulgaris*
*Vireo belli belli*
*Vireo gilvus gilvus*
*Vireo gilvus swainsoni*
*Mniotilta varia*
*Vermivora peregrina*
*Vermivora celata celata*
*Compsothlypis americana pusilla*
*Dendroica aestiva aestiva*
*Dendroica magnolia*
*Dendroica coronata*
*Dendroica auduboni auduboni*
*Dendroica cerulea*
*Dendroica fusca*
*Dendroica striata*
*Seiurus aurocapillus*
*Oporornis formosus*
*Geothlypis trichas trichas*
*Icteria virens virens*
*Passer domesticus domesticus*
*Dolichonyx oryzivorus*
*Sturnella magna magna*
*Sturnella neglecta*
*Agelaius phoeniceus phoeniceus*
*Agelaius phoeniceus fortis*
*Icterus spurius*
*Certhia familiaris americana*
*Thryothorus ludovicianus ludovicianus*
*Heleodytes brunneicapillus couesi*
*Icterus galbula*
*Icterus bullocki*
*Euphagus carolinus*
*Euphagus cyanocephalus*
*Quiscalus quiscula aeneus*
*Molothrus ater ater*
*Molothrus ater artemisiae*
*Molothrus ater obscurus*
*Piranga ludoviciana*
*Piranga erythromelas*
*Piranga rubra rubra*
*Richmondena cardinalis cardinalis*
*Richmondena cardinalis canicauda*
*Pyrrhuloxia sinuata texana*
*Hedymeles ludovicianus*
*Hedymeles melanocephalus papago*
*Guiraca caerulea caerulea*
*Guiraca caerulea interfusa*
*Passerina cyanea*
*Spiza americana*
*Carpodacus mexicanus frontalis*
*Spinus pinus pinus*
*Loxia* sp.
*Loxia curvirostra pusilla*
*Pipilo erythropthalmus erythropthalmus*
*Pipilo maculatus arcticus*
*Pipilo maculatus montanus*
*Calamospiza melanocorys*
*Ammodramus savannarum australis*
*Passerherbulus caudacutus*
*Pooecetes gramineus confinis*
*Chondestes grammacus strigatus*
*Aimophila cassini*
*Junco hyemalis hyemalis*
*Junco caniceps*
*Spizella arborea arborea*
*Spizella arborea ochracea*
*Spizella pusilla pusilla*
*Zonotrichia querula*
*Zonotrichia leucophrys leucophrys*
*Melospiza lincolni lincolni*
*Melospiza georgiana*
*Calcarius lapponicus alascensis*
*Calcarius pictus*
*Taeniogypio castanotis*
*Serinus* sp.

To date I have not found the bone in a number of families of North American birds, namely: Gaviidae, Pelecanidae, Anatidae, Cathartidae, Tetraonidae, Perdicidae, Meleagrididae, Gruidae, Rallidae, Charadriidae, Scolopacidae, Laridae, Cuculidae, Tytonidae, Strigidae, Caprimulgidae, Micropodidae and Trochilidae. In some of these families the os opticus has been reported but because of the lack of material I am not including them. The most striking gaps in the list are the ones among the water-inhabiting birds and the owls. I have, however, found the bone in the Eastern Green Heron (*Butorides virescens virescens*) and I believe that when I can secure more specimens some of these gaps will be filled.

Possibly the development of the bone is a phylogenetic character in the development of the birds and therefore absent in the more primitive forms. Examination of the eyes of an ostrich and an emu revealed that the os

opticus was not present in those particular specimens of the two forms. I am convinced that in the Order Passeriformes every family is represented by forms in which the bone appears.

It is quite certain that the os opticus can not be used as a diagnostic character in the separation of species because there is too much variation within the same species. There may, indeed, be considerable variance in the two eyes of the same bird.

Upon the assumption that the function of the os opticus is protection of the optic nerve at its entrance into the eyeball, it would be difficult to explain why it is so well developed in the flycatchers, swallows, and other birds whose methods of securing food are quite different from that of the woodpeckers. It would also be difficult to explain why in one order of birds, namely the Falconiformes, it seems to be universally present in the members of the Family Falconidae and only very seldom present in the Accipitriidae.

It appears to be the concensus of opinion of former workers that one of the chief purposes of the pecten is for the nourishment of the vitreous and retina of the eye. I feel that there is a very definite relationship between the pecten of the eye and the os opticus other than that of spatial relationship. In many of the bones, that are exceptionally well developed, there is a small opening on one side and at the base of the bone for the passage of the different blood vessels of the pecten.

It is my intention to continue my investigation of the os opticus, particularly the condition in the nestling, and if possible to ascertain specific changes due to age.

I am greatly indebted to Mr. C. D. Bunker of the University of Kansas Museum who suggested this investigation and who placed at my disposal the extensive collection of bird skeletons for examination. I am also indebted to Dr. C. R. Schroeder of the New York Zoological Park, and to Mr. C. C. Sperry and Mr. Ralph H. Imler of the Food Habits Research Laboratory at Denver, for valuable study material. I wish to thank Dr. E. H. Taylor of the University of Kansas, for helpful suggestions and criticisms.

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# 20.

## Treatment of Amoebic Dysentery in an Orang-utan.

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&
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On July 2, 1938, a male orang-utan (*Pongo pygmaeus*) was purchased for the collection of the New York Zoological Park. The animal was a young male estimated about three years of age and weighing about 21 lbs. It had been captured in North Borneo, brought to Baltimore, Md., and finally bought by a New York dealer who sold it to the Park.

During the first few weeks that this orang was in the Hospital and Laboratory for routine quarantine prior to being placed on exhibition, it had an intermittent diarrhea. Examination of a fecal sample on July 18, 1938, showed the presence of a few amoebic trophozoites with the morphology of *Endamoeba histolytica*. In a watery stool passed on July 20 both trophozoites and cysts were very numerous.

On July 20 treatment was begun. Carbarsone (0.05 gms.) was administered three times daily either mixed with milk or in a slice of banana. This treatment was continued for seven days. Smears of fecal material made during treatment seemed to indicate a marked decrease in the number of trophozoites present. By the end of the week of treatment the orang was passing well-formed stools in which no amoebae could be demonstrated by the direct smear method. Eleven days following the completion of the treatment the animal again became diarrhetic. A few trophozoites were demonstrable in a fecal smear. The Carbarsone treatment was repeated three times daily for three days, when the diarrhea had been corrected and no parasites could be seen in a fecal smear. Since this last treatment about a year ago fecal smears have been examined more or less periodically, particularly whenever a loose stool was passed, but no trophozoites or cysts of *Endamoeba histolytica* could be demonstrated.

Since the animal arrived in the Park it has been kept under the best sanitary conditions possible with an exhibit primate. Its cage is cleaned at least daily and absorbent, dried, sugarcane stalks are used for bedding so that the risk of reinfection has been at a minimum.

The authors believe this case represents complete elimination of *Endamoeba histolytica* from the orang-utan by treatment with Carbarsone.

# 21.

## *Deltokeras multilobatus*, a New Species of Cestode (Parauterininae : Dilepiididae) from the Twelve-wired Bird of Paradise (*Seleucides m. melanoleucus* (Daudin). : Passeriformes).[1,2]

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(Plate I).

A collection of cestodes obtained from a twelve-wired bird of paradise that had died at the New York Zoological Park was submitted to the author for study through the courtesy of Dr. Carlton M. Herman. The vial contained a large number of specimens, totaling about one hundred in all, approximately half of which are *Hymenolepis brevicirrosa* Fuhrmann, 1912, and the remainder an undescribed species of the genus *Deltokeras* Meggitt, 1927. The name *Deltokeras multilobatus* n. sp. is proposed, being suggested by the many-lobed condition of the ovary.

### ***Deltokeras multilobatus*** n. sp.

*Description*: Strobilae up to 45 mm. long, proglottides nearly as thick as long, width of mature segments 470-525 $\mu$, length 292-324 $\mu$, thickness 243 $\mu$ in posterior part; ripe segments 616-696 $\mu$ wide by 393-486 $\mu$ long. Scolex rounded, diameter 243-324 $\mu$, length 243-324 $\mu$; rostellum short, its length, 64-99 $\mu$, about equal to its width, 72-91 $\mu$, dome shaped with truncated part directed cephalad; because of their caducous nature only two rostellar hooks remained, length 17-19 $\mu$, ventral root short and with very broad base, its distal extremity provided with a large knob that is bisected, dorsal root with or without terminal knob. Suckers approximately circular, 87-102 $\mu$ wide by 80-91 $\mu$ long, located laterally near equator of scolex, unarmed. Neck distinct, length 508-1060 $\mu$, width at base of scolex 146-190 $\mu$. Dorsal excretory canals small, about 4 $\mu$ in diameter, ventral canals large, about 27 $\mu$ in diameter, located immediately mesad from nerve cords, transverse canal in caudal part of segment. Genital pores unilateral, very small, 12 $\mu$ in diameter, located near middle of lateral margin of proglottid. Genital ducts pass between excretory canals and dorsal to nerve cords. Cirrus pouches long and slender, extending anterio-mesad to a point beyond excretory canals, length 121-133 $\mu$, width 19-23 $\mu$; cirrus very slender, diameter 3 $\mu$, aspinose; cirrus and that portion of vas deferens within pouch looped; internal and external seminal vesicles absent; vas deferens forms a number of loops in anterior portion of proglottid before passing caudad over dorsal surface of ovary; testes posterior and lateral to ovary, 12-16 in number, diameter about 34 $\mu$, both testes and ovary persist until uterus is well filled with immature ova. Vaginal

[1] Paper No. 1732 Scientific Journal Series Minnesota Agricultural Experiment Station, St. Paul.
[2] In cooperation with the Minnesota Conservation Department, Division of Game and Fish.

opening caudad from male pore, vagina extends as a thin tube parallel with and on caudal side of cirrus pouch to beyond excretory canals where it bends meso-caudad, increasing greatly in diameter to form an elongated seminal receptacle that lies dorsal to ovary. Ovary located centrally in proglottid, multilobated, there being 8-9 pedunculated lobes filling greater portion of space between longitudinal excretory canals. Vitelline gland at caudal margin of ovary, oval, 61-76 $\mu$ long by 38 $\mu$ wide. Uterus with lobes, the interior being divided into compartments by extensions of the wall, fills entire intercanalular space; parauterine organ very poorly developed, being represented by a very meager amount of tissue spread evenly over entire surface of uterine wall. Ova few, with three membranes, 53-57 $\mu$ long by 30 $\mu$ wide (sectioned specimens), embryoes 30-31 $\mu$ long by 23-27 $\mu$ wide, hooks of embryo 13 $\mu$ long. Ova not encapsulated in uterine cavity.

*Host*: *Seleucides melanoleucus melanoleucus* (Daudin).

*Habitat*: Intestine.

*Locality*: New York Zoological Park.

*Cotypes*: U. S. Nat. Mus. Helm. Coll. No. 9291, others in Univ. Minn. Helm. Coll., New York Zool. Soc. Coll. and of author.

## Discussion.

*Deltokeras multilobatus* n. sp. may be recognized by the characteristic lobation of the ovary, the lobes being on long pedunculated stalks. The ovary of *D. ornitheios* Meggitt, 1927, is sac-like and at most only slightly lobed; *D. delachauxi* Hsu, 1935, is strongly bilobed. In the case of *D. campylometra* Joyeux, Gendre & Baer, 1928, the description of the female glands is dismissed with the statement that they "ne présentent pas de particularités," which is taken to indicate that they are similar to those of *D. ornitheios*. The size and shape of the rostellar hooks serve to further differentiate the four species. In *D. ornitheios*, they are the largest, being 27-31 $\mu$ long, and most similar in shape to *D. multilobatus*, while in both *D. campylometra* and *D. delachauxi* they are smaller than in *D. multilobatus*, being 10-15 $\mu$ and 14-15 $\mu$ long, respectively, as compared to 17-19 $\mu$ long as in the case of the latter, as well as being very different in shape (cf. Figs. 2, 4, 6 and 7).

Meggitt (1927) stated that while the species of *Bunteria* have a parauterine organ *D. ornitheios* does not, nor does the uterine wall show any of the characteristic fibrinous structure of that organ. Joyeux et al (1928) for *D. campylometra* and later Hsü (1935) for *D. delachauxi* reported a definite thickening of tissue surrounding the uterus and pointed out that it is a form of the parauterine organ. Hsü believed the presence of the parauterine organ a characteristic of the genus and emended the generic concept accordingly. These authors are of the opinion that the specimens of *D. ornitheios* were too young to show the parauterine organ although Meggitt stated that while the oldest proglottides were not gravid "the most fully developed segment showed a lobed sac filled with eggs, occupying the former position of the ovary and extending to the anterior margin of the proglottis." In considering the opinion of these authors in their belief that the specimens of *D. ornitheios* were too immature to show the parauterine organ, it is interesting to note that Joyeux et al found their specimens "ne sont pas assez mur pour nos permettre d'observer l'organe complètement developpé;" even so it is figured as being very conspicuous and Hsü figured a sexually mature proglottid, not gravid, in which the organ is sufficiently well developed to be quite as obvious as the ovary and equal to it in size. This leads to the opinion that even though Meggitt's specimens were not fully gravid they were undoubtedly sufficiently developed to show at least some indications of the presence of a parauterine organ, if it were to develop at all. The case of *D. multilobatus* appears to be intermediate between *D. ornitheios*, as described by Meggitt, on the one hand, and *D. campylometra* and *D. delachauxi* on the other. Here the parauterine

tissue is present in fully gravid segments but very sparingly as shown in sections, and furthermore, it is evenly dispersed over the entire uterus. This condition appears to be analogous to that which Joyeux et al noted for species having a parauterine organ which has not reached its full development.

In view of the above discussion on the parauterine organ in *Deltokeras*, it is suggested that possibly here is a group of cestodes that represents a transitional stage between those genera having no parauterine organ and *Biuterina* and related genera having a well developed and specialized one.

The species may be differentiated by means of the following key.

Key to the species of *Deltokeras*.

1. Genital pores irregularly alternate; rostellar hooks 14-15 $\mu$ long; 15-17 testes; ovary bilobed.
*Deltokeras delachauxi* Hsü, 1935

Genital pores unilateral 2

2. Ovary with 8-9 long pedunculated lobes; hooks 17-19 $\mu$ long; 12-16 testes.
*Deltokeras multilobatus* n. sp.

Ovary not with long pedunculated lobes but sac-shaped 3

3. Hooks 27-31 $\mu$ long, 80 in number, dorsal root longer than ventral root or blade, knob on dorsal or ventral roots relatively small in comparison to size of hook.
*Deltokeras ornitheios* Meggitt, 1927

Hooks 10-15 $\mu$ long, 46 in number, dorsal and ventral roots of equal length and with knobs which are extremely large in comparison to size of hook.
*Deltokeras campylometra* Joyeux, Gendre and Baer, 1928

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## EXPLANATION OF THE PLATE.

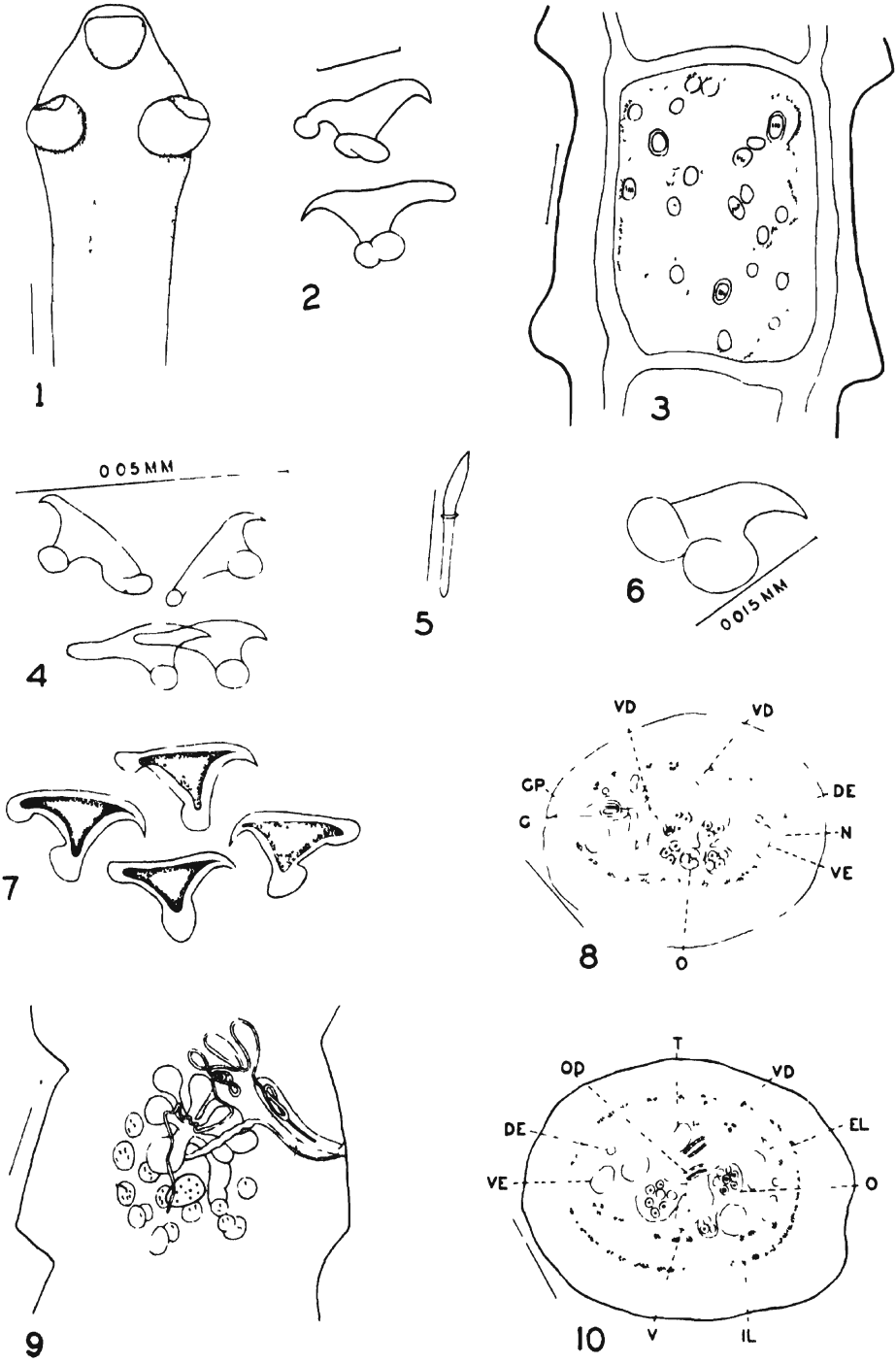
### PLATE I.

All drawings made with the aid of a camera lucida. Scale of enlargement 0.1 mm. except in Figs. 2 and 5, where it is 0.01 mm. or as otherwise noted.

Fig. 1. Scolex of *Deltokeras multilobatus.*
Fig. 2. Rostellar hooks of *D. multilobatus.*
Fig. 3. Frontal section of gravid proglottid showing uterus with parauterine tissue. Partly reconstructed.
Fig. 4. Hooks of *D. ornitheios.* After Meggitt, 1927.
Fig. 5. Hook from intrauterine embryo of *D. multilobatus.*
Fig. 6. Hook of *D. campylometra.* After Joyeux, Gendre & Baer, 1928.
Fig. 7. Hooks of *D. delachauxi.* After Hsü, 1935.
Fig. 8. Cross-section through anterior portion of mature segment.
Fig. 9. Mature segment showing reproductive glands.
Fig. 10. Cross-section taken near middle of same segment as in Fig. 8.

Key to abbreviations.

| | |
|---|---|
| C | cirrus |
| CP | cirrus pouch |
| DE | dorsal excretory canal |
| EL | external longitudinal muscle |
| IL | internal longitudinal muscles |
| N | nerve |
| O | ovary |
| OD | oviduct |
| T | testes |
| V | vitelline gland |
| VD | vas deferens |
| VE | ventral excretory canal |




DELTOKERAS MULTILOBATUS, A NEW SPECIES OF CESTODE FROM THE TWELVE WIRED BIRD OF PARADISE SELEUCIDES M. MELANOLEUCUS (DAUDIN).

# 22.

## The Urinary Nitrogen Distribution of Representative Members of the Carnivora.

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(Text-figures 1-5).

One of the many interesting chapters in our knowledge of comparative biochemistry is that dealing with the form in which nitrogen is excreted from the animal body. An excellent perspective of a considerable number of the quantitative investigations in this field is provided in a table compiled by Needham (1931, pp. 1139-41). With few exceptions among both the invertebrates and vertebrates, ammonia, urea and uric acid have been shown to account for the bulk of the nitrogen eliminated, and according to Needham (1931, p. 1132), these three compounds appear to be the only substances "which are available in the animal kingdom for carrying away the nitrogenous waste resulting from protein breakdown." There are to be found in the urine, of course, quite a number of other nitrogenous constituents, but their combined nitrogen content is usually only a small fraction of the total nitrogen. Baldwin has summarized the salient facts concerning the excretory products of protein and purine metabolism in vertebrates as shown in Table I.

The fascinating evolutionary aspects of the biochemical differences briefly surveyed above, though outside the province of this paper, have been dealt with in several contributions (cf. Needham (1929; 1931, p. 1132), Smith (1932; 1935), Baldwin (1937) and Florkin (1935)).

The mammalian class exhibits a monotonous regularity in the employment of urea as the chief end-product of nitrogen metabolism. This holds even for the egg-laying mammal, *Echidna aculeata* (Neumeister (1898); Robertson (1923); Mitchell (1931)). One variation of note in the urinary nitrogen partition pertains to the excretion of hippuric acid. Though the synthesis of this substance is by no means limited to the herbivorous animals, the latter, after ingesting large amounts of hay and other benzoic acid-yielding feed, may excrete a considerable fraction of the total nitrogen as hippuric acid. Again, the diet of the herbivora is often predominantly base-forming and this leads apparently to a diminished production and elimination of nitrogen in the form of ammonium salts. A variation of more fundamental significance, inasmuch as it is related to specific metabolic processes rather than to dietary habits, is that evinced by various mammalian species in the extent of oxidation of the purine bodies before elimina-

* The authors wish to acknowledge the generous cooperation of the late Dr. Charles V. Noback in the early part of this investigation.

TABLE I.

After Baldwin (1937, p. 61).†

| | *End-product of* | |
|---|---|---|
| | *Protein metabolism* | *Purine metabolism* |
| Mammalia | Urea | Allantoin‡ |
| Aves | Uric acid | Uric acid |
| Reptilia: | | |
| Snakes, lizards | Uric acid | Uric acid |
| Turtles | Urea | Allantoin ? |
| Amphibia | Urea | Urea |
| Pisces | | |
| Elasmobranchii | Urea | Urea |
| Teleostei | Ammonia | Urea |

† From "An Introduction to Comparative Biochemistry," by Ernest Baldwin, by permission of Cambridge University Press, London.
‡ Uric acid in man, higher apes and Dalmatian dog.

tion. Man, the anthropoid apes, and to a degree the Dalmatian dog, excrete uric acid as an end-product of purine metabolism whereas the remaining mammalian forms, as far as data are available to show, carry the oxidation a stage further to allantoin. With regard to the excretion of creatinine and creatine, Hunter (1928, pp. 104-5) states that creatinine is never absent from the urine of mammals and further that "it is probable . . . that every adult mammal, when placed under standard conditions upon a creatine-free diet, excretes only creatinine."

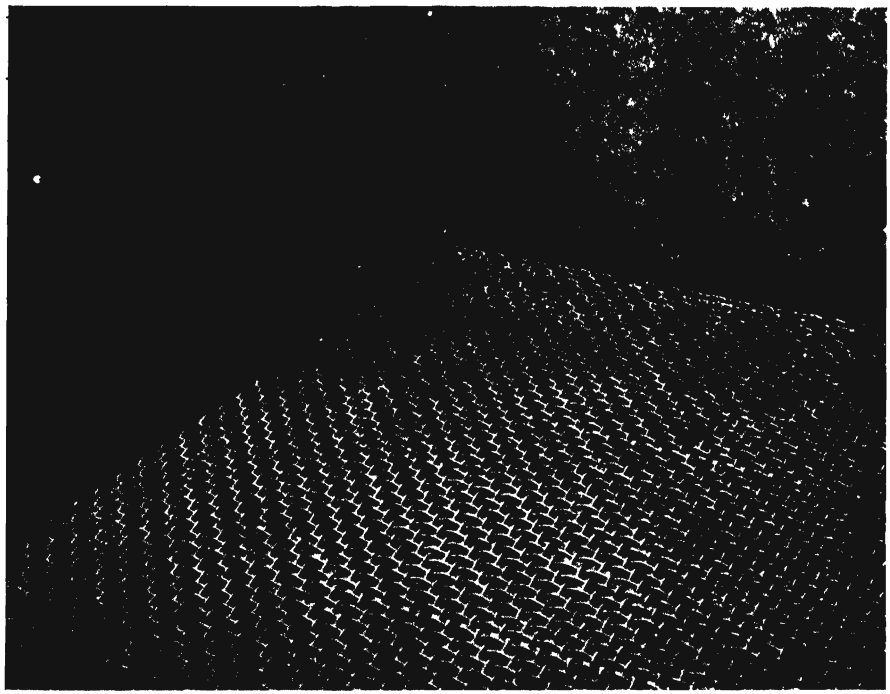
The nitrogen distribution in the urine of the order Carnivora, as represented by the domestic cat and dog, conforms to what has been said above concerning the general character of mammalian urine. Urea is the dominant nitrogen-containing component, and the main product of purine metabolism is allantoin. Studies of the nitrogenous substances in the urine of some of the wild members of the Carnivora date back to the early part of the nineteenth century (see Milne Edwards (1862)) but these studies naturally were limited in scope and accuracy. Investigations dealing with non-domesticated Carnivora and involving the use of modern methods of urine analysis, insofar as revealed by our search of the literature, are as follows: of the coyote by Swain (1905) and by Hunter & Givens (1910-11); of the fox and coyote by Hawk (1910-11); of the weasel, raccoon dog (*Nyctereutes viverrinus*), tiger, leopard and hyena by Fuse (1925); and of the seal by Smith (1936)[1]. Also, Hunter and associates (1914 and 1920) showed that the uricolytic index[2] of the raccoon, black bear, badger, coyote and dingo, as of the domestic cat and dog, is high, the excretion of allantoin being in large excess over that of uric acid. Without going further into a detailed analysis of these contributions, it may be stated that they all point to a similar pattern in the urinary nitrogen distribution of the Carnivora. In contrast to this picture of uniformity was the finding of S. R. Benedict (1916) that the pure strain Dalmatian coach dog excretes an unusual amount of its purine end-product as uric acid. The uricolytic index is in

[1] Swain & Rakestraw (1928) reported the presence of uric acid in the urine of the sea lion.
[2] This term is defined on a subsequent page.

**Text-figure 1.**
Exterior view of metabolism cage.

the neighborhood of 30-40, intermediate between the much higher values found for other Carnivora and the very low figures in the case of man and anthropoid apes. This rather strange aberration in an otherwise fairly uniform series indicates that it is at least possible that other similar instances of significant variation in urinary nitrogen partition may await detection—even among the different families and species of one order as, for example, the Carnivora.

We were therefore interested, when the opportunity arose in connection with experiments initiated for the purpose of studying the kynurenic acid excretion by representative species of the Carnivora, in determining as well the nitrogen distribution of the urines of these animals. In our work, analyses were made for total, urea, ammonia, creatinine and creatine nitrogen, and as far as facilities would permit, for allantoin and uric acid nitrogen. The volume of urine voided in a given period, generally 24 or 48 hours, and the specific gravity of each sample, have a'so been recorded. As will be seen, some of the species included in our study have been investigated before. However not all of the previous analyses were made on samples collected over a definite period, and in some cases the analyses were not sufficiently extensive to account for the most of the urinary nitrogen.

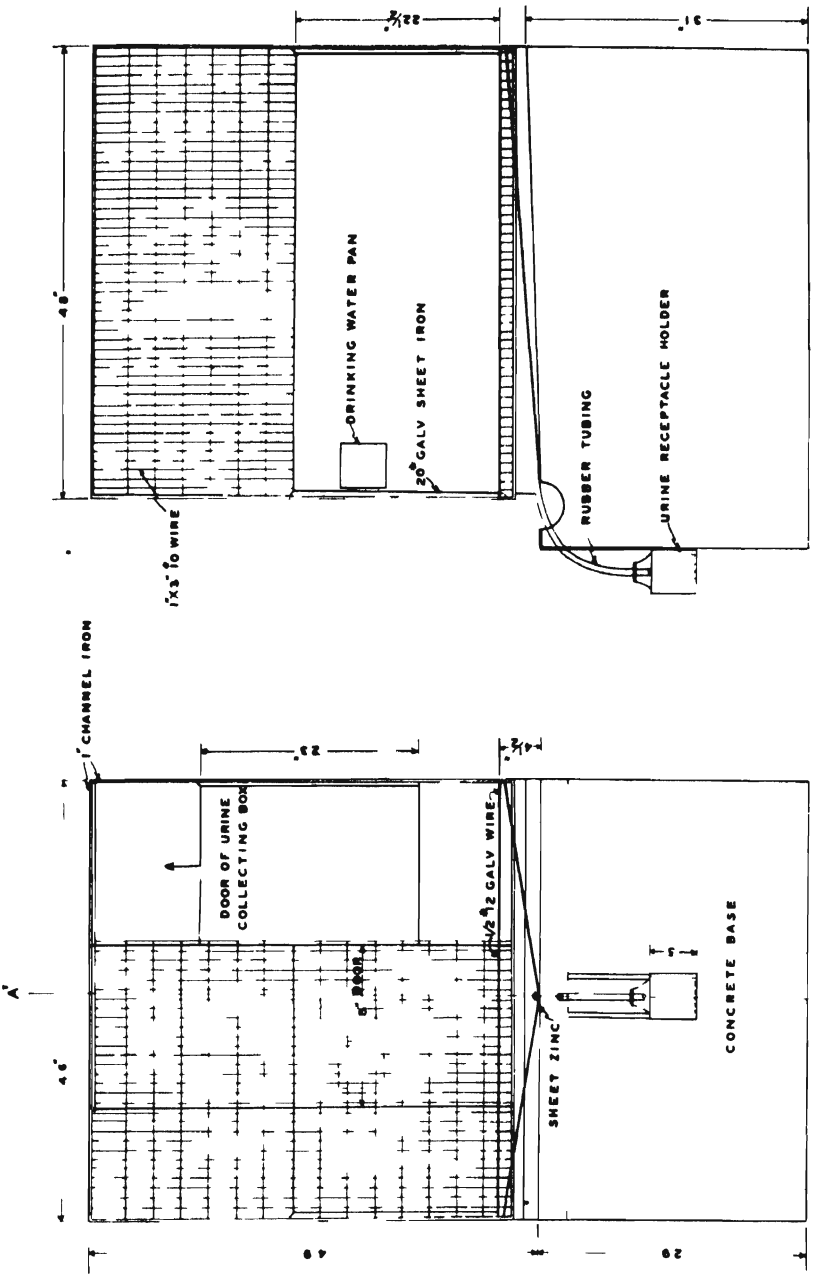


Text-figure 2.
Interior view of metabolism cage.

## EXPERIMENTAL.

For the collection of urine, the genets and the skunk were confined in a small metabolism cage of the type ordinarily employed with rabbits. For the remainder of the animal subjects, excepting the bear, a special cage was constructed by modifying one of the cages available at the Zoological Park Hospital. The original cage is about 4 feet along each edge and is constructed of heavy wire mesh mounted on angle iron and is bolted to an elevated concrete floor. The alteration of this cage for our purpose was accomplished by building and inserting a snugly fitting unit consisting of a urine collecting box with deep side walls to insure against loss of urine, and with a heavy false bottom to protect the lighter solid zinc metal bottom below and to hold back fecal material. The false bottom in position rests on lugs but may be raised free of these and, if desired, removed from the cage, to facilitate cleaning. All seams of the urine collecting box are soldered so that except for the door it is water tight. The door, like the sidewalls, is constructed of galvanized iron. It is inserted vertically through channels in the adjacent side walls and extends to a point below the door sill and also below the false bottom. This door is contiguous with the door of the cage proper. The complete metabolism cage is illustrated in Text-figs. 1, 2 and 3. It has served excellently for animals ranging in size from the raccoon and fox to the cheetah and hyena.

In order to collect urine from the Tibetan bear, it was necessary to prepare still another cage (see Text-figs. 4 and 5). This was effected by placing a close-fitting, shallow, flat, galvanized iron pan on the bottom of a heavily constructed crate ordinarily used for shipping bears. This pan extends from the rear of the crate about three-quarters of the way forward



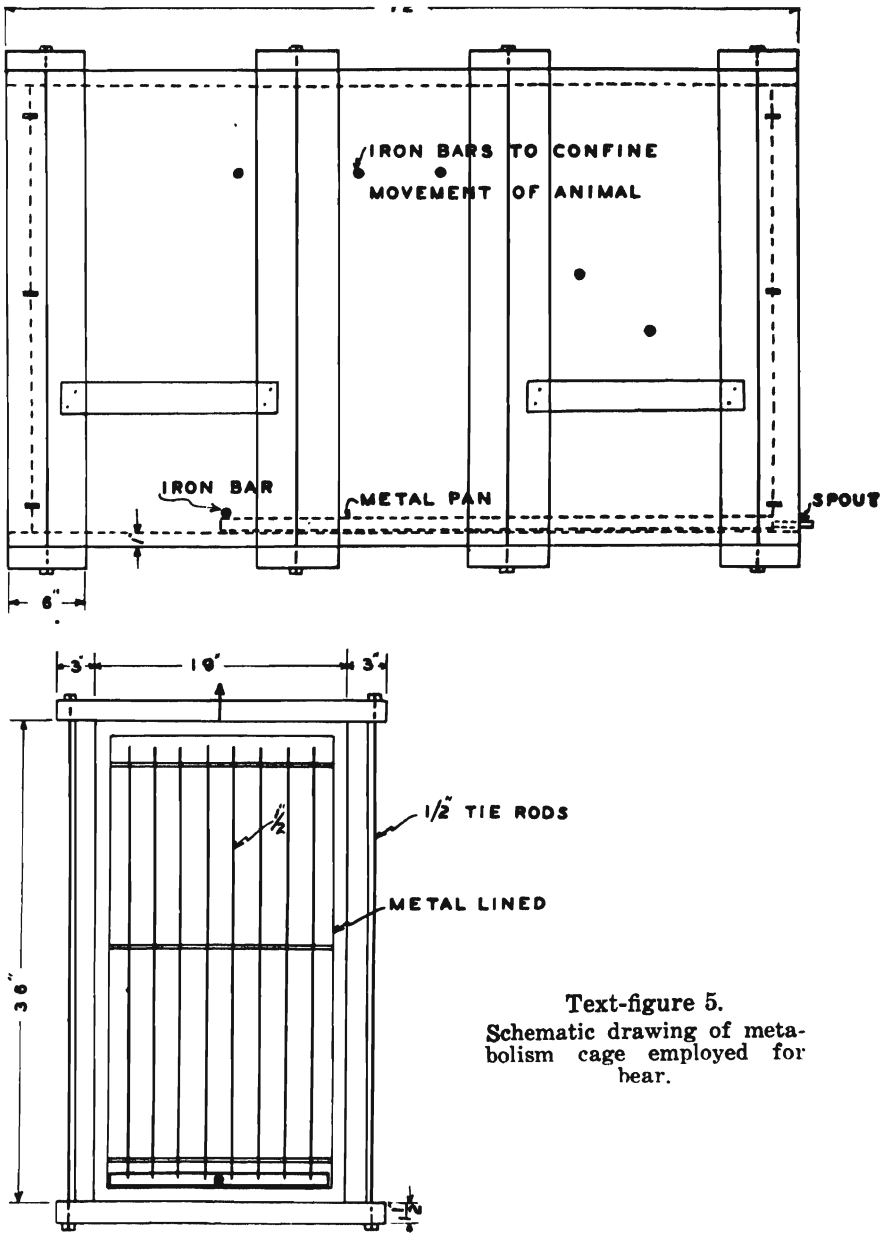

Text-figure 3
Schematic drawing of metabolism cage

Text-figure 4.
Photograph of cage with pan, used in metabolism experiments on bear.

so that with a male animal no urine is lost. In use, the cage is placed on blocks with the front end slightly elevated thus to promote the flow of the urine to the rear of the pan through the tubulature to the collecting bottle. By having the urine collecting pan of such length as not to extend forward beneath the head of the bear, it is possible to supply water periodically without danger of its being spilled into the urine. The predilection of our bear subject for using his front paws to bend up the front end of the urine-collecting pan was thwarted by inserting a heavy iron bar laterally through the cage and just over the front end of the pan.

All of the animals studied by us were ingesting diets composed entirely or largely of meat or of fish. Water was supplied *ad libitum* unless the individual exhibited a persistent tendency to dislocate the water container with danger of diluting the urine. In this event, drinking water was given at intervals during the day. The sea lion was generally permitted to secure his supply of water from his generous daily quota of fresh (frozen) fish However, in order to guard against physical discomfort of the sea lion while under experiment, the animal was occasionally moistened with a fine mist of water from an insect gun, or wet sheets were hung about the cage.

All specimens of urine, with the exception of one which was secured from the bladder at autopsy, were collected from the metabolism cages directly into bottles containing toluene. The samples were filtered at room temperature to remove any hair or occasional slight contamination of fecal material, and then immediately stored under toluene at a temperature of 5° C. preliminary to analysis. The analytical procedures employed were as follows: total nitrogen by the Kjeldahl method; urea plus ammonia nitrogen by the urease-aeration-titration procedure of Van Slyke & Cullen (1914 and 1916); ammonia by the method of Folin & Bell (1917); creatinine by Folin's colorimetric method (see Hawk & Bergeim (1937)); creatine according to Benedict (1914); allantoin by Larson's method (1932); and uric acid by the indirect precipitation method of Benedict & Hitchcock




Text-figure 5.
Schematic drawing of metabolism cage employed for bear.

(1915). With the advice of Dr. Benedict, we incorporated two modifications of the procedure for determination of uric acid. The arsenophosphotungstate reagent of Benedict (1922) was substituted for that of Folin & Denis, and 15% of urea was added to the sodium carbonate solution to prevent turbidity (cf. Folin (1930) and Christman & Ravwitch (1932)). Acidity of the urines was tested with litmus paper, and the specific gravity was determined by means of a urinometer.

## Discussion.

The results of our experiments on fifteen different species representing eight different families of the Carnivora are presented in Tables II and III. It is to be emphasized that the information given relative to the diets is, as stated, a rough estimate. The food was ordinarily not weighed and the amount of food intake was therefore subject to fluctuation. The diet compositions show nevertheless that all the animals were on a comparable basis in the ingestion of a high-protein diet. In connection with a study of kynurenic acid excretion to be reported elsewhere, tryptophane was administered in some of the experiments. Inasmuch as this procedure did not appear to alter the distribution of nitrogen, these experiments have been included in the tables. Again, it should be pointed out that the figures for urine volume and total nitrogen are for the stated collection period. In the case of the genet, for example, the values (Table II) are for two animals over a period of 45 hours. Furthermore, the urine volumes are those collected from the cage and cannot be taken as necessarily representing the exact amounts of urine produced during the experimental periods. The urines with few exceptions were acid to litmus. The exceptions were doubtless the result of some conversion of urea to ammonia despite the precautions taken to prevent bacterial action.

The distribution of nitrogen is much the same for all species studied by us, and is generally similar to that reported in previous experiments on members of the Carnivora. The majority of the values for the different nitrogenous constituents, expressed as nitrogen in per cent. of total nitrogen, fall within the following ranges: urea, 80 to 86, ammonia, 2 to 5, urea plus ammonia, 83 to 89, creatinine, 1 to 2, creatine, 1.5 to 3, allantoin, 2 to 4, uric acid, 0.05 to 0.20. The extent of deviation from these ranges may be seen by inspection of the tables. The few values for ammonia nitrogen which are over 7% of the total nitrogen are very likely the result of some bacterial conversion of urea, inasmuch as either the urine was actually alkaline (Exp. 37, Table II) or there had been opportunity for soiling of the cage during the immediately preceding collection periods (Exps. 33a, 29a, 35c, and 32a, Table III). A part of our program was carried out during warm weather which, of course, would be especially conducive to ammonia production. However, in no instance was there evidence of any extensive decomposition of the urine specimen. The relatively low percentages for urea and the corresponding elevated values for some of the other constituents in the bear experiments (Table III) may owe their explanation to a relatively lower nitrogen intake or to the storage of nitrogen.

The uricolytic index, that is, the per cent. allantoin nitrogen of total allantoin and uric acid nitrogen excreted, was determined by Hunter and his co-workers on animals which were either fasting or ingesting a diet low in purines. The purpose, of course, was to confine the criterion to the endogenous purine metabolism and thereby to eliminate the variable and disturbing influence of the exogenous metabolism of purines in the diet. Nevertheless, Hunter & Givens (1910-11) in their early studies on the coyote found that when the animal was ingesting a meat diet supplying relatively considerable quantities of purine material, the allantoin nitrogen constituted more than 95% of the total allantoin and purine (including uric acid) nitrogen excreted. The authors state, "Whether, therefore, endogenous or exogenous purines be concerned, it is evident that among the end-products of their metabolism allantoin plays an enormously preponderating part." What Hunter & Givens report in regard to the allantoin-uric acid relationship for the coyote ingesting a meat diet, we have found essentially to be true also for the fox, dingo, cheetah, serval, civet, badger, Tibetan and grizzly bears, raccoon and sea lion, all likewise ingesting a diet wholly or mainly of flesh. In the case of the grizzly bear, the allantoin nitrogen constituted 84% of the total allantoin and uric acid nitrogen excreted, in the other cases, the values were 92% or higher. Fuse found a similar pre-

ponderance in the allantoin nitrogen over the uric acid nitrogen excreted under comparable conditions by the weasel, raccoon dog, leopard and hyena. The previously collected data of Hunter and associates showed that the uricolytic index, secured under conditions of endogenous metabolism, ranged from 94 to 98 for the raccoon, black bear, badger, cat, coyote, dog and dingo.

The most or all of the creatine and a part of the creatinine excreted by the animals in our experiments were derived presumably from the content of these substances in the meat and fish of the diets ingested. The creatine nitrogen happened to exceed the creatinine nitrogen more often than was the reverse. In continuing the search for species or group differences in nitrogen metabolism, it might be worth while to consider the elimination of meat from the diet, or even the administration of a uniform protein-free diet such as has been employed by Terroine and associates (1933) in studies on a group of domesticated animals. In many instances, the endogenous metabolism may be expected to be more characteristic than the combined endogenous and exogenous metabolisms.[3]

## SUMMARY.

Data on the urinary nitrogen distribution are reported for the coyote, fox, dingo, wolf, hyena, cheetah, serval, civet, genet, badger, skunk, Tibetan bear, grizzly bear, raccoon and sea lion.

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[3] We wish also to report here an analysis of the urine of a member of another order. A male pigmy hippopotamus (*Choeropsis liberiensis*) weighing 66 kg. died (9/27/38) from pulmonary abscesses. 210 cc. of urine (Sample No. 38) were removed from the bladder. The specimen was acid to litmus, had a specific gravity of 1.011, and contained 2.33 gm. of nitrogen distributed as follows: urea 77.2, ammonia 5.3, creatinine 1.1, and creatine 1.2%.

TABLE II.

Distribution of Nitrogen in the urine of the Carnivora (Felidae, Viverridae, Hyaenidae and Canidae).

| *Family, common name, species* | *Weight and sex* | *Exp. No. and date* | *Daily diet* (rough estimate)* | *Period of collection* | *Urine volume and reaction* | *Specific gravity at 15.6°* | *Total N* | *Distribution of N in per cent of total N* | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | *Urea N* | *Ammonia N* | *Creatinine N* | *Creatine N* | *Allantoin N* | *Uric acid N* | *Undetermined N* |
| | *Kg.* | | *lb.* | *hr.* | *cc.* | | *gm.* | | | | | | | |
| **Felidae** | | | | | | | | | | | | | | |
| Cheetah (*Acinonyx jubatus*) | 40.5♂ | 12 10/28/36 | Meat 3 to 4 | 24 | 1360 (acid) | 1.038 | 47.7 | 82.5 | 2.4 | 1.7 | 1.3 | 2.3 | 0.06 | 9.7 |
| Cheetah (same animal) | " | 13 10/29/36 | " " 5T | 24 | 1300 (acid) | 1.042 | 51.5 | 80.5 | 2.4 | 1.6 | 2.3 | 2.2 | 0.07 | 10.9 |
| Serval (*Felis serval*) | 8.1♂ | 31-31a 6/29/38 | Meat 2/3 | 48 | 118 (acid) | 1.070 | 7.93 | 85.6 | 3.2 | 2.7 | 1.4 | 2.0 | 0.08 | 5.0 |
| Serval (*Felis serval*) | 9.1♀ | 30 12/4/37 | " " 5T | 48 | 390 (acid) | 1.067 | 22.2 | 85.1 | 2.7 | 1.5 | 2.0 | | 0.04 | |
| **Viverridae** | | | | | | | | | | | | | | |
| Civet (*Civettictis civetta*) | 7.6♂ | 34 7/1/38 | Meat ½ | 24 | 76 (acid) | 1.042 | 3.15 | 84.1 | 5.2 | 2.3 | 0.6 | 2.4 | 0.04 | 5.4 |
| Civet (same animal) | " | 34a 7/2/38 | " " | 24 | 112 (acid) | 1.051 | 5.35 | 87.1 | 3.2 | 2.1 | 1.7 | 2.8 | trace | 3.1 |
| Civet (*Civettictis civetta*) | 8.3♂ | 22 10/22/37 | Meat 1 6T | 45 | 400 (acid) | 1.049 | 17.1 | 82.9 | 3.6 | 1.6 | 2.2 | | | |
| Genet 2 animals (*Genetta ludia*) | † 1.8 for pair | 21 10/15/37 | Meat ½ 3T | 45 | 155 (acid) | 1.050 | 7.40 | 85.4 | 2.6 | total = 2.5 | | | | |
| **Hyaenidae** | | | | | | | | | | | | | | |
| Hyena (*Hyaena hyaena*) | 49.1♀ | 27 11/24/37 | Meat 2 to 3 6T | 24 | 640 (acid) | 1.072 | 41.1 | 86.2 | 2.9 | 1.3 | 1.9 | | 0.056 | |
| Hyena (same animal) | " | 27a 11/25/37 | Meat 2 to 3 | 24 | 450 (acid) | 1.077 | 33.2 | 86.3 | 2.2 | 1.3 | 1.8 | | 0.054 | |
| **Canidae** | | | | | | | | | | | | | | |
| Coyote (*Canis latrans*) | † 9.6♂ | 9 10/13/36 | Meat 1 to 2 | 24 | water spilled (acid) | | 38.6 | 86.5 | 3.2 | 0.60 | 1.0 | 1.4 | 0.13 | 7.2 |
| Coyote (same animal) | " | 10 10/14/36 | Meat 1 to 2 4T | 24 | 560 (acid) | | 30.1 | 86.1 | 2.8 | 0.93 | 1.4 | 1.6 | 0.12 | 7.1 |
| Red fox (*Vulpes fulva*) | 4.1♂ | 17 11/19/36 | Meat ½ & other items | 48 | 155 (acid) | 1.051 | 8.3 | 83.3 | 3.9 | 1.8 | 2.1 | 2.2 | 0.16 | 6.5 |
| Red fox (same animal) | " | 18 11/21/36 | " " 4T | 48 | 300 (acid) | 1.051 | 15.8 | 78.6 | 5.3 | 1.1 | 2.2 | 2.0 | 0.11 | 10.7 |
| Dingo (*Canis dingo*) | 13.1♀ | 37 7/12/38 | Meat 1 | 24 | 190 (alkaline) | 1.030 | 7.76 | 82.2 | 7.2 | 1.4 | 1.4 | 3.2 | 0.12 | 4.5 |
| Wolf (*Canis nubilus*) | 32.8♂ | 23 10/27/37 | Meat 2 to 3 6T | 24 | 1300 (acid) | 1.038 | 41.7 | 90.3 | 2.7 | 1.2 | 2.5 | | | |
| Wolf (same animal) | " | 23a 10/28/37 | Meat 2 to 3 | 17 | 500 (acid) | 1.039 | | | | | | | | |

† Specimens not fully grown; all remaining subjects were adult.
* The symbol T is for tryptophane administered in some of the experiments in connection with another study; see text. The number preceding the symbol indicates the amount in gm. given during the entire period whether 24 or 48 hours, etc.

## TABLE III.

Distribution of Nitrogen in the urine of the Carnivora (Ursidae, Procyonidae, Mustelidae and Otariidae).

| *Family, common name, species* | *Weight and sex* | *Exp. No. and date* | *Daily diet* (rough estimate)* | *Period of collection* | *Urine volume and reaction* | *Specific gravity at 15.6°* | *Total N* | *Distribution of N in per cent of total N* | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | *Urea N* | *Ammonia N* | *Creatinine N* | *Creatine N* | *Allantoin N* | *Uric acid N* | *Undetermined N* |
| | *Kg.* | | *lb.* | *hr.* | *cc.* | | *gm.* | | | | | | | |
| **Ursidae** | | | | | | | | | | | | | | |
| Tibetan bear (*Ursus arctos pruinosus*) | 102♂ | 35a 7/1/38 | Meat 1½ Fish ½ Bread 2 Apples 2 | 10 8 A.M. to 6 P.M. | 910 (acid) | 1.010 | 5.09 | 75.2 | 6.7 | 5.2 | 2.3 | 7.6 | 0.33 | 2.7 |
| Tibetan bear (same animal) | " | 35b 7/1/38 | " " | 6 6 P.M. to 12 P.M. | 1650 (acid) | 1.003 | 2.64 | | | | | | | |
| Tibetan bear (same animal) | " | 35c 7/2/38 | " " | 8 12 P.M. to 8 A.M. | 1125 (acid) | 1.013 | 7.43 | 72.0 | 8.1 | 5.7 | 1.4 | 5.7 | 0.19 | 6.9 |
| Tibetan bear (same animal) | 136♂ | 28 11/25/37 | Meat 2 Few apples, tomatoes. 7T | 23 | 1300 (neutral) | 1.019 | 14.7 | 58.0 | 5.0 | 6.8 | 6.9 | | 0.25 | |
| Tibetan bear (same animal) | " | 28a 11/26/37 | Meat 2 Few apples, tomatoes. | 25 | 1080 (neutral) | 1.027 | 20.0 | 66.4 | 3.4 | 4.9 | 5.5 | | 0.14 | |
| Grizzly bear (*Ursus horribilis*) | 173♀ | 20 12/3/36 | Animal destroyed because it was vicious. Urine sample taken from bladder. | | 210 (acid) | 1.012 | 1.73 | 66.4 | 4.7 | 7.2 | 1.1 | 3.8 | 0.75 | 16.0 |
| **Procyonidae** | | | | | | | | | | | | | | |
| Raccoon (*Procyon lotor lotor*) | 6.3♂ | 32 6/21/38 | Meat 1/3 | 24 | 175 (alkaline) | 1.026 | 3.13 | 82.0 | 3.8 | 1.3 | 2.1 | 4.4 | 0.35 | 6.1 |
| Raccoon (same animal) | " | 32a 6/22/38 | " | 24 | 193 (acid) | 1.035 | 5.40 | 79.2 | 7.6 | 1.4 | 0.3 | 4.5 | 0.28 | 6.7 |
| Raccoon (*Procyon lotor lotor*) | 6.8♂ | 26 11/18/37 | Meat 1/3 & banana 4T | 48 | 320 (acid) | 1.036 | 9.48 | 79.6 | 3.2 | 1.5 | 3.3 | | 0.26 | |
| **Mustelidae** | | | | | | | | | | | | | | |
| European badger (*Meles meles*) | 8.1♀ | 33 6/24/38 | Meat ½ | 24 | 185 (acid) | 1.031 | 5.35 | 84.0 | 5.0 | 1.1 | 2.5 | 3.3 | 0.09 | 4.0 |
| European badger (same animal) | " | 33a 6/25/38 | " | 24 | 301 (acid) | 1.031 | 4.56 | 79.0 | 7.2 | 1.8 | 4.1 | 5.0 | 0.13 | 2.8 |
| European badger (same animal) | 8.3♀ | 29 11/30/37 | Meat 1 5T | 24 | 440 (acid) | 1.033 | 11.46 | 81.4 | 4.1 | 0.87 | 2.7 | | | |
| European badger (same animal) | " | 29a 12/1/37 | Meat 1 | 24 | 590 (neutral) | 1.025 | 13.03 | 78.1 | 7.5 | 0.63 | 1.8 | | | |
| Skunk (*Mephitis mephitis*) | 2.0♀ | 12/1/37 | Ate little or nothing | Random sample | 25 (slightly alkaline) | 1.037 | 0.75 | total = 87.7 | | | 1.7 | 2.4 | | |
| **Otariidae‡** | | | | | | | | | | | | | | |
| Sea lion (*Zalophus californianus*) | 93.4♀ | 36 7/6/38 | Butterfish 4 to 5 | 24 | 600 (acid) | 1.030 | 15.81 | 82.9 | 1.3 | 1.5 | 1.3 | 4.4 | 0.08 | 8.5 |
| Sea lion (*Zalophus californianus*) | † 54.5♂ | 24 11/2/37 | Butterfish 4 to 5 6T | 26 | water spilled (acid) | | 42.9 | 84.5 | 3.1 | 1.6 | 2.6 | | 0.07 | |
| Sea lion (same animal) | " | 24a 11/3/37 | Butterfish 4 to 5 | 17 | 345 (acid) | 1.043 | 12.94 | 80.9 | 2.7 | 2.3 | 1.5 | | | |
| Sea lion (same animal) | " | 25 11/9/37 | " " 6T | 24 | 930 (acid) | 1.056 | 44.4 | 78.7 | 2.3 | 1.2 | 3.0 | | | |
| Sea lion (same animal) | " | 25a 11/10/37 | Butterfish 4 to 5 | 24 | 330 (acid) | 1.054 | 17.69 | 84.3 | 3.7 | 1.1 | 2.1 | | 0.08 | |

† Specimens not fully grown; all remaining subjects were adult.
* The symbol T is for tryptophane administered in some of the experiments in connection with another study; see text. The number preceding the symbol indicates the amount in gm. given during the entire period whether 24 or 48 hours, etc
‡ Although the Otariidae and allied families are now considered as having ordinal rank, they are here treated as in previous classifications, as members of the Carnivora.

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# 23.

# A New Nematode, *Ascaris schroederi,* from a Giant Panda, *Ailuropoda melanoleuca.*

ALLEN MCINTOSH

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(Text-figures 1 & 2).

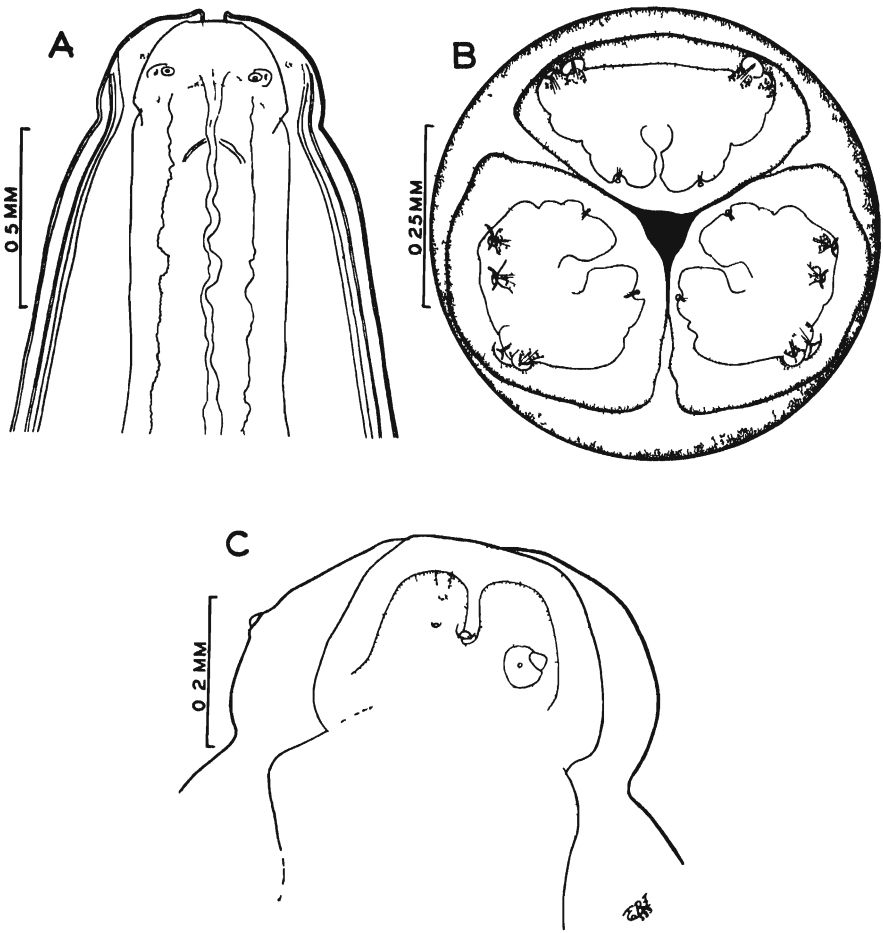
On June 29, 1939, Dr. Charles R. Schroeder, New York Zoological Park, forwarded to the Bureau of Animal Industry some specimens of ascarids from a giant panda, *Ailuropoda melanoleuca,* for identification. Dr. Schroeder stated in correspondence that the giant panda, an immature male, was received May 2, 1939, from West China Union University, Chengtu, Szechwan Province, China. The animal had repeatedly passed *Ascaris* eggs in its stools, and on June 27 it passed several roundworms. These specimens were found on examination to represent 4 males and 5 females of what is believed to be a new species of the genus *Ascaris.*

### ***Ascaris schroederi*** n. sp.

Length 9.75 cm. (male) to 12.5 cm. (female), breadth 2 mm. (male) to 2.6 mm. (female). Body white, tapering toward both ends; cuticula striated. Head (Text-fig. 1, A, C) with slight neck-like constriction at base of the three simple lips; interlabia absent. Dorsal lip apparently somewhat shorter than ventrolateral lips. Cephalic sensory organs (Text-fig. 1, B) similar to those figured by Chitwood & Chitwood (1938, An introduction to Nematology, p. 60), for *Ascaris lumbricoides.* Lip pulp divided anteriorly into two lobes; dentigerous ridges not conspicuous. Esophagus about 1/13 of body length, broadest near posterior end, without ventriculus. Neither esophageal nor intestinal diverticula present.

*Male*: Tail (Text-fig. 2, E) terminating in small button-like protuberance of parenchymatous origin; cloaca about 510$\mu$ from posterior end. Preanal papillae numerous, about 70 pairs situated in two rows; the proximal portion of the preanal group of papillae are fairly uniform in arrangement, while those more distant from the cloaca are often situated at irregular intervals, and with an occasional one out of line. A pair of double adanal papillae present, lateral and posterior to cloaca. Four pairs of postanal papillae present on middle third of tail, the anterior pair being double; of the remaining 3 pairs of postanal papillae the middle pair is the smallest. Spicules equal, about 600$\mu$ long, by 80$\mu$ wide anteriorly; they taper gradually, ending rather bluntly. A number of digitate processes, about 10$\mu$ long, present on the elevated anterior and posterior lips of cloaca.

*Female*: Tail (Text-fig. 2, D) tapering gradually but terminating bluntly; anus situated 1.42 mm. from end of tail. A pair of papillae (phas-




Text-figure 1.

*Ascaris schroederi* n. sp. **A**—Head, dorsal aspect; **B**—Head, cephalic aspect; **C**—Head, right lateral aspect.

mids) located subventrally about 350$\mu$ from end of tail. Vulva about 1/3 of body length from anterior end. Eggs (Text-fig. 2, F) mammillated, 75$\mu$ long by 55$\mu$ wide.

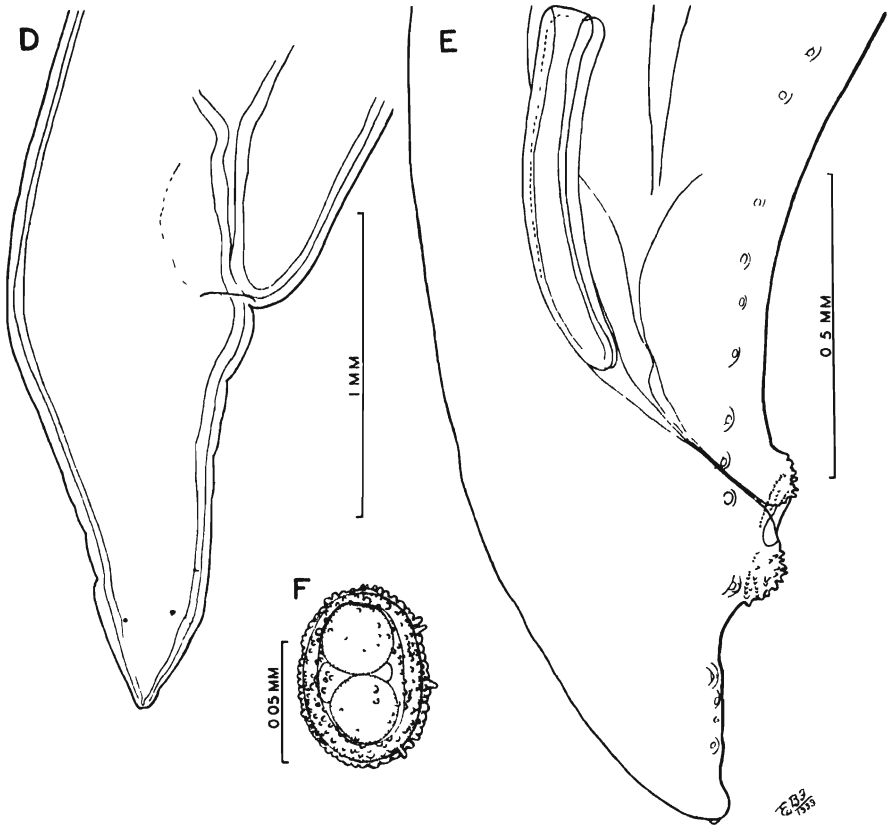
*Host*: Giant panda, *Ailuropoda melanoleuca*.

*Location*: Intestine (passed with stool).

*Locality*: New York Zoological Park. (Host recently received from Chengtu, Szechwan Province, China).

*Specimens*: U. S. N. M. Helm. Coll. No. 44059 (holotype, male, and allotype, female) and No. 44060 (paratypes, 3 males and 4 females).

Of the species remaining in the genus *Ascaris*, the new species appears to be more closely related to *Ascaris columnaris* Leidy, 1856. The males of these two species, however, may be separated by the greater number of preanal papillae present in *A. schroederi* n. sp., which are approximately twice the number reported for *A. columnaris*. The pronounced cuticular digitate




Text-figure 2.

*Ascaris schroederi* n. sp. **D**—Tail, female, lateral aspect; **E**—Tail, male, lateral aspect; **F**—Egg.

processes on the anterior and posterior lips of the cloaca also distinguish the new species from the other members of the genus. The females of *A. schroederi* and *A. columnaris* differ in the position of the vulva and the anus. In *A. schroederi* the anus is removed from the tail almost twice the distance as in *A. columnaris;* the vulva in the former is situated about 1/3 of the length of the body from the anterior end, while in the latter it is situated at about ¼ of the length of the body from the anterior end. The new species may be further separated from *A. columnaris* by the length of the esophagus in proportion to the body length; the esophagus in *Ascaris schroederi* is about 1/13 of the body length as compared with 1/30 as given by Goodey & Cameron (1923, *Jour. Helminthol.* 1:1-8) for *Ascaris columnaris.*

# 24.

# A Study of the Yellow-lipped Snake, *Rhadinaea flavilata* (Cope).

EDMOND MALNATE
*Zoological Society of Philadelphia*

(Plate I; Text-figure 1).

Since the original description of *Rhadinaea flavilata* in 1871 by E. D. Cope, little has been published about this rather uncommon snake. While a few facts have appeared in literature, no complete study of the species has been made. The present author is fully aware that his work is by no means complete; however, this study is a review of previous knowledge, plus further data gained through a careful examination of all available study material, 55 specimens. Since specimens are lacking entirely from many areas, it is impossible to review critically the aspects of distribution, geographical variation and relationships. It is hoped that mention of some of the problems involved will stimulate interest in the gathering of more material.

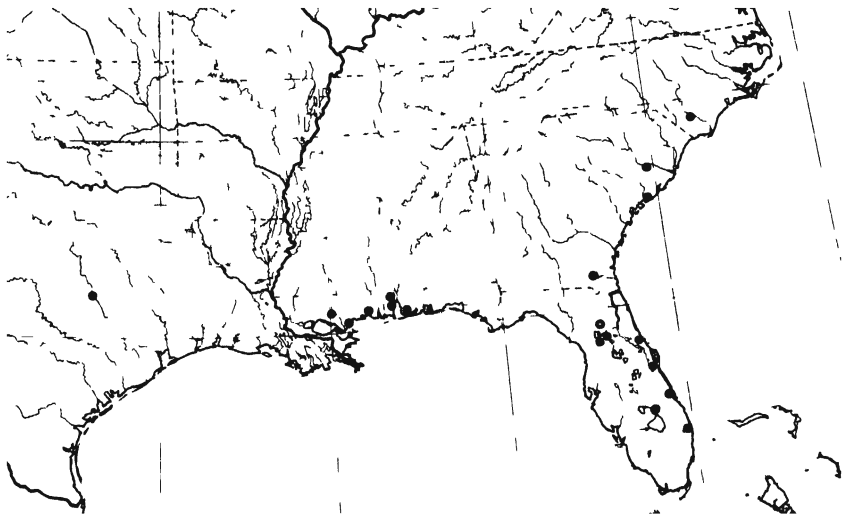
The methods of study followed are those of common practice, with a few deviations. The scale row formula was determined by making scale counts at eight points along the body length, the first one-half inch behind the head, and the last one-quarter inch anterior to the anal. Hemipenial and dental characters were studied in specimens selected from various portions of the range of the species. Comparison with the type could only be made through the original description, for most unfortunately the type specimen (ANSP 5583) has been lost.

Habit and habitat notes were gathered through correspondence with collectors, from notes in literature and from personal field and laboratory observations.[1]

The following abbreviations are used where reference is made to definite museum specimens:

| | |
|---|---|
| AMNH | American Museum of Natural History |
| ANSP | Academy of Natural Sciences of Philadelphia |
| ASM | Alabama State Museum |
| ChM | Charleston Museum |
| CFK | Carl F. Kauffeld Collection |
| CM | Carnegie Museum |
| CU | Cornell University Museum |
| FMNH | Field Museum of Natural History |
| FNB | Frank N. Blanchard Collection |
| UMMZ | University of Michigan Museum of Zoology |
| USNM | United States National Museum |
| ZSP | Zoological Society of Philadelphia |

[1] The author wishes to thank the following persons, (responsible for the herpetological collections in their respective museums), for the loan of the necessary material to make this study: Doris M. Cochran, United States National Museum; Mrs. Helen T. Gaige, Museum of Zoology, University of Michigan; Charles M. Bogert, American Museum of Natural History; Dr. E. R. Dunn, Academy of Natural Sciences of Philadelphia; D. I. De Jarnette, Alabama State Museum; M. Graham



Text-figure 1.

Distribution of *Rhadinaea flavilata*. Solid circles indicate localities from which specimens have been examined; hollow circles, localities in literature from which specimens are not available.

## SYNONOMY.

*Rhadinaea flavilata* (Cope)

*Dromicus flavilatus:*

Cope 1871, *Proc. Acad. Nat. Sci. Phila.*, Vol. XXIII, pp. 222-223; 1875, *Bull. U. S. N. M.*, No. 1, p. 38; 1892, *Proc. U. S. N. M.*, Vol. XIV, No. 882, p. 618.

*Rhadinaea flavilata:*

Cope 1894, *Proc. Acad. Nat. Sci. Phila.*, Vol. XLVI, p. 428; 1895, *Trans. Amer. Philos. Soc.*, Vol. XVIII, p. 202; 1900, *Rep't United States Nat. Mus.*, p. 759; Brown 1901, *Proc. Acad. Nat. Sci. Phila.*, Vol. LII, p. 88; Dunn 1932, *Occ. Pap. Mus. Zool., Univ. Mich.*, No. 251, pp. 1-2; Stejneger & Barbour 1933, Check-list No. Amer. Amphib. Rept., Ed. 3, p. 105; Netting 1936, *Copeia*, No. 2, p. 114; Stejneger & Barbour 1939, Check-list No. Amer. Amphib. Rept., Ed. 4, p. 100; Campbell & Stickel 1939, *Copeia*, No. 2, p. 105.

*Liophis flavilatus:*

Boulenger 1894, Cat. Snakes Brit. Mus. (Nat. Hist.), Vol. II, p. 143.

Netting, Carnegie Museum; Karl P. Schmidt, Field Museum of Natural History; Harold Trapido, Cornell University Museum. Especial thanks are due Dr Howard K. Gloyd for his kindness in permitting the study of specimens from the collection of the late Dr. Frank N. Blanchard. Carl F. Kauffeld allowed me the use of material from his private collection.

To the herpetologists who have collected this snake in the field, the author wishes to extend his thanks for their generosity in turning over their field notes for his use. Dr. Leonhard Stejneger and Joseph R. Bailey, for aid in defining certain data, and J. Laird Starr of Philadelphia, for help in the accumulation of data, earn the appreciation of the author. Mark Mooney, Jr., Zoological Society of Philadelphia, was kind enough to supply the photograph.

Roger Conant has been both guide and critic. His suggestions and views on critical points have been invaluable. For these I offer my sincere gratitude.

*Leimadophis flavilatus:*

Stejneger & Barbour 1917, Check-list No. Amer. Amphib. Rept., Ed. 1, p. 86; 1923, *Ibid.* Ed. 2, p. 96; Blanchard 1924, *Pap. Mich. Acad. Arts, Sci. and Lett.*, Vol. IV, Pt. II, p. 41.

*Rhadinaea flavilata* was originally described by Cope in 1871 on the basis of a single specimen collected by Dr. Yarrow (1878, p. 27) "on the Boque banks, some eight miles south of Ft. Macon (Beaufort, North Carolina), near marshy ground." Placing the species in the genus *Dromicus* in 1871, Cope later (1894) referred it to *Rhadinaea*, basing his change on the hemipenial characteristics. The same year, 1894, Boulenger allocated *flavilata* to *Liophis*. Boulenger had never seen a specimen of *flavilata* and evidently his procedure was founded on descriptions in literature. It is interesting to note that in 1898, two specimens from Bay St. Louis, Mississippi, reached the British Museum, and it is indicated from notes on the bottle and in his catalogue that Boulenger immediately recognized his error in referring *flavilata* to *Liophis*. (Malcolm Smith, in corres. March 10, 1939.)

In 1917, Stejneger & Barbour (p. 86) placed *flavilata* in the genus *Leimadophis*. Boulenger (*l.c.*) had placed the species in *Liophis*, congeneric with *almadensis*. Stejneger regarded *almadensis* and *flavilata* as probably congeneric, but disagreed with Boulenger in placing the two forms in *Liophis*, and consequently put both in *Leimadophis*, type *almadensis*. The species remained in this genus until 1932, when Dunn (pp. 1-2) referred it once again to *Rhadinaea*, considering the form as congeneric with *vermiculaticeps* (type *Rhadinaea* Cope, by original designation).

DESCRIPTION: Habit slender; head 1.50 to 2.25 times as long as wide, slightly wider than the neck. Tail 27.7 to 37.7% of the total length. Scales smooth, without apical pits, in 17 rows—occasionally 18 or 19 rows immediately behind the head. Ventrals 123-141; anal plate divided; subcaudals 60-83. Supralabials 7, rarely 8; third and fourth entering the orbit, sixth the largest. Infralabials 9, occasionally 8, rarely 7 or 10; first five bounding the genials, fourth and fifth the largest. Postgenials slightly longer than pregenials. One preocular; two postoculars, the lower very small. Occasional individuals may have a small extra postocular plate lying between the lower postocular and the fifth supralabial (one specimen each from Florida, Alabama and Mississippi). Loreal small, as high as long. Two nasals, the nostril entirely within the prenasal. Rostral much wider than high, scarcely visible from above. Internasals nearly quadrate; prefrontals wider than long. Frontal long, narrow; parietals elongate, truncate posteriorly.

The hemipenis is single, extends to the ninth subcaudal; sulcus spermaticus forked opposite the sixth subcaudal. Calyculate apically, calyces slightly papillose, capitate. Spinous distally, spines arranged in 5 to 7 longitudinal rows, the two median rows enlarged, forming a central cluster of enlarged spines. Basal portion of organ smooth.

Maxillary teeth 13, the last two slightly enlarged and separated from the others by a short interspace. Mandibular teeth 13 to 17, subequal; palatine teeth 9.

Dorsal color rich amber brown (color nomenclature from Ridgway) fading to light orange-yellow or orange-buff on the fourth to the second scale rows and edges of the ventral plates. (Some individuals may have the first three scale rows finely stippled with amber brown.) The scales of the median row are tipped at their posterior edge with auburn, producing a broken, but distinct median stripe, which, however, may be faint or even lacking in some specimens. Not infrequently specimens show a broken lateral stripe on the third scale row, more prominent on the anterior quarter of the body, and which is formed in the same manner as the median stripe. Ventral surface pale martius or marguerite yellow, fading to whitish on

the chin and throat. Top of head auburn, irregularly marked with minute, paler vermiculations. Labials light maize yellow or sulphur yellow. A chestnut line extending from the tip of the snout through the orbit, along the upper edge of the supralabials to the angle of the jaw, finely edged with black above; less distinct anterior to the eye. Rostral and the first two supralabials light hazel; infralabials and mental sparsely spotted with auburn. Occasional individuals show light, black-edged spots on the common parietal suture; others may have very indistinct light patches on each side of the neck.

Average adult length, 299 mm.; largest female, 377 mm., largest male, 340 mm.

VARIATIONS: Sexual dimorphism in *flavilata* is not great. The range of ventrals in the males is from 123 to 135, averaging 128.5, and in the females from 128 to 141, averaging 133.6. The number of subcaudals in males varies from 69 to 83, averaging 75.5, while the range in the females is from 60 to 70, the average being 66.3.

Of the total number of specimens examined, 35% have a portion of the tail missing. With a series of nineteen males and seventeen females used in determining the tail ratio in each sex, these figures were obtained: males, .287 to .337, average .321; females, .277 to .314, average .301.

Blanchard (1931, p. 35) calls attention to the fact that the males of certain smooth-scaled snakes possess keel-like ridges on the scales of the anal region. Among the species observed by him as possessing this character is *Leimadophis flavilatus* ( = *Rhadinaea flavilata*). Blanchard further states that he believes that these anal ridges are not homologous with the true keel. A microscopic study of the anal ridges found on the males of the species under discussion proves this to be the case.

As seen with the naked eye, the scales of the anal region of male *flavilata* bear distinct ridges, extending from the base of the scale approximately one-quarter to three-quarters of the distance to the apex. When examined under the microscope, an entirely different aspect is obtained. No keel is apparent and the cellular construction of the scale is the same as that found in true smooth scales. Of what importance this character may prove to be, is at present unknown. Further study is planned and it is hoped that some interpretation can be made in the future.

Male *flavilata* examined of a length greater than 236 mm. possess anal ridges, and those of 300 mm. and over exhibit the character to a marked degree (two specimens, of 275 mm. and 305 mm. respectively, lack the ridges). The largest specimen not showing anal ridges, is one of 206 mm. Specimens between this size (206 mm.) and 236 mm. are not at present available for study. If these ridges be considered correlated with the attainment of sexual maturity in male *flavilata*, it is suggested that maturity is probably reached at about 215 mm., but a larger series of males is to be desired before definite conclusions can be set down. Anal ridges are not present on any of the females examined.

Geographical variation within the species is slight. The number of ventrals has been found to be higher in the East (North and South Carolina, Georgia and Florida) where ventral counts range from 126 to 141 (males, 126 to 135; females 128 to 141), averaging 132 (av. male, 130; av. female, 134). In the western portion of the range (Alabama, Mississippi, Louisiana and Texas) the ventral count varies from 123 to 135 (males, 123 to 132; females, 131 to 135), averaging 130 (av. male, 129; av. female, 133). Subcaudal counts tend to be higher to the west. In the East these counts range from 60 to 79 (males, 69 to 79; females, 60 to 69), averaging 69 (av. male, 74; av. female, 67), while the western counts of subcaudals show the variation to be from 63 to 83 (males, 70 to 83; females, 63 to 70) with an average of 70 (av. male, 74; av. female, 66).

Labial characters are rather constant throughout the range. Of the material examined from Florida, 35% has a reduction of the infralabial count to eight, but only on one side of the head. One specimen has the formula 7-8. An individual from Mississippi shows an increase of infralabials to 10-10. There is but one deviation from the normal supralabial count of 7-7; an Alabama specimen possessing the count of 8-8.

Color variation in *flavilata* is individual, but with an apparent correlation with geographic range. This variation is restricted to the more or less distinctiveness of the dark dorsal striping. In general, eastern specimens are uniform in color, the striping being noted only by the occasional appearance of the median stripe. In the west, the median stripe becomes more prominent, and the lateral stripes make their appearance.

HABITS AND HABITAT:[2] *Rhadinaea flavilata* is decidedly a lowland form. Locality records show it to be confined to a narrow coastal strip, and no specimen has been collected at an altitude in excess of 120 feet, with the single exception of the one Texas specimen, collected at 620 feet.

Known altitude records for the localities at which this species has been collected are as follows: NORTH CAROLINA: Councils, 70 feet; SOUTH CAROLINA: Alvin, 50 feet; 15 m. NE Mt. Pleasant, 30 feet; GEORGIA: Chesser's Island, Okeefinokee Swamp, 120 feet; FLORIDA: near Opal, 40 feet; Sebastian, 19 feet; 10 m. Silver Springs, 47-65 feet; ALABAMA: 10 m. S. Foley, 2 feet; Mobile, 8-75 feet; MISSISSIPPI: Biloxi, 19-23 feet; Bay St. Louis, 21-28 feet; LOUISIANA: Sun, 11-50 feet; TEXAS: Clifton, 620 feet.

The Yellow-lipped Snake is secretive in its habits, rarely appearing on the surface of the ground. Haltom (1931, p. 48) writes that it "burrows in soft soil, leaves and decaying logs," and Van Hyning (1933, p. 6) has found it "under bark or logs." Löding (1922, p. 33) reports the species as being "not uncommon in low, cut-over pine lands under logs in early spring," and Allen (1932, p. 14) has taken it "beneath the bark of stumps . . . under pile of straw in company with *O. ventralis*."

The present author collected three specimens in South Carolina on the edge of the Santee Swamp (Alvin, 7 m. E of St. Stephens), in May, 1938. One was discovered under dead leaves at the base of a fence running through rather open pine woods. The others, taken at the same spot, the edge of a large area that is flooded with each rain, were found approximately two inches under the surface of loose, damp, sandy soil. In this, and in similar habitats in the same region, *Hyla squirella, Leiolopisma unicolor, Diadophis p. punctatus* and *Storeria occipito-maculata* are common.

Stewart Springer collected *flavilata* near Biloxi, Mississippi, under similar conditions. The Biloxi locality, along the Tohoulacaboeffa River, is a pine-woods flat with occasional gum- and cypress-surrounded ponds, and the entire area is flooded once in two years. The species is common under logs along with *Virginia* ( = *Haldea*), and *Rana hecksheri* is the most abundant frog in the area.

In Florida, the conditions preferred by *flavilata* are somewhat modified. This species in Florida is one of the open dry flatwoods, though always in close proximity to water. Carl F. Kauffeld has taken the snake under fallen tree stumps on a palmetto prairie with a sprinkling of pines, near Lake Okeechobee. *Ophisaurus* and *Diadophis* were taken close by. Campbell & Stickel (1939, p. 105) write of *flavilata* being found in quartz sand country

[2] Recently, E. Ross Allen (*Copeia*, 1939, No. 3, p. 175) has presented some additional notes concerning this species. Three eggs were laid by a female in his possession, August 19, 1937, measuring 23 × 8 mm. These eggs hatched in September, 1937, the young snakes averaging 167 mm. in length, the tail 41 mm. Individuals taken by Allen have been found under logs and bark in open flat woods of pine and oak. In captivity they have eaten *Bufo quercicus* and *Acris gryllus*. The largest specimen in a series of 60 Florida adults is one of 402 mm. (sex?). Additional localities noted by him are Sarasota and Glades counties.

in Florida, as well as in the peat regions, but when found in such a locality, it is in as damp a spot as possible.

Food notes in literature are practically non-existant. Haltom (*l.c.*) says that *flavilata* feeds "on small insects," a statement that appears doubtful in view of the findings noted below. Campbell & Stickel (*l.c.*) fed a captive specimen for a time on *Microhyla carolinensis*. Examination of the stomach remains of specimens studied by the author yielded unidentifiable remains of small frogs (*Hyla?*) and the tail of a *Leiolopisma unicolor*. In the laboratory of the writer various animals were offered as food to captive specimens, including small insects, earthworms, salamanders, small frogs (yg. *Rana catesbeiana* and *Hyla crucifer*), small lizards (*Anolis carolinensis*), and baby mice. Of the above, *A. carolinensis*, a small individual of *Rana catesbeiana* and one of *Hyla crucifer* were taken. Unfortunately, only the eating of the *Anolis* was witnessed.

On the introduction of the *Anolis* into the cage containing a single specimen of *flavilata*, the lizard scurried about the cage, the *flavilata* remaining hidden under the water pan. As the anole rested momentarily by the water dish, the snake suddenly projected its head from the hiding place, immediately seizing the lizard with its jaws at mid-body. No attempt was made to constrict, the snake simply retaining its hold, chewing occasionally, until the anole had ceased its struggling. At cessation of struggle by the lizard the snake worked its jaws along the lizard's body to the head, where it at once began swallowing operations. During the entire time, from when the snake first bit the lizard, until it had completely swallowed it, the snake never projected more than an inch or two of its head and body from its place of concealment.

The anole was, tail inclusive, approximately the same length as the snake, though the snake was at no time in discomfort. The process of eating, from the first bite to the complete disappearance of the lizard into the mouth of the snake, took about twenty-five minutes.

Though not uncommon where found, *flavilata* seems restricted to a definite ecological niche, and very rarely is it found in extra-limital habitats. The communities in which it lives are essentially hygrocolous. *Rhadinaea*, and the forms with which it is intimately associated, *Hyla, Microhyla, Rana, Anolis, Leiolopisma, Ophisaurus, Virginia, Diadophis, Lampropeltis* and *Storeria* inhabit damp-ground areas. The soil, regardless of composition, may be damp, usually is loose. Secretive, as are most of its associates, *flavilata* is rarely found in the open, showing preference for hiding or burrowing in the sub-soil, in rotten logs, under loose bark (either on living trees or on rotting trunks), or under the ground carpet of fallen leaves. The presence of *flavilata* in this type of community and the food habits as far as known, are in close correlation. The examination of stomach contents and laboratory experiments have shown that this species feeds on small frogs, ground-living lizards, and, in all probability, on smaller individuals of other secretive species of snakes (i.e. *Storeria, Diadophis*). It is hypothesized that *flavilata* arrived in these communities after their establishment with enough force to become a sub-dominant influence in the association, being itself dominated by such forms as *Ophisaurus* and *Lampropeltis*. The time of its arrival and the method are unknown, and the only datum that may be construed as evidence of an exotic origin is the foreign position of its inter-generic allies.

RANGE: A narrow coastal strip from Carteret County, North Carolina, south through peninsular Florida to Palm Beach County; west along the Gulf Coast to Tammany County, Louisiana; Bosque County, Texas.

Specimens have been examined from the following localities: NORTH CAROLINA: Councils, Bladen County (CU 6740); SOUTH CAROLINA: Alvin, Berkeley County (ChM 39.4.1-.2; ZSP 1068); 15 m. NE Mt. Pleasant,

Charleston County (FMNH 4076); GEORGIA: Chesser's Island, Okeefinokee Swamp, Charlton County (FNB); FLORIDA: Georgiana, Brevard County (USNM 11989, 13642, 13649, 13661, 13708); Sebastian, Indian County (UMMZ 56987); near Silver Springs, Marion County (CM 9636-46; CU 2211); Florida Route 29, N of Okeechobee, near Opal, Okeechobee County (CFK 329-30; AMNH 50491); Lake Worth, Palm Beach County (UMMZ 85110); Volusia, Volusia County (ANSP 10800); Warren County (ANSP 11730); ALABAMA: Alabama (ASM); 10 m. S Foley, Baldwin County (CM 9879); Mobile, Mobile County (FNB; CU 1739; USNM 51888, 56445-46); MISSISSIPPI: Bay St. Louis, Hancock County (ANSP 12061-62; USNM 24452-54, 56443-44); near Biloxi, Harrison County (CM 5240; CU 1867; FMNH 12000, 21533; UMMZ 76827); LOUISIANA: Sun, Tammany County (FNB); TEXAS: near Clifton, Bosque County (CM 8937).

Locality records in literature from which specimens were not examined, are as follows: NORTH CAROLINA: Fort Macon (Beaufort), Carteret County (Cope, 1871); FLORIDA: Gainsville, Alachua County (Van Hyning, 1933).

AFFINITIES: The well-differentiated characters and the isolated range of *flavilata* preclude the possibility of close affinity to any of the other forms of *Rhadinaea*. The appearance of striping on western specimens may be indicative of relationship to Central American *Rhadinaea*, possibly through *laureata* of the Mexican Plateau.

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## EXPLANATION OF THE PLATE.

### PLATE I.

*Rhadinaea flavilata* collected at Alvin, Berkeley County, South Carolina, by the author, May, 1938. The dark stippling of the lateral scale rows is rather distinct in this specimen. Photograph by Mark Mooney, Jr., Zoological Society of Philadelphia.

A STUDY OF THE YELLOW LIPPED SNAKE, RHADINAEA FLAVILATA (COPE)

# 25.

## Variations in the Nesting Habits of *Ameiurus nebulosus* (Le Sueur).

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(Plates I & II; Text-figures 1-3).

### Introduction.

A study of the reproductive habits of *Ameiurus nebulosus* (Le Sueur) based on aquarium observations together with comments on nematognath reproduction in general was made the subject of an earlier communication in this journal, Breder (1935). The present paper represents the results of further studies on the same species made under less restricted conditions, with special reference to interactions between parents and young and between adjacent family groups.

For purposes of this study and others a pool was constructed on the author's property at Mahwah, N. J. The general configuration is shown in Text-figure 1 and was arrived at partly by following the general contours of the land with fairly proportionate increases in depth. As wide a variety of environmental conditions as possible, within its limitations, was provided. The pool was lined with concrete as the sandy nature of the soil (glacial till) precluded the formation of any permanent standing water. Water is supplied from the house piping to an inlet brooklet at the southwest corner of the pool. To all intents and purposes this is to say it is spring fed, since the water supply is obtained, untreated, from a natural spring about one-half mile distant. This water is very soft, has a pH of about 7.0 and is exceptionally clear. The pool is not continually fed but simply enough is added from time to time to make up for evaporation, which may be considerable in mid-summer.

The pool was built and filled with water on June 26, 1937, and has not since been drained. In previous years it was used for other fishes. The bottom has a covering of leaves from the previous seasons which overlay a bedding of sand in some places providing a very satisfactory pond bottom which is now well seasoned and inhabited by a large number of aquatic invertebrates which in one way or another have become established. They include such forms as *Physa, Asellus,* hydracarinids and many of the winged aquatic insects, such as *Dytiscus, Hydrophilus* and the nymphs of various Odonata. The open water and surface is inhabited by *Corixia, Notonecta, Gyrinus* and *Gerris.* Mosquito larvae have apparently been kept in complete check by the fishes.

The only vertebrates that have established themselves are frogs, including *Rana catesbeiana* and *R. clamitans. Hyla crucifer* and *Bufo americanus* are there in season and occasionally a wandering *R. palustris* puts in an appearance.

At the time the catfish were introduced the only planted animal organisms consisted of a small school of *Rhodeus amarus* and a few *Unio complanatus* which had wintered over from the preceding year.

Since this pool has not been disturbed since originally established it has arrived at a more or less balanced state and the water is usually of such clarity as to be excellent for observational purposes.

Into this setting six catfish were placed on April 26, 1939, in the hope that at least one mating would result. These fish were supplied through the good services of Mr. W. C. Bennett, Engineer of the New York Aquarium, who had obtained them from a stream near Red Bank, New Jersey. It was near here that the first pair of fishes on which the earlier studies were based had been obtained, so that the present ones should be strictly comparable and may easily bear a close family relationship to the former. Judging from their size it is inferred that the present six fish had never spawned before and presumably were only a year old.

## Reproductive Schedule.

*Pre-spawning Behavior.*

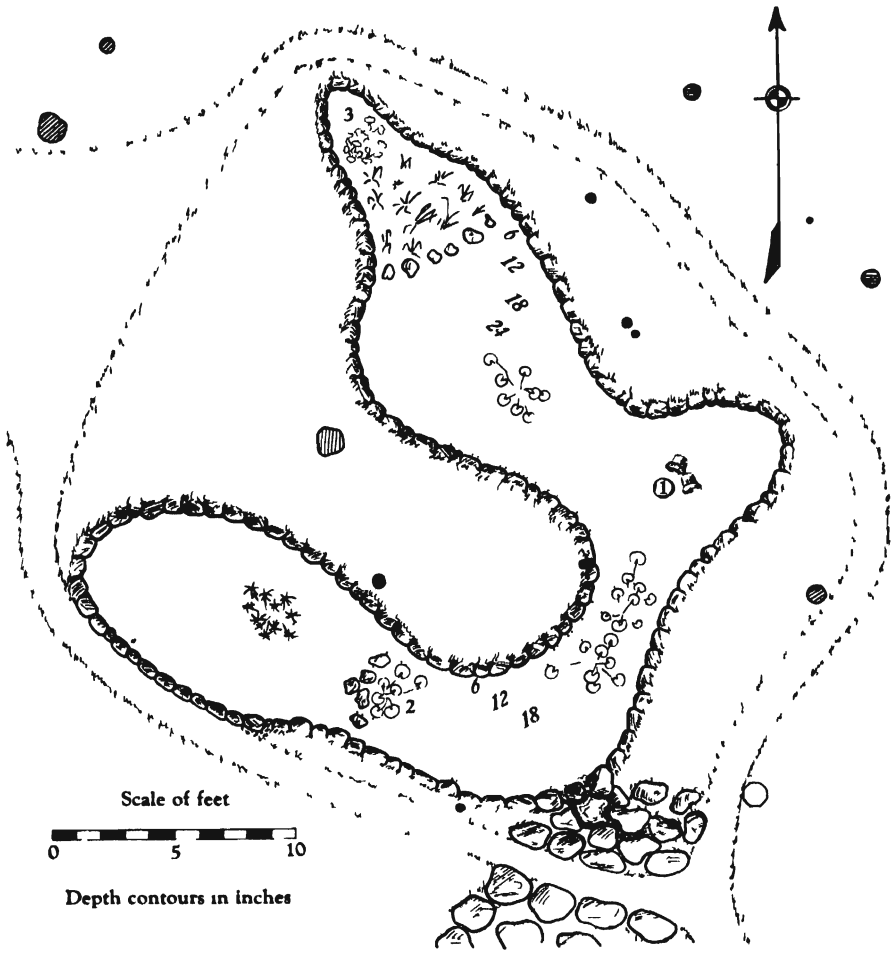
Reproductive activity put in its appearance gradually. It was first noticed that the fish became more active and tended to aggregate at times near the surface or near the shore line. This would be alternated with rooting around all over the pool as though nesting sites were being sought. Insofar as six fish are able to form an aggregation the behavior of these groups was decidedly like that of the supposed pre-nuptial behavior described for *Ameiurus natalis* by Pearson & Miller (1935). After this had gone on for a time, the fish began to show slight injuries as a result of their activities.

*Nest Construction.*

Gradually the rooting process became more and more intense until the fish had the pool in such a state that visibility was seriously restricted. Although what had been thought to be adequate nesting sites had been provided by the various rocks which held the sand in place, the fish seriously damaged the planting arrangements. These sand breaks are indicated in Text-figure 1 in the two main arms of the pool, only the protruding portions of the rocks being shown. A potted water lily was rooted out of its pot, the pot cleaned completely of all earth, although allowed to remain in a standing position. This was in the face of two identical empty pots laid on their sides especially for the fish not six inches from the other. See the northeast corner of the pool, Text-figure 1. The first pair to spawn used this standing flower pot. With unexpected good fortune it developed that of the six fish placed in the pool three pairings resulted.

The second pair selected a site at the base of another lily pot without disturbing it while the third selected the shallowest and most restricted cove in the entire shore line. The nests are indicated as "1," "2" and "3" in Text-figure 1.

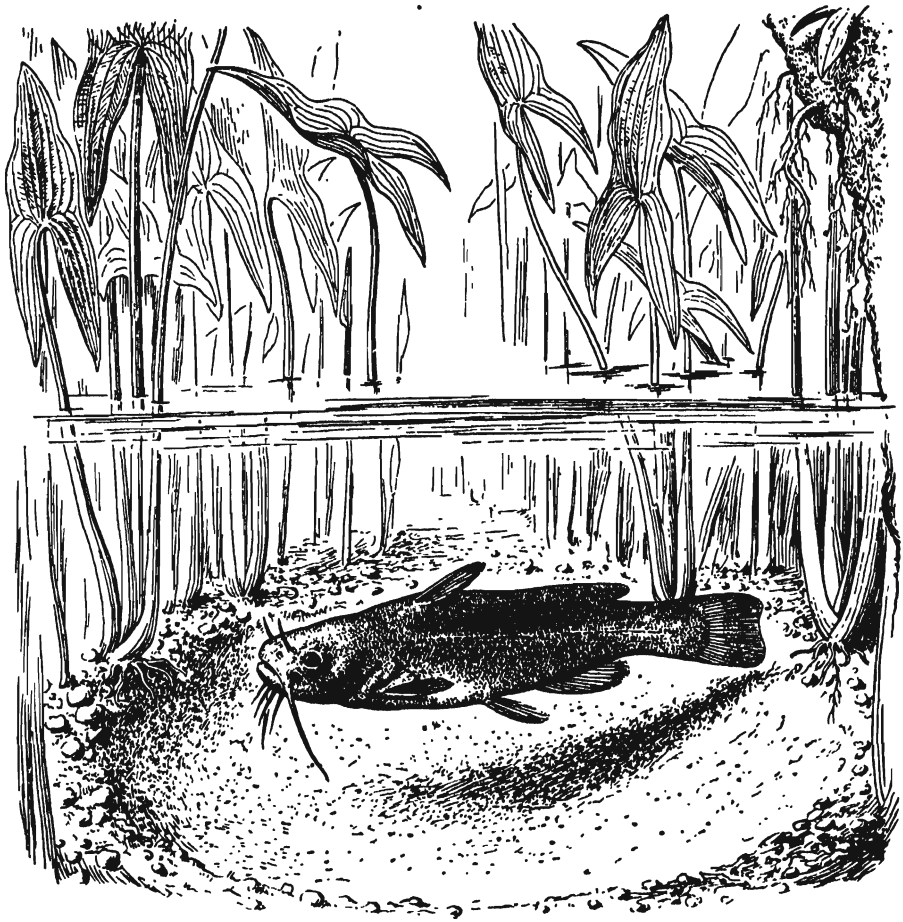
Accustomed to catfishes of this genus and especially of this species spawning in rock cavities, old tin pails, under overhanging logs, roots and so forth, the form of the second two nests came as a surprise. Photographs of typical nests of *Ameiurus nebulosus* are shown by Breder (1935). These were taken in aquaria, as such nests in a wild state are almost impossible to photograph because of their positions. Gill (1907) published an idealized drawing of a nest of this species unlike any seen by the writer or apparently by others. Of this Breder (1935) wrote, "Gill's (1907a) drawing of an *Ameiurus* nest (ideal) is not like any described in the literature or seen by the author, but more nearly resembles a centrarchid nest." His figure is




Text-figure 1.

Sketch map of the pool in which the present studies were made. The numbers 1, 2 and 3 indicate the sites of the three catfish nests The contour lines indicate the depth of water to the present bottom of sand and leaves. The underlying concrete, below the 12" contour, is in most places at least a foot deeper. The aquatic vegetation, *Cyperus*, *Nymphaea*, *Typha*, *Sparganium* and *Eichhornia*, are indicated by appropriate symbols. The immediately surrounding tree trunks are indicated as follows: Locust—black, Plum—horizontal lines, Cherry—diagonal lines, Pear—vertical lines. Footpath around margin of pool indicated as grass edging.

here reproduced as Text-figure 2. Actually it could well represent an idealized condition of the second two nests under discussion, and if sunfish had been in the pool the structures would have undoubtedly attributed to those fishes. Our nests differ from Gill's drawing only in the species of the vegetation surrounding them, a matter in which the fish could exercise small selection. Plate I shows the third nest and clearly indicates the nature of the construction. It was impossible to obtain a good photograph of the second nest because of the greater depth of water in which it was situated and the lingering turbidity from the earlier rooting period.



Text-figure 2.
Catfish (*A. nebulosus*) on nest (Ideal). After Gill (1907), including caption.

*Attention to Eggs.*

The first nest was placed in such an awkward position as to make normal attention peculiarly difficult for the parent fishes. At the bottom of a small flower pot of less diameter than the length of the fish, the attending parent was forced either to coil itself in too tight a circle for a catfish or stand free in the water at an angle. The latter position was used almost exclusively. This required continuous active swimming on the part of the parent during the entire incubation period. Occasionally it would attempt to coil itself down over the eggs and beat them with its ventral fins. This could scarcely be accomplished and was not tried very often. Thus it appears that this typical catfish activity is not vital to the hatching of the eggs, as this nest produced a large brood. The fish for most part contented itself with fanning the eggs with the tip of the tail as is indicated in Text-figure 3. Here, too, photography was impossible because of the reasons already mentioned.

In the other two nests, which were not constricted in any such way, the attendant parent continually made use of the ventral fins. This behavior

differed from that described by Breder (1935) only in that the motion involved somewhat similar motions of the pectoral fins while the entire fish rocked slightly. As the pectorals were usually over the edge of the egg cluster and the ventrals over its middle the latter supplied most of the effective agitation, as is indicated in Plate II. This was so violent that in the third nest the mass of eggs became broken up into several smaller clusters before hatching. Thus loosened from the ground the eggs were driven against the rim of the nest where they hung while they received only the benefits of the currents produced by the fish which was still working in the center of the nest where the eggs had been originally situated. When the barbels of the parent came in contact with such a cluster of eggs the fish would show signs of agitation but made no effort to return them to the nest proper. The movements of the ventral fins alone in a nest built in a rock cavity as described by Breder (1935) and the present rocking of the entire fish would seem to be purely a mechanical circumstance. Without the rocks on which to steady itself the fish naturally is thrown from side to side by the action of the ventral fins, or, looked at the other way, in an open nest there is no inhibition to more violent activity. In the light of the specialized pelvic musculature of this group of fishes as discussed by Shelden (1937), the activity is certainly primarily of pelvic origin.

The cluster of eggs in the second nest was not broken up as in the third, but remained intact until hatching.

Although the sexing of these fish in a pool is not easy, it is thought that the female did all of the incubating in each case. Individuals could be easily recognized since each had some slight scar that was obtained during the courtship activity. A white crescent across the head of the attendant parent of the third nest, which may be seen in Plates I and II, marked that individual from all the rest. Text-figure 3 indicates the conditions in the first pair. At least, then, one individual did all the incubating and before the eggs hatched apparently never left the nest. Fingers, sticks and so forth introduced in the nest would be faced with open mouth, seldom bitten but frequently butted out of the nest.

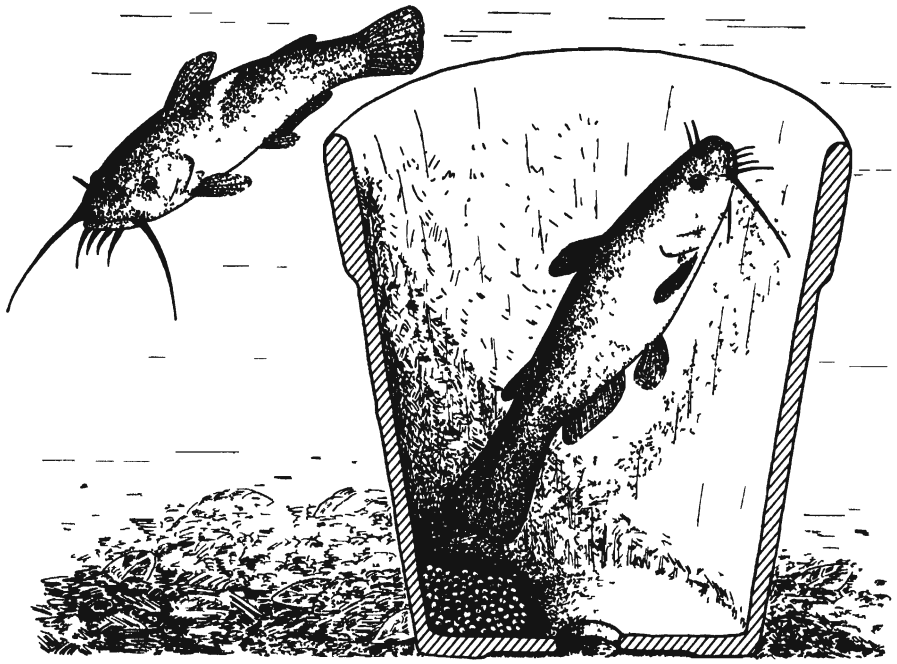
In the case of the first nest, the second parent continually circled the flower pot in a circle with a diameter of about three feet, as if a guard patrolling a circuit. For most part the barbels were held distinctly forward when engaged in this activity, as is indicated in Text-figure 3. In the case of the other two there was no such evident cooperation. The alternate parent of the second nest was once seen to approach the nest but was vigorously driven off by the attendant. This fish, however, was never seen out of the arm of the pool that held its nest, but this may be due to merely being held in the one arm, as any near approach to the first nest resulted in the active resentment of the patrolling parent of that nest.

The alternate parent of the third nest was found for most time resting in the nearby bulrushes. Like that of the second it was prevented from wandering far by the position of the first nest.

It may be noted from Text-figure 1 that the selection of depths varied greatly but the nests are as far apart as they could well be. Each was definitely out of sight of the others. The fact that the southwest arm in its upper reaches was not used may be attributed to the fact that its large shallow area was relatively unprotected with plants as compared with the more abrupt shallowing and heavy planting of the northwest arm. Likely the proximity of deep water and vegetation has a bearing on this selection.

*Family Relationships.*

After hatching, the young of the first nest, when able to swim up out of the flower pot, were attended attentively by both parents very much after the fashion of those discussed by Breder (1935). The parent of each of the



Text-figure 3.

The nesting behavior of pair number 1. The light curved marks on each fish were received in the courtship and spawning procedure and served as identification marks. The attitudes shown of the two parents were characteristic of this pair. The flower pot is eight inches across the top.

other nests which did not incubate was never seen to take as much notice of its young as did that of the first. One of the purposes of this study was to determine if possible how families were controlled in this species. When the young of the first nest were moving about in a school attended by both parents, the third nest still contained only partly pigmented larvae not yet able to leave the nest. Those in the second nest were somewhat more advanced. The following description of what transpired between the first and third family which was observed in full goes far to illuminate the relationship between parent and offspring in this species.

When once the first family approached the third nest the following activity ensued. On the sight of the approaching large fish the attendant at the nest became agitated and swam rapidly in small circles while the parents with their brood were poking along behind but over the rear of their group. A few of the vanguard of the young school apparently sighted the nesting fish, made more evident by its increased activity. These immediately swam to it, as they ordinarily do to their parents when they increase their activity. Others following in the mass of the school and naturally more influenced by their fellows nearby did not follow these outriders. The true parents at this point apparently became aware that something unusual was taking place and they in turn became agitated with the result that their young flocked to them and the whole group retreated in the opposite direction leaving about half a dozen young with the other fish. The entry of these larger and darker individuals into the nest caused the attendant to become further agitated. It turned and faced first one and then another of the intruders as they tried to nestle under it and wedge into the

pack of smaller fishes. Finally they were accepted and remained there until her own brood was large enough to swim freely.

The second nest had caught some young also, at an earlier time, but it was not understood how this took place until the above observation was made. The sequence of these various items is given in tabular form in Table I. When finally the broods of numbers two and three left the nests they carried with them some of the slightly larger young of number one which could still be clearly distinguished from their brothers and sisters by adoption.

Although the three families could not be under continual observation it is clear that they soon rapidly became mixed and shortly after broke up as distinct schools. At one time the first spawning parents gathered

TABLE I.

Schedule of events in reproducing *Ameiurus*.

| *Dates* | *Pair Number* | | | *Events* |
|---|---|---|---|---|
| | 1 | 2 | 3 | |
| June 12 | | | | Excavating and rooting period for all. |
| 13 | | | | Water lily uprooted from pot by Pair #1. |
| 14 | | | | |
| 15 | | | | |
| 16 | | | | |
| 17 | · | | | |
| 18 | | | | |
| 19 | | | | |
| 20 | | | | |
| 21 | | | | |
| 22 | *(E)*[1] | | | |
| 23 | | | | |
| 24 | E | | | Eggs present—Pair #1. |
| 25 | | | | |
| 26 | | | | |
| 27 | | E | | Eggs present—Pair #2. |
| 28 | | | | |
| 29 | *(H)* | | E | Eggs present—Pair #3. |
| 30 | | | | |
| July 1 | | | | |
| 2 | | | | |
| 3 | H | | | Eggs hatched—Pair #1. |
| 4 | L | H | | Eggs hatched—Pair #2. Left nest—Pair #1.[2] |
| 5 | | | | |
| 6 | | | H | Eggs hatched—Pair #3. |
| 7 | | W | | Young of #1 in nest #2. |
| 8 | | | W | Young of #1 in nest #3. |
| 9 | | L | | Young left nest (in part)—Pair #2. |
| 10 | | | | |
| 11 | | | L | Young left nest—Pair #3. |
| 12 | | | | |
| 13 | | | | Schools of young completely mixed. |
| 14 | | | | Disintegration of family schools from here on. |
| Aug. 20 | | | | Pair #1 still gives some slight attention to a wandering young one when it approaches. |
| 26 | | | | Parental solicitude fully ceased. |

[1] Probable true dates indicated in italics in parentheses. Observations in Nest No. 1 extremely difficult because of position and depth.
E—Eggs present.
H—Eggs hatched.
L—Left nest.
W—In wrong nest.

[2] Pair #3—Egg cluster broken into small bits.

what appeared to be all the young fish into one large school. This apparently took place because of the far greater attentions that this pair bestowed upon its young. The attentions of the other two pair when the young were off the nest was at best desultory and interspersed with what seemed to be renewed courtship activities.

The dates of egg-laying, hatching and nest-leaving in nests 2 and 3 as given in Tables I and II are accurate, but due to the position of nest 1 and the consequent difficulties of detailed study, the actual dates of deposition of ova and their hatching are uncertain. Corrected dates, as based on what one would expect from the behavior of the others, are given in parenthesis and italics.

TABLE II.

The duration of the nesting period in *Ameiurus*.

| *Pair of fish*[1] | *Date of egg laying* | *Days to hatch* | *Days to swim* | *Total days in nest* | *Water depth in inches* | *Mean temp. °C* |
|---|---|---|---|---|---|---|
| A 1931 | Aug. 18 | 6 | 10 | 16 | 48 | 21.1 |
| A 1933 | July 15 | 10 | 16 | 26 | 48 | 21.1 |
| A 1933 | Aug. 13 | 9 | — | — | 48 | 21.1 |
| B 1934 | July 5 | 6 | 7 | 13 | 48 | 23.3 |
| 1 1939 | June 24 (*22*)[2] | 9 (*7*) | 1 (*5*) | 10 (*12*) | 28 | 20.8 |
| 2 1939 | June 27 | 7 | 5 | 12 | 16 | 20.8 |
| 3 1939 | June 29 | 7 | 5 | 12 | 7 | 20.8 |
| Mean | July 15 | 8— | 7+ (*8*) | 15 — (*15+*) | 35 — | 21.3 — |
| Maximum | Aug. 18 | 10 | 16 | 26 | 48 | 23.3 |
| Minimum | June 24 (*22*) | 6 | 1 (*5*) | 10 (*12*) | 7 | 20.8 |

[1] Original data on lettered nests prior to 1939 is given by Breder (1935).
[2] The italic numbers in parentheses indicate values corrected according to the estimates in Table I.

## DISCUSSION.

From the evidence of the present study it would appear clear that *Ameiurus* basically undertakes to build a saucer-shaped nest similar to, if not indistinguishable from, those of the Centrarchidae. The reason that it is seldom seen as such is because of the proclivity of the species to seek out cavities which inhibit the full expression of the circular form. When, however, a nest is built in the open it takes on a most sunfish-like appearance.

The differences between the usual nests of these two vastly different fishes would seem to be definitely referable to the basic differences in the reaction of the Ameiuridae and Centrarchidae to light. Since the sunfishes normally seek the sunniest spots for their nests and consequently the most open places, it is natural that their nests are not frequently distorted from the circular by large obstructions, as is discussed by Breder (1936), and conversely since catfish are very negatively phototropic it follows that they seldom build in open places.

How, then, is it that in the present study two pairs of catfish built in relatively open places and all three were unprotected above? The answer to this would appear to be that the amount of shading of the pool was such that the fish were not especially driven to seek the shadows of overhanging objects. The spotting of the trees in Text-figure 1 gives only a meager indication of the shading, for there is also an amount of tall-growing shrubs

while the southern shore is protected by a fern bank that rises steeply to about eight feet above the water level in a distance of about twelve feet, and there are other trees just outside the limit of the map. Although the light was sufficient to permit the blooming of various *Nymphaea* plants, most of it was slanting and did not penetrate the water too well. The illumination was greatly less than that in the aquaria previously studied. Although bearing in mind that the optical estimation of light intensity is uncertain, the total units of radiant energy on these nests must have been less than that obtained in the aquarium laboratory, for as pointed out by Breder (1935) it was impossible to incubate eggs there unless they were shaded, of which he wrote, "These eggs were found to be as susceptible to daylight as trout eggs, possibly more so, which is certainly not to be unexpected considering the normal positions of catfish nests." In this connection it should be borne in mind that the attendant parent spent much time shading the eggs with its own body.

The actual mechanics of nest building seem to be merely a paddling with the ventral fins and a continual pivoting about on them. The tail movements incidental to this aid greatly in discharging the stirred up detritus from the area of the nest. Thus the catfish nest is not much greater in diameter than the length of the fish, or more properly, the radius about equals the distance from the insertion of the pelvic fins to the tail's tip.

The nests of the sunfishes, on the other hand, about equal the entire length of the fish in their radii. This is due to the fact that these fish, with their differently constituted form and finnage, pivot at their nose or tail tip, depending which way they happen to be facing.

Considering the large number of unrelated fishes that construct more or less circular nest excavations, it would seem that this simple form of effort may well underlie ichthyic nesting generally, coming to the surface again and again in various guises as other conditions permit or demand.

The selection of nesting sites, as already mentioned, seems to have scant reference to depth. General proximity to shelter, in the form of plants or deeper water, and the avoidance of neighbors would seem to be much more important.

Although it was found that these eggs could not be hatched artificially without considerable agitation, Eycleshymer (1901) and Breder (1935), clearly they can be hatched with only the circulation supplied by the tail of the parent as with pair number one. Since these were young fish and the resulting egg clusters not too massive, it may be that such is possible only when the central mass is not too remote from the periphery of the cluster.

It has been indicated again in these studies that the catfish essentially incubates the spot where the eggs are laid rather than the eggs themselves, as already discussed by Breder (1935).

The mixing of the young and the difference in attitude of the parents confirms the observations of Eycleshymer, (1901), Kendall (1910) and Breder (1935), all of whom described considerable variation from one family to another. Fowler (1917) mentioned variation in the choice of nesting sites, mentioning depths ranging from several feet to a few inches. He further wrote, "Though only a few nests were noticed in a restricted area, sometimes a dozen or more may be found on one shoal and close to one another." Such crowding would suggest a dearth of suitable breeding areas somewhat analogous to that discussed for the Centrarchidae by Breder (1936). Fowler further noted, "Frequently the fish take advantage of any objects, such as logs, rocks, etc., for sheltering the nest." This would certainly indicate that he had familiarity with unprotected nests, but he does not amplify it further. He also mentions that the eggs are deposited at intervals. In all cases of which we have personal knowledge these

intervals are short and occupy a few hours at most, giving in effect a single clutch of eggs. A later and separate spawning may sometimes take place.

So far as it was possible to determine, a single parent, in the present studies, was responsible for each nest. In the aquarium catfishes previously studied both parents incubated and looked after the young and many times in the field two attendants to broods of young have been noted, although also many broods have been seen with a single adult. It is interesting to note that in the present studies only one parent incubated where a nest was built in the open. Since this was presumably the first time that these fishes spawned, it may be that the full details of parental care do not find their complete expression until the fishes have had some experience. In this connection it may be noted that the aquarium studies were all based on much larger and older fishes.

Table II gives the important dates and time in the series of nests studied together with the maximum, minimum and mean conditions. It will be noted that there are marked variations even under closely similar conditions and in some cases in the same pair of fish.

One is tempted to think of catfish in seeking shelter for their nests as somewhat of a protection from various enemies. When it is recalled that sunfish seek the reverse positions, often in the same ponds, one wonders how significant such protection is, especially as catfish seem to be able to raise successful broods in sunfish-like localities. In this connection it is interesting to note that it was earlier found that the common goldfish could not be kept in this pool because of visitations of kingfishers from a nearby creek. It thus may actually be that catfish seek hollows for spawning merely as a result of their normal avoidance of bright light without imputing any survival value that such behavior might conceivably hold.

The early and thorough mixing of the broods found to occur during the present studies may well have been intensified by the exposed positions of two of the nests. Well hidden nests would seem to be less likly to be entered by the young of other broods. Also if they did it would be less readily observed. Since a good crop of young fish were derived from these nests it would be difficult for this and for theoretical reasons to impute any survival value, positive or negative, to this mixing of families when conditions permit or force it.

## SUMMARY.

1. Although usually nesting in natural cavities, *Ameiurus nebulosus* may at times construct saucer-shaped nests not unlike those of centrarchids. The extent of shading in the spawning area may be associated with this.

2. Eggs can be successfully incubated without recourse to the use of the ventral fins for agitating them, tail waving being adequate for the purpose.

3. Broods of clearly different sizes in nearby nests may become inextricably mixed from the time they first are able to swim.

4. There is considerable variation between one pair and another in regard to all the phases of breeding activity.

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## EXPLANATION OF THE PLATES.

### PLATE I.

The nest of pair number 3. The sunfish-like nature of the construction is well indicated. The spawning mark, on the head of the attending fish, may also be seen.

### PLATE II.

The attendant of pair number 3 at the moment of beating the eggs with the ventral fins. Note their spread position. At most other times they are hidden under the body. The water striders on the surface were given no attention, but the snail crawling into the nest caused some agitation but no definite action.

VARIATIONS IN THE NESTING HABITS OF AMEIURUS NEBULOSUS (LE SUEUR).

VARIATIONS IN THE NESTING HABITS OF AMEIURUS NEBULOSUS (LE SUEUR).

# 26.

# The Occurrence of Trematode Ova, *Hapalotrema constrictum* (Leared), in Fibro-epithelial tumors of the Marine Turtle, *Chelonia mydas* (Linnaeus).

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&

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(Plates I-V).

In an earlier paper a description was given of a cutaneous disease occurring in large marine turtles, *Chelonia mydas* (Linnaeus), captured in waters south of Key West (Smith & Coates, 1938). This disease is characterized by multiple fibro-epithelial tumors varying in size, occupying chiefly the cutaneous region of the neck, axillae, groins, eyelids, the conjunctivae and the cornea (Figs. 1, 2). The tumors followed two types: a papillary or coral-like growth with hyperplasia of keratinizing epithelium supported by a firm fibrous core; and a smooth round or oval fibrous form of tumor composed of dense and frequently hyalinized connective tissue covered externally by slightly thickened epithelium. At times both types of growth co-existed, thus forming confluent masses in which both forms of growth are distinguishable (Fig. 3). When tumors arose from pigmented skin, they were of a dark gray or black color, due to the large number of perivascular melanophores in the substance of the growth.

Histologically the fibro-epithelial tumors of *Chelonia mydas* seem to be of benign character. Epithelium of papillomas may show extensive downgrowth into the stroma with "pearl" formation. In one tumor, which was taken from the lower eyelid, an irregular adenomatous change occurred, somewhat suggestive of early malignancy (Fig. 4).

In our earlier observations, the possibility of a virus origin for these tumors was discussed. It was thought that larger parasites or their ova were a negligible factor in the disease. However, the study of larger amount of material, consisting of about 250 tumors, indicates that in more than half of the tumors parasitic ova can be detected readily with the aid of a dissecting microscope in thin slices of gross tumor tissue or in prepared microscopic sections. The ova may exist at the bases or in other parts of the stroma of both small tumors (3 mm.) as well as in larger growths (Figs. 5, 6, 7). They are present in both the papillomatous or fibromatous type of growth. Ova may be widely scattered in the fibrous stroma, or arranged in collections (Fig. 9). Frequently they occupy tissue spaces which resemble small venules or lymphatics. There is at times

found a mild inflammatory reaction about the ova or in adjacent tissue composed of lymphocytes, leukocytes and fibroblasts. Occasionally there are eosinophilic cells in the tumor. Parasitic ova lying either in the region of hyperplastic surface epithelium or in the deeper fibrous stroma of the growth usually exhibit epithelioid cells distributed along the outer surface of the chitinous membrane of the egg (Fig. 8). Such epithelioid cells may be fused into a syncytium or form multinucleated giant cells. At times, ova seem to elicit no cellular response whatever. Normal skin attached to the tumors has appeared to be free of ova.

Ova are yellow in color and consist of a body with two polar filaments. The covering is a firm chitinous-like membrane. The cellular arrangement of the egg enclosed within the membrane suggests often the first cleavage stage of larvae (miracidium). Ova removed from tumor tissue fixed in 10% formalin (Figs. 9, 10) show a length (including filaments) of 260-310 microns and a width (in middle of miracidium) of 30-40 microns.

It is thought that the ova found associated with the turtle fibro-epithelial tumors are identical with or related to those belonging to a trematode or blood fluke described by Looss (1902) and referred to as *Hapalotrema constrictum* (Leared). Both the morphology of the eggs and their measurements correspond to descriptions given for *Hapalotrema constrictum*. This digenetic trematode belonging to the family Spirorchidae was found by Looss (1898-9) in the blood and visceral tissues of two species of turtles, *Thalassochellys cortica* and *Chelonia mydas* caught along the coast of Egypt.[1]

It is probable that ova are deposited in pre-existing vascular tumor tissue by the migrating blood fluke, and remain there without affecting the subsequent course of the growth. The localization of ova in the stroma and in the venous or lymphatic spaces of turtle tumors recalls a similar localization of ova in the tissues of the human bladder in bilharziosis. Such an infection of the human bladder, as is well known, may result in papillomatous and malignant changes. Phylogenetically, *Hapalotrema constrictum* of turtles and *Schistosoma haematobium* responsible for bilharziosis are closely related.

During the past year, two smaller specimens of *Chelonia mydas* (150 lbs.), caught in Biscayne Bay, Florida, have been kept under observation for a period of about three months in the large salt water tanks of the New York Aquarium.[2] It is noteworthy that at autopsy no evidence of ova were found in heart, lungs, liver, spleen or kidneys of these two turtles, nor were there ova in any of the numerous cutaneous tumors or in those of the eyelid and cornea, although a great many microscopic preparations were examined.

These last findings indicate, therefore, that the parasitic ova of such turtle tumors are probably not of primary importance as a factor in the etiology of the disease. The blood fluke itself has not been found in the tumors examined.

## SUMMARY.

The presence of parasitic ova of a blood fluke, *Hapalotrema constrictum* (Leared), has been noted in many of the growths which occur in the marine turtle, *Chelonia mydas*. This neoplastic disease in the turtle is characterized by multiple cutaneous growths and may at times involve the eyelids and cornea. The parasitic ova, as such, probably do not act as the immediate cause of the disease.

[1] We are greatly indebted for identification of the ova to Dr. T. R. Ruebush of the Osborn Zoological Laboratory, Yale University; to Dr. Ross F. Nigrelli of the New York Aquarium, and to Dr. H. W. Stunkard of New York University.

[2] These two specimens were received through the kindness of Dr. Thomas Otto of Miami, Florida. Photographs of the live specimens were made by Mr. S. C. Dunton of the New York Aquarium.

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## EXPLANATION OF THE PLATES.

### PLATE I.

**Figs. 1 & 2.** ***Chelonia mydas*** (Linnaeus), weight 150 lbs., showing distribution of fibro-epithelial tumors.

### PLATE II.

Fig. 3. Tumor mass composed of confluent papillomas (P) and fibromas (F).

**Fig. 4. Papillomatous tissue from an eyelid. Extreme adenomatous hyperplasia.** ×30.

### PLATE III.

Figs. 5 & 6. Cross-section of ova (X) located at base of a small papilloma. ×75 and ×150.

### PLATE IV.

Fig. 7. Fragments of ova (X) located in the stroma of a papilloma. ×80.

Fig. 8. Cross-section of parasitic egg (X) surrounded by epithelioid cells (E). ×250.

### PLATE V.

Fig. 9. Collection of ova lying in a thin slice of tumor tissue, photographed by direct illumination. Actual measurements given in text.

Fig. 10. Teased preparation of single parasitic egg, of *Hapalotrema constrictum* shrunken after fixation in 10% formalin. For measurements see text.

FIG 1

FIG 2

OCCURRENCE OF TREMATODE OVA HAPALOTREMA CONSTRICTUM (LEARED), IN FIBRO EPITHELIAL TUMORS OF THE MARINE TURTLE, CHELONIA MYDAS (LINNAEUS)

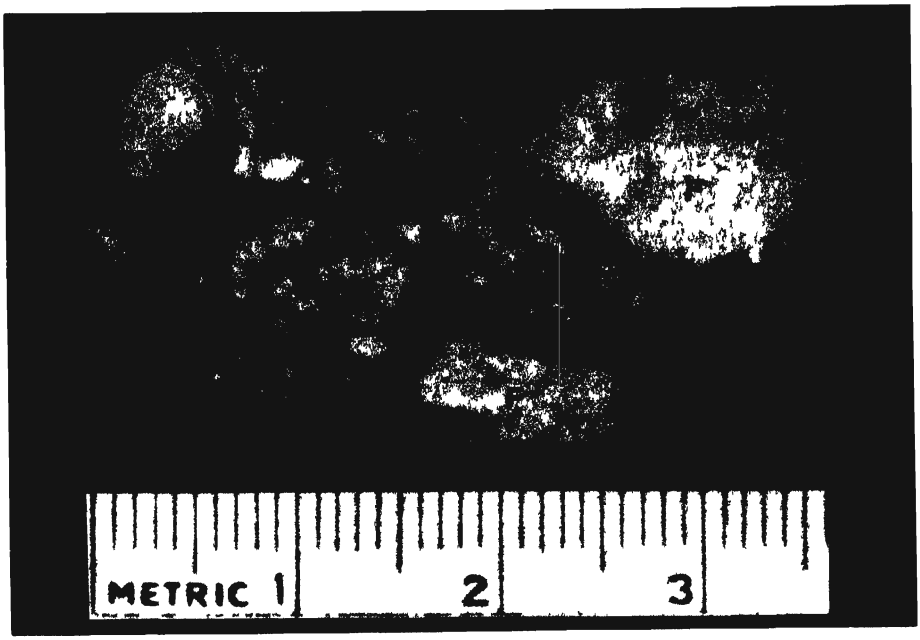


FIG 3

FIG 4

OCCURRENCE OF TREMATODE OVA HAPALOTREMA CONSTRICTUM (LEARED) IN FIBRO EPITHELIAL* TUMORS OF THE MARINE TURTLE CHELONIA MYDAS (LINNAEUS)

FIG 5

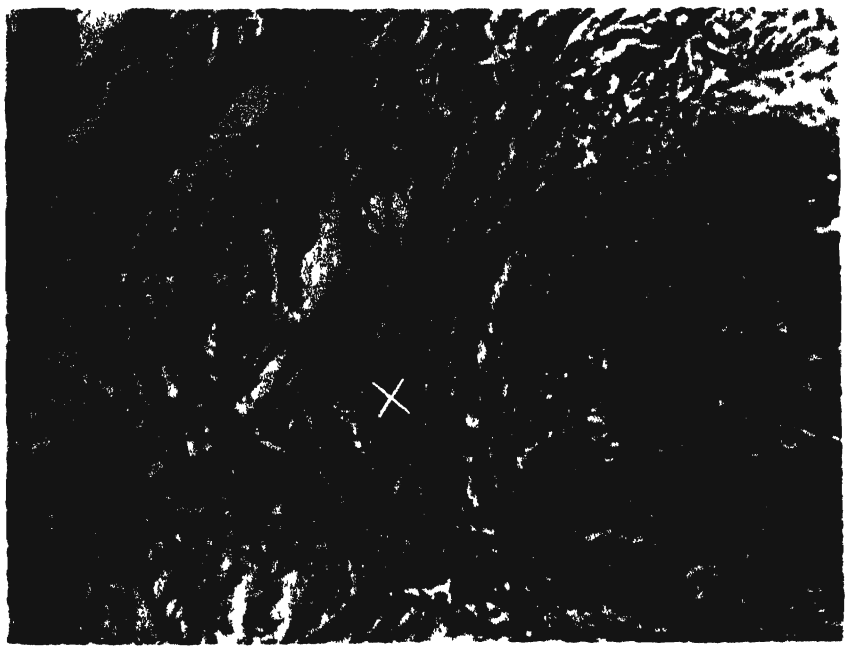

FIG 6

OCCURRENCE OF TREMATODE OVA HAPALOTREMA CONSTRICTUM (LEARED) IN FIBRO EPITHELIAL TUMORS OF THE MARINE TURTLE CHELONIA MYDAS (LINNAEUS)

FIG 7

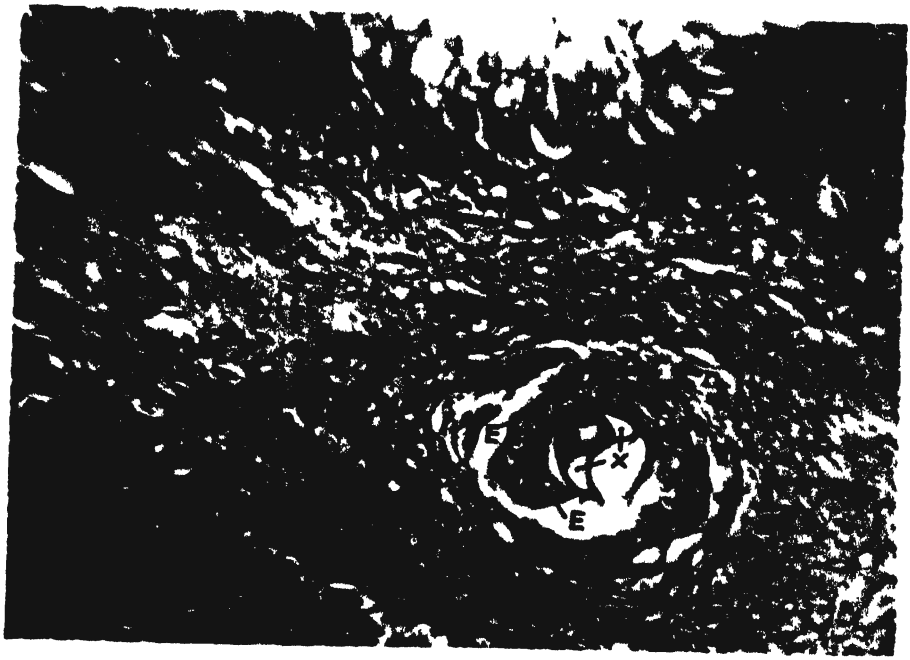


FIG 8

OCCURRENCE OF TREMATODE OVA HAPALOTREMA CONSTRICTUM (LEARED) IN FIBRO EPITHELIAL TUMORS OF THE MARINE TURTLE CHELONIA MYDAS (LINNAEUS)

FIG 9

FIG 10

OCCURRENCE OF TREMATODE OVA HAPALOTREMA CONSTRICTUM (LEARED) IN FIBRO EPITHELIAL TUMORS OF THE MARINE TURTLE CHELONIA MYDAS (LINNAEUS)

# NOTES

**A Record Size (480 mm.) John Dory *(Zenopsis ocellatus)* with Notes on Its Distribution in Our North and Middle Atlantic Waters.** —At the annual meeting of the Boston Society of Natural History in 1858, Dr. Storer described the first American species of John Dory, naming it *Zeus ocellatus*. Subsequent changes in the nomenclature have altered this name to *Zenopsis ocellatus*. This fish, six inches long, was found at Provincetown, Mass., and from that time until 1912, no further records are known to the author. On this latter date (1912) Mr. J. T. Nichols, of the American Museum of Natural History, saw half a dozen taken by a trawler off New York, on the outer part of the continental shelf in 52 to 86 fathoms.

Bigelow and Welch in their "Fishes of the Gulf of Maine," 1924,[1] mention only these two occurrences of the species and state that "the continental shelf is presumably its normal habitat." The next published record for *Zenopsis ocellatus* was in 1932 when Mr. J. C. Pearson, of the U. S. Bureau of Fisheries,[2] reported a specimen taken in a trawl net during the winter of 1930-31 in 20 to 60 fathoms about east of Bodie Island, N. C.

During the winters of 1932-33 and 1935-36, while stationed at Norfolk, Va., making observations of the winter trawl fishery activities, I collected a total of about 40 specimens up to ten inches in length, but which were not saved, because of lack of preserving materials. They were all taken in trawl nets along the continental slope, from Okracoke Inlet, N. C., to Cape May, N. J., in 20 to 75 fathoms. In the intervening years when I was not

1 *Bulletin of the U. S. Bur. of Fish.* Vol. XL, 1924, Pt. 1.

2 Winter trawl fishery off the Virginia and North Carolina coasts. J. C. Pearson. *U. S. Bur. of Fish. Investigational Repts.*, No. 10. Vol. 1, 1932.

*Photo by Amer. Mus. Nat. Hist.*

Text-figure 1.

*Zenopsis ocellatus*. Record size John Dory, 480 mm.

in Virginia I have learned from reports of the fishermen who know the species, that these John Dories were still quite abundant in this area.

Furthermore, in April, 1933, at Cape May, N. J., a trawler fishing about southeast of Five Fathom Bank Lightship in 40 to 45 fathoms, brought in several specimens taken in one trip. I had an opportunity to measure them and found one of unusual size. It measured fifteen inches in total length, and was for the time a record size.

The evidence up to this point appears to establish both summer and winter habitats of the species, for, in recent studies of the Bureau's survey of the fauna off Cape May in the summers of 1929 to 1932 inclusive, numerous specimens of the John Dory were found from Five Fathom Bank Lightship up to and in the mouth of Delaware Bay. However, the latest record of this fish extends the distribution to the north.

A specimen of *Zenopsis ocellatus* 160 mm. long was taken in the trawl net of the Str. *Penguin,* November 19, 1936, about 45 miles W x N of Sable Island (Lat. 43:50, Long. 61:30) in 30 fathoms. This fish was presented to me for identification and was later turned over to the Boston Society of Natural History. It was a juvenile, for it had the familiar long black filamentous rays on the ventral fins (50 mm. long) characteristic of this early age.

On January 2, 1937, the Str. *Fordham,* fishing between La Have and Browns Bank (Lat. 42:45, Long. 64:30) in 52 to 60 fathoms, hauled up in its trawl net a John Dory measuring 19¼ inches, the largest on record.

The following description includes some interesting data concerned with its great size: 480 mm. total length; 457 mm. to middle rays of caudal; 385 mm. standard; 210 mm. deep. Head 2⅞ in standard length; depth 2 in length; eye 6 in head. Weight 3¼ pounds round. Caudal fin subtruncate, normally truncate. Pectoral equal in length to maxillary. First dorsal VIII, 27, anal II-I, 25, pectoral 12, ventral 6.

The skin is naked except for a series of bony plates or "bucklers," each with a recurved or hooked spine, arranged as follows: 7 plates along the base of the dorsal on the left, but only 6 plates on the right side; 4 plates along the base of the anal on the right side, but 5 on the left. The normal number of plates given in the literature is 7 pairs along the dorsal and 4 pairs along the anal. In light of the fact that no study of the range of fin or plate counts has ever been made it is impossible to state whether or not there is an anomaly here, or if this is simply within the normal range of variation.

In the following respects this fish is most unusual: (1) It is the largest ever to be recorded—480 mm. (19¼ inches) from tip of snout to tip of longest rays of the caudal; (2) the discovery of this and the *Penguin's* catch extends the northerly range of the species to Sable Island, in the offing of Nova Scotia—FRANK E. FIRTH, *Biological Collector, U. S. Bureau of Fisheries, Biological Laboratories, Cambridge, Mass.*

# 27.

# Studies on Fish Parasites of Lake Erie. Distribution Studies.[1]

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[1] This is the fourth of a series of papers on fish parasites of Lake Erie. The others contained descriptions of new species. See Bibliography. It was not feasible to include all of the more recent nomenclatorial changes in hosts and parasites. This is especially true of the Strigeidae.

[2] With the aid of a grant from the Charles Himrod Denison Research Fund in Biology.

## Section I. Introduction.

This study was initiated in 1928 as a part of the joint Cooperative Biological Survey of Lake Erie. The program was made possible through the cooperation of the United States Bureau of Fisheries, the New York State Conservation Department, the Ohio Division of Conservation and the Province of Ontario. The fish were collected from the east end of the lake only during the summer of 1928 while the collections from the opposite end extended from 1927 through 1929. In working on these collections emphasis was placed upon the helminths, although each fish was examined for evidence of infection by ectoparasites, as leeches, flukes and copepods. The primary object of this study has been threefold: (1) to identify the parasites collected, (2) to describe any new species encountered, (3) to study the regional distribution of these parasites and compare the infection (a) by families of fishes and (b) by degree of infestation.

During the early portion of this program much time was spent in identifying the various parasites encountered. During the interval from 1928 on, many of the species found were described by colleagues who had met these same forms in the course of their own work. Thus we are indebted particularly to the recent publications of Van Cleave & Mueller (1932, 1934) and Mueller & Van Cleave (1932), while Moulton (1931), Hopkins (1931, 1931a, 1934) and others have added adequate descriptions of other fish parasites. Many forms remained to be considered, however, and the earlier sections of the "Studies on Fish Parasites of Lake Erie" were confined to morphological descriptions of new species (Hunter & Bangham, 1932, 1933; Bangham & Hunter, 1936). The present paper is primarily an attempt to record the presence, distribution and severity of infection of the various fish parasites encountered. With so much recent and excellent material available it did not seem necessary to include figures of the parasites studied.

While finishing the manuscript the final section of the Lake Oneida studies was issued. While our material is treated in a somewhat different manner, nevertheless certain comparisons may be made. Van Cleave & Mueller (1934) record 90 species of worm parasites, while we found approximately 96, excluding 16 different ectoparasites. In the Oneida Lake studies 1,227 fish belonging to 34 species were examined while the present paper covers a total of 2,156, belonging to 79 species of fish. A further check reveals a surprisingly large number of parasites and hosts common to both localities.

A general survey of this type would be impossible without the able and willing assistance of many colleagues. Therefore the authors wish to acknowledge gratefully the assistance of the following: the United States Bureau of Fisheries, the New York State Conservation Department, the Ohio Division of Conservation and the Province of Ontario for furnishing the opportunity, funds and equipment necessary for this task; Mr. E. L. Wickliff, Ohio Division of Conservation, and Dr. J. R. Greeley, New York State Conservation Department, for the identification of the fish; Dr. Charles B. Wilson, State Normal College, Westfield, Mass., for the identification of the parasitic copepods from the east end of the lake; Dr. Andrew E. Zillig for material; Wanda Sanborn Hunter for many helpful suggestions and the compilation of much of the data; Mr. Wilbur N. Tidd for identification of parasitic copepods from the western end of the lake and for furnishing preserved parasites from more than 100 fish from the same area; the directors of the Stone Laboratory of Ohio State University and the State Fish Hatchery, both located at Put-in-Bay, Ohio, who furnished laboratory facilities where much of the preliminary work of examination and identification of parasites from the western region was done.

In this work the nomenclature of Dr. Carl L. Hubbs, Fisheries Institute, Ann Arbor, Michigan, has been followed in the host identification.

*Habitat*: Some information about Lake Erie may be gleaned from a

number of sources. However certain general features of the lake should be called to the reader's attention. In the first place, Lake Erie is the shallowest of the Great Lakes. For our purpose it may be roughly divided into three parts. The western end, extending from Peele Point, Ontario, to Cedar Point, Ohio, is characterized by great quantities of shoal water filled with many weed beds and is an area well adapted to the propagation of fish. The maximum depth for this area is about 8 fathoms. The middle region of Lake Erie (as designated here) extends from Peele Point to Long Point, Ontario, and from Cedar Point, Ohio, to the Pennsylvania-New York state line. This comprises the greatest portion of the lake from the standpoint of area. Here the shoreline drops off quite sharply and the maximum depth gradually increases from 7 to 8 fathoms at its western limits to the deep hole of 35 fathoms off Long Point. The eastern end includes the remainder of the lake, which gradually becomes more shoal as the mouth of the Niagara River is approached. The shore is much the same as that noted for the middle portion, with the exception of Long Point Bay which is a well-protected, shallow, weedy area forming an excellent breeding ground for fish.

There are many streams flowing into Lake Erie. The three largest inlets are the St. Clair, Maumee and Grand Rivers. All other inlets are much smaller. The shallowness of the western end of Lake Erie has been noted. Here the shore and surrounding terrain are likewise flatter than the more easterly portion, thus producing a more meandering type of stream. This is even more strikingly shown along the Canadian shore, while east of Sandusky, Ohio, the terrain becomes more rolling and many streams drop relatively rapidly to reach the lake. East of Silver Creek, N. Y., the country again becomes flatter. These differences are correlated in a general way with the amount of shallow water, the number of weed beds, etc., present in the lake proper.

## Methods of Collection and Preservation.

*Hosts*: The fish were secured from a variety of sources. Seining parties of the various interested groups secured many forms from the shallower waters. Trap nets and gill nets used in experiments on mesh at the west end of Lake Erie were set with those of the commercial fishermen, mainly towards Peele Island and off Cedar Point. Both of these devices were utilized extensively at the east end of the lake. In some instances material was secured through the commercial fishermen, principally those working out of Ashtabula and Sandusky, Ohio, Erie, Pa., and Port Dover, Ont. Trawls, hook and line, as well as set lines, were resorted to occasionally. Stations at the west end were visited at regular intervals during the summer months. The fish were always preserved in formalin and their identification verified by a competent ichthyologist.

*Parasites*: Insofar as possible the material was examined while it was still fresh. In some instances identifications were made on the living parasites, this being done whenever possible on the encysted Strigeidae. The parasites were preserved in 5% formalin, a saturated aqueous solution of mercuric chloride, Bouin's or Gilson's fixing fluids.

Wherever possible identifications were made from toto mounts. Carmine, alum cochineal, Delafield's and Ehrlich's hematoxylin were the stains which were used for trematodes, cestodes and Acanthocephala. Whenever the occasion warranted serial sections were made, the material being stained in Delafield's hematoxylin and counterstained with eosin. Tapeworms were frequently stained in a mixture of Ehrlich's and Delafield's hematoxylin. Nematodes were usually mounted unstained in glycerine jelly and ringed, or were studied as temporary mounts in lacto-phenol.

## Collecting Stations.

*Eastern End of Lake Erie*: The area herein designated as the eastern end of Lake Erie covers all of the lake east of an imaginary line drawn from Long Point, Ontario, to the New York-Pennsylvania state line. The area likewise includes the Niagara River, principally above the Niagara Falls, as well as mouths and the lower portions of the various tributary streams flowing into Lake Erie. The streams on the New York side were much more intensively covered than those along the Canadian shore.

There is much more shallow water (and therefore presumably better breeding grounds) in the western end of the lake. The vast middle portion of the lake, while not intensively studied, could scarcely be expected to yield markedly divergent results as the shore line resembles the eastern portion in many respects. In the first place, this large middle area of Lake Erie, as already noted, receives a series of short streams draining into the lake, which is also characteristic of the eastern end, and in the next place the 21-foot contour line extends about as far into the lake as it does along the eastern end (except for the Long Point region). The maximum depth of Lake Erie increases gradually from west to east, reaching the so-called deep hole of 35 fathoms off Long Point.

All of the collections at the eastern end were made between June and September in 1928. Most of the fish were secured from seine hauls along the shore, or at the mouths of streams. A few were collected by hook and line while others were received from the nets of various commercial fishermen. The Long Point Bay area was fairly intensively covered in a single expedition made during August. No regular seining stations along Lake Erie were established and in most cases a locality was only studied once. This was necessary as the Lake Erie studies were undertaken as a part of the survey of the entire Erie-Niagara watershed within the borders of New York. Consequently the picture is not as complete as that presented for the opposite end of the lake. Nevertheless we believed the work at both ends of the lake covered such different types of water that a study of fish parasites would yield really fundamental differences in parasitism.

There were 33 different localities in the eastern area from which fish were taken; of these 17 representing typical "lake" stations, i.e., several miles offshore or some spot along the lake shore other than the mouth of a stream; 3 were Niagara River stations and 13 were located at the mouths of streams flowing into the lake or Niagara River.

*Western End of Lake Erie*: The area discussed in this paper as the western end of Lake Erie is the region west of an imaginary line between Cedar Point, Ohio, and the tip of Peele Point, Ontario. This is a smaller portion of the lake but contains the chief spawning areas for many species of fish as it is relatively shallow, contains the necessary protection and has many islands. This is clearly shown by the greater distance the 21-foot contour line extends out into the lake.

During September, October and November, 1927, many of the fish examined for parasites were obtained from experimental trap and gill nets set off of Cedar Point and in the vicinity of Kelly's Island. Many fish were examined that were taken in the latter part of the summers of 1928 and 1929 from a Petersen fish trawl. Hauls from this trawl were taken from the regular stations in the open lake where limnological data were obtained. The greater number of the fish studied from this area were secured in seine hauls made in selected areas along the shore line and along the islands. Two seining trips were made during the summer of 1928 and four at intervals of about three weeks during that of 1929. A 100-foot seine was used at all stations and an effort was made at each haul to cover an area of 10,000 square feet. The net used was graded from three-fourths inch square mesh on the ends to one-eighth inch square mesh in the bag.

The 40 seining stations in this area include the following: 7 in Sandusky Bay, 5 of which were filled with weeds and large stones, the 2 on the west side of the Bay near the lake being shallow with sand bottoms; 10 along the Ohio shore, located at intervals from west of the mouth of Sandusky Bay to the Maumee Bay, with sand or gravel bottoms with occasional patches of pond weeds or rushes; 4 inside Maumee Bay, those on the east side near the lake being filled with pond weeds and those farther inside with but little vegetation and a bottom of oil-saturated clay; 3 along the Michigan shore, which were shallow with scattered rushes and pond weeds; 8 along the Canadian shore from near the mouth of the Detroit River to the vicinity of Kingsville, Ontario; 13 along the shores of Kelly's, Middle, Peele, East Sister, North Bass, Sugar, Middle Bass and South Bass islands where a suitable area was located. In protected bays weed beds were encountered and in more open places the bottom was of sand or gravel. In addition to these stations occasional visits were made to the shallow, weedy, spawning areas in East and West Harbors and in the "ponded" portion near the mouth of the Portage River above Port Clinton. The fish secured in these latter areas were chiefly young forms.

The data for a few fish secured outside the designated area are included in the tables and descriptions of parasites of fish from the western area. These are chiefly records for cisco, whitefish and the long-nosed dace.

## Section II. Parasitism in General.

*Historical Account of Studies upon Fish Parasites.* Although the literature upon fish parasites is quite extensive it should be recalled that most of the work has been done within the last forty years. Futhermore it should be borne in mind that most of the forms encountered by the early workers were new to science. Consequently most of these contributions were of a strictly taxonomic nature. Perhaps the best known worker of this early era was Leidy who described many new parasites from 1851 to 1888. Linton (1891-1925), who followed him, began to produce more ecologically-framed papers, particularly those dealing with salt water forms. Herein attention will be directed toward the parasites of fresh water fishes. Other workers of the same general era, who made contributions to the morphology of parasites, were Ward (1894-1918), Stafford (1900-1904), Marshall & Gilbert (1905), Osborn (1902-1919) and Cooper (1914-1920).

The first adequate summary of this early literature was made by Pratt (1900-1902) and Ward & Whipple (1918) brought the American literature upon the subject up to date. Intensive monographic taxonomic studies of small groups of fish parasites and others have been undertaken principally by Dr. Ward and his students. Ward (1910) investigated the parasitic fauna of the Sebago salmon. Some of these studies contained a limited amount of material on host relationships. Thus LaRue (1914) published a monograph upon the Proteocephalidae, while Cooper (1919), Manter (1926), Essex (1928), Hunter (1930) and Hopkins (1934) published respectively upon the Pseudophyllidea, Azygiidae, Corallobothrium, Caryophyllaeidae and Allocreadiidae. More recent publications should include the taxonomic contributions of Van Cleave & Mueller (1932) and Mueller & Van Cleave (1932). Other workers who have contributed are legion. Some of the more important of them might be mentioned: Bangham (1925, 1927), Cooper (1915, 1920), Cort (1913), Essex (1928, 1928a, 1928b, 1929, 1929a), Faust (1918, 1919), Guberlet (1922, 1927, 1929), Holl (1928, 1929, 1929a), Hughes (1927-1929), Hunter (1927-1933), the Hunters (1929-1934), LaRue and his group of students and associates (1909-1932), Mueller (1930, 1933, 1934), Simer (1929, 1931), Thomas (1929, 1930), Woodhead (1926, 1929, 1930, 1932) and Van Cleave (1916, 1919).

Interest in the distribution, degree of infection and other more complex aspects of the host-parasite relationship as viewed from an ecological angle has been largely lacking. Probably the first contribution of this type is Ward's (1894) record of an examination of 20 species of fish from Lake St. Clair. Marshall & Gilbert followed this in 1905 by a study of the food and parasites of 13 species of fish taken from the lakes near Madison, Wisconsin. Several years later Ward (1912) published accumulated data on 991 fish representing 62 species. These data were treated statistically and the various percentages of infection with different groups of parasites were recorded. Cooper (1915b) contributed to our knowledge of the regional distribution of fish parasites from Canadian waters while Pearse (1924) studied the parasites of the yellow perch. Throughout the year and later (1924a) he treated of parasitism in fishes taken from the upper Mississippi (Lake Pepin) and certain Wisconsin lakes. Essex & Hunter (1926) recorded data from 652 fish and compared the percentage of infection in fishes from lakes and rivers in the various classes of helminths. This was followed in 1933 by a paper by Dolley who studied the distribution of plant and animal forms along the St. Joseph River. Other surveys of fish parasites have been made by the Hunters from 1929 on as a part of the New York State Conservation Department's Biological Survey Program. These have dealt primarily with distribution of various parasites and the general degree of infestation in the fishes of different watersheds.

Cross (1933, 1935), in studying host-parasite relationships of fish from Wisconsin lakes, suggests that certain parasites have a retarding effect upon the growth of their hosts. In 1934 he cited evidence for a case of non-specific immunity between Acanthocephala and tape worms of the cisco.

Adams & Hankinson (1928) contributed to our knowledge of the fishes of Oneida Lake and included some data on fish parasites gleaned from the literature. Holl (1932) makes an ecological analysis of certain fish and amphibian parasites. Van Cleave & Mueller in 1934 presented their completed ecological analysis of the fish hosts and their parasites from Oneida Lake.

*Parasitism in General:* During this study 2,156 fish belonging to 79 species and 22 families were examined and of this number 1,257 or 58.3% were found to harbor one or more species of parasites. This represents a moderately high degree of infestation since numerous young fish are included. Essex & Hunter (1926), in a study of fish parasites from lakes and streams of the central states, found 39% of 652 fish infested with parasitic worms. However, they examined a relatively large proportion of fish which generally have but few parasites. When these, gizzard shad, carp and young channel catfish were excluded from their computations, nearly 50% of the remainder carried some form of parasitic helminths. Bangham in 1930 made a study of fish parasites of Buckeye Lake, a comparatively small Ohio Lake of approximately 4,200 acres. The unpublished data show that 65.7% of 514 fish harbored one or more species of parasites. These fish belonged to the same families as those covered in the Lake Erie study. The number of different parasites encountered was much less in the Buckeye Lake fish than in the same host taken from Lake Erie. Species of fish examined that had been secured from streams flowing into Lake Erie yielded both fewer parasites and a smaller variety of infecting forms than the same species of fish taken from Lake Erie. The data of stream fish are not included in this report and are unpublished except for a portion of the records covering large- and small-mouthed black bass (Hunter & Hunter, 1931, and Bangham, 1934).

As will be pointed out in numerous instances in comparisons of individual species taken at opposite ends of Lake Erie, there is very often a larger variety of infesting forms and a higher degree of infection in the fish examined from the western area. The reason for this condition appears to

be the greater area of shallow, warmer water and weedy regions favorable to the production and growth of quantities of snails, crustacea and small fish, which act as primary hosts for many of the fish parasites.

The majority of the fish examined belonged to six families as follows: 108 to the Coregonidae, 92 to the Catostomidae, 672 to the Cyprinidae, 75 to the Ameiuridae, 428 to the Percidae and 395 to the Centrarchidae. These yielded respectively 52.7, 28, 43.3, 73.3, 69.4 and 73.6% infection by parasites. In the family Esocidae two species were examined while in the remaining 15 families but a single species of fish was examined in each. In certain groups such as Gasterosteidae, Cottidae, Salmonidae, Atherinidae and Umbridae there were but one or two kinds of parasites found in each fish. In the Amiidae, Lepisosteidae, Percopsidae, Percidae, Centrarchidae and Sciaenidae many different forms were often encountered in each infected fish. Individuals belonging to the last group of families include many larger forms which frequently have as a part of their diet smaller fish carrying larval stages of parasites which mature in these carnivorous fish. With the exception of the trout perch belonging to the Percopsidae and the darters of the Percidae, the fish harbored a majority of adult parasites.

Even though certain Lake Erie fish carry a large variety of species, parasites are not in general a serious menace. So far, no infestations of epidemic nature have been found although most of the forms which cause outbreaks under the crowded, somewhat unnatural conditions of the inland hatcheries were secured from these lake fish. A large proportion of the fish free from parasites were either young or adults belonging to a few species such as stickleback, miller's thumb, gizzard shad, carp and most of the suckers. In the tables giving parasitism by families, whenever young fish were examined they were separated from the adults in compiling the data.

*Parasitism and Pollution*: No correlation could be established between water pollution and degree of infestation. Fish taken from Maumee Bay near Toledo and from the lake shore near the mouth of the Detroit River were not more heavily infected than the same species obtained from the relatively clean water near the shores of the Bass Islands. However, fish secured from the weedy marshes which open into Lake Erie near Port Clinton, Ohio, did show a higher degree of infestation for almost all fish species when compared with the same forms taken along the shore of the lake. This shallow, clean water was an ideal breeding area for many fish as well as for numerous snails, Copepoda, Cladocera, Amphipoda and other forms which act as first intermediate hosts for the parasites of these fish.

*Parasitism and the Host:* Larval stages of certain helminths often reach young fish early in their development. Six young small-mouthed black bass 10 to 15 mm. in length taken June 17, 1928, had from 1 to 10 larval plerocercoids, *Proteocephalus pearsei* LaRue, in their intestinal tracts. Three young large-mouthed black bass 11 to 18 mm. in length taken June 28, 1929, from West Harbor carried from 2 to 10 mesentery cysts of a cestode, probably *Proteocephalus ambloplitis* (Leidy). Young whitefish were obtained in the Petersen trawl in May and June, 1928, from the western portion of the lake. Four of these measured 18, 24, 26 and 30 mm., respectively, and carried 3 to 9 larval cestodes in their intestinal tracts. One was approaching maturity and was identified as *Proteocephalus exiguus* LaRue. The smallest pike perch examined was a 27 mm. individual secured June 27, 1929, and it carried in its intestine four larval cestodes which belonged to the species *Proteocephalus stizostethi* Hunter & Bangham. All of these cestode parasites were found while the food of the young fish was chiefly limited to smaller Entomostraca. As the fish became larger and changed their food habits the parasitic fauna became more varied.

In a few instances the parasitism caused noticeable harm to the host as seen in the case of sterility in large-mouthed and small-mouthed black

bass due to an infestation in the reproductive organs of larval cestodes, *Proteocephalus ambloplitis* (Leidy). Emaciation in certain fish appeared correlated with the presence of hundreds of Acanthocephala whose spiny proboscides were embedded in the intestinal walls. Some fish, notably the spot-tailed minnow, carry in their body cavities 1 to 5 larval cestodes, *Ligula intestinalis* (Linn.). These render the host potbellied and sluggish; such fish are easily captured by birds constituting the definitive host. Many fish such as certain adult whitefish, yellow perch and pike perch often carry large numbers of small to medium-sized cestodes free in their intestinal tracts with but little apparent injury to the host. The mesenteries were full of fat and the fish appeared to be vigorous. The commercial value of many fish is destroyed even though there may be no great physical harm to the host, through the presence of the disfiguring lymphocystis disease or the presence of encysted metacercariae under the scales and throughout the flesh. Both saugers and pike perch were found to be so afflicted.

Although these fish were examined carefully, no evidence of fish infected with the plerocercoid larvae of the broad tapeworm of man, *Diphyllobothrium latum*, was found.

*Parasitism by Families of Fish*: As was mentioned previously, representatives of 22 families of fish were examined for parasites. In some instances sufficient numbers of individuals were not examined to warrant any conclusion being drawn, but in other cases it is apparent that there is ample material. Certain sources of error should be borne in mind as, (1) the difference in numbers of a given species examined from either end of the lake; (2) the absence of any appreciable numbers of fish from the central portion of the lake; (3) the inclusion of a few records of fish which should be definitely characterized as stream fish; (4) the impossibility of always procuring comparable samples through the use of identical equipment; (5) the collection of samples from given stations at the western end compared with a single visit to comparable locations in the eastern end. This is one of the most serious drawbacks, for repeated visits probably resulted in a more complete picture of the parasitic fauna than could be ascertained by a single visit.

However, it is the sincere hope of the authors that the attempt to bring together data on the parasites of 2,156 fish representing 79 of the reported 95 species from one of the largest fresh water lakes ever studied in this fashion, will prove to be sufficiently useful to warrant the overlooking of certain unavoidable discrepancies in planning and execution of this program. Much closer cooperation would have been possible if we had become imbued with the idea of formulating a joint paper at the beginning of the work instead of the end. Certainly there is a real advantage to the joint recording and study of these data over the separate publication of reports upon the parasites of fish from the eastern and western ends. In a surprisingly large number of cases the numbers of hosts are sufficient to warrant comparisons.

Two tables are appended. Table A indicates the total number of fish examined from each family and the percentage of those which were infected. A glance at this shows that the Lepisosteidae (88.8 %), Amiidae (100 %), Salmonidae (63.5 %), Esocidae (61.5 %), Percidae (69.4 %), Centrarchidae (73.6 %), Sciaenidae (91.6 %) and the Gadidae (100 %) might all be grouped together. These figures are of course based principally upon examinations of adult fish. It should be pointed out that these roughly fall into the groups of so-called "carnivorous or piscivorous fishes," a large proportion of whose diet consists of other good-sized fish, other vertebrates and certain of the larger invertebrates, as the molluscs, crustacea and insects. If we add the Percopsidae (82.4 %) and the Ameiuridae (73.3 %), we have all the fish families having more than the average percentage of infection. It is interesting to note that the species examined by us as representatives of

these families are all known to include significant quantities of other fish, aquatic larvae, crustacea and molluscs, all of which in turn are known to carry helminths in various intermediate stages of development. On the other hand, those which specialize upon plants, or some one group as bottom feeders, like so many of the Cyprinidae (43.3 %), or plankton feeders, as the Gasterosteidae (18.1 %), show a percentage of infection significantly below the average. While this correlation has not been checked mathematically, it would appear that a fair correlation might be expected.

TABLE A.

Percentage of Parasitism by Families of Fish.

| *Family* | *Number Examined* | *Percentage Infected* |
|---|---|---|
| 1. Acipenseridae | 2 | 100.0 |
| 2. Lepisosteidae | 9 | 88.8 |
| 3. Amiidae | 4 | 100.0 |
| 4. Hiodontidae | 28 | 53.8 |
| 5. Clupeidae | 5 | 20.0 |
| 6. Coregonidae | 108 | 52.7 |
| 7. Salmonidae | 63 | 63.5 |
| 8. Catostomidae | 92 | 28.2 |
| 9. Cyprinidae | 672 | 43.3 |
| 10. Ameiuridae | 75 | 73.3 |
| 11. Umbridae | 12 | 50.0 |
| 12. Esocidae | 13 | 61.5 |
| 13. Cyprinodontidae | 31 | 41.9 |
| 14. Percopsidae | 53 | 82.4 |
| 15. Serranidae | 34 | 88.2 |
| 16. Percidae | 428 | 69.4 |
| 17. Centrarchidae | 395 | 73.6 |
| 18. Atherinidae | 45 | 22.2 |
| 19. Sciaenidae | 48 | 91.6 |
| 20. Cottidae | 7 | 28.6 |
| 21. Gasterosteidae | 22 | 18.1 |
| 22. Gadidae | 10 | 100.0 |
| Total examined | 2,156 | |
| Total parasitized | 1,257 | |
| Percentage infected | 58.3 | |

The three families with the lowest percentage of infection are the Gasterosteidae with only 18.1 %, the Clupeidae with 20 %, the Atherinidae with but 22.2 %. Unpublished data (Hunter & Grant) on the first family indicates a decided preference for plankton with larvae (as *Chironomus*) coming in at certain seasons of the year. Members of the next two groups are listed by Sibley (1929) as being groups whose diet was primarily plankton. It would thus appear that those families of fish whose food is largely secured from plankton would be correlated with a lower degree of parasitism.

Table B is an attempt to furnish some concept of the numbers examined of each family of fish. This does not, of course, mean that the same species were always included nor even the same numbers of a given species. But again it does suggest that we may be hopeful of securing sufficient data for comparison of the families as a whole (assuming more or less equal representation of species) in some of the cases. One fact stands out quite clearly—the fish from the western end of Lake Erie are more universally infected than those from the eastern end. This also holds for given families, as the Hiodontidae, where there is a difference of nearly 40%, the Ameiuridae with differences of more than 65%, and the Centrarchidae with about a 20% discrepancy. Probably the Cyprinodontidae should be included as there is a range of 21.4 to 58.8% between those taken from the eastern and western extremities of Lake Erie. Others which show rather striking differences are

the Catostomidae with a difference of something more than 60% and the Atherinidae whose extremes ranged between uninfected fish and a one-third infection at the western end. Possibly the Coregonidae should be included, too, except for the assumption that they are even more migratory than the others which were encountered. Likewise both the Cyprinidae and Percidae might be mentioned although the differences are not so marked. The Esocidae furnish the only divergence from this general plan, for in this one instance the Esocidae were all infected in the eastern region while less than 30% from the opposite end were carrying parasites.

TABLE B.

Comparison by Regions of Percentage of Parasitism by Families of Fish.

| | *Eastern End* | | *Western End* | |
|---|---|---|---|---|
| *Family* | *Number Examined* | *Per cent. Infected* | *Number Examined* | *Per cent. Infected* |
| Acipenseridae | 0 | 0 | 2 | 100.0 |
| Lepisostidae | 1 | 0 | 8 | 100.0 |
| Amiidae | 0 | 0 | 4 | 100.0 |
| Hiodontidae | 16 | 37.5 | 12 | 75.0 |
| Clupeidae | 0 | 0 | 5 | 20.0 |
| Coregonidae | 72 | 30.0 | 36 | 97.2 |
| Salmonidae | 63 | 63.5 | 0 | 0 |
| Catostomidae | 77 | 18.1 | 15 | 80.0 |
| Cyprinidae | 326 | 37.4 | 342 | 48.8 |
| Ameiuridae | 15 | 20.0 | 60 | 86.6 |
| Umbridae | 3 | 0 | 9 | 66.6 |
| Esocidae | 6 | 100.0 | 7 | 28.5 |
| Cyprinodontidae | 14 | 21.4 | 17 | 58.8 |
| Percopsidae | 7 | 71.4 | 46 | 95.7 |
| Serranidae | 2 | 50.0 | 32 | 90.6 |
| Percidae | 137 | 59.8 | 291 | 73.8 |
| Centrarchidae | 113 | 59.3 | 282 | 79.4 |
| Atherinidae | 15 | 0 | 30 | 33.3 |
| Sciaenidae | 3 | 100.0 | 45 | 91.1 |
| Cottidae | 0 | 0 | 7 | 28.6 |
| Gasterosteidae | 20 | 15.0 | 2 | 50.0 |
| Gadidae | 3 | 100.0 | 7 | 100.0 |

## SECTION III. A COMPARISON OF PARASITISM WITHIN THE FAMILIES OF FISH.

In the following pages, we have discussed the parasites in the different families of fish. As complete records are given in the tables, this discussion is merely to emphasize salient points and summarize findings listed.

### ACIPENSERIDAE:

LAKE STURGEON, *Acipenser fulvescens* Rafinesque: Two specimens of the lake sturgeon were the only members of this family examined. These were taken from pound nets near Peele Isle. Both individuals carried small numbers of the trematode, *Crepidostomum lintoni* (Pratt in Linton, 1901) and the nematode *Cucullanus clitellaris* Ward & Magath, while one was infected with *Allocreadium* sp.

### LEPISOSTEIDAE.

LONG-NOSED GAR, *Lepisosteus osseus* (Linn.): The long-nosed gar was the only representative of this family examined and the single specimen from the east end was uninfected. Eight taken in seine hauls from the west end were all heavily infested. Seven harbored numerous encysted ple-

rocercoids of *Proteocephalus ambloplitis* (Leidy); these were found chiefly in the liver. *Proteocephalus singularis* LaRue were found as adults in the intestinal tracts of six fish. The trematode *Macroderoides spiniferous* Pearse was found in small numbers in five fish. Two specimens only carried nematodes; these constituted a new species and have been described as *Cystidicola lepisostei* (Hunter & Bangham, 1933). *Bothriocephalus* sp. and *Leptorhynchoides thecatus* were each present in one fish.

### AMIIDAE.

BOWFIN, *Amia calva* Linn: This species was taken only from the western end of Lake Erie. Three adults and one young yielded a 100% infection. One small adult had 25 adult *Proteocephalus ambloplitis* (Leidy), 8 *Crepidostomum cornutum* Osborn, 15 *Microphallus opacus* Ward, one *Haplobothrium globuliforme* Cooper and one *Haplonema immutatum* Ward & Magath in its intestinal tract. *Macroderoides typicum* (Winfield), *Leuceruthrus micropteri* Marshall & Gilbert and the acanthocephalid, *Leptorhynchoides thecatus* (Linton), were also present in this species. This relatively large number of parasites further substantiates the findings in other localities (Ward (1912), Essex & Hunter (1926), Hunter & Hunter (1930, 1932)). Five species of parasites found in the bowfin were also secured from the small-mouthed black bass. These were *P. ambloplitis, C. cornutum, M. opacus, L. micropteri* and *L. thecatus*. The small-mouthed black bass was found in the few locations where the bowfin was secured and also in more open waters in many other areas. According to Forbes & Richardson (1909), Coker (1917) and Rimsky-Korsakoff (1930), the food of the bowfin is chiefly animal, being composed largely of fishes with smaller numbers of crayfish, molluscs and adult insects comprising the remainder of the diet.

### HIODONTIDAE.

MOON-EYE, *Hiodon tergisus* Le Sueur: A total of 28 moon-eyes, *Hiodon tergisus*, were examined from Lake Erie. Two species of nematodes only were recovered from the 16 fish from the east end; these were *Rhabdochona cascadilla* Wigdor (1918) and *Camallanus oxycephalus* Ward & Magath (1917). The 12 fish from the west end harbored the same two nematodes. It should be noted that the fish from the west end not only carried a slightly heavier infection with these parasites, but also were infected by both trematodes and cestodes.

Three-fourths of the fish from the west end were infected compared with the 37.5% of the fish from the east end. Two of the trematodes were identified to genus only, *Leuceruthrus* and *Tetracotyle*, while the third proved to be *Crepidostomum illinoiense* Faust, 1918. Pearse (1924, 1924a) reports *C. illinoiense* from the moon-eye from Lake Pepin in the Mississippi River. Hunter in unpublished records on 8 more *Hiodon tergisus* from the St. Lawrence River and Black Lake, N. Y., reports three individuals carrying *C. illinoiense* as well as two with unidentified nematodes. The tapeworms encountered were an immature proteocephalid and *Bothriocephalus cuspidatus* Cooper (1917).

In this connection it might be recalled that Forbes (1888) found the food of five specimens of the moon-eye to consist wholly of insects (two-thirds of them terrestrial) with the exception of a trace of univalve Mollusca. Sibley (1929), in specimens 106 to 146 mm. long, found some *Cladocera* (6%) but terrestrial insects were the most abundant food. Boesal (unpublished data) reports on the food of 17 moon-eyes from the western area of Lake Erie obtained from five seining stations, three of which had sandy bottoms either lacking vegetation or with scattered *Potamogeton* and

*Scirpus* while the other two had hard clay bottoms with *Potamogeton* extending far out into the lake. All specimens not over 39 mm. in length fed on Entomostraca while those above 57 mm. fed entirely on insects and amphipods. These older forms had secured their food largely from the surface of the water.

With this host there appears a rather striking difference between the parasites encountered in fish from the opposite ends of the lake. As pointed out elsewhere this difference is undoubtedly partially attributable to the relatively greater area of the west end which is given over to shallow, weedy regions which are naturally productive of great numbers of first intermediate hosts of the helminths.

## CLUPEIDAE.

GIZZARD SHAD, *Dorosoma cepedianum* (Le Sueur): The gizzard shad was not often taken in our collections from Lake Erie; none were collected from the eastern end. In all, only five specimens were examined; one young fish had an unidentified larval nematode in the intestine. According to Tiffany (1921) these fish mainly feed on phytoplankton and are valuable food for game fish when they occur in sufficient numbers.

Van Cleave (1916), in reporting on the examination of 300 gizzard shad for parasites, found but two species of Acanthocephala belonging to the genus *Neoechinorhynchus*. He found that *Gracilisentis gracilisentis* (Van Cleave, 1913) enters this host in early fall and in April or May it attains sexual maturity and is lost from the host, not being found during the summer. On the other hand, *Tanaorhamphus longirostris* (Van Cleave) parasitizes the gizzard shad in the summer, reaching full sexual maturity by midwinter, disappearing entirely from spring to early summer. Essex & Hunter (1926) report no parasites in an examination of over a hundred gizzard shad taken from the Rock and Mississippi Rivers. Gizzard shad are very abundant in Buckeye Lake, Ohio, where the Ohio Division of Conservation conducted a survey in 1930. Here they often carry a very heavy infestation of a myxosporidian which forms large white cysts in the body cavities of the fish. The losses due to this type of infestation are especially high in young fish during the late summer and early fall, August and September. All of fifteen adult gizzard shad from Buckeye Lake examined by Bangham (unpublished data) were free of parasites and ten of twelve young carried many of the above mentioned encysted forms. These small fish were often quite "pot-bellied."

## COREGONIDAE.

A total of 108 fish belonging to two species, the lake herring, *Leucichthys artedi* (Le Sueur), and the whitefish, *Coregonus clupeaformis* (Mitchill), were examined from this family. In the latter species, the young and adults were considered separately.

LAKE HERRING OR CISCO, *Leucichthys artedi* (Le Sueur): Sixty-three lake herring were obtained from the east end and yielded a 25.4% infection compared with 15 obtained from the west end, 14 of which, or 95.5%, were infected. *Proteocephalus exiguus* LaRue was the dominant parasite in both areas; *P. wickliffi* Hunter & Bangham (1933) also was present in both regions, while *Abothrium crassum* (Bloch) was found only in fish from the west end.

Neither trematodes nor Acanthocephala were found in this species, and the nematodes were represented in but one instance at the west end where *Cystidicola stigmatura* (Leidy, 1886) was found encysted in the wall of the air bladder.

WHITEFISH, *Coregonus clupeaformis* (Mitchill): Nine whitefish were examined from the east end of the lake and of these 6 carried *P. exiguus* and one had an adult *A. crassum.* All of 15 adults and 6 young whitefish from the other end of the lake carried parasites. The only parasites of the young fish were larval and partly mature *P. exiguus.* These forms are obtained with the first food as two young whitefish 18 mm. long carried two each of plerocercoids similar to those in older fish which could be identified as *P. exiguus.* A young whitefish 30 mm. in length had 8 larval and one adult *P. exiguus.* Only three of the adult fish in this group carried this cestode but two of these fish each had from two to three hundred individuals in their upper intestinal tracts. The young fish and the three adults just referred to were examined in the summer while the remainder of the whitefish from the western area were obtained and examined in the fall.

The infestation of *P. exiguus* may be seasonal. As these fish feed on animal plankton as well as molluscs, they may obtain these cestodes directly from the first intermediate host. To quote Forbes & Richardson (1920), "The gill-rakers of the adult are of a size and number to enable it to separate from the water organisms as small as Entomostraca, and where these are abundant they make a large percentage of the food." Sibley & Rimsky-Korsakoff (1931) record 100% animal plankton for 18 whitefish and 70% animal plankton and 30% snails for two other fish taken later. Unpublished data on the food of the whitefish of western Lake Erie bear out these findings. In a 39 cm. whitefish from the Kelly's Isle region a plerocercoid was found in the auricular cavity. This appears to be similar to the one referred to by Linton (1925), Moore (1925, 1926) and identified later as *Schistocephalus* sp. by T. B. Magath. In certain regions species of coregonid fishes are so heavily infested with this form that it is a problem of real economic importance. Moore (1926) refers to the high frequency of infection in whitefish of Upper Saranac and Clear Lakes. These fish were introduced from the Great Lakes and have a higher mortality than the frostfish *Prosopium quadrilaterale* (Richardson) which are native to these lakes. Hunter & Hunter (1930) report finding this form in larger numbers in the frostfish of Chazy Lake, New York. The total infection with this *Schistocephalus* sp. at Chazy Lake was 17.7% and was much higher in fish found dead along the shore than in fish obtained in gill nets.

No significant comparison can be made between the degree of infestation of the fish in the two areas of the lake, as data for certain fish from the middle of the lake were obtained by both authors and are contained in the table for the western area. Furthermore, these fish migrate in the fall from the deeper eastern waters to their spawning beds in the shallower region at the opposite end.

## SALMONIDAE.

BROOK TROUT, *Salvelinus fontinalis* (Mitchill): Sixty-three brook trout were examined from the upper portions of streams flowing into eastern Lake Erie, between Buffalo and the Pennsylvania State line. Forty of these carried light infections of the nematode *Cystidicloides harwoodi* (Chandler). These findings corroborate those of Hunter & Hunter (1931) who called attention to the fact that brook trout from streams in that portion of New York harbored only intestinal nematodes.

## CATOSTOMIDAE.

The parasite fauna of this family is important since its members constitute a significant part of the diet of game fishes (Sibley, 1929). Seven species from four genera of fish were represented in the total of 92 examined. These were the white carp, *Carpiodes cyprinus* (Le Sueur); common sucker, *Catostomus commersonnii* (Lacépède); hog sucker, *Hypentelium nigri-*

*cans* (Le Sueur); red-fin mullet or red horse sucker, *Moxostoma aureolum* (Le Sueur); fine-scaled red-fin mullet or red horse sucker, *Moxostoma duquesnii* (Le Sueur); short-headed red-fin mullet or red horse sucker, *Moxostoma lesueurii* (Richardson); white-nosed red-fin mullet or red horse sucker, *Moxostoma anisurum* Raf.

Seventy-seven were examined from the eastern end and 15 from the western area. Of these 14 and 12, respectively, were infected, thus showing clearly a heavier infection at the latter end. This is further substantiated by the presence of only 7 species of parasites from the eastern area contrasted with 10 from the western.

WHITE CARP, *Carpiodes cyprinus* (Le Sueur): Thirteen of the 16 fish examined were from the east end and 5 of these were infected with *Rhabdochona cascadilla* Wigdor, one harbored *Hypocaryophyllaeus paratarius* Hunter. The three from the western area were negative.

COMMON SUCKER, *Catostomus commersonnii* (Lacépède): Eight of 13 from the east end were infected; four carried *Glaridacris catostomi* Cooper; two, *Ligula intestinalis* in the body cavity; one, *Triaenophorus nodulosus* larva and three carried *Octospinifer macilentus*. All 8 examined from the west end were infected; one carried larval *Triaenophorus nodulosus;* one, larval *L. intestinalis;* another *Agamonema;* four, *Neoechinorhynchus crassus;* one, *O. macilentus* and two harbored *Pomphorhynchus bulbocolli.*

HOG SUCKER, *Hypentelium nigricans* (Le Sueur): In all, 21 were examined and all but one were free from parasites. This one was the sole specimen taken from the west end and it carried only a slight infection of Myxosporidia.

RED HORSE SUCKERS, *Moxostoma aureolum* (Le Sueur), *M. duquesnii* (Le Sueur), *M. lesueurii* (Richardson) and *M. anisurum* Raf: One of the two common red horse suckers (*M. aureolum*) from the east end carried a nematode; nothing but a few encysted metacercariae belonging to the genus *Neascus* were found in the one from the west end.

Fourteen *M. duquesnii,* all from the east end, were negative. Six *M. lesueurii* from the east end were negative while the two from the west end were both parasitized; one with *Rhabdochona cascadilla* Wigdor and one with Myxosporidia.

Nine *M. anisurum,* all from the east end, were negative.

As is shown in the above, the common sucker, *C. commersonnii,* is the species most heavily infected. However, none of the parasites encountered in the various members of the family was found in sufficient numbers to be of economic significance.

## CYPRINIDAE.

A total of 672 fish from 23 species and 13 genera of Cyprinidae were examined from both ends of Lake Erie. It is significant to note in this connection that 326 fish came from the eastern end of the lake compared with 346 from the western end. Of these 122, or 37.7%, and 167, or 48.2%, respectively, were infected. These figures indicate rather forcibly the fact, more or less apparent heretofore, that the fish from the western end of Lake Erie may be expected to be more heavily parasitized. In addition the table shows that the infection deals with about an equal number of species of parasites since 13 were encountered in minnows from the east end compared with 14 from the west end. This condition is not typical, as a greater variety of parasites has usually been encountered in the fish taken from the west end of the lake. The equality of the infection data can undoubtedly be accounted for by the similarity of the environments of these fishes. Regardless of the locality from whence they came identical species would be found in similar environments. In order to make comparisons easier the species of fish and the number examined are listed in the following table.

| Species | Number examined from east end | Number examined from west end |
|---|---|---|
| (1) German carp, *Cyprinus carpio* (Linn.) | 7 | 6 |
| (2) Goldfish, *Carassius auratus* (Linn.) | 2 | 11 |
| (3) River chub, *Nocomis micropogon* (Cope) | 18 | .. |
| (4) Storer's chub, *Erinemus storerianus* (Kirtland) | .. | 31 |
| (5) Black-nosed dace, *Rhinichthys atronasus* (Mitchill) | 54 | .. |
| (6) Long-nosed dace, *R. cataractae* (Cuv. & Val.) | 41 | 10 |
| (7) Horned dace, *Semotilus atromaculatus* (Mitchill) | 40 | .. |
| (8) Pug-nosed minnow, *Opsopoeodus emiliae* Hay | .. | 10 |
| (9) Black-nosed shiner, *Notropis heterodon* (Cope) | .. | 8 |
| (10) Black-nosed minnow, *N. heterolepis* Eigenm. & Eigenm. | .. | 8 |
| (11) Minnow, *N. volucellus* (Cope) | .. | 14 |
| (12) Straw-colored minnow, *N. deliciosus stramineus* (Cope) | 3 | 9 |
| (13) Spot-tailed minnow, *N. hudsonius* (Clinton) | 11 | 83 |
| (14) Steel-colored minnow, *N. whipplii* (Girard) | 9 | 49 |
| (15) Lake shiner, *N. atherinoides* (Raf.) | 63 | 81 |
| (16) Rosy-faced minnow, *N. rubrifrons* (Cope) | .. | 1 |
| (17) Common shiner, *N. cornutus* (Mitchill) | 34 | 1 |
| (18) Red-fin shiner, *N. umbratilis* (Girard) | 13 | .. |
| (19) Silvery-jawed minnow, *Ericymba buccata* (Cope) | .. | 3 |
| (20) Golden shiner, *Notemigonus crysoleucas* (Mitchill) | 5 | 7 |
| (21) Blunt-nosed minnow, *Hyborhynchus notatus* (Raf.) | 3 | 10 |
| (22) Fat-head minnow, *Pimephales promelas* (Raf.) | 9 | 2 |
| (23) Stone roller, *Campostoma anomalum* (Raf.) | 14 | 2 |

The above table clearly indicates that comparisons between the hosts, i.e., species of fish, will be difficult since equal numbers of the same species of minnow were not collected from both ends of the lake. Yet some interesting comparisons should be possible in a family containing 672 specimens. It appears feasible to compare infections primarily by groups of parasites encountered.

Only two families of trematodes were encountered, Strigeidae and Allocreadiidae. The former were found more frequently than the latter and are represented by several genera and species compared with one species for the second family. This latter form was new and was described as *Lebouria cooperi* Hunter & Bangham (1932); it was encountered from a single species of minnow, *N. whipplii*, from the eastern end. From the opposite end *L. cooperi* was encountered in *E. storerianus, R. cataractae, O. emiliae, N. volucellus, N. deliciosus stramineus, N. hudsonius, N. whipplii, N. atherinoides, E. buccata* and *H. notatus*. This evidence clearly suggests that this species may be designated as a parasite of the Cyprinidae even though this, or a closely related species, was also encountered in the darters.

It is interesting to note that Strigeidae were found in many of the minnows from both ends of the lake. Nine of 16 different species carried encysted strigeid metacercariae from the east end while 13 of 19 species from the west end were infected. *Neascus vancleavei* from the liver and mesenteries proved to be particularly interesting as it is undoubtedly one of the most widely distributed parasites. One new strigeid, *Neascus rhinichthysi* W. S. Hunter (1933) was encountered in the flesh and under the scales of both species of *Rhinichthys*. This minute parasite appears to be confined to the members of this genus and has not been reported elsewhere. It is interesting that this parasite is closely allied to *Neascus bulboglossa* but differs from it in the presence of an acetabulum and other morphological features. It should be noted that many of the forms from the western end of the lake were identified to genus only.

Both *Bothriocephalus cuspidatus* Cooper (1917) and *Ligula intestinalis* (Linn.) were encountered in minnows from both ends of Lake Erie. In the case of both parasites the infection consisted of larval forms, the *B. cuspidatus* being found in the digestive tract while the *L. intestinalis* was of

course secured only from the coelom. The former species occurred in three *N. atherinoides* from either end; the latter was found in three species, *N. deliciosus stramineus, N. hudsonius* and *N. cornutus* from the eastern end of the lake and from *E. storerianus, O. emiliae, N. hudsonius, N. whipplii* and *H. notatus* at the western end. It should be noted here that more than half the 58 infected spot-tailed minnows carried *L. intestinalis.* This unusually high percentage may have been associated with the fact that these infected minnows were usually collected near colonies of terns which have been reported as definitive hosts by European workers. Such high percentage of infection with *L. intestinalis* has been previously reported, as Hunter & Hunter (1931) noted that 17 of 34 suckers from Lower Chateaugay Lake were infected with 1 to 7 of these parasites. In Adirondack waters *N. cornutus* and the common sucker are most frequently found to carry *Ligula* (Hunter unpublished data). *N. atherinoides* contained a probable new and as yet undescribed species of *Proteocephalus* represented by a single strobila. *Camallanus oxycephalus* Ward & Magath was the only nematode identified from the east end of the lake and this occurred but once in *R. cataractae.* The same parasite was found in the same host and also in *N. heterodon, N. hudsonius, N. whipplii, N. atherinoides* and *E. buccata. Rhabdochona cascadilla* Wigdor was found in three minnows, *N. volucellus, N. hudsonius* and *N. whipplii.*

Acanthocephala occurred but once and twice respectively from the east and west ends. Myxosporidia, however, appeared but twice from the eastern end compared with 5 from the western end. One leech, *Piscicola punctata,* was found upon a single specimen of *N. whipplii* from the western area.

### Ameiuridae (Siluridae).

A total of 75 members of the Ameiuridae were examined from both ends of Lake Erie, 7 species and 5 genera being represented. Four times as many fish came from the western end of the lake as the eastern end where 6 species were examined, contrasted with 3 from the eastern end.

Channel Catfish, *Ictalurus punctatus* (Raf.): Two of the seven fish from the east end were infected with *Corallobothrium fimbriatum* Essex while 15 of the 29 from the west end harbored this species. We found a 100% parasitization in this region, with 6 species of trematodes, 2 of cestodes, 3 of nematodes, 2 of Acanthocephala, 2 of copepods and Myxosporidia represented. The trematode, *Megalogonia ictaluri* Surber (1928) found in this fish, constitutes the first record of this species from the Great Lakes. Likewise the occurrence of *Acetodextra amiuri* Pearse (1924), is worthy of note. This parasite was reported by Pearse (1924a) from the swim bladders of "the yellow, black and speckled bullheads in Lake Pepin (Mississippi River); in the black and speckled bullheads in Lake Michigan." Our records indicate that the parasite occurred in the gonads of the channel catfish. Hunter (unpublished data) reports the ovary of a single bullhead, *Ameiurus nebulosus,* infected with this parasite when taken from a tributary of the Oswegatchie River system, while Van Cleave & Mueller (1934) record it from fish from Oneida Lake.

Common Bullhead, *Ameiurus nebulosus* (Le Sueur): This was the second species of this family to be taken at the eastern end of the lake and its seven representatives were all free from parasites. The one specimen from the western end, however, carried trematodes, cestodes, nematodes and Acanthocephala.

Lake Catfish, *Villarius lacustris* (Walbaum): One representative only of this species was examined and this from the eastern end. No parasites other than lymphocystis cysts were found.

Other Catfishes: The four species taken solely from the western area are the black bullhead, *Ameiurus melas* Raf., the yellow stone cat,

*Noturus flavus* Raf., the tadpole stone cat, *Schilbeodes gyrinus* (Mitchill) and the spotted stone cat, *Schilbeodes miurus* (Jordan). A fairly heavy infection with an interesting distribution is evident in the table.

It should be mentioned at this point that the Ohio Division of Conservation makes it a practice to plant undersized channel catfish, black and common bullheads in the various streams of Ohio when they are taken by commercial fishermen. This practice may lead to the building up of greater numbers of these forms in the rivers of Ohio but the practice is questionable from the viewpoint of the parasitologist since it may well mean the establishment of undesirable parasites in uninfected streams. In some cases this is very harmful as has been proved by the bass (*loc. cit.*).

### UMBRIDAE.

MUD MINNOW, *Umbra limi* (Kirtland): But a single species of this family, the mud minnow, was examined. No infection occurred in the three specimens secured from the east end of the lake while six of the nine from the west end were parasitized by an immature nematode of the genus *Spiroxys* which matures in turtles and snakes (Yorke & Maplestone, 1926). All of these infested mud minnows were secured from a small weedy marsh which contained many turtles. While no examination was made of these latter forms, the fact that the parasites were of genus *Spiroxys* suggests the probability of these carrying the adult of the stage reported in the fish.

### ESOCIDAE.

THE PICKERELS, *Esox vermiculatus*, *E. lucius*: Too few individuals of this family were examined to give much idea of the degree of infestation. Five little pickerels, *Esox vermiculatus* Le Sueur, were examined from streams at the west end entering Sandusky Bay and only one was found to be parasitized. It carried two species of trematodes in the intestinal tract, *Azygia angusticauda* (Stafford, 1904) and *Centrovarium lobotes* (MacCallum, 1895); one cestode, *Proteocephalus pinguis* LaRue, 1911, and one nematode, *Spinitectus gracilis* Ward & Magath, 1917.

Of the eight specimens of northern pike, *Esox lucius* Linn., six were from eastern Lake Erie and two from the opposite end. All those taken from the eastern end and one from the western end were infested with *Proteocephalus pinguis* LaRue. Two from the eastern end carried *Neoechinorhynchus tenellus* (Van Cleave).

### CYPRINODONTIDAE.

TOP MINNOW, *Fundulus diaphanus menona* Jordan & Copeland: Thirty-one top minnows present an interesting picture of the difference in regional distribution of the parasites in Lake Erie. Fourteen were taken from the eastern end and three, or 21.4% were infected, compared with 17 taken from the western end where 10, or 58.8%, were infected. In contrast to the almost equal distribution of the hosts examined, it should be noted that the percentage of infection is more than doubled at the western end and five classes of parasites are found in comparison with two from the east. The trematode, *Neascus vancleavi* (Agersborg), was present in fish from both localities.

All but one of the individuals examined from the western area were obtained from the shallow, "ponded" areas of East and West Harbors where many other species of fish were more heavily parasitized than those from more open waters. A large proportion of the infesting forms were larval stages.

PERCOPSIDAE.

TROUT PERCH, *Percopsis omisco-maycus* (Walbaum): This was the only representative of the family studied. Of the 53 examined, all but 7 were taken at the western end of the lake. *Neascus vancleavi* (Agersborg), *Crepidostomum isostomum* Hopkins, *Centrovarium lobotes* (MacCallum), *Triaenophorus* sp. and *Bothriocephalus cuspidatus* Cooper were found distributed among 5 of the 7 fish from the east end.

At the west end, a proportionately high percentage of infection was found, there being 44, or 95.7%, of 46 fish infested. *Tetracotyle diminuta* Hughes, *N. vancleavi* (Agersborg) and *C. isostomum* Hopkins represent the trematodes, while larval *Triaenophorus* sp., *Bothriocephalus claviceps* (Goeze) and *Proteocephalus pearsei* LaRue were the cestodes encountered. *Triaenophorus* sp. outnumbered the other two cestodes, being found in 16 fish compared with 4 and 6, respectively. Seventeen hosts harbored *Camallanus oxycephalus* Ward & Magath while one carried a few *Agamonema. Leptorhynchoides thecatus* (Linton) was found encysted in one host and Myxosporidia infected 6 beneath the skin and under opercula.

It is evident that this little species is the natural host of a relatively large number of parasites; not only were all but 4 of the 53 fish infected, but each showed a variety of different forms and some overlapping of infection. A number had moderately heavy infestations.

A word on the distribution of the immature *C. lobotes* encysted in the flesh of this host might well be interjected at this point. It is significant to note in this connection that Bangham (unpublished data) has never encountered this parasite in other Ohio lakes. MacCallum (1895), who first described this form, presumably secured his material from fish from Lake Erie and the Grand River, Ontario, although this is only mentioned as the source of his *Anallocreadium armatum* (MacCallum, 1895). Stafford (1904) reports *C. lobotes* from the stomachs of the northern pike, *Esox lucius* Linn., and the wall-eyed pike, *Stizostedion vitreum* Mitchill, secured from Montreal markets. Cooper (1915) found the species adult in the intestine of *Ambloplites rupestris* (Raf.) from the Go-Home Bay, Lake Huron, Ontario. Ward & Whipple (1918) list it from Ontario and Pearse (1924a) reports the same species from the intestine of *Notropis hudsonius* (DeWitt Clinton) in Lake Michigan. This parasite is reported in this paper from both ends of Lake Erie. Hunter (1930) and Hunter & Hunter (1931) report the experimental infection of the small-mouthed black bass, *Micropterus dolomieu* Lacépède, thus adding another definitive host. These authors also have encountered encysted metacercariae from the following species: the trout perch, *Percopsis omisco-maycus*, from Lake Erie and Champlain watersheds; the blunt-nosed minnow, *Hyborhynchus notatus*, from the Lake Champlain and St. Lawrence River watersheds; the straw-colored minnow, *Notropis deliciosus stramineus*, and Cayuga minnow, *Notropis bifrenatus*, from Lake Champlain; the common shiner, *Notropis cornutus*, and the black-nosed minnow, *Notropis heterolepis*, from the St. Lawrence River watershed. Van Cleave & Mueller (1934) report metacercariae from the trout perch and young or mature adults from the intestines of *P. flavescens*, *S. vitreum*, *M. dolomieu* and *A. natalis*.

SERRANIDAE.

WHITE BASS, *Lepibema chrysops* (Raf.): The only representative of this family examined from Lake Erie is the white bass, *Lepibema chrysops* (Raf.). Of the two specimens examined from the eastern portion of the lake but one was infested; this contained only individuals of a small trematode, *Allacanthochasmus varius* Van Cleave. All of 23 adults and 6 of 9 young from the west end of Lake Erie were infected. These carried four species of trematodes, three of cestodes, four of nematodes and one species of

encysted glochidium of a mollusc. *A. varius* Van Cleave was found in 16 of the adults. Another fluke belonging to the Gyrodactyloidea was found on the gills of nine. These forms are found on many species of fish and sometimes cause noticeable losses, especially in fish confined to hatcheries. In none of these fish were there ectoparasites abundant enough to cause apparent damage. Three species of cestodes were found, two of which were larvae. *Proteocephalus pearsei* LaRue, a small form, was abundant in the intestinal tracts of 11. Many adult *Bothriocephalus cuspidatus* Cooper were found in one fish while 7 others contained only larvae. Light infections of *P. ambloplitis* (Leidy) were noted in the mesenteries of 3 hosts. The only nematode found in quantity was *Camallanus oxycephalus* Ward & Magath; three other species were found in small numbers. Due to the unequal collections of this host, a fair regional comparison of their parasites cannot be made. However, the heavy infection at the west end thus far found would probably continue to exceed that of the opposite end.

PERCIDAE.

A total of 429 fish belonging to 14 species in this family was examined from both ends of the lake. The species examined were as follows: yellow perch, *Perca flavescens* (Mitchill); sauger, *Stizostedion canadense griseum* (DeKay); wall-eyed pike, *Stizostedion vitreum* (Mitchill); blue pike, *Stizostedion glaucum* Hubbs; black-sided darter, *Hadropterus maculatus* (Girard); log perch, *Percina caprodes* (Raf.); Copeland's darter, *Rheocrypta copelandi* Jordan; sand darter, *Ammocrypta pellucida* (Baird); Johnny darter, *Boleosoma nigrum* (Raf.); rainbow darter, *Poecilichthys coeruleus* Storer; Iowa darter, *Poecilichthys exilis* (Girard); fan-tailed darter, *Catonotus flabellaris* (Raf.); least darter, *Microperca punctulata* Putnam; green-sided darter, *Etheostoma blennoides* Raf.

YELLOW PERCH, *Perca flavescens* (Mitchill): Of the 69 adult yellow perch examined, 24 were taken from the eastern end of Lake Erie and 45 from the western end. Infestation was universally high as 20 and 40 were parasitized, respectively, from the eastern and western areas. Of the 59 young yellow perch collected, 44 and 15 were examined, being taken, respectively, from the eastern and western ends, and 25 and 13 of these carried parasitic infections. No significant difference occurred between the degree of infection at either end of the lake.

The infection by trematodes, however, was much heavier both in degree and variety of parasites in the fish taken from the west end of the lake. Only two, *Bunodera luciopercae* (O. F. Mueller) from the intestine and *Diplostomum scheuringi* (Hughes) from the aqueous humor of the eye, were encountered in fish from the eastern end and then only in 3 and 2 instances, respectively. In contrast to this is the opposite end where the fish carried 6 species of trematodes, namely: *Crepidostomum cooperi* Hopkins, *Cryptogonimus chyli* (Osborn), *Clinostomum marginatum* (Rud.), *Neascus* sp., *Microphallus opacus* (Ward) and *Leuceruthrus* sp. The first-named parasite was the most common, being present in 12 of the 45 examined, while the larval *Neascus* sp. occurred in 5 instances, *Cryptogonimus chyli* in two and each of the others in but a single host. Trematode infection in the young of the species is negligible, for no fluke infection occurred in those taken at the eastern end and but one of those from the western end carried a fluke, *Neascus* sp., in the flesh. It is significant to note that no trematodes appeared to be prevalent all over the lake, although it should be borne in mind that members of the species as a whole carried 9 and 15 species from the eastern and western areas.

Most of the cestodes carried by the yellow perch were larval forms. In the eastern area three species were found, these being *Bothriocephalus cuspidatus* (Cooper), *Proteocephalus pearsei* LaRue and *Proteocephalus*

*ambloplitis* (Leidy). In the western area 17 adult perch carried one or more of the species just named. In addition 11 had *Proteocephalus pearsei* LaRue and two encysted *Triaenophorus* sp. Evidence is accumulating which suggests the existence of a third species of *Triaenophorus* from North America. Only a single specimen of the adult was obtained and we did not feel it advisable to base a description upon this alone. With the exception of the latter form, the same species were carried by the young yellow perch. The small species of cestode *P. pearsei* appeared more often in these young fish, as would be expected from its life cycle (Bangham, 1925).

The nematode *Dichelyne cotylophora* Ward & Magath was the most common representative of this group of parasites, being taken in 13 and 22 instances from the adults of the eastern and western areas, respectively. No other species of nematode was found in the yellow perch of the eastern end while one of those at the opposite end carried *Camallanus oxycephalus* Ward & Magath and one had a *Philometra cylindracae* (Ward & Magath) in its body cavity. Acanthocephala, leeches and the ectoparasitic fungus *Saprolegnia*, were also present in a few instances.

SAUGER, *Stizostedion canadense griseum* (De Kay): All of 10 saugers from the eastern area of Lake Erie and all but one of 33 from the opposite end were infested. There were 4 species of parasites from the former and 9 from the latter fish and the degree of infestation was also heavier in specimens from the western area.

One species of trematode, *Centrovarium lobotes* (MacCallum), was found in this fish from both regions and in addition the saugers from the west end carried *Bucephalus pusillus* (Stafford) in 6 instances and in one an encysted *Neascus* sp. The cestode *Bothriocephalus cuspidatus* (Cooper) was the most common parasite in these fish from both areas. These small intestinal forms do not appear to cause marked damage to the host even when present in large numbers. The only other species of cestode found in the sauger from the eastern regions was *Bothriocephalus claviceps* (Goeze) while 6 from the opposite end carried larval cysts of *Triaenophorus* sp. and 2 were infested with *Proteocephalus stizostethi* Hunter & Bangham (1933).

The only nematode reported was *Camallanus oxycephalus* Ward & Magath (1917), which was recovered from 12 of the 33 saugers from the western area. Seven of the fish at the eastern end carried members of the ectoparasitic gill copepod *Ergasilis centrarchidarum* Wright while on the gills of 3 of those at the opposite end were found *Ergasilus caeruleus* Wilson. Fish from the latter region also carried an infection of Acanthocephala, Myxosporidia, Lymphocystis and glochidia.

WALL-EYED PIKE, *Stizostedion vitreum* (Mitchill): Nine of 10 adult wall-eyed pike from the eastern region and all but one of 48 from the opposite end carried parasites. In the former area there were 4 species of parasites represented and in the latter 16 species, showing the same increase already noted for those coming from the western portion of the lake.

*Neascus vancleavei* (Agersborg) was the only trematode found in the eastern wall-eyed pike while the following forms were taken from this species from the other region: *Neascus* sp., *Azygia angusticauda* (Stafford), *C. lobotes* and *B. pusillus*, the latter being the most common.

The fish from both areas carried large numbers of *B. cuspidatus*. In the western region certain of the wall-eyed pike also carried liver cysts of *Triaenophorus* sp. and *P. ambloplitis* while *P. stizostethi* occurred in the intestines of 13 of these fish.

Of the other species infesting the wall-eyed pike the same form of nematodes and of parasitic copepods found in the sauger were present and in addition a single species of Acanthocephala. Seven of the fish being discussed had a "warty" skin showing evidences of the Lymphocystis disease.

Fish showing such a condition are usually discarded by commercial fishermen even though the flesh is not involved. Certain workers, Woodcock (1904) and Awerinzew (1907, 1911), think the causal agents are the single cell-like inclusions within the cysts and believe that they belong to the subclass Neosporidia, while others hold that these cells are not the infective organisms and that the disease is due to a filterable virus. Dr. R. R. Hyde of Johns Hopkins University writes: "Lymphocystis, a disease of certain fishes, has been known in Europe for a long time. It was mentioned by Lowe in 1874 and by McIntosh in 1884. Sandermann in 1892 described the disease in some detail and advanced the theory that the peculiar cells which compose the tumor-like outgrowths were the eggs of parasites, a view upheld by Zschiesche in 1910. Woodcock in 1904 advanced the idea that the lymphocystic cells were parasitic protozoan which he described as *Lymphocystis johnstonii.* The idea was adhered to by Awerinzew in 1907. Weissenberg in 1914 stated that the disease is due to the intracellular location of a virus that could not be demonstrated microscopically. In 1921 he published an extensive treatise on the subject confirming his previous studies in regard to its etiology. While the filterability of this agent has not been definitely established, it is our opinion that it is to be classified with the filterable viruses." These cysts are usually confined to the lymph spaces of the skin, but in one or two fishes there were large masses of them about the heart. There is need for more research on this disease which affects the three species of pike perch.

Twelve of 15 young wall-eyed pike taken in seine hauls in the extreme western part of Lake Erie yielded the same parasites as the adults with the exception of *P. ambloplitis* and *S. gracilis* which were not in adults.

BLUE PIKE, *Stizostedion glaucum* Hubbs: The remaining species of pike perch, the blue pike, carried many of the same forms as the other two members of the genus. Nearly all from both regions carried the cestode *B. cuspidatus* and *P. stizostethi.* These were the only parasites encountered in 7 of 10 blue pike in the eastern region while all of 10 from the opposite end yielded 10 species of parasites. One of these, an adult *P. ambloplitis*, constitutes a new definitive host record for this species.

Ten species of darters were examined, but 3 forms were all that were examined for both areas, so these are the only ones that can be compared as to degree and numbers of species. These small fish are of economic importance only so far as they act as food for game and commercial fish and bear stages of parasites which thus find their way to the larger fish.

LOG PERCH, *Percina caprodes* (Raf.): Nine of 13 log perch from the eastern area and 20 of 32 from the opposite end were parasitized. The 3 species of larval forms found in the former were, *Neascus* sp., *B. cuspidatus* and *Leptorhynchoides thecatus* (Linton) while in the western region 12 species of parasites were taken. *B. cuspidatus* was not found in the log perch from the latter area but the other 2 species were present and in addition the following: *Allocreadium boleosomi,* (Pearse), unidentified Strigeidae, *P. pearsei, P. stizostethi, C. oxycephalus, Agamonema* sp., *P. punctata,* and myxosporidian cysts. We thus see that these fish carry a number of forms which could infest other fish if taken as food.

Greeley & Bishop (1932) say concerning this fish, "The log perch is often used as a bait fish for black bass and is also a common food item of this and other game fishes." According to unpublished data of Wickliff, these fish are very widely distributed in western Lake Erie, 383 specimens of log perch being taken at 34 of the 37 stations visited on the seining trip from September 7 to 18, 1928.

JOHNNY DARTER, *Boleosoma nigrum* (Raf.): Two of 7 Johnny darters from the eastern region carried the following forms: *C. marginatum, Neascus* sp. and *Proteocephalus* sp., while 13 of 16 from the opposite area yielded *Leuceruthrus* sp., *Neascus vancleavei* and *Agamonema* sp.

FAN-TAILED DARTER, *Catonotus flabellaris* (Raf.): The fan-tailed darter from the eastern portion of Lake Erie carried encysted *Neascus* sp., *C. marginatum* and *Tetracotyle communis* (Hughes) while the only forms encountered from those at the opposite end were *Neascus* sp. in the mesenteries and *L. thecatus* in the intestine of one.

Of the remainder of the darters examined from the western area, none showed a large number of parasites. Four least darters, *Microperca punctulata* Putnam were clean. Three of 10 green-sided darters, *Etheostoma blennoides* Raf., harbored unidentified Strigeidae, Allocreadiidae, and Myxosporidia. Of 7 Iowa darters, *Poecilichthys coeruleus* Storer, 4 carried Allocreadiidae, Strigeidae, larval *B. cuspidatus* and *L. thecatus*, respectively, and 5 had larval nematodes. Nine of 15 sand darters, *Ammocrypta pellucida* (Baird), were infested: one with a fluke tentatively identified as *Lebouria cooperi* (see discussion in Hunter & Bangham, 1932); another with several *Neascus* sp. in the liver; three with unidentified encysted Strigeidae; three with *C. oxycephalus* and 6 with unidentified nematodes. Only 8 of 34 Copeland's darters, *Rheocrypta copelandi* (Jordan), carried parasites; these being *Neascus* sp., *L. cooperi*, *B. cuspidatus* and *Camallanus* sp. One of 2 black-sided darters, *Hadropterus maculatus* (Girard), had a specimen of *C. oxycephalus* in its intestinal tract.

## CENTRARCHIDAE.

A total of 395 fish of this family from 8 genera and 9 species were examined for parasites during the course of these studies. These were small-mouthed black bass, *Micropterus dolomieu* Lacépède; large-mouthed black bass, *Aplites salmoides* (Lacépède); green sunfish, *Apomotis cyanellus* (Raf.); blue gill, *Helioperca incisor* (Cuvier & Valenciennes); pumpkinseed sunfish, *Eupomotis gibbosus* (Linn.); rock bass, *Ambloplites rupestris* (Raf.); white crappie, *Pomoxis annularis* Raf.; calico bass, *Pomoxis sparoides* (Lacépède); long-eared sunfish, *Xenotis megalotis* (Raf.).

In this group, which included many important game fish, 113 were examined from the eastern area and 282 from the western area and of these fish 67, or 59.2% and 234, or 82.9%, respectively, were infected. The data from this group bear out the previously noted heavier infestation of fish in the western region. As will be shown when comparing parasites of the same species at the opposite ends of Lake Erie, there were more forms in the western region and the degree of infestation was usually higher.

SMALL-MOUTHED BLACK BASS, *Micropterus dolomieu* Lacépède: Of the 57 adult small-mouthed black bass examined, 28 were taken from the eastern area and 29 from the opposite end. Infection was very high, as 24 and 28 respectively, were parasitized. Of the 64 young small-mouthed bass collected, 13 and 51 were examined, taken respectively from the eastern and western ends and 7 and 48 of these were infested.

Three species of trematodes were found in the adult bass from the eastern area: *Crepidostomum cornutum* (Osborn), *Centrovarium lobotes* (MacCallum), *Cryptogonimus chyli* Osborn, the first-named species being the most common. In contrast to this is the western end where the fish carried 5 species; in addition to the 3 forms already noted there were *Leuceruthrus micropteri* Marshall & Gilbert and *Gyrodactyloidea*, the latter forms being taken from the gills of one bass. In the young bass of the eastern area *C. cornutum* was recovered from 2 fish while in the young bass from the opposite region, in addition to the forms above named, 7 other species were taken as follows: *C. chyli*, *Gyrodactyloidea*, *Clinostomum marginatum*, (Rud.), *Microphallus opacus* Ward, *Neochasmus umbellus* Van Cleave & Mueller, *Azygia angusticauda* (Stafford) and *Bucephalus papillosus* Woodhead. Only the first two species were very abundant; none appeared to cause great harm to the host.

Only one species of cestode, *Proteocephalus ambloplitis* (Leidy), was obtained from 13 adult and 5 young small-mouthed bass from the eastern area, while from the opposite end this form appeared in 21 of 29 adult and 23 young bass. In addition, adult bass carried larval *Triaenophorus* sp., *Bothriocephalus claviceps* (Goeze) and *Proteocephalus pearsei* LaRue in 1, 1 and 3 instances, respectively. Of the 48 infected young bass from this area 21 had *P. pearsei* in their intestinal tracts.

Nematodes were not found to infest the small-mouthed bass very heavily from either end of Lake Erie. In the eastern area there were 3 species present: *Spinitectus carolini* Holl, *Dichelyne cotylophora* Ward & Magath and *Agamonema* sp. in 9, 3 and 6 cases, respectively, while at the opposite end the first-named form was found in 3 instances and *Camallanus oxycephalus* in two adults. Almost the same type of nematode infestation was found in the young bass. One species of Acanthocephala, *Leptorhynchoides thecatus* (Linton), was encountered very frequently in each area. This form with larvae and adults of the cestode *P. ambloplitis* were parasites taken most often and in greatest numbers. Young small-mouthed bass rarely carried this form. Another Acanthocephala, *Neoechinorhynchus cylindratus* (Van Cleave), was taken from bass in 1 and 3 cases from the eastern and western areas, respectively.

Other parasites not already mentioned from small-mouthed bass in the eastern area were the ectoparasitic copepods *Ergasilus centrarchidarum* Wright taken from gills of 5 fish, and *Achtheres ambloplitis* Kellicott from the gills of one. In addition the other region yielded two other species of copepods, two protozoa, one leech, and the fungus *Saprolegnia parasitica.*

LARGE-MOUTHED BLACK BASS, *Aplites salmoides* (Lacépède): No comparison can be made regarding the parasitism of the large-mouthed bass in the two regions as but 3 adults and no young were examined in the eastern area while 24 adults and 105 young were examined in the opposite region. *Crepidostomum cornutum* (Osborn) and *Spinitectus carolini* Holl were the only parasites of the 5 species found in the eastern large-mouthed bass which were not also found in this species of bass from the opposite end.

Twenty of the adults and 87 of the young from the western area carried parasites. Fewer species of trematodes were taken than from the small-mouthed bass. The following flukes were secured from 4, 4, and 3 of the adults, respectively: *Leuceruthrus micropteri* Marshall & Gilbert, *Cryptogonimus chyli* Osborn and Gyrodactyloidea. The same species of parasites in the same order were secured from 18, 10 and 10 of the young bass; 4 also had liver cysts of the larval fluke *Neascus vancleavei* (Agersborg).

Six and 3 of the young and adult large-mouthed black bass were infected, respectively, with *P. pearsei* while 37 and 10, respectively, carried *P. ambloplitis.* Adults of this species occurred in the intestinal tract while plerocercoids were encysted in the liver, spleen, mesenteries and gonads. Among the persons who have reported the damage to the host caused by this larval form are Riley, (1919), Rich (1923), Bangham (1925, 1928a and 1934), Moore (1926), Hunter (1928) and Hunter & Hunter (1930 and 1931).

The degree of infestation for this form was quite heavy both in the small-and large-mouthed black bass examined from the western area of Lake Erie. Certain adult bass had from 5 to 8 of these large cestodes in their intestinal tracts and large numbers of the plerocercoids encysted in their viscera. In certain fish the infestation by the larvae was so heavy and so much scar tissue was present in their reproductive organs that there was apparently no spawning. Many states formerly secured their hatchery breeding stock of small-and large-mouthed black bass from Lake Erie but this practice has been largely discontinued because so many of these fish prove to be poor breeders, many becoming sterilized through the

activity of the parasite. Records of the Ohio Conservation Division show that since 1881 bass have been transported from Lake Erie to streams and lakes within the state. This form has been found in black bass from all lakes in Ohio where these fish were examined but fortunately this species is almost entirely confined to lake bass, Hunter & Hunter (1931). Stream bass usually carry another species, *Proteocephalus fluviatilis* Bangham, which has no encysted stage in the fish.

In one or two fish in each instance the following nematodes were found in the western large-mouthed bass: *Contracaecum brachyurum* (Ward & Magath), *Camallanus oxycephalus* Ward & Magath, *Dichelyne cotylophora* Ward & Magath, *Dioctophyme* sp. and *Agamonema* sp. The same two species of Acanthocephala that appeared in the small-mouthed bass were taken but *N. cylindratus* was more frequent and abundant. Of the other parasites the same species as those encountered in the small-mouthed bass were found with the addition of two more protozoan forms. One of the latter was encysted on the gill filaments of 25 of the young fish and belonged to the Myxosporidia. It is interesting that this fish, which is not very abundant in Lake Erie, harbors so many different species of parasites.

COMMON SUNFISH, *Eupomotis gibbosus* (Linn.): Common sunfish from both areas were examined; 12 of 18 from the eastern portion and 19 of 23 from the opposite end were infested. One to 4 of the fish from the eastern area carried the following species of parasites: *Allocreadium* sp., *Crassiphiala ambloplitis* (Hughes), *Neascus vancleavei, Bothriocephalus* sp., *P. ambloplitis, S. carolini* Holl, *Agamonema* sp., *L. thecatus,* while this host from the opposite end sheltered from 1 to 7 of the same parasites per fish and in addition larval *C. marginatum* in the flesh of one, *C. oxycephalus* in one, Myxosporidia on the gills of 3 and the leech, *P. punctata* on one.

ROCK BASS, *Ambloplites rupestris* (Raf.): In the eastern area 21 of 28 and in the other area 11 of 12 rock bass were parasitized with 8 and 14 species, respectively. The parasites common to both areas were *C. chyli,* metacercariae of *Crassiphiala ambloplitis* (Hughes), *P. ambloplitis, S. carolini* Holl, *L. thecatus, E. centrarchidarum.* Only two forms were recovered from rock bass in the eastern portion of Lake Erie, these being *L. micropteri* and *P. pearsei* while the following were taken in the opposite end: *C. ambloplitis* Hopkins (1931), metacercariae of *C. marginatum* and *N. vancleavei, B. claviceps, Rhabdochona* sp., *Contracaecum* sp., *Agamonema* sp., *C. oxycephalus* and *Achteres ambloplitis* Kellicott. In most cases the infestation with one of the above species in either area was limited to 1 to 5 fish, the exception being in the eastern area when 6 and 7 rock bass carried *L. micropteri* and *C. ambloplitis,* respectively.

WHITE CRAPPIE, *Pomoxis annularis* Raf: A single nematode, *S. gracilis,* was the only parasite found in the examination of 8 white crappies from the eastern area, while 8 of 17 from the other portion of the lake yielded the following forms in from 1 to 5 fish: *C. oxycephalus, Agamonema* sp., *L. thecatus, E. centrarchidarum* and an encysted myxosporidian form.

CALICO BASS, *Pomoxis sparoides* Lacépède, AND LONG-EARED SUNFISH, *Xenotis megalotis* (Raf.): Calico bass were not heavily infested. These fish were examined only in the western area and but three species of parasites were present in small numbers. The single long-eared sunfish taken in this area yielded only cysts of *N. vancleavei.*

Our data just discussed show a very wide distribution of many of the parasites both as to general dispersal over Lake Erie and the presence of the same species in many forms belonging to the family Centrarchidae. With the exceptions already noted, there is but slight evidence that these forms cause marked damage to the host unless crowded, as under hatchery conditions.

ATHERINIDAE.

BROOK SILVERSIDES, *Labidesthes sicculus* (Cope): The brook silverside was the only representative of this family examined. Fifteen of these slender, graceful fish were taken from the east end of the lake and all were free from parasites. Of the 30 from the west end, 10 carried light infections. Adult *Camallanus oxycephalus* Ward & Magath were found in a single instance. All other parasites encountered were sexually immature; *Neascus* sp., *Allacanthochasmus varius* Van Cleave, *P. ambloplitis* (Leidy) and some *Agamonema* were encysted in liver and mesenteries, while *Allocreadium* sp., *Bothriocephalus* sp. and other *Agamonema* were found in the alimentary canal.

This fish usually lives but one season (Hubbs, 1921; Cahn 1927). It is therefore interesting that so many parasites have adapted themselves to this short-lived form; the presence of so many immature parasites suggests that *L. sicculus* may prove to be either an accidental host or an intermediate host for at least four species.

SCIAENIDAE.

SHEEPSHEAD OR FRESH-WATER DRUM, *Aplodinotus grunniens* Rafinesque: This is the only representative of this family to be recorded from Lake Erie. A total of 48 individuals was examined and showed an unusually high degree of infestation since all but four carried parasites of one sort or another. Furthermore, this species sheltered an unusually diversified list of parasites, some of which are remarkably interesting. A regional infestation comparison is again impractical as only three specimens were taken from the eastern end. However, all of these three were infected.

*Anallocreadium armatum* (MacCallum) was the only trematode encountered in the fish from the eastern end; none of these were obtained from the western end, but 10 fish carried a new fluke of the same genus, *Anallocreadium pearsei* Hunter & Bangham (1932). Other new trematodes were discovered as ectoparasites of 5 of the fish from the western end of the lake. These were identified as *Microcotyle spinicirrus* (MacCallum) and *M. eriensis* and were described by Bangham & Hunter (1936).

No other unusual forms were met; three other flukes were found, two Strigeidae and one *Crepidostomum*. Two cestodes, both sexually immature, were taken and four species of nematodes, as well as some *Agamonema*. It should be noted that three of these nematodes, *Camallanus oxycephalus*, *Dichelyne cotylophora* and *Spinitectus gracilis*, were often found in the intestines of the Esocidae, Percidae and Centrarchidae. Acanthocephala, Myxosporidia, leeches and glochidia were also present in considerable quantity.

COTTIDAE.

MILLER'S THUMB, *Cottus bairdii* Girard: Seven specimens of miller's thumb or sculpin, *Cottus bairdii* Girard, were examined from about the Bass Islands and inlets of cold streams of the west end of the lake. Only two of these were infected with parasites and then with a single larva. One carried a cyst of a larval *Proteocephalus ambloplitis* (Leidy) in the liver and the other a young plerocercoid of *Proteocephalus* sp. in the alimentary canal. It had five well-developed suckers and may belong to an undescribed species.

GASTEROSTEIDAE.

BROOK STICKLEBACK, *Eucalia inconstans* (Kirtland): Comparisons of the infection of the brook stickleback, *Eucalia inconstans* (Kirtland), are

not significant as nearly all of the forms were taken at the east end of the lake. The most interesting parasite encountered was *Bunoderina eucaliae* Miller, 1936, from the intestine. This small trematode is apparently widely distributed, for it has been found not only in the Lake Erie watershed, but also in the Lake Champlain and St. Lawrence River watersheds (Hunter unpublished data). It occurs typically in fish from warm, shallow, weedy, marshy areas. The percentage of infection of this host in the Lake Erie watershed is very low; only 3 of 22 fish were parasitized and these with light infections.

GADIDAE.

BURBOT OR LING, *Lota maculosa* (Le Sueur): The burbot, *Lota maculosa* (Le Sueur), is the only representative of this family examined. A total of 10 fish taken from gill nets in the deeper parts of the lake yielded a 100% infection with *Abothrium crassum* (Bloch); adults were often numerous in pyloric caeca and the rest of the digestive tract. In five cases the larvae were encysted in the stomach wall giving it a rough, warty appearance. The roundworm, *Haplonema hamulatum* Moulton, was found in two specimens from the east end. These three hosts also harbored Acanthocephala belonging to the species *Echinorhynchus coregoni* Linkins.

The ectoparasitic leech, *Piscicola punctata* (Verrill), was found in moderate numbers upon three of the seven hosts examined from the western end. Many other burbots, not examined for internal parasites, were found to be infected with one to 10 of these leeches.

SECTION IV. PARASITES OCCURRING IN MORE THAN ONE HOST.

Forty-nine species of parasites were found in but a single host species of fish from Lake Erie. Several forms were identified only to family or genus and several species may be represented in these groups. In most cases the same parasites are found in closely related fishes but a few parasitic forms are widely distributed throughout many fish. Those parasites followed by the letter "E", are from fish obtained in the eastern area and those by "W", from the western area of Lake Erie.

TREMATODES. *Allacanthochasmus varius* Van Cleave. This trematode was common in the intestines of white bass (E & W), and an encysted larva of this species was found in a brook silversides (W).

Allocreadiidae. Unidentified trematodes belonging to this family were taken from the intestines of silvery-jawed minnow (W), brook silversides (W), pumpkinseed (E) and lake sturgeon (W).

*Bucephalus pusillus* (Stafford). These small trematodes were found in the stomach and pyloric caeca of blue pike (W), sauger (W) and wall-eyed pike (W).

*Centrovarium lobotes* (MacCallum). In the intestine and pyloric caeca of trout perch (E), little pickerel (W), sauger (E & W), wall-eyed pike (W), blue pike (W) and small-mouthed black bass (E & W). Metacercariae of this species were reported from the trout perch in Cattaraugus Creek while the following species from other parts of New York were reported to harbor these encysted stages: blunt-nosed minnow (*H. notatus*), straw-colored minnow (*N. deliciosus stramineus*), Cayuga minnow (*N. bifrenatus*), common shiner (*N. cornutus frontalis*) and the black-nosed minnow (*N. heterolepis*) (Hunter & Hunter, 1931).

*Clinostomum marginatum* (Rud.). This larval form was present encysted in the flesh of black bullhead (W), Johnny darter (E), log perch (W), fan-tailed darter (E), small-mouthed black bass (W), blue gill (W), pumpkinseed (W) and rock bass (W).

*Crepidostomum cornutum* (Osborn). This was found in the intestine and stomach of black bullhead (W), bowfin (W), small-mouthed black bass (E & W), large-mouthed black bass (E) and rock bass (E & W).

*Cryptogonimus chyli* Osborn. This small form was found chiefly in the pyloric caeca of the yellow perch (E), small-mouthed black bass (E & W), large-mouthed black bass (W) and rock bass (W).

Gyrodactyloidea. Species belonging to this group were often found on the gills of white bass (W), channel catfish (W), small-mouthed black bass (W), large-mouthed black bass (W) and blue gill (W). Because of the large numbers of new species now being named and the lack of living material, identification of the species in this superfamily was not attempted.

*Lebouria cooperi* Hunter & Bangham. This species was characteristically found in the intestine of the following minnows: *Notropis volucellus* (W), spot-tailed minnow (W), lake shiner (W), steel-colored minnow (E & W), long-nosed dace (W), Storer's chub (W) and pug-nosed minnow (W). The same or a related species was also found in the Iowa darter (W), Copeland's darter (W) and sand darter (W).

*Leuceruthrus micropteri* Marshall & Gilbert. Adults belonging to this species were obtained from the stomach of bowfin (W), black bull-head (W), rock bass (E), small-mouthed black bass (W) and large-mouthed black bass (W). Unidentified larval forms belonging to this genus were found in the intestinal tracts of white bass (W), moon-eye (W), yellow perch (W), log perch (W) and Johnny darter (W).

*Megalogonia ictaluri* Surber. These small intestinal trematodes were present in the channel catfish (W), black bullhead (W), spotted stone catfish (W) and yellow stone catfish (W).

*Microphallus opacus* Ward. This species occurred in the bowfin (W), yellow perch (W) and small-mouthed black bass (W).

*Neascus rhinichthysi* W. S. Hunter. These cysts occurred in black-nosed dace (E) and long-nosed dace (E).

*Neascus vancleavei* (Agersborg). These larval forms were encysted in the liver and mesenteries of trout perch (E & W), Menona top minnow (E & W), black-nosed dace (E), horned dace (E), *Nocomis micropogon* (E), spot-tailed minnow (E & W), common shiner (E), stone roller (E), *Notropis volucellus* (W), lake shiner (W), blunt-nosed minnow (W), Johnny darter (W), wall-eyed pike (E), pumpkinseed (E & W), large-mouthed black bass (W), blue gill (W), rock bass (W), calico bass (W) and long-eared sunfish (W).

Other metacercariae of the *Neascus* group were identified in German carp (W), Storer's chub (W), pug-nosed minnow (W), black-nosed shiner (W), straw-colored minnow (W), steel-colored minnow (W), fat-head minnow (W), pumpkinseed (E), Copeland's darter (W), sheepshead (W), white bass (W), tadpole catfish (W), *Nocomis micropogon* (E), common shiner (E), golden shiner (E), blunt-nosed minnow (E), stone roller (E), log-perch (E & W), Johnny darter (E), fan-tailed darter (E & W), yellow perch (W), sauger (W) and wall-eyed pike (W).

Other Strigeidae. Some cysts from the lake shiner (W), Storer's chub (W), log perch (W), sand-darter (W), Iowa darter (W) and green-sided darter were identified only to family.

*Tetracotyle* sp. Cysts of trematodes belonging to this group were found in moon-eye (W), spot-tailed minnow and blue gill (W). Unidentified trematodes were found in the stickleback (E) and Menona top minnow (E).

CESTODES. *Abothrium crassum* (Bloch). This species occurred free in the intestine as an adult in the burbot (E & W), white fish (E & W), and lake herring (W); the larval stage was also found encysted in the stomach of the burbot.

*Bothriocephalus claviceps* (Goeze). This species was occasionally found in the intestines of sheepshead (E), trout perch (W), sauger (E), small-mouthed black bass (W) and rock bass (W).

*Bothriocephalus cuspidatus* Cooper. Larval forms were obtained from the intestinal tracts of sheepshead (W), moon-eye (W), lake shiner (E & W), log perch (W), Copeland's darter (W), Iowa darter (W) and white bass (W). Adults were common in sauger (E & W), wall-eyed pike (E & W), blue pike (E & W) and yellow perch (E & W).

Immature forms identified only to genus were present in brook silversides (W), long-nosed gar and pumpkinseed (E), and a mature form from the tadpole catfish was identified only to genus.

*Corallobothrium fimbriatum* Essex. This was secured from the intestine of channel catfish (E & W), black bullhead (W), yellow stone catfish (W) and spotted catfish (W).

*Corallobothrium* n. sp. This small form was found in the intestine of black bullhead (W) and common bullhead (W).

*Ligula intestinalis* (Linn.). In certain regions many of the following fish carried these forms in their peritoneal cavities: common sucker (E & W), straw-colored minnow (E), common shiner (E), spot-tailed minnow (E & W), Storer's chub (W), pug-nosed minnow (W), steel-colored minnow (W) and blunt-nosed minnow (W).

*Proteocephalus ambloplitis* (Leidy). Cysts of the plerocercoids were present in miller's thumb (W), brook silversides (W), white bass (W), black bullhead (W), yellow stone catfish (W), long-nosed gar (W), lake shiner (W), spot-tailed minnow (W), yellow perch (E & W), wall-eyed pike (W), blue pike (W), blue gill (W), pumpkinseed (E & W), rock bass (E & W), bowfin (W), small-mouthed black bass (E & W) and large-mouthed black bass (E & W).

Intestinal forms were secured from long-nosed gar (W), bowfin (W), small-mouthed bass (E & W), large-mouthed black bass (W) and rock bass (W).

*Proteocephalus exiguus* Larue. This occurred in the intestines of whitefish (E & W) and lake herring (E & W).

*Proteocephalus fluviatilis* Bangham. This interesting parasite was found in the intestine of a pumpkinseed (E), as well as small-mouthed and large-mouthed bass from the streams emptying into Lake Erie; however none were obtained from these fish examined from Lake Erie.

*Proteocephalus pearsei* Larue. This species was especially common in the intestines of young sheepshead (W), white bass (W), trout perch (W), yellow perch (E & W), log perch (W), rock bass (E), small-mouthed black bass (W), large-mouthed black bass (W) and blue gill (W).

*Proteocephalus pinguis* Larue. Tapeworms belonging to this species were present in the intestine of northern pike (E & W), little pickerel (W), horned dace (E), lake shiner (E) and spot-tailed minnow (W). The specimens from the last three fish were sexually immature.

*Proteocephalus stizostethi* Hunter & Bangham. This was taken from the intestine of the blue pike (E & W), sauger (W) and wall-eyed pike (W).

Larval representatives of this genus were obtained from stickleback (W), miller's thumb (W), Menona top minnow (W), moon-eye (W), log perch (W), yellow perch (E) and Johnny darter (E). An adult of a new species was taken from the intestine of a lake shiner minnow (W).

*Triaenophorus* sp. Liver and visceral cysts were present in yellow perch, (W), sauger (W), wall-eyed pike (E & W), blue pike (W), small-mouthed black bass (W), and an adult was found in the intestine of the blue pike (W). Immature cysts of a different species were found in trout perch (W) and common sucker (E & W).

NEMATODES. *Agamonema* sp. Larval nematodes were obtained from the following fish: sheepshead (W), brook silversides (W), white bass (W), Menona top minnow (W), channel catfish (W), common bullhead (W), common sucker (W), gizzard shad (W), *Nocomis micropogon* (E), horned dace (E), steel-colored minnow (E & W), German carp (W), goldfish (W), pug-nosed minnow (W), spot-tailed minnow (W), golden shiner (W), yellow perch (W), wall-eyed pike (W), log perch (W), sand darter (W), Johnny darter (W), Iowa darter (W), small-mouthed black bass (E & W), large-mouthed black bass (W), blue gill (E), pumpkinseed (W), rock bass (W) and white crappie (W).

*Camallanus oxycephalus* Ward & Magath. This was the most common and widely distributed species of nematode, especially in the western area. This red form was found near the posterior of the intestinal tract in sheepshead (W), brook silversides (W), white bass (W), trout perch (W), channel catfish (W), yellow stone catfish (W), moon-eye (E & W), long-nosed dace (E & W), black-nosed shiner (W), spot-tailed minnow (W), steel-colored minnow (W), lake shiner (W), silvery-jawed minnow (W), yellow perch (W), sauger (W), wall-eyed pike (W), black-sided darter (W), log perch (W), Copeland's darter (W), sand darter (W), green-sided darter (W), small-mouthed black bass (W), large-mouthed black bass (W), blue gill (W), pumpkinseed (W), rock bass (W), calico bass (W) and white crappie (W).

*Cystidicola stigmatura* (Leidy). This was found in the air bladder of lake herring (W) and whitefish (W). It is one of the more unusual nematodes.

*Dichelyne cotylophora* (Ward & Magath). This form was present in the intestine of sheepshead (E & W), white bass (W), black bullhead (W), wall-eyed pike (W), small-mouthed black bass (E), large-mouthed black bass (W), blue gill (W) and yellow perch (E & W). It was most often found in the last-named fish.

*Philometra cylindracea* (Ward & Magath). This species was encysted in the peritoneum of sheepshead (W), yellow perch (W) and blue pike (W).

*Rhabdochona cascadilla* Wigdor. This parasite appeared in the intestine of the common red horse (E), moon-eye (E & W), *Moxostoma lesueurii* (W), *Notropis volucellus* (W), spot-tailed minnow (W), steel-colored minnow (W) and rock bass (W).

Other Rhabdochona which were not identical with the above species were present in white bass (W), Menona top minnow (W) and blue gill (W).

*Spinitectus gracilis* Ward & Magath. These intestinal nematodes were recovered from sheepshead (E & W), northern pike (W), channel catfish (W), yellow stone catfish (W), wall-eyed pike (W) and white crappie (E).

*Spinitectus carolini* Holl. These small nematodes were secured from the intestinal tracts of small-mouthed black bass (E & W), large-mouthed black bass (E), pumpkinseed (E & W) and rock bass (E).

ACANTHOCEPHALA. *Echinorhynchus* sp. Larval and adult forms belonging to this genus were carried by white fish (W), wall-eyed pike (W), blue pike (W), log perch (W) and Iowa darter (W).

*Leptorhynchoides thecatus* (Linton). This form was found as an immature specimen encysted in the mesenteries of trout perch (W), channel catfish (W), black bullhead (W), fan-tailed darter (E), calico bass (W), and common as a mature individual attached to the inner wall of the intestine in sheepshead (W), yellow stone catfish (W), bowfin (W), long-nosed gar (W), Storer's chub (W), log perch (E & W), yellow perch (W), small-mouthed black bass (E & W), pumpkinseed (E & W), rock bass (E & W), blue gill (W), large-mouthed black bass (W) and white crappie (W).

*Neochinorhynchus cylindratus* (Van Cleave). This parasite appeared

in the intestine of wall-eyed pike (E), small-mouthed black bass (E & W) and large-mouthed black bass (E & W).

Members of the genus were present in the Menona top minnow (W) and sauger (W).

LEECHES. *Piscicola punctata* (Verrill). This interesting ectoparasite occurred on burbot (W), sheepshead (W), black bullhead (W), steel-colored minnow (W), yellow perch (W), wall-eyed pike (W), log perch (W), small-mouthed black bass (W), blue gill (W) and pumpkinseed (W).

PROTOZOA. *Ichthyophthirius multifiliis* Fouquet. Small skin cysts of this form were present on large-and small-mouthed black bass (W).

*Lymphocystis* sp. A form belonging to this genus was found on big catfish (E), sauger (W), wall-eyed pike (W) and blue pike (W).

MYXOSPORIDIA. Gill cysts occupied by representatives of this order were taken from sheepshead (W), channel catfish (W), red horse (W), lake shiner (W), straw-colored minnow (W), golden shiner (W), large-and small-mouthed black bass (W), pumpkinseed (W), white crappie (W), and flesh of visceral cysts of this order from fat-head minnow (E), blunt-nosed minnow (W), sauger (W), log perch (W) and hog sucker (W).

COPEPODS. *Achtheres micropteri* Wright. This parasitic crustacean was found on the gills of the large-and small-mouthed black bass (W).

*Achtheres pimelodi* Krøyer. Members of this species occurred on the gills of the channel catfish (W) and common bullhead (W).

*Ergasilus caeruleus* Wilson. This was taken from the gills of sauger (W), wall-eyed pike (W) and blue pike (W).

*Ergasilus centrarchidarum* Wright. This ectoparasite was attached to the gills of the sauger (E), wall-eyed pike (W), small-mouthed black bass (E & W), large-mouthed black bass (E & W), blue gill (W) and rock bass (W).

*Ergasilus versicolor* Wilson. This was found on the gills of channel catfish (W) and yellow stone catfish (W).

FUNGUS. *Saprolegnia parasitica.* Fish were more often taken with this fungus on their bodies in the spring. The following fish which were examined had this form: yellow perch (E), green-sided darter (W), small-mouthed black bass (W) and large-mouthed black bass (W).

MOLLUSCS. Glochidia were found only on the gills of the following fish: sheepshead (2 species, W), white bass (W), sauger (W), blue gill (W), calico bass (W). Most of the infested fish were taken from Lake Erie near the mouth of the Detroit River.

## SECTION V. CHECK LIST OF FISH PARASITES FROM LAKE ERIE.

### TREMATODA.

*Acetodextra amiuri* (Stafford, 1900)
*Allacanthochasmus varius* Van Cleave, 1922
*Allocreadium armatum* (MacCallum, 1895)
*Allocreadium boleosomi* Pearse, 1924
*Allocreadium* sp. 4 species
*Alloglossidium corti* (Lamont, 1921)
*Anallocreadium pearsei* Hunter & Bangham, 1932
*Azygia angusticauda* (Stafford, 1904)
*Azygia* sp.
*Bucephalus papillosus* Woodhead, 1929
*Bucephalus pusillus* (Stafford, 1904)
*Bunodera luciopercae* (O. F. Mueller, 1776)
*Bunoderina eucaliae* Miller, 1936
*Centrovarium lobotes* (MacCallum, 1895)
*Clinostomum marginatum* (Rud., 1819)

*Crassiphiala ambloplitis* (Hughes, 1927)
*Crepidostomum cooperi* Hopkins, 1931
*Crepidostomum cornutum* (Osborn, 1903)
*Crepidostomum isostomum* Hopkins, 1931
*Crepidostomum illinoiense* Faust, 1918
*Crepidostomum lintoni* (Pratt in Linton, 1901)
*Cryptogonimus chyli* Osborn, 1903
*Diplostomum scheuringi* Hughes, 1929
*Lebouria cooperi* Hunter & Bangham, 1932
*Leuceruthrus micropteri* Marshall & Gilbert, 1905
*Leuceruthrus* sp.
*Macroderoides spiniferus* Pearse, 1924
*Macroderoides typicum* (Winfield, 1929)
*Megalogonia ictaluri* Surber, 1928
*Microcotyle eriensis* Bangham & Hunter, 1936
*Microcotyle spinicirrus* MacCallum, 1918
*Microphallus opacus* (Ward, 1894)
*Neascus bulboglossa* (Van Haitsma, 1925)
*Neascus rhinichthysi* W. S. Hunter, 1933
*Neascus vancleavei* (Agersborg, 1926)
*Neascus wardi* W. S. Hunter, 1928
*Neascus* sp. 3 species
*Neochasmus umbellus* Van Cleave & Mueller, 1932
*Phyllodistomum superbum* Stafford, 1904
*Tetracotyle communis* Hughes, 1928
*Tetracotyle diminuta* Hughes, 1928
*Tetracotyle* sp.
*Vietosoma parvum* Van Cleave & Mueller, 1932

CESTODA.

*Abothrium crassum* (Bloch, 1779)
*Bothriocephalus claviceps* (Goeze, 1782)
*Bothriocephalus cuspidatus* Cooper, 1917
*Bothriocephalus* sp.
*Corallobothrium fimbriatum* Essex, 1928
*Corallobothrium giganteum* Essex, 1928
*Corallobothrium* n. sp.
*Cyathocephalus americanus* Cooper, 1917
*Haplobothrium globuliforme* Cooper, 1914
*Ligula intestinalis* (Linn., 1758)
*Proteocephalus ambloplitis* (Leidy, 1887)
*Proteocephalus exiguus* LaRue, 1919
*Proteocephalus fluviatilis* Bangham, 1925
*Proteocephalus pearsei* LaRue, 1919
*Proteocephalus pinguis* LaRue, 1911
*Proteocephalus singularis* LaRue, 1911
*Proteocephalus stizostethi* Hunter & Bangham, 1933
*Proteocephalus wickliffi* Hunter & Bangham, 1933
*Proteocephalus* sp.
*Schistocephalus* sp.
*Triaenophorus nodulosus* (Pallas, 1781)
*Triaenophorus* sp.

CESTODARIA.

*Glaridacris catostomi* Cooper, 1920
*Hypocaryophyllaeus paratarius* Hunter, 1927

NEMATODA.

*Agamonema* sp.
*Camallanus oxycephalus* Ward & Magath, 1917
*Contracaecum* sp.
*Contracaecum brachyurum* (Ward & Magath, 1917)
*Cucullanus clitellarius* Ward & Magath, 1917

*Cystidicola lepisostei* Hunter & Bangham, 1933
*Cystidicola stigmatura* (Leidy, 1886)
*Cystidicoloides harwoodi* (Chandler, 1931)
*Dichelyne cotylophora* (Ward & Magath, 1917)
*Dioctophyme* sp.
*Haplonema hamulatum* Moulton, 1931
*Haplonema immutatum* Ward & Magath, 1917
*Philometra cylindracea* (Ward & Magath, 1917)
*Rhabdochona cascadilla* Wigdor, 1918
*Rhabdochona* sp.
*Spinitectus carolini* Holl, 1928
*Spinitectus gracilis* Ward & Magath, 1917
*Spiroxys* sp.

ACANTHOCEPHALA.

*Echinorhynchus coregoni* Linkins (in Van Cleave, 1919)
*Echinorhynchus* sp.
*Leptorhynchoides thecatus* (Linton, 1891)
*Neoechinorhynchus crassus* Van Cleave, 1919
*Neoechinorhynchus cylindratus* (Van Cleave, 1913)
*Neoechinorhynchus tenellus* (Van Cleave, 1913)
*Neoechinorhynchus* sp.
*Octospinifer macilentus* Van Cleave, 1919
*Pomphorhynchus bulbocolli* Linkins (in Van Cleave, 1919)
*Pomphorhynchus* sp.

PROTOZOA.

*Cyclochaeta domerguei* Wallengren, 1897
*Ichthyophthirius multifiliis* Fouquet, 1876
*Lymphocystis johnstonei* Woodcock, 1904
Myxosporidia
Vorticellidae

COPEPODA.

*Achtheres ambloplitis* Kellicott, 1880
*Achtheres micropteri* Wright, 1882
*Achtheres pimelodi* Krøyer, 1863
*Argulus catostomi* Dana & Herrick, 1837
*Ergasilus caeruleus* Wilson, 1911
*Ergasilus centrarchidarum* Wright, 1882
*Ergasilus versicolor* Wilson, 1911
Lernaeidae

MOLLUSCA.

Glochidia

FUNGUS.

*Saprolegnia parasitica* Coker, 1923

HIRUDINEA.

*Piscicola punctata* (Verrill, 1872)
*Placobdella montifera* Moore, 1912

## SECTION VI. PARASITES OCCURRING IN ONE HOST OR OF RARE OCCURRENCE.

The check list which follows gives the parasites which were found in one host. These parasites were usually mature and as may be seen from the tables for parasites by families of fish were occasionally forms rare in fish of this lake. Many were restricted as to habitat. As in the previous list, "E" indicates the host secured from the eastern portion of Lake Erie and "W" following the host indicated the western area.

| TREMATODES | HOSTS | REGION |
|---|---|---|
| *Acetodextra amiuri* | Channel catfish | W |
| *Allocreadium armatum* | Sheepshead | E |
| *Allocreadium boleosomi* | Log perch | W |
| *Anallocreadium pearsei* | Sheepshead | W |
| *Alloglossidium corti* | Tadpole cat | W |
| *Azygia angusticauda* | Blue pike | W |
| *Bunodera luciopercae* | Yellow perch | W |
| *Crassiphiala ambloplitis* | Rock bass | E & W |
| *Crepidostomum cooperi* | Yellow perch | W |
| *Crepidostomum isostomum* | Trout perch | E & W |
| *Crepidostomum hiodontos* | Moon-eye | W |
| *Crepidostomum lintoni* | Lake sturgeon | W |
| *Diplostomum scheuringi* | Yellow perch | E |
| *Macroderoides spiniferus* | Long-nosed gar | W |
| *Macroderoides typicum* | Bowfin | W |
| *Microcotyle eriensis* | Sheepshead | W |
| *Microcotyle spinicirrus* | Sheepshead | W |
| *Neascus bulboglossa* | Horned dace | E |
| *Neascus wardi* | Blue gill | E |
| *Neochasmus umbellus* | Small-mouth black bass | W |
| *Phyllodistomum superbum* | Common bullhead | W |
| *Tetracotlye communis* | Fan-tailed darter | E |
| *Tetracotyle diminuta* | Trout perch | W |
| CESTODES | | |
| *Corallobothrium giganteum* | Channel catfish | W |
| *Cyathocephalus americanus* | Whitefish | W |
| *Haplobothrium globuliforme* | Bowfin | W |
| *Proteocephalus singularis* | Long-nosed gar | W |
| *Proteocephalus wickliffi* | Lake herring | E & W |
| NEMATODES | | |
| *Contracaecum brachyurum* | Small-mouthed black bass | W |
| *Contracaecum* sp. | Rock bass | W |
| *Cucullanus clitellarius* | Lake sturgeon | W |
| *Cystidicola lepisostei* | Long-nosed gar | W |
| *Cystidicoloides harwoodi* | Brook trout | E |
| *Dicotophyme* sp. | Small-mouthed black bass | W |
| *Haplonema hamulatum* | Burbot | W |
| *Haplonema immutatum* | Bowfin | W |
| *Spiroxys* sp. | Mud minnow | W |
| ACANTHOCEPHALA | | |
| *Echinorhynchus coregoni* | Whitefish | W |
| *Neoechinorhynchus crassus* | Common sucker | W |
| *Neoechinorhynchus tenellus* | Northern pike | E |
| *Octospinifer macilentus* | Common sucker | E & W |
| *Pomphorhynchus bulbocolli* | Common sucker | W |
| CESTODARIA | | |
| *Glaridacris catostomi* | Common sucker | E |
| *Hypocaryophyllarus paratarius* | American carp | E |
| PROTOZOA | | |
| *Cyclochaeta domerguei* | Small-mouthed black bass | W |
| *Vorticellidae* | Small-mouthed black bass | W |
| COPEPODS | | |
| *Achtheres ambloplitis* | Rock bass | W |
| *Argulus catostomi* | Black bullhead | W |
| LEECH | | |
| *Placobdella montifera* | Large-mouthed black bass | W |

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## APPENDIX. SUMMARY OF PARASITISM BY SPECIES OF FISH.

This appendix contains the detailed host records on all fish examined by families and species of fish. The total number of each species of fish examined is indicated before the name of the host. This figure is then subdivided into data for the eastern and western ends of the lake, under "E" and "W." The number examined from each end is indicated, while the number of infected fish occurs in parentheses. The species of parasites is then listed together with data on the number and degree of infection as well as the location in the host. See also footnote 1, page 385.

### Abbreviations in Tables.

E—East
W—West
*—1-9 parasites
**—10-49 parasites
***—50 parasites and over
†—larval or immature form
A—air bladder
C—coelom
D—digestive tract
E—external
F—flesh
G—gills
I—intestine
K—kidneys
L—liver
M—mesenteries
P—pericardial cavity
R—reproductive organs
S—spleen
U—urinary bladder

TABLE 1.
Summary of Parasitism in the Acipenseridae.

| *Hosts* | *Parasites* | *Number infected & degree* | *Location in host* |
|---|---|---|---|
| 2 *Acipenser fulvescens* | TREMATODES | | |
| Raf. | *Crepidostomum lintoni* | W 2 * | D |
| Lake sturgeon | *Allocreadium* sp. | W 1 * | D |
| 2 (2) W. | NEMATODES | | |
| | *Cucullanus clitellarius* | W 2 * | D |

TABLE 2.

Summary of Parasitism in the Lepisosteidae.

| *Hosts* | *Parasites* | *Number infected & degree* | *Location in host* |
|---|---|---|---|
| 9 *Lepisosteus osseus* (Linn.) Long-nosed gar 1 (0) E; 8 (8) W. | TREMATODES | | |
| | *Macroderoides spiniferus* | W 4 * | D |
| | | 1 ** | D |
| | CESTODES | | |
| | *Proteocephalus singularis* | W 6 * | D |
| | †*Proteocephalus ambloplitis* | W 2 * | M & L |
| | | 1 ** | M & L |
| | | 3 * | L |
| | | 1 ** | L |
| | †*Bothriocephalus* sp. | W 1 * | D |
| | NEMATODES | | |
| | *Cystidicola lepisostei* | W 2 * | I |
| | ACANTHOCEPHALA | | |
| | *Leptorhynchoides thecatus* | W 1 * | D |

TABLE 3.

Summary of Parasitism in the Amiidae.

| *Hosts* | *Parasites* | *Number infected & degree* | *Location in host* |
|---|---|---|---|
| 3 *Amia calva* Linn. Bowfin 3 (3) W. | TREMATODES | | |
| | *Crepidostomum cornutum* | W 1 * | D |
| | *Microphallus opacus* | W 1 ** | D |
| | *Leuceruthrus micropteri* | W 1 * | D |
| | CESTODES | | |
| | *Proteocephalus ambloplitis* | W 2 ** | D |
| | *Haplobothrium globuliforms* | W 1 * | D |
| | NEMATODES | | |
| | *Haplonema immutatum* | W 1 * | D |
| | ACANTHOCEPHALA | | |
| | *Leptorhynchoides thecatus* | W 1 * | D |
| 1 young *Amia calva* | TREMATODES | | |
| | *Macroderoides typicum* | W 1 ** | D |

TABLE 4.

Summary of Parasitism in the Hiodontidae.

| *Hosts* | *Parasites* | *Number infected & degree* | *Location in host* |
|---|---|---|---|
| 28 *Hiodon tergisus* Le Sueur Moon-eye 16 (6) E; 12 (9) W. | TREMATODES | | |
| | *Crepidostomum illinoiense* | W 5 * | D |
| | | 2 ** | D |
| | *Leuceruthrus* sp. | W 1 * | D |
| | *Tetracotyle* sp. | W 1 * | M |
| | CESTODES | | |
| | *Bothriocephalus cuspidatus* | W 1 * | D |
| | †*Proteocephalus* sp. | W 1 * | D |
| | NEMATODES | | |
| | *Rhabdochona cascadilla* | E 4 * | D |
| | | W 6 * | D |
| | *Camallanus oxycephalus* | E 5 * | D |
| | | 1 ** | D |

TABLE 5.
Summary of Parasitism in the Clupeidae.

| *Hosts* | *Parasites* | *Number infected & degree* | *Location in host* |
|---|---|---|---|
| 1 young *Dorosoma cepedianum* (Le Sueur) | NEMATODES | | |
| Gizzard shad | *Agamonema* sp. | W 1 * | D |
| 1 (1) W. | | | |

4 adults of this species examined from the western end were negative.

TABLE 6.
Summary of Parasitism in the Coregonidae.

| *Hosts* | *Parasites* | *Number infected & degree* | *Location in host* |
|---|---|---|---|
| 78 *Leucichthys artedi* (Le Sueur) | CESTODES | | |
| Lake herring | *Proteocephalus exiguus* | E 9 * | D |
| 63 (16) E; 15 (14) W. | | 6 ** | D |
| | | 1 *** | D |
| | | W 7 * | D |
| | | 3 ** | D |
| | †*Abothrium crassum* | W 4 * | 3 M |
| | | | 1 I |
| | *Proteocephalus wickliffi* | E 3 * | D |
| | | W 6 * | D |
| | NEMATODES | | |
| | *Cystidicola stigmatura* | W 1 * | A |
| 24 *Coregonus clupeaformis* (Mitchill) | TREMATODES | | |
| Whitefish | Unidentified | W 1 * | D |
| 9 (6) E; 15 (15) W. | CESTODES | | |
| | *Abothrium crassum* | E 1 * | D |
| | | W 2 * | D |
| | †*Schistocephalus* sp. | W 1 * | P |
| | *Proteocephalus exiguus* | E 2 * | D |
| | | 3 ** | D |
| | | 1 *** | D |
| | | W 1 * | D |
| | | 2 *** | D |
| | NEMATODES | | |
| | *Cystidicola stigmatura* | W 3 * | A |
| | ACANTHOCEPHALA | | |
| | *Echinorhynchus coregoni* | E 1 * | D |
| | | 4 ** | D |
| | | W 10 * | D |
| | | 4 ** | D |
| | †*Echinorhynchus* sp. | W 1 * | C |
| 6 young *C. clupeaformis* | CESTODES | | |
| | †*Proteocephalus exiguus* | W 4 ‡ * | D |
| 6 (6) W. | | 2 ** | D |

‡ One carried 8 larval and a single adult form of this cestode.

TABLE 7.
Summary of Parasitism in the Salmonidae.

| *Hosts* | *Parasites* | *Number infected & degree* | *Location in host* |
|---|---|---|---|
| 63 *Salvelinus fontinalis* (Mitchill) | NEMATODES | | |
| Brook trout | *Cystidicoloides harwoodi* | E 40 * | D |
| 63 (40) E. | | | |

TABLE 8.
Summary of Parasitism in the Catostomidae.

| *Hosts* | *Parasites* | *Number infected & degree* | *Location in host* |
|---|---|---|---|
| 16 *Carpiodes cyprinus* (Le Sueur) | CESTODARIA | | |
| | *Hypocaryophyllaeus paratarius* | E 1 * | D |
| White carp | NEMATODES | | |
| 13 (5) E; 3 (0) W. | *Rhabdochona cascadilla* | E 5 * | D |
| 21 *Catostomus commersonnii* (Lacépède) | CESTODARIA | | |
| | *Glaridacris catostomi* | E 4 * | D |
| Common sucker | CESTODES | | |
| 13 (8) E; 8 (8) W. | †*Ligula intestinalis* | E 2 * | C |
| | | W 1 * | C |
| | †*Triaenophorus nodulosus* | E 1 * | L |
| | | W 1 * | L |
| | NEMATODES | | |
| | *Agamonema* sp. | W 1 * | D |
| | ACANTHOCEPHALA | | |
| | *Octospinifer macilentus* | E 3 * | D |
| | | W 1 * | D |
| | *Neoechinorhynchus crassus* | W 3 * | D |
| | | 1 ** | D |
| | *Pomphorhynchus bulbocolli* | W 2 * | D |
| 21 *Hypentylium nigricans* (Le Sueur) | PROTOZOA | | |
| | Myxosporidia | W 1 * | F |
| Hog sucker | | | |
| 20 (0) E; 1 (1) W. | | | |
| 3 *Moxostoma aureolum* (Le Sueur) | TREMATODES | W 1 * | L |
| | *Neascus* sp. | | |
| Common red horse or Red-fin mullet | NEMATODES | E 1 * | D |
| 2 (1) E; 1 (1) W. | Unidentified | | |
| 8 *Moxostoma lesueurii* (Richardson) | NEMATODES | | |
| | *Rhabdochona cascadilla* | W 1 * | D |
| Short-headed red-fin mullet or Red horse | PROTOZOA | | |
| 6 (0) E; 2 (2) W. | Myxosporidia | W 1 ** | G |

14 *Moxostoma duquesnii* (Le Sueur), fine-scaled red-fin mullet, and 9 *M. anisurum* Raf., white-nosed red-fin mullet, were examined from the eastern end of the lake and found to be negative.

TABLE 9.

Summary of Parasitism in the Cyprinidae.

| *Hosts* | *Parasites* | *Number infected & degree* | *Location in host* |
|---|---|---|---|
| 13 *Cyprinus carpio* Linn. | TREMATODES | | |
| German carp | *Neascus vancleavei* | W 1 * | M |
| 7 (1) E; 6 (2) W. | CESTODES | | |
| | In those from eastern end, outer wall of digestive tract riddled with degenerated cysts. | | |
| | NEMATODES | | |
| | *Agamonema* sp. | W 2 * | D |
| | ACANTHOCEPHALA | | |
| | *Leptorhynchoides thecatus* | E 1 * | D |
| 18 *Carassius auratus* (Linn.) | NEMATODES | | |
| | *Agamonema* sp. | W 8 * | D |
| Goldfish | ACANTHOCEPHALA | | |
| 2 (0) E; 11 (4) W. | *Pomphorhynchus* sp. | W 1† * | D |
| 18 *Nocomis micropogon* (Cope) | TREMATODES | | |
| | *Neascus vancleavei* | E 4 * | M |
| | | 3 ** | L |
| 18 (9) E. | *Neascus* sp. | E 2 * | F |
| | | 1 ** | F |
| | | 1 *** | F |
| | NEMATODES | | |
| | *Agamonema* sp. | E 1 * | D |
| 31 *Erimemus storerianus* (Kirtland) | TREMATODES | | |
| | *Neascus* sp. | W 4 * | M |
| Storer's chub | Strigeidae | W 6 * | M |
| 31 (20) W. | *Lebouria cooperi* | W 7 * | D |
| | | 3 ** | D |
| | CESTODES | | |
| | †*Ligula intestinalis* | W 2 * | C |
| | NEMATODES | | |
| | *Agamonema* sp. | W 2 * | D |
| | ACANTHOCEPHALA | | |
| | *Leptorhynchoides thecatus* | W 1 * | D |
| 54 *Rhinichthys atronasus* (Mitchill) | TREMATODES | | |
| | *Neascus vancleavei* | E 1 * | L |
| Black-nosed dace | *Neascus rhinichthysi* | E 13 * | F |
| 54 (27) E. | | 11 ** | F |
| | | 3 *** | F |
| 51 *Rhinichthys cataractae* (Cuvier & Valenciennes) | TREMATODES | | |
| | *Neascus rhinichthysi* | E 6 * | F |
| | | 2 ** | F |
| Long-nosed dace | *Lebouria cooperi* | W 8 * | D |
| 41 (13) E; 10 (4) W. | NEMATODES | | |
| | *Camallanus oxycephalus* | W 1† * | D |
| | | W 1 * | D |

Summary of Parasitism in the Cyprinidae.—Continued

| Hosts | Parasites | Number infected & degree | Location in host |
|---|---|---|---|
| 40 *Semotilus atromaculatus* (Mitchill) Horned dace 40 (24) E. | TREMATODES | | |
| | *Neascus vancleavei* | E 1 * | L |
| | | 1 ** | L |
| | *Neascus bulboglossa* | E 1 * | F |
| | | 6 ** | F |
| | | 15 *** | F |
| | CESTODES | | |
| | *Proteocephalus* sp. | E 1 * | D |
| | NEMATODES | | |
| | *Agamonema* sp. | E 1 * | D |
| 10 *Opsopoeodus emiliae* Hay Pug-nosed minnow 10 (2) W. | TREMATODES | | |
| | *Neascus* sp. | W 1 * | M |
| | *Lebouria cooperi* | W 1 * | D |
| | CESTODES | | |
| | †*Ligula intestinalis* | W 2 * | C |
| 8 *Notropis heterodon* (Cope) Black-nosed shiner 8 (3) W. | TREMATODES | | |
| | *Neascus* sp. | W 1 * | M |
| | NEMATODES | | |
| | *Agamonema* sp. | W 1 * | D |
| | *Camallanus oxycephalus* | W 1 * | D |
| 14 *Notropis volucellus* (Cope) 14 (7) W. | TREMATODES | | |
| | *Neascus* sp. | W 1 * | M |
| | *Lebouria cooperi* | W 6 * | D |
| | NEMATODES | | |
| | *Rhabdochona cascadilla* | W 1 * | D |
| 12 *Notropis deliciosus stramineus* (Cope) Straw-colored minnow 3 (1); 9 (4) W | TREMATODES | | |
| | *Neascus* sp. | W 1 * | M |
| | *Lebouria cooperi* | W 4 * | D |
| | CESTODES | | |
| | †*Ligula intestinalis* | E 1 * | C |
| | PROTOZOA | | |
| | Myxosporidia | W 1 * | G |
| 94 *Notropis hudsonius* (Clinton) Spot-tailed minnow 11 (5) E; 83 (58) W | TREMATODES | | |
| | *Neascus vancleavei* | E 1 * | M |
| | *Neascus* sp. | W 8 * | M |
| | *Tetracotyle* sp. | W 4 * | M |
| | *Lebouria cooperi* | W 15 * | D |
| | CESTODES | | |
| | †*Ligula intestinalis* | E 2 * | C |
| | | W 37 * | C |
| | †*Proteocephalus ambloplitis* | W 1 * | L |
| | *Proteocephalus* sp. ‡ | W 1 * | D |
| | NEMATODES | | |
| | *Agamonema* sp. | W 1 * | D |
| | *Camallanus oxycephalus* | W 3 * | D |
| | *Rhabdochona cascadilla* | W 2 * | D |
| | PROTOZOA | | |
| | Myxosporidia | E 2 *** | F |
| | | W 2 ** | F |
| | | 1 * | F |

‡ A single strobila representing a new undescribed species.

Summary of Parasitism in the Cyprinidae.—Continued

| *Hosts* | *Parasites* | *Number infected & degree* | *Location in host* |
|---|---|---|---|
| 58 *Notropis whipplii* (Girard) | TREMATODES | | |
| Steel-colored minnow | *Lebouria cooperi* | E 5 * | D |
| 9 (5); 49 (20) W | | W 6 * | D |
| | *Neascus* sp. | W 1 * | L |
| | | 2 ** | F, L |
| | CESTODES | | |
| | †*Ligula intestinalis* | W 4 * | C |
| | NEMATODES | | |
| | *Agamonema* sp. | E 1 * | D |
| | | W 1 * | D |
| | *Camallanus oxycephalus* | W 5 * | D |
| | *Rhabdochona cascadilla* | W 11 * | D |
| | LEECHES | | |
| | *Piscicola punctata* | W 1 * | E |
| 144 *Notropis atherinoides* Raf. | TREMATODES | | |
| Lake shiner | Strigeidae | W 1 * | M |
| 63 (10) E; 81 (35) W | *Leuceruthrus* sp. | W 1 * | D |
| | *Lebouria cooperi* | W 26 * | D |
| | | 1 ** | D |
| | *Neascus vancleavei* | W 3 * | L |
| | CESTODES | | |
| | †*Proteocephalus pinguis* | E 7 * | D |
| | †*Bothriocephalus cuspidatus* | E 3 * | D |
| | | W 2 * | D |
| | | 1 ** | D |
| | †*Proteocephalus ambloplitis* | W 3 * | M |
| | *Proteocephalus* sp. | W 2† * | D |
| | | 1 * | D |
| | NEMATODES | | |
| | *Camallanus oxycephalus* | W 1 * | D |
| | PROTOZOA | | |
| | Myxosporidia | W 1 ** | G |
| 35 *Notropis cornutus* (Mitchill) | TREMATODES | | |
| Common shiner | *Neascus vancleavei* | E 2 * | L |
| 34 (14) E; 1 (0) W. | | 1 ** | M |
| | *Neascus* sp. | E 4 * | F |
| | | 4 ** | F |
| | | 1 *** | F |
| | CESTODES | | |
| | †*Ligula intestinalis* | E 2 * | C |
| 3 *Ericymba buccata* Cope | TREMATODES | | |
| Silvery-jawed minnow | *Neascus bulboglossa* | W 1 ** | D |
| 3 (1) W | NEMATODES | | |
| | *Camallanus oxycephalus* | W 1 * | D |
| 12 *Notemigonus crysoleucas* (Mitchill) | TREMATODES | | |
| | *Neascus* sp. | E 2 * | F |
| Golden shiner | NEMATODES | | |
| 5 (2) E; 7 (1) W. | *Agamonema* sp. | W 1 * | D |
| | PROTOZOA | | |
| | Myxosporidia | W 1 *** | G |

Summary of Parasitism in the Cyprinidae.—Continued

| Hosts | Parasites | Number infected & degree | Location in host |
|---|---|---|---|
| 13 *Hyborhynchus notatus* (Raf.) Blunt-nosed minnow 3 (2) E; 10 (3) W. | TREMATODES | | |
| | *Neascus* sp. | E 2 * | F |
| | *Lebouria cooperi* | W 1 * | D |
| | *Neascus vancleavei* | W 1 * | L |
| | CESTODES | | |
| | †*Ligula intestinalis* | W 1 * | C |
| | PROTOZOA | | |
| | Myxosporidia | W 1 ** | E |
| 11 *Pimephales promelas* Raf. Fat-head minnow 9 (2); 2 (2) W | TREMATODES | | |
| | *Neascus* sp. | W 2 * | L |
| | PROTOZOA | | |
| | Myxosporidia | E 2 *** | I |
| 16 *Campostoma anomalum* (Raf.) Stone roller 14 (7) E; 2 (1) W. | TREMATODES | | |
| | *Neascus vancleavei* | E 4 * | L |
| | | W 1 * | L |
| | *Neascus* sp. | E 1 * | F |
| | | 1 ** | F |
| | | 1 *** | F |

8 *Notropis heterolepis*, Eigenmann & Eigenmann, from the western end, 1 *Notropis rubrifrons* (Cope) from the western end and 13 *Notropis umbratilis* (Girard) from the eastern end were negative.

TABLE 10.

Summary of Parasitism in the Ameiuridae (Siluridae).

| Hosts | Parasites | Number infected & degree | Location in host |
|---|---|---|---|
| 36 *Ictalurus punctatus* (Raf.) Channel catfish 7 (2) E; 29 (29) W. | TREMATODES | | |
| | Gyrodactyloidea | W 1 * | G |
| | | 2 ** | G |
| | *Megalogonia ictaluri* | W 4 * | D |
| | | 1 ** | D |
| | *Vistosoma parvum* | W 2 * | D |
| | *Acetodextra amiuri* | W 1 * | R |
| | *Macroderoides* sp. | W 1 * | D |
| | *Phyllodistomum* sp. | W 1 * | U |
| | CESTODES | | |
| | *Corallobothrium fimbriatum* | E 2 * | D |
| | | W 7 * | D |
| | | 2 ** | D |
| | | 2† * | D |
| | | 4† ** | D |
| | *Corallobothrium giganteum* | W 1 * | D |
| | NEMATODES | | |
| | *Spinitectus gracilis* | W 4 * | D |
| | *Agamonema* sp. | W 4 * | D |
| | †*Camallanus oxycephalus* | W 1 * | D |
| | ACANTHOCEPHALA | | |
| | †*Leptorhynchoides thecatus* | W 4 * | M |
| | *Pomphorhynchus* sp. | W 1 * | D |

Summary of Parasitism in the Ameiuridae (Siluridae).—Continued

| *Hosts* | *Parasites* | *Number infected & degree* | *Location in host* |
|---|---|---|---|
| 36 *Ictalurus punctatus* (Raf.) continued | COPEPODS | | |
| | *Ergasilus versicolor* | W 4 * | G |
| | *Achtheres pimelodi* | W 1 * | G |
| | PROTOZOA | | |
| | Myxosporidia | W 5 * | G |
| | | 8 ** | G |
| | | 1 *** | G |
| 1 *Villarius lacustris* (Walbaum) Lake catfish 1 (1) E. | PROTOZOA | | |
| | Lymphocystis | E 1 ** | L, K & M |
| 19 *Ameiurus melas* Raf. Black bullhead 19 (12) W. | TREMATODES | | |
| | *Megalogonia ictaluri* | W 1 * | D |
| | *Clinostomum marginatum* | W 1 * | F |
| | *Leuceruthrus micropteri* | W 1 * | D |
| | *Crepidostomum* sp. | W 1 * | D |
| | CESTODES | | |
| | *Corallobothrium fimbriatum* | W 3 * | D |
| | *Corallobothrium* n. sp. | W 1 * | D |
| | †*Proteocephalus ambloplitis* | W 2 * | M |
| | NEMATODES | | |
| | *Dichelyne cotylophora* | W 1 * | D |
| | ACANTHOCEPHALA | | |
| | †*Leptorhynchoides thecatus* ‡ | W 1 * | M |
| ‡ New definitive host record. | LEECHES | | |
| | *Piscicola punctata* | W 3 * | E |
| 8 *Ameiurus nebulosus* (Le Sueur) Common bullhead 7 (0) E; 1 (1) W. | TREMATODES | | |
| | *Phyllodistomum superbum* | W 1 * | U |
| | *Clinostomum marginatum* | W 1 * | F |
| | CESTODES | | |
| | *Corallobothrium* n. sp. | W 1 * | D |
| | NEMATODES | | |
| | *Agamonema* sp. | W 1 * | D |
| 5 *Noturus flavus* Raf. Yellow stone cat. 5 (4) W. | TREMATODES | | |
| | *Megalogonia ictaluri* | W 1 * | D |
| | CESTODES | | |
| | *Corallobothrium fimbriatum* | W 2 * | D |
| | †*Proteocephalus ambloplitis* | W 1 * | L |
| | NEMATODES | | |
| | *Spinitectus gracilis* | W 1 * | D |
| | *Camallanus oxycephalus* | W 2 * | D |
| | ACANTHOCEPHALA | | |
| | *Leptorhynchoides thecatus* | W 2† * | M |
| | | 2 * | D |
| 3 *Schilbeodes gyrinus* (Mitchill) Tadpole stone cat 3 (3) W. | TREMATODES | | |
| | *Acetodextra amiuri* | W 3 * | D |
| | *Alloglossidium corti* | W 1 * | D |
| | COPEPODS | | |
| | *Ergasilus versicolor* | W 1 * | G |

Summary of Parasitism in the Ameiuridae (Siluridae).—Continued

| *Hosts* | *Parasites* | *Number infected & degree* | *Location in host* |
|---|---|---|---|
| 3 *Schilbeodes miurus* (Jordan) Spotted stone cat 3 (3) W. | TREMATODES | | |
| | *Megalogonia ictaluri* | W 1 * | D |
| | | 1 ** | D |
| | *Neascus* sp. | W 1 * | M |
| | CESTODES | | |
| | *Corallobothrium fimbriatum* | W 1 * | D |
| | *Bothriocephalus* sp. | W 1 * | D |

TABLE 11.

Summary of Parasitism in the Umbridae.

| *Hosts* | *Parasites* | *Number infected & degree* | *Location in host* |
|---|---|---|---|
| 12 *Umbra limi* (Kirtland) Mud minnow 3 (0) E; 9 (6) W. | NEMATODES | | |
| | †*Spiroxys* sp. | W 6 * | D |

TABLE 12.

Summary of Parasitism in the Esocidae.

| *Hosts* | *Parasites* | *Number infected & degree* | *Location in host* |
|---|---|---|---|
| 5 *Esox vermiculatus* Le Sueur Little pickerel 5 (1) W. | TREMATODES | | |
| | *Azygia angusticauda* | W 1 * | D |
| | *Centrovarium lobotes* | W 1 * | D |
| | CESTODES | | |
| | *Proteocephalus pinguis* | W 1 * | D |
| | NEMATODES | | |
| | *Spinitectus gracilis* | W 1 * | D |
| 8 *Esox lucius* Linn. Northern pike 6 (6) E; 2 (1) W. | CESTODES | | |
| | *Proteocephalus pinguis* | E 4 * | D |
| | | 2 ** | D |
| | | W 1 * | D |
| | ACANTHOCEPHALA | | |
| | *Neoechinorhynchus tenellus* | E 2 * | D |

TABLE 13.

Summary of Parasitism in the Cyprinodontidae.

| *Hosts* | *Parasites* | *Number infected & degree* | *Location in host* |
|---|---|---|---|
| 31 *Fundulus diaphanus menona* Jordan & Copeland | TREMATODES | | |
| | *Neascus vancleavei* | E 3 * | L |
| | | W 4 * | L |
| Top minnow | CESTODES | | |
| 14 (3) E; 17 (10) W. | †*Proteocephalus* sp. | W 1 * | D |
| | NEMATODES | | |
| | *Agamonema* sp. | W 2 * | M |
| | *Rhabdochona* sp. ‡ | E 1 * | D |
| | ACANTHOCEPHALA | | |
| | †*Neoechinorhynchus* sp. | W 5 * | M |
| | | 2 * | L |
| | PROTOZOA | | |
| | Myxosporidia | W 1 ** | F |

‡ Represents a new species, but not enough material secured for an adequate description.

TABLE 14.

Summary of Parasitism in the Percopsidae.

| *Hosts* | *Parasites* | *Number infected & degree* | *Location in host* |
|---|---|---|---|
| 53 *Percopsis omiscomaycus* | TREMATODES | | |
| | *Neascus vancleavei* | E 1 * | M |
| | | W 10 * | M |
| | | 3 ** | L |
| Trout perch | *Crepidostomum isostomum* | E 4 * | D |
| 7 (5) E; 46 (44) W. | | W 13 * | D |
| | *Centrovarium lobotes* | E 2 ** | F |
| | *Tetracotyle diminuta* | W 18 * | M |
| | CESTODES | | |
| | †*Triaenophorus* sp. | E 2 * | M |
| | | W 16 * | L & M |
| | *Bothriocephalus cuspidatus* | E 1 * | D |
| | | 2† * | M |
| | *Bothriocephalus claviceps* ‡ | W 4 * | D |
| | *Proteocephalus pearsei* | W 1 * | D |
| | | 5† * | D |
| | NEMATODES | | |
| | *Agamonema* sp. | W 1 * | I |
| | *Camallanus oxycephalus* | W 16 * | D |
| | | 1 ** | D |
| | ACANTHOCEPHALA | | |
| | †*Leptorhynchoides thecatus* | W 1 * | M |
| | PROTOZOA | | |
| | Myxosporidia | W 6 ** | F |

TABLE 15.
Summary of Parasitism in the Serranidae.

| *Hosts* | *Parasites* | *Number infected & degree* | *Location in host* |
|---|---|---|---|
| 25 *Lepibema chrysops* Raf. White bass 2 (1) E; 23 (23) W. | TREMATODES | | |
| | *Allacanthochasmus varius* | E 1 ** | D |
| | | W 3 * | D |
| | | 6 ** | D |
| | | 7 *** | D |
| | *Leuceruthrus* sp. | W 2 * | D |
| | *Neascus* sp. | W 5 * | L |
| | | 4 ** | M |
| | Gyrodactyloidea | W 1 * | G |
| | | 4 ** | G |
| | Unidentified | W 1 * | D |
| | CESTODES | | |
| | *Bothriocephalus cuspidatus* | W 7† 5 * | D |
| | | 1 3 ** | D |
| | †*Proteocephalus pearsei* | W 3 * | D |
| | | 5 ** | D |
| | | 1 *** | D |
| | †*Proteocephalus ambloplitis* | W 3 * | M |
| | NEMATODES | | |
| | *Dichelyne cotylophora* | W 1 * | D |
| | *Camallanus oxycephalus* ‡ | W 11 * | D |
| | | 2 ** | D |
| | *Agamonema* sp. | W 1 * | M |
| | *Rhabdochona* sp. | W 1 * | D |
| ‡ One of these identified to genus only. | MOLLUSCA | | |
| | Glochidia | W 1 *** | G |
| 9 Young *L. chrysops* 9 (6) W. | TREMATODES | | |
| | Gyrodactyloidea | W 1 * | G |
| | | 3 ** | G |
| | *Neascus* sp. | W 2 * | M |
| | CESTODES | | |
| | †*Proteocephalus pearsei* | W 2 ** | D |
| | NEMATODES | | |
| | *Camallanus oxycephalus* ‡ | W 2 * | D |
| | *Agamonema* sp. | W 1 * | M |

TABLE 16.

Summary of Parasitism in the Percidae.

| *Hosts* | *Parasites* | *Number infected & degree* | *Location in host* |
|---|---|---|---|
| 69 *Perca flavescens* (Mitchill) Yellow perch. 24 (20) E; 45 (40) W. | TREMATODES | | |
| | *Bunodera lucioperca* | E 3 * | D |
| | *Clinostomum marginatum* | W 1 * | F |
| | *Diplostomum scheuringi* | E 2 * | Q |
| | *Crepidostomum cooperi* | W 11 * | D |
| | | 1 ** | D |
| | *Cryptogonimus chyli* | W 1 * | D |
| | | 1 ** | D |
| | *Neascus* sp. | W 2 * | F |
| | | 3 ** | F |
| | *Microphallus opacus* | W 1 * | D |
| | †*Leuceruthrus* sp. | W 1 * | D |
| | CESTODES | | |
| | *Bothriocephalus cuspidatus* | E 1† * | D |
| | | W 6 * | D |
| | | 1 ** | D |
| | *Proteocephalus pearsei* | E 3† * | D |
| | | W 3† * | D |
| | | 8 * | D |
| | †*Proteocephalus ambloplitis* | E 1 * | L |
| | | W 9 * | M |
| | | 1 ** | L & D |
| | †*Triaenophorus* n. sp. | W 2 * | L & D |
| | NEMATODES | | |
| | *Dichelyne cotylophora* | E 12 * | D |
| | | 1 ** | D |
| | | W 20 * | D |
| | | 2 ** | D |
| | *Camallanus oxycephalus* | W 1 * | D |
| | *Philometra cylindracea* | W 1 * | C |
| | ACANTHOCEPHALA | | |
| | *Leptorhynchoides thecatus* | W 1 * | M |
| | LEECHES | | |
| | *Piscicola punctata* | E 2 * | E |
| | FUNGUS | | |
| | *Saprolegnia* sp. | E 3 * | F |
| 59 young *P. flavescens* 44 (25) E; 15 (13) W. | TREMATODES | | |
| | *Neascus* sp. | W 1 * | F |
| | CESTODES | | |
| | †*Bothriocephalus cuspidatus* | E 1 ** | D |
| | | W 2 * | D |
| | †*Proteocephalus ambloplitis* | E 3 * | M |
| | | W 7 * | L & M |
| | *Proteocephalus pearsei* | E 3 * | D |
| | | W 1† 9 * | D |
| | | 9 1 ** | D |
| | †*Proteocephalus pinguis* | E 18 * | D |
| | NEMATODES | | |
| | *Dichelyne cotylophora* | W 1 * | D |
| | *Agamonema* sp. | W 2 * | D |

Summary of Parasitism in the Percidae.—Continued

| Hosts | Parasites | Number infected & degree | Location in host |
|---|---|---|---|
| 43 *Stizostedion canadense griseum* (De Kay) Sauger 10 (10) E; 33 (32) W. | TREMATODES | | |
| | *Centrovarium lobotes* | E 1 * | D |
| | | 1 ** | D |
| | | W 5 * | D |
| | *Bucephalus pusillus* | W 4 * | D |
| | | 2 ** | D |
| | *Neascus* sp. | W 1 ** | M |
| | CESTODES | | |
| | *Bothriocephalus cuspidatus* | E 8 * | D |
| | | 2 ** | D |
| | | W 12† 1 * | D |
| | | 17 27 ** | D |
| | | 1 *** | D |
| | *Bothriocephalus claviceps* | E 1 * | D |
| | *Triaenophorus* n. sp. | W 6 * | D, L & M |
| | *Proteocephalus stizostethi* | W 1† ** | D |
| | | 1 ** | D |
| | NEMATODES | | |
| | *Camallanus oxycephalus* | W 3† * | D |
| | | 9 * | D |
| | ACANTHOCEPHALA | | |
| | *Neoechinorhynchus* sp. | W 1 * | D |
| | COPEPODS | | |
| | *Ergasilus centrarchidarum* | E 3 * | G |
| | | 4 ** | G |
| | *Ergasilus caeruleus* | W 3 * | G |
| | PROTOZOA | | |
| | Myxosporidia | W 1 ** | G |
| | Lymphocystis | W 1 ** | E |
| | MOLLUSCA | | |
| | Glochidia | W 1 ** | G |
| 58 *Stizostedion vitreum* (Mitchill) Wall-eyed pike. 10 (9) E; 48 (47) W. | TREMATODES | | |
| | *Neascus vancleavei* | E 1 * | L |
| | *Neascus* sp. | W 1 * | M |
| | *Azygia angusticauda* | W 1 * | D |
| | *Centrovarium lobotes* | W 2 * | D |
| | *Bucephalus pusillus* | W 3 * | D |
| | | 5 ** | D |
| | CESTODES | | |
| | *Bothriocephalus cuspidatus* | E 6 * | D |
| | | 2 ** | D |
| | | 1 *** | D |
| | | W 20† 8 * | D |
| | | 25 32 ** | D |
| | | 5 *** | D |
| | *Triaenophorus* n. sp. | W 1 * | L |
| | †*Proteocephalus stizostethi* | W 8† 6 * | D |
| | | 5 7 ** | D |
| | NEMATODES | | |
| | *Dichelyne cotylophora* | W 2 * | D |
| | *Camallanus oxycephalus* | W 3 * | D |
| | | 2 ** | D |
| | *Agamonema* sp. | W 1 * | D |
| | ACANTHOCEPHALA | | |
| | *Neoechinorhynchus cylindratus* | E 1 * | D |
| | *Leptorhynchoides thecatus* | W 1 * | D |

Summary of Parasitism in the Percidae.—Continued

| *Hosts* | *Parasites* | *Number infected & degree* | *Location in host* |
|---|---|---|---|
| 58 *Stizostedion vitreum* (Mitchill) | LEECHES | | |
| | *Piscicola punctata* | W 1 * | E |
| continued | COPEPODS | | |
| | *Ergasilus centrarchidarum* | E 4 ** | G |
| | *Ergasilus caeruleus* | W 4 * | G |
| | | 2 ** | G |
| | PROTOZOA | | |
| | Lymphocystis | W 1 * | 6F |
| | | 3 ** | 1D |
| | | 3 *** | |
| 15 Young *Stizostedion vitreum* | TREMATODES | | |
| | *Neascus* sp. | W 1 * | M |
| 15 (12) W. | *Bucephalus pusillus* | W 1 * | D |
| | | 2 ** | D |
| | CESTODES | | |
| | †*Bothriocephalus cuspidatus* | W 5 * | D |
| | *Triaenophorus* n. sp. | W 1 * | L |
| | †*Proteocephalus ambloplitis* | W 3 * | M |
| | NEMATODES | | |
| | *Camallanus oxycephalus* | W 3† * | D |
| | | 3 * | D |
| | *Spinitectus gracilis* | W 1 * | D |
| | COPEPODS | | |
| | *Ergasilus caeruleus* | W 1 * | G |
| 20 *Stizostedion glaucum* | TREMATODES | | |
| Blue pike | *Centrovarium lobotes* | W 2 * | D |
| 10 (7) E; 10 (10) W. | *Bucephalus pusillus* | W 2 * | D |
| | | 2 ** | D |
| | CESTODES | | |
| | *Bothriocephalus cuspidatus* | E 5 * | D |
| | | W 4† 13 ** | D |
| | | 11 2 *** | D |
| | *Triaenophorus* n. sp. | W 1 * | D |
| | ‡*Proteocephalus ambloplitis* | W 1 * | D |
| | *Proteocephalus stizostethi* | E 6 * | D |
| | | 1 ** | D |
| | | W 2† 2 * | D |
| | | 5 5 ** | D |
| | NEMATODES | | |
| | *Philometra cylindracea* | W 1 * | C |
| | ACANTHOCEPHALA | | |
| | †*Leptorhynchoides* sp. | W 1 * | M |
| | COPEPODS | | |
| | *Ergasilus caeruleus* | W 2 * | G |
| | | 1 ** | G |
| ‡ Constitutes a new definitive host record. | PROTOZOA | | |
| | Lymphocystis | W 1 ** | E |
| 2 *Hadropterus maculatus* (Girard) | NEMATODES | | |
| Black-sided darter | *Camallanus oxycephalus* | W 1 * | D |
| 2 (1) W. | | | |

Summary of Parasitism in the Percidae.—Continued

| Hosts | Parasites | Number infected & degree | Location in host |
|---|---|---|---|
| 45 *Percina caprodes* (Agassiz) | TREMATODES | | |
| Log perch | *Diplostomum* sp. | E 1 * | M |
| 13 (9) E; 32 (20) W. | *Clinostomum marginatum* | W 1 * | F |
| | *Neascus* sp. | W 1 * | L |
| | *Leuceruthrus* sp. | W 1 * | D |
| | *Allocreadium boleosomi* | W 2 * | D |
| | *Tetracotyle* sp. | W 4 * | M |
| | CESTODES | | |
| | †*Bothriocephalus cuspidatus* | E 1 * | D |
| | *Proteocephalus pearsei* | W 1 * | D |
| | †*Proteocephalus stizostethi* | W 2 * | D |
| | NEMATODES | | |
| | *Camallanus oxycephalus* | W 8 * | D |
| | | 1 ** | D |
| | *Agamonema* sp. | W 3 * | 2M, 1D |
| | ACANTHOCEPHALA | | |
| | *Leptorhynchoides thecatus* | E 7 * | M & I |
| | | W 6† 6 * | 6 M |
| | | 1 1 ** | 1 D |
| | LEECHES | | |
| | *Piscicola punctata* | W 2 * | E |
| | PROTOZOA | | |
| | Myxosporidia | W 1 * | G |
| | | 2 ** | G |
| 34 *Rheocrypta copelandi* Jordan | TREMATODES | | |
| Copeland's darter | *Neascus* sp. | W 6 * | L & M |
| 34 (8) W. | *Lebouria cooperi* | W 3 * | D |
| | CESTODES | | |
| | *Bothriocephalus cuspidatus* | W 1 * | D |
| | NEMATODES | | |
| | *Camallanus oxycephalus* | W 1 * | M |
| 15 *Ammocrypta pellucida* (Baird) | TREMATODES | | |
| Sand darter | *Neascus* sp. | W 1 * | L |
| 15 (9) W. | *Tetracotyle* sp. | W 3 * | M |
| | *Lebouria cooperi* | W 1 * | D |
| | NEMATODES | | |
| | *Camallanus oxycephalus* | W 3 * | D |
| | *Agamonema* sp. | W 6 * | D |
| 23 *Boleosoma nigrum* (Raf.) | TREMATODES | | |
| Johnny darter | *Clinostomum marginatum* | E 1 * | F |
| 7 (2) E; 16 (13) W. | †*Leuceruthrus* sp. | W 1 * | D |
| | *Neascus vancleavei* | W 4 * | L |
| | | 3 ** | M |
| | *Neascus* sp. | E 1 ** | F |
| | CESTODES | | |
| | *Proteocephalus pearsei* | E 1 * | D |
| | NEMATODES | | |
| | *Agamonema* sp. | W 4 * | D |
| | | 2 ** | D |

Summary of Parasitism in the Percidae.—Continued

| *Hosts* | *Parasites* | *Number infected & degree* | *Location in host* |
|---|---|---|---|
| 7 *Poecilichthys exilis* (Girard) Iowa darter 7 (5) W. | TREMATODES | | |
| | *Allocreadium* sp. | W 1 * | D |
| | *Tetracotyle sp.* | W 1 * | M |
| | CESTODES | | |
| | †*Bothriocephalus cuspidatus* | W 1 * | D |
| | NEMATODES | | |
| | *Agamonema* sp. | W 5 * | 2 M 2 D |
| | ACANTHOCEPHALA | | |
| | *Leptorhynchoides thecatus* | W 1 * | D |
| 23 *Catonotus flabellaris* (Raf.) Fan-tailed darter 18 (10) E; 5 (1) W. | TREMATODES | | |
| | *Clinostomum marginatum* | E 1 * | F |
| | *Neascus* sp. | E 5 * | F |
| | | 1 ** | F |
| | | W 1 * | F |
| | *Tetracotyle communis* | E 3 * | P |
| 10 *Etheostoma blennoides* Raf. Green-sided darter 10 (3) W. | TREMATODES | | |
| | *Allocreadium* sp. | W 1 * | D |
| | *Tetracotyle* sp. | W 1 * | M |
| | NEMATODES | | |
| | *Camallanus oxycephalus* | W 1 * | D |
| | FUNGUS | | |
| | *Saprolegnia* sp. | W 1 ** | E |

One *Poecilichthys coeruleus* Storer, the rainbow darter, was examined from the eastern end of Lake Erie and was found to be negative, as were four least darters, *Microperca punctulata* Putnam, from the western end of the lake.

TABLE 17.

Summary of Parasitism in the Centrarchidae.

| *Hosts* | *Parasites* | *Number infected & degree* | *Location in host* |
|---|---|---|---|
| 57 *Micropterus dolomieu* Lacépède Small-mouthed black bass 28 (24) E; 29 (28) W. | TREMATODES | | |
| | *Crepidostomum cornutum* | E 4 * | D |
| | | 4 ** | D |
| | | 8 *** | D |
| | | W 10 * | D |
| | *Centrovarium lobotes* | E 1 ** | D |
| | | W 1 * | D |
| | *Leuceruthrus micropteri* | W 5 * | D |
| | *Cryptogonimus chyli* | E 1 ** | D |
| | | 2 *** | D |
| | | W 6 ** | D |
| | Gyrodactyloidea | W 1 ** | G |
| | CESTODES | | |
| | *Proteocephalus ambloplitis* | E 11 * | D |
| | | 2† ** | M, L S & R |
| | | W 7 * | D |
| | | 14† ** | L, |
| | †*Triaenophorus* sp. | W 1 * | L |
| | *Bothriocephalus claviceps* | W 1 * | D |
| | *Proteocephalus pearsei* | W 2 * | D |
| | *Proteocephalus fluviatilis* | W 1 * | D |

Summary of Parasitism in the Centrarchidae.—Continued

| *Hosts* | *Parasites* | *Number infected & degree* | *Location in host* |
|---|---|---|---|
| 57 *Micropterus dolomieu* Lacépède | NEMATODES | | |
| | *Spinitectus carolini* | E 9 * | D |
| | | W 3 * | D |
| continued | *Agamonema* sp. | E 2 * | D |
| | | 4 ** | D |
| | *Dichelyne cotylophora* | E 3 * | D |
| | *Camallanus oxycephalus* | W 2 * | D |
| | ACANTHOCEPHALA | | |
| | *Neoechinorhynchus cylindratus* | E 1 * | D |
| | *Leptorhynchoides thecatus* | E 9 * | D |
| | | 7 ** | D |
| | | 1 *** | D |
| | | W 5 * | 20 D |
| | | 11 ** | 1 M |
| | | 5 *** | |
| | COPEPODS | | |
| | *Ergasilus centrarchidarum* | E 4 * | G |
| | | 1 *** | G |
| | | W 2 * | G |
| | *Achtheres micropteri* | W 2 * | G |
| | *Achtheres ambloplitis* | E 1 * | G |
| | Lernaeidae | W 1 * | F |
| | PROTOZOA | | |
| | *Myxobolus* sp. | W 1 * | G |
| | *Ichthyophthirius multifiliis* | W 1 ** | E |
| | FUNGUS | | |
| | *Saprolegnia parasitica* | W 1 * | G & E |
| 64 young *M. dolomieu* 13 (7) E; 51 (48) W. | TREMATODES | | |
| | *Crepidostomum cornutum* | E 2 * | D |
| | | W 1 * | D |
| | *Cryptogonimus chyli* | W 4 * | D |
| | | 5 ** | D |
| | Gyrodactyloidea | W 2 * | G |
| | | 1 ** | G |
| | *Clinostomum marginatum* | W 1 * | F |
| | *Microphallus opacus* | W 1 * | D |
| | *Neochasmus umbellus* | W 2 * | D |
| | | 1 ** | D |
| | *Azygia angusticauda* | W 1 * | D |
| | *Bucephalus papillosus* | W 1 * | D |
| | CESTODES | | |
| | †*Proteocephalus ambloplitis* | E 4 * | L |
| | | 1 ** | M & R |
| | | W 20 * | L |
| | | 3 * | M & R |
| | *Proteocephalus pearsei* | W 12 * | D |
| | | 9 ** | D |
| | NEMATODES | | |
| | *Spinitectus carolini* | E 2 * | D |
| | | W 1 * | D |
| | *Camallanus oxycephalus* | W 8 * | D |
| | *Agamonema* sp. | W 3 * | D & M |
| | ACANTHOCEPHALA | | |
| | *Leptorhynchoides thecatus* | E 1 * | D |
| | | W 5† * | M |
| | *Neoechinorhynchus cylindratus* | W 1 * | D |
| | LEECHES | | |
| | *Piscicola punctata* | W 1 * | E. |

Summary of Parasitism in the Centrarchidae.—Continued

| *Hosts* | *Parasites* | *Number infected & degree* | *Location in host* |
|---|---|---|---|
| 27 *Aplites salmoides* (Lacépède) Large-mouthed black bass 3 (2) E; 24 (20) W. | TREMATODES | | |
| | *Crepidostomum cornutum* | E 1 * | D |
| | *Leuceruthrus micropteri* | W 4 * | D |
| | *Cryptogonimus chyli* | W 4 ** | D |
| | Gyrodactyloidea | W 3 ** | G |
| | CESTODES | | |
| | *Proteocephalus ambloplitis* | E 1 * | D |
| | | 1† ** | M & L |
| | | W 8 * | L, M, R, S |
| | | 2 ** | L, M, R, S |
| | *Proteocephalus pearsei* | W 3 * | D |
| | NEMATODES | | |
| | *Spinitectus carolini* | E 1 * | D |
| | *Contracaecum brachyurum* | W 1 * | D |
| | *Dioctophyme* sp. | W 1 * | C |
| | *Camallanus oxycephalus* | W 1 * | D |
| | *Dichelyne cotylophora* | W 1 * | D |
| | *Agamonema* sp. | W 1 * | S |
| | ACANTHOCEPHALA | | |
| | *Neoechinorhynchus cylindratus* | E 1 * | D |
| | | W 5 * | D |
| | | 8 ** | D |
| | *Leptorhynchoides thecatus* | W 2 * | D |
| | | 2 ** | D |
| | COPEPODS | | |
| | *Ergasilus centrarchidarum* | E 1 * | G |
| | | W 2 ** | G |
| | *Achtheres micropteri* | W 2 * | G |
| | PROTOZOA | | |
| | *Myxobolus* sp. | W 1 * | G |
| 105 young *A. salmoides* 105 (87) W. | TREMATODES | | |
| | *Leuceruthrus micropteri* | W 18 * | D |
| | *Cryptogonimus chyli* | W 6 * | D |
| | | 4 ** | D |
| | *Neascus vancleavei* | W 4 * | L |
| | Gyrodactyloidea | W 4 * | G |
| | | 6 ** | G |
| | CESTODES | | |
| | *Proteocephalus pearsei* | W 6 * | D |
| | *Proteocephalus ambloplitis* | W 24 * | 5D |
| | | 12 ** | L, M |
| | | 1 *** | |
| | NEMATODES | | |
| | *Dioctophyme* sp. | W 1 * | C |
| | *Camallanus oxycephalus* | W 2 * | D |
| | *Agamonema* sp. | W 1 * | L |
| | ACANTHOCEPHALA | | |
| | *Leptorhynchoides thecatus* | W 10 * | 5 D |
| | | 1 ** | 6 M |
| | *Neoechinorhynchus cylindratus* | W 7 * | D |
| | COPEPODS | | |
| | *Ergasilus centrarchidarum* | W 6 * | G |
| | *Achtheres micropteri* | W 1 * | G |
| | PROTOZOA | | |
| | Myxosporidia | W 4 * | G |
| | | 14 ** | G |
| | | 7 *** | G |
| | *Cyclochaeta domerguei* | W 1 ** | E |
| | Vorticellidae | W 2 *** | E |

Summary of Parasitism in the Centdarchidae.—Continued

| *Hosts* | *Parasites* | *Number infected & degree* | *Location in host* |
|---|---|---|---|
| 105 young *A. salmoides* continued | LEECHES | | |
| | *Placobdella montifera* | W 1 * | E |
| | FUNGUS | | |
| | *Saprolegnia* sp. | W 1 * | E |
| 10 *Helioperca incisor* (Cuvier & Valenciennes) | TREMATODES | | |
| | Gyrodactyloidea | W 1 * | G |
| | | 2 ** | G |
| Blue gill | *Clinostomum marginatum* | W 1 * | F |
| 10 (8) W. | *Tetracotyle* sp. | W 1 * | P |
| | *Neascus vancleavei* | W 1 * | L |
| | | 2 ** | L |
| | *Crassiphiala ambloplitis* | W 1 * | F |
| | CESTODES | | |
| | *Proteocephalus pearsei* | W 1 * | D |
| | *Proteocephalus ambloplitis* | W 2† * | L & D |
| | NEMATODES | | |
| | *Camallanus oxycephalus* | W 1 * | D |
| | *Dichelyne cotylophora* | W 1 * | D |
| | *Rhabdochona* sp. | W 1 * | D |
| | ACANTHOCEPHALA | | |
| | *Leptorhynchoides thecatus* | W 3 * | 3 M 1 D |
| | COPEPODS | | |
| | *Ergasilus centrarchidarum* | W 1 * | G |
| | LEECHES | | |
| | *Piscicola punctata* | W 2 * | E |
| | MOLLUSCA | | |
| | Glochidia | W 1 ** | G |
| 41 *Eupomotis gibbosus* (Linn.) | TREMATODES | | |
| | *Allocreadium* sp. | E 4 * | D |
| Pumpkinseed | *Crassiphiala ambloplitis* | E 3 *** | F |
| 18 (12) E; 23 (19) W. | *Neascus vancleavei* | E 2 * | L & M |
| | | W 5 * | L |
| | | 2 ** | L |
| | *Clinostomum marginatum* | W 1 * | F |
| | Unidentified | W 2 * | D |
| | CESTODES | | |
| | †*Bothriocephalus* sp. | E 1 ** | D |
| | †*Proteocephalus ambloplitis* | E 4 * | L & M |
| | | W 6 * | L & M |
| | NEMATODES | | |
| | *Spinitectus carolini* | E 4 * | D |
| | | W 1 * | D |
| | *Agamonema* sp. | E 3 * | D |
| | | W 1 * | D |
| | *Camallanus oxycephalus* | W 1 * | D |
| | ACANTHOCEPHALA | | |
| | *Leptorhynchoides thecatus* | E 1 * | D |
| | | W 3† * | 2 M 1 D |
| | PROTOZOA | | |
| | Myxosporidia | W 3 *** | G |
| | LEECHES | | |
| | *Piscicola punctata* | W 1 * | E |

Summary of Parasitism in the Centrarchidae.—Continued

| *Hosts* | *Parasites* | *Number infected & degree* | *Location in host* |
|---|---|---|---|
| 40 *Ambloplites rupestris* (Raf.) Rock bass 28 (21) E; 12 (11) W. | TREMATODES | | |
| | *Leuceruthrus micropteri* | E 6 * | D |
| | *Cryptogonimus chyli* | E 3 * | D |
| | | W 4 * | D |
| | | 1 ** | D |
| | *Crassiphiala ambloplitis* | E 7 *** | F |
| | | W 2 ** | F |
| | *Crepidostomum cornutum* | W 2 * | D |
| | *Clinostomum marginatum* | W 1 * | F |
| | *Neascus vancleavei* | W 2 * | M |
| | CESTODES | | |
| | *Proteocephalus pearsei* | E 2 * | D |
| | *Proteocephalus ambloplitis* | E 1† * | L |
| | | 1† ** | M |
| | | W 2 * | D |
| | *Bothriocephalus claviceps* | W 1 * | D |
| | NEMATODES | | |
| | *Spinitectus carolini* | E 5 * | D |
| | | W 4 * | D |
| | *Contracaecum* sp. | W 1 * | D |
| | *Camallanus oxycephalus* | W 2 * | D |
| | *Agamonema* sp. | W 1 * | D |
| | *Rhabdochona* sp. | W 1 * | D |
| | ACANTHOCEPHALA | | |
| | *Leptorhynchoides thecatus* | E 3 * | D |
| | | W 5† * | 3 M 2 D |
| 15 young *A. rupestris* examined from eastern end of Lake Erie were negative. | COPEPODS | | |
| | *Ergasilus centrarchidarum* | E 2 * | G |
| | | W 1 ** | G |
| | *Achtheres ambloplitis* | W 4 * | G |
| 25 *Pomoxis annularis* Raf. White crappie 8 (1) E; 17 (8) W. | NEMATODES | | |
| | *Spinitectus gracilis* | E 1 * | D |
| | *Camallanus oycephalus* | W 4 * | D |
| | *Agamonema* sp. | W 2 * | D |
| | ACANTHOCEPHALA | | |
| | *Leptorhynchoides thecatus* | W 5 * | D |
| | PROTOZOA | | |
| | Myxosporidia | W 1 ** | G |
| 9 *Pomoxis sparoides* (Lacépède) Calico bass 9 (4) W. | TREMATODES | | |
| | *Neascus vancleavei* | W 1 * | M |
| | NEMATODES | | |
| | *Camallanus oxycephalus* | W 1 * | D |
| | ACANTHOCEPHALA | | |
| | *Leptorhynchoides thecatus* | W 1 * | M |
| | MOLLUSCA | | |
| | Glochidia | W 1 * | G |
| 1 *Xenotis megalotis* (Raf.) Long-eared sunfish 1 (1) W. | TREMATODES | | |
| | *Neascus vancleavei* | W 1 * | L |

One *Apomotis cyanellus* from the western end was negative.

TABLE 18.

Summary of Parasitism in the Atherinidae.

| *Hosts* | *Parasites* | *Number infected & degree* | *Location in host* |
|---|---|---|---|
| 45 *Labidesthes sicculus* (Cope) Brook silversides 15 (0) E; 30 (10) W. | TREMATODES | | |
| | *Neascus* sp. | W 2 * | L |
| | †*Allacanthochasmus varius* | W 1 * | M |
| | †*Allocreadium* sp. (1213) | W 1 * | D |
| | CESTODES | | |
| | †*Bothriocephalus* sp. | W 1 * | D |
| | †*Proteocephalus ambloplitis* | W 1 * | L & M |
| | NEMATODES | | |
| | *Agamonema* sp. | W 2 * | M |
| | | 2 * | D |
| | *Camallanus oxycephalus* | W 1 * | D |
| | | 1 †* | D |

TABLE 19.

Summary of Parasitism in the Sciaenidae.

| *Hosts* | *Parasites* | *Number infected & degree* | *Location in host* |
|---|---|---|---|
| 48 *Aplodinotus grunniens* Raf. Sheepshead 3 (3) E; 45 (41) W. ‡ Lost. Identified to genus only. | TREMATODES | | |
| | *Anallocreadium armatum* | E 1 * | D |
| | *Anallocreadium pearsei* | W 8 * | D |
| | | 2 ** | D |
| | *Crepidostomum* sp. ‡ | W 1 * | D |
| | *Microcotyle spinicirrus* | W 5 * | D |
| | *Microcotyle eriensis* | W 5 * | D |
| | *Neascus* sp. | W 9 * | M |
| | | 5 ** | M |
| | *Tetracotyle* sp. | W 1 * | M |
| | CESTODES | | |
| | *Bothriocephalus claviceps* | E 2 * | D |
| | †*Bothriocephalus cuspidatus* | W 5 * | D |
| | †*Proteocephalus pearsei* | W 2 * | D |
| | NEMATODES | | |
| | *Camallanus oxycephalus* | W 10 †* | 1 C |
| | | 8 * | 18 D |
| | *Dichelyne cotylophora* | E 1 * | D |
| | | W 2 * | D |
| | *Spinitectus gracilis* | W 1 * | D |
| | *Philometra cylindracea* | W 6 * | D |
| | *Agamonema* sp. | W 5 * | 3 M |
| | | | 2 D |
| | ACANTHOCEPHALA | | |
| | *Leptorhynchoides thecatus* | W 1 * | D |
| | PROTOZOA | | |
| | Myxosporidia | W 2 ** | G |
| | LEECHES | | |
| | *Piscicola punctata* | W 2 * | E |
| | MOLLUSCA | | |
| | Glochidia | W 8 * | G |
| | | 7 ** | G |
| | | 1 *** | G |

TABLE 20.
Summary of Parasitism in the Cottidae.

| *Hosts* | *Parasites* | *Number infected & degree* | *Location in host* |
|---|---|---|---|
| 7 *Cottus bairdii* Girard | CESTODES | | |
| Miller's thumb | †*Proteocephalus ambloplitis* | W 1 * | L |
| 7 (2) W. | †*Proteocephalus* sp. | W 1 * | D |

TABLE 21.
Summary of Parasitism in the Gasterosteidae.

| *Hosts* | *Parasites* | *Number infected & degree* | *Location in host* |
|---|---|---|---|
| 22 *Eucalia inconstans* | TREMATODES | | |
| (Kirtland) | *Bunoderina eucaliae* | E 1 * | D |
| Brook stickleback | CESTODES | | |
| 20 (3) E; 2 (1) W | †*Proteocephalus* sp. | W 1 * | D |
| | NEMATODES | | |
| | *Agamonema* sp. | E 2 * | D |

TABLE 22.
Summary of Parasitism in the Gadidae.

| *Hosts* | *Parasites* | *Number infected & degree* | *Location in host* |
|---|---|---|---|
| 10 *Lota maculosa* | CESTODES | | |
| (Le Sueur) | *Abothrium crassum* | E 1 * | D |
| Burbot, ling | | 1 ** | D |
| 3 (3) E; 7 (7) W. | | 1 *** | D |
| | | W 2 * | 7 D |
| | | 5 ** | 5 I |
| | NEMATODES | | |
| | *Haplonema hamulatum* | E 1 * | D |
| | | 1 ** | D |
| | ACANTHOCEPHALA | | |
| | *Echinorhynchus coregoni* | E 2 * | D |
| | | 1 ** | D |
| | LEECHES | | |
| | *Piscicola punctata* | W 3 * | E |

Trematodes and Acanthocephala were recovered from two hosts at the western end, but the material was lost prior to identification.

# 28.

# Young *Megalops cyprinoides* from Batavia, Dutch East India, Including a Study of the Caudal Skeleton and a Comparison with the Atlantic Species, *Tarpon atlanticus*.[1]

GLORIA HOLLISTER

(Text-figures 1-21).

## OUTLINE.


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## INTRODUCTION.

Dr. C. Holstvoogd of the Laboratorium Voor Het Onderzoek Der Zee, Batavia, Dutch East India, in a letter dated September 28, 1937, urgently requested specimens of *Albula vulpes* in order to complete his study on the kidneys of teleost fishes. The substance of this letter reads: "To check and complete the results of my investigations on the kidneys of the teleosts, I should very much like to have at my disposal some material of *Albula*. I have written to three Zoological stations in the United States and to one in Mexico, but in vain. In each case I was informed that the material required by me was not present and was not to be caught either, or only with too much trouble and expense. As regards the publication 'Caudal Skeleton of Bermuda Shallow Water Fishes' in Zoologica, Vol. XXI, part 4, I apply to you with more hope. Only 4 specimens would be sufficient. In my turn I am able to place at your disposal material of *Megalops* which is rather rare in the neighbourhood of Bermuda as I read in the above mentioned publication. If you agree to it I shall publish my results in Treubia together with those about the kidneys of *Elops* and *Megalops*, but if you insist upon it I'm also willing to publish the part which specially deals with *Albula* in Zoologica."

Consequently five specimens of *Albula vulpes*, collected in Bermuda at the field station, Nonsuch, were sent to Dr. Holstvoogd. Four of these were in the leptocephalus stage and ranged from 26 mm. to 40 mm. One specimen was a young fish of 55 mm. in length.

[1] Contribution No 586, Department of Tropical Research, New York Zoological Society Contribution from the Bermuda Biological Station for Research, Inc.

On March 22, 1939, a small package arrived from Dr. Holstvoogd, Batavia, and contained 45 specimens of young *Megalops cyprinoides*. The oldest, which is 34 mm. in length, is a miniature of its parent. The youngest, in the leptocephalus form, is 21 mm. long. On October 13, 1939, five more specimens in leptocephalus stage were received from Dr. Holstvoogd which he writes are "the youngest and consequently longest I have seen to date." These fish measure 22 mm. to 24 mm. and were preserved in Bouin's fluid and then Cedar Oil. This forms a most complete series of young *Megalops* and shows the changes which occur when the young stage becomes compact and shrinks while developing into a small fish. We are very much indebted to Dr. Holstvoogd for these valuable specimens.

We have been fortunate in observing this same transformation in a *living* isospondylid. After catching a leptocephalus *Albula vulpes* off the wharf at Nonsuch, Bermuda, we reared it for ten days. It was 55 mm. in length on the night of capture and during the ten days it shrank to 20 mm. in length and came to resemble the adult in form.[2]

The length of specimens in this paper is standard length unless otherwise stated.

For caudal fin terminology, key to caudal fin of Bermuda shallow water Isospondyli including *Tarpon*, complete caudal bibliography, and method of preparing cleared specimens for this study, refer to Part I of Caudal Skeleton of Bermuda Fishes, Hollister, 1936.2.

We take this opportunity to thank staff members of the United States National Museum for putting at our disposal the collection of *Megalops cyprinoides*, the loan of two *Megalops cyprinoides* and one *Tarpon atlanticus*. We are indebted to Dr. C. M. Breder, Jr. for 4 small *Tarpon* caught August, 1939, at Sanibel Island, Florida. These specimens came to the New York Aquarium with forty-odd others for exhibition. The cooperation of Dr. William Beebe, Director of this department, and Mr. John Tee-Van, General Associate, is gratefully acknowledged.

All the drawings are by Miss Harriet Bennett, with the exception of two (Text-figs. 2, 21), which are by Mr. George Swanson.

## Taxonomic Discussion.

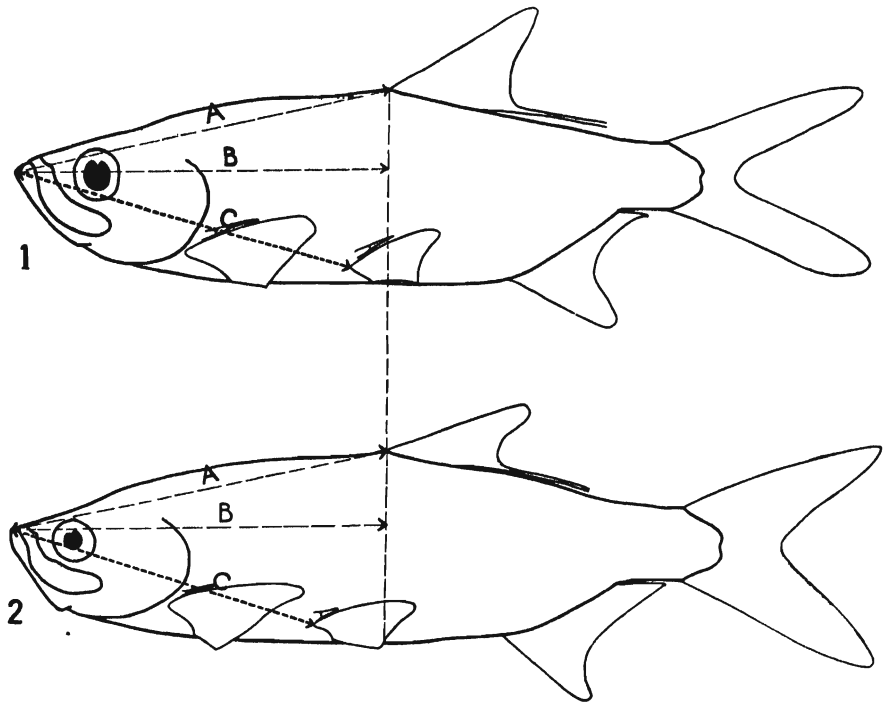
(Text-fig. 1).

Tate Regan in "A revision of the fishes of the genus *Elops*"[3] bases this revision principally on vertebral counts. It is also notable that the species with different counts live in different geographical areas. But Regan did not consider these characters and other differences sufficient to establish a new genus for any of the species of *Elops*.

*Megalops cyprinoides* is the type of its genus and the Pacific and Indian Ocean species. A closely related form lives in the Atlantic and was first described as *Megalops atlanticus*.[4] This latter form was later renamed *Tarpon* by Jordan & Evermann.[5] Their reason for this was: "The posterior insertion of the dorsal fin distinguishes the single species of *Tarpon* from the East Indian *Megalops cyprinoides*, a fish of similar habit, in which the dorsal is inserted above the ventrals."

This particular character is not a valid one. A comparative study has been made of nine *Megalops cyprinoides* which range in size from 20 mm. to 300 mm., together with twenty-seven specimens in the collection of the United States National Museum at Washington. These have been compared with ten *Tarpon atlanticus* ranging from 51 to 238 mm. It is apparent that the dorsal fin is in the same position in the two species, that is, in the

[2] Hollister, 1936.1.
[3] Regan, 1909.
[4] Cuvier & Valenciennes, 1846.
[5] Jordan & Evermann, 1896.




Text-figure 1.

In outline 1, of *Megalops cyprinoides*, the distance represented by line **C** is longer than the distance represented by line **C** in outline 2 of *Tarpon atlanticus*. The position of the ventrals is farther from the tip of the snout in *Megalops* than in *Tarpon*. Lines **A** and lines **B** are equal in *Megalops* and *Tarpon*, showing that the position of the dorsal fins is identical in the two species.

same relative distance from the snout. But the ventral fins in *Tarpon* are nearer the snout than in *Megalops*, giving the illusion of the dorsal being more posterior in position in *Tarpon* than in *Megalops*. According to actual measurements, Jordan & Evermann's character for describing a new genus must have been based on appearance instead of measurements (Text-fig. 1).

As in the case of *Elops*, there are other differences in addition to the position of the ventral fins. These include considerable variation in the vertebral counts of the Atlantic and Pacific species, *Tarpon* having 57 and *Megalops* 68. Some other differences are: dorsal fin counts, *Tarpon* having 12 to 15 rays and *Megalops* 19 to 21; anal fin counts, *Tarpon* having 19 to 22 rays and *Megalops* 24 to 27. Caudal skeleton variations are shown in the key and the text. In general appearance *Tarpon* is more slender than *Megalops* and the eye of *Tarpon* is not as large as the eye of *Megalops*. Regan (1910) found a difference in the dorsal caudal rays of the two species.

In view of these differences and of the disconnected geographical ranges, the two forms should be kept apart in their respective genera.

The word *Tarpon* is probably of American Indian origin with its exact meaning still uncertain. It occurs in early descriptions of travels in Florida by Captain William Dampier in his "Second Voyage to the Bay of Campeche," 1675, and published in Masefield's Edition of his works. In the West Indies and in South America this splendid fish has many other popular and native names.

YOUNG *Megalops* AND YOUNG *Tarpon*.

(Text-figs. 2 & 3).

An excellent start has been made by Dr. Charles Breder[6], of the Society's New York Aquarium, at the recently established field station on Palmetto Key on the west coast of Florida. Here important initial and tedious work is being carried on systematically, that of tagging *Tarpon* in order to try to solve the fascinating mystery of their spawning habits.

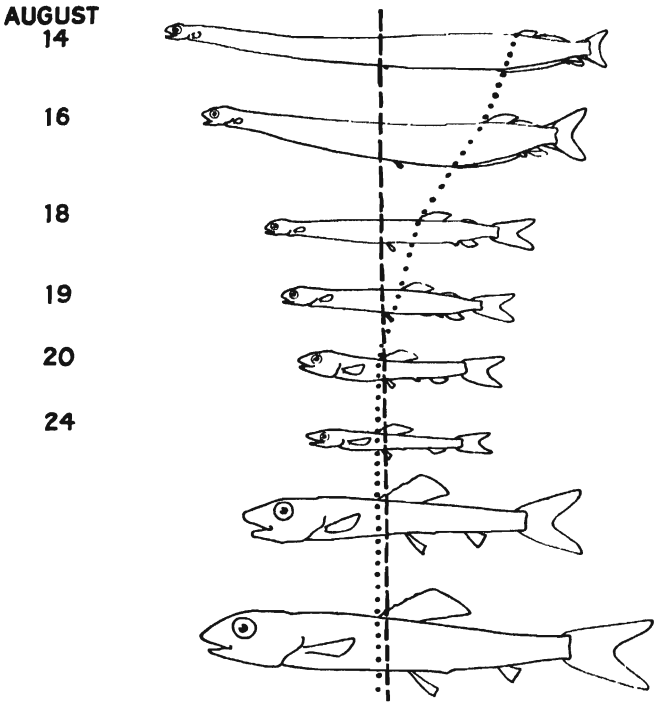
There has been considerable conjecture concerning where the eggs are deposited, whether or not they float or sink, whether the larvae live on the surface and where they exist until they grow to be about three inches long. According to numerous reports, many three-inch *Tarpon* can be found[6]. But only twice, previous to Dr. Breder's recent catch[7], have *Tarpon* been reported which are smaller than three inches.[8] One specimen has no description and cannot be located[9]. The other small specimen is described by Dr. Hildebrand[10], Ichthyologist of the U. S. Bureau of Fisheries, who has shown that the American *Tarpon* presumably passes through a leptocephalus stage. This small *Tarpon* of 20 mm. in length was in the transitional post-larval stage and compares approximately to Text-fig. 7, on page 457, of *Megalops cyprinoides*.

Economic necessity of the coastal people has brought to ichthyologists of Batavia, Java, knowledge of the young *Megalops*. Here larvae have been had in numbers ever since Kampen[11] first recognized the leptocephalus stage in 1908. In the month of January, fish larvae appear in the brackish water of the harbor canals of Batavia. The total length of the larvae collected varies from 23 to 30 mm. and all appear to be in the same stage of development. Kampen stated that older stages have not yet been found, and the development of the larvae is unknown. Later Dr. Holstvoogd[12] tells of the young appearing on the coast near Tegal, 400 kilometers from Batavia, and standing the journey to Batavia by train and being raised in aquaria and gradually being moved into fresh water. They were reared on mosquito larvae and fresh water copepods. Their length when appearing on the coast averages a little more than 23 mm. Dr. Holstvoogd states that "in the case of our breeding experiment this took seven weeks. During this time the young *Megalops* shrink from 23 to 17 mm. and then grow to about 24 mm."

Near relatives of *Megalops* and *Tarpon*, such as *Albula* and *Elops*, are known to pass through a leptocephalus metamorphosis and they are also known to be oviparous. From all evidence it is now almost certain that our Atlantic *Tarpon* is comparable in its early metamorphosis with the Pacific species, *Megalops cyprinoides*. (These facts should certainly dismiss the idea of *Tarpon* being viviparous according to observations of an experienced *Tarpon* fisherman, the short account of which is published on page 54 in the *Bulletin* of the New York Zoological Society, Vol. XXXI, No. 2, March-April, 1928).

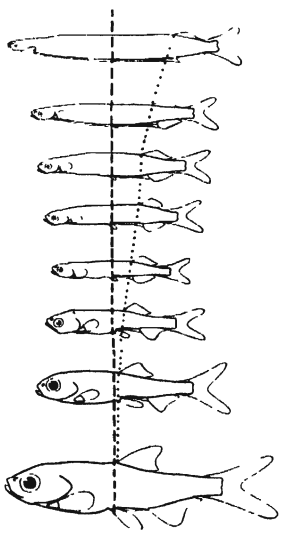
The observation of the growth of our *Albula vulpes* leptocephalus gives us some clue to the rapidity of this transformation. In ten days this leptocephalus shrank from 55 mm. to 20 mm., when it resembled the adult (Text-fig. 2). Dr. Holstvoogd does not mention the exact time it took his leptocephalus *Megalops* to go through the shrinking phase but in our *Albula* this was very rapid. But he does state that the complete change took seven weeks for *Megalops* to shrink from 23 mm. to 17 mm. and then grow to 24 mm. It is conspicuous that the larvae of *Megalops* are not as long as those of *Albula* in the same stage of development (Text-fig. 3).

[6] Breder, 1939.1.
[7] Breder, 1939.2.
[8] See Sections IV and V in Bibliography.
[9] Eigenmann, 1904.
[10] Hildebrand, 1934.
[11] Kampen, 1909.
[12] Holstvoogd, 1936.




Text-figure 2.

*Albula vulpes.* This series is reproduced to show the development from the leptocephalus stage to the young fish which is comparable with *Megalops.* During ten days the 55 mm. leptocephalus *Albula,* shown at the top, shrank to 20 mm., when it resembled the adult. The observation of the transformation in a living isospondylid gives a clue to the rapidity of this change. (Natural size).



Text-figure 3.

*Megalops cyprinoides.* This series shows the development from the leptocephalus stage to the young fish. The leptocephalid *Megalops* at the top is from Kampen and 26.5 mm. long. As in *Albula,* the length diminishes during the transformation and the posterior position of the dorsal changes to a forward position at the mid-length on the dorsal surface. The larvae of *Megalops* are not as long as the larvae of *Albula* in the same stage of development. (Natural size).

Fish having the demersal type of eggs, or possessing some form of parental care, usually produce a much smaller number of eggs. It is also known that fish having the pelagic type of eggs produce the highest number. *Elops* is a good example, with an estimated number of about five million eggs and Cod have been estimated to have a maximum number of nine million eggs.

In regard to *Tarpon* eggs, Dr. John Nichols estimated the number and size of the eggs in a 142-pound Tarpon[13] at twelve million. The eggs were non-adhesive, unripe and exceedingly small. Dr. Nichols found that they ranged from 0.6 to 0.75 mm. in diameter. Recently, Dr. Breder[14] published a photograph of an egg, which "may be that of a *Tarpon*," and measured "not quite 2 mm. in diameter." The eggs from the 142-pound *Tarpon* were unripe and preserved whereas the egg of Dr. Breder was fresh and alive. It was also non-adhesive and found on the bottom. Mr. Babcock discovered through repeated experiments that *Tarpon* eggs sink and he also tells of a reliable and experienced fisherman who reports that he has seen *Tarpon* spawning in white sand holes along the shoals.

The habit of *Tarpon* of breaking the surface of the water and its ability to acquire air this way no doubt accounts for the fact that *Tarpon* can exist for long periods of time in pools of stagnant and foul water. The handsome *Tarpon* living in the New York Aquarium can be seen breaking the surface for air. Leptocephalus *Megalops cyprinoides* regularly rise to the surface for air according to Beaufort[15] and also Delsman & Hardenberg[16]. In *Megalops* larvae the air bladder is well developed in the youngest larvae, which are caught on the surface as they work their way in toward fresh water. According to literature and also experiments at Nonsuch, our field station in Bermuda[17], a number of species can adapt to salt or fresh water and during the life development of certain species this change is vital. The smallest recorded *Tarpon* have been found away from the sea[18].

## Description and Figures of *Megalops cyprinoides*, Including a Comparison with *Tarpon atlanticus*.

(Text-figs. 4-13).

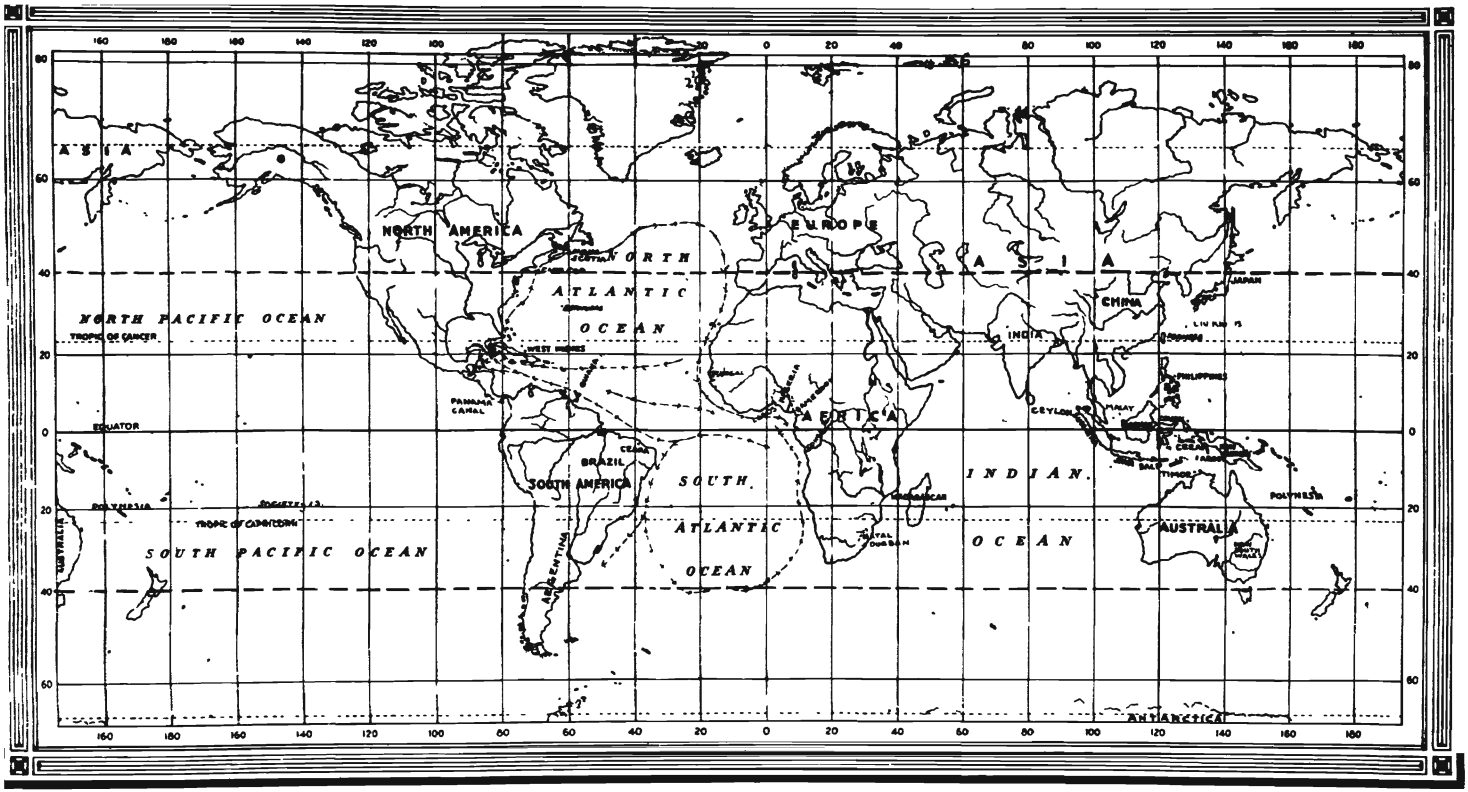
### *Range.*

The map shows that *Megalops* and *Tarpon* are circumtropical with world-wide distribution (Text-fig. 4). References indicate that the northern and southern range is roughly between 40° north latitude and 40° south latitude.

A geographical section of the bibliography was not arranged for *Megalops* because the habitats of this species are well established. References included in the annotated bibliography show that *Megalops* is found from about the region of the island of Formosa, south along the coast of China, around the islands of the East Indies and Polynesia and along the coast of Australia as far south as New South Wales. *Megalops* is recorded off the coast of India and the islands of the Indian Ocean, and also along the east coast of Africa as far south as Durban. The reported eastern range is the Society Islands in the Pacific.

We are finding that *Tarpon* has a more extensive range than has been generally recognized in American literature and because of this the repeated statement of "Cape Cod to Brazil" should be revised. The northernmost record, Nova Scotia, is considered rare and the specimen a straggler. In

[13] Nichols, 1929.
[14] Breder, 1939.2.
[15] Beaufort, 1909.
[16] Delsman and Hardenberg, 1934.
[17] Hollister, 1934.
[18] See Section IV and V in Bibliography.




## Text-figure 4.

References indicate that *Megalops* and *Tarpon* are circumtropical with world-wide distribution and that the northern and southern range is approximately between 40° north latitude and 40° south latitude, which is shown by the heavy dashed lines. For *Tarpon* the extreme locations are shown as Nova Scotia, Cape Cod, Bermuda, the Pacific side of the Panama Canal and the west coast of Africa. The Gulf Stream, Equatorial and Connecting Currents are indicated by the arrows. For *Megalops* the southernmost reference is Natal, Africa, and New South Wales, Australia and the most eastern the Society Island.

addition to the many records of *Tarpon* along the Atlantic and Gulf coasts, the West Indies and miles up rivers, there is now definite proof that *Tarpon* have reached the Pacific side of the Panama Canal. Also, *Tarpon* are known to inhabit the eastern Atlantic off the west coast of Africa. References have been found for *Tarpon* at Senegal and south to the Congo River. It is reported that many large *Tarpon* are in Lagos Harbour, Nigeria.

The extent of the Gulf Stream, the Equatorial and Connecting Currents, is indicated on the map (Text-fig. 4).

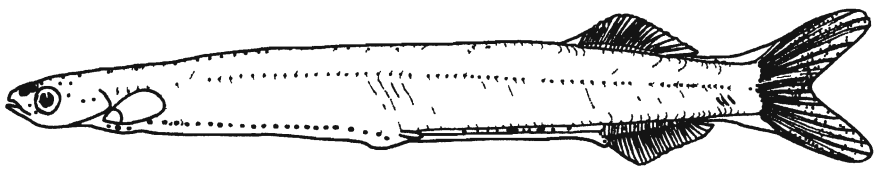
### *Material Studied.*

*Megalops cyprinoides:* 50 young specimens, 24 mm. larva to 34 mm. fish, Batavia, Java, Cat. No. 28,900 and 28,903 (Text-figs. 5-8). 1 specimen, 56 mm., Philippine Isls., U. S. Nat. Mus. No. 51,970. 1 specimen, 300 mm., Queensland, Australia, U. S. Nat. Mus. No. 47,800 (Text-fig. 9). In addition, 22 specimens in the collection of the United States National Museum were examined for the position of the fins and the prolonged posterior dorsal ray.

*Tarpon atlanticus:* 4 specimens, 51, 55, 58 and 59 mm., Sanibel Island, Florida, Cat. No. 28,902. 1 specimen, 78 mm., Source Matelas, Haiti, Cat. No. 7,303 (Text-fig. 10). 3 specimens, 115, 140, 150 mm., Source Matelas, Haiti, Cat. No. 7,303. 1 specimen, 238 mm., West Indies, U. S. Nat. Mus. No. 33,347 (Text-fig. 11).

### *Megalops cyprinoides.*

Four distinct stages in the transition from the leptocephalus form to a small fish resembling the adult have been selected to illustrate the metamorphosis in *Megalops cyprinoides* (Broussonet).

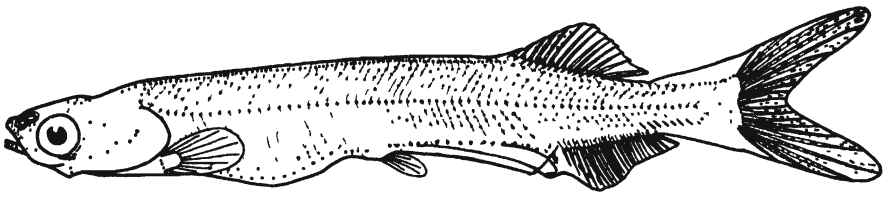


Text-figure 5.

*Megalops cyprinoides.* This 21 mm. leptocephalus is flat, band-like and almost transparent. The dorsal is posterior in position and the ventrals very small. (× 4.7).

The 21 mm. specimen is flat, band-like and almost transparent. Definite pigmentation occurs only along the mid-line of the body, with one dark spot on every myomere, and between the pectorals and ventrals. The other scattered pigment spots are shown accurately in Text-fig. 5. There is a total of 67 myomeres, 45 from the head to the anterior of the dorsal fin and 27 from the head to the ventral fins. The rays of the paired fins cannot be distinguished and those of the median fins are visible but delicate. The pectorals are large and flap-like. The ventrals are very small and approximately midway between the snout and caudal. The dorsal fin is posterior in position and immediately anterior to the caudal peduncle. The intestine is visible between the ventral and the anal fins.

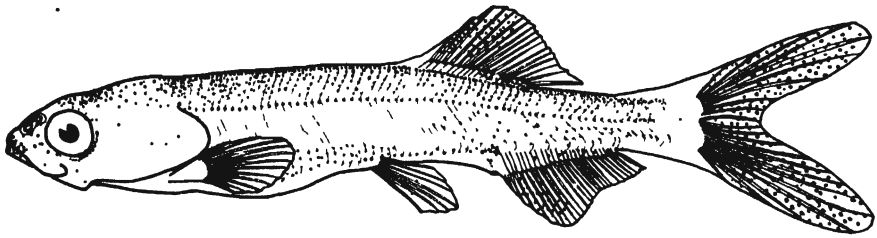
The 15 mm. specimen is the shortest transitional larva among our specimens. It is fairly flat but less band-like than the 21 mm. specimen and not as transparent. Definite pigmentation is along the mid-line as in the 21 mm. specimen. There is more pigmentation in this specimen with a noticeable increase along the dorsal side between the head and the dorsal fin. There is



Text-figure 6.

*Megalops cyprinoides.* This 15 mm. specimen is the shortest larva in our series and transitional in development. (× 6.3).

also a general increase all over the body as illustrated in the accurate Text-fig. 6. There is a total of 65 myomeres; 40 from the head to the anterior of the dorsal fin and 23 from the head to the ventrals. There is a noticeable decrease, as compared with the 21 mm. specimen, in the number of the myomeres and the length of the body in these two regions. The rays of the paired fins are visible but delicate and those of the median fins are more definite than in the 21 mm. specimen. The pectorals are proportionately larger than in the 21 mm. specimen. The ventrals have greatly increased in size and are in the same position as in the 21 mm. fish. The dorsal fin is more anterior than in the 21 mm. fish and the caudal peduncle more elongated. The intestine is still visible between the ventral and the anal fins.

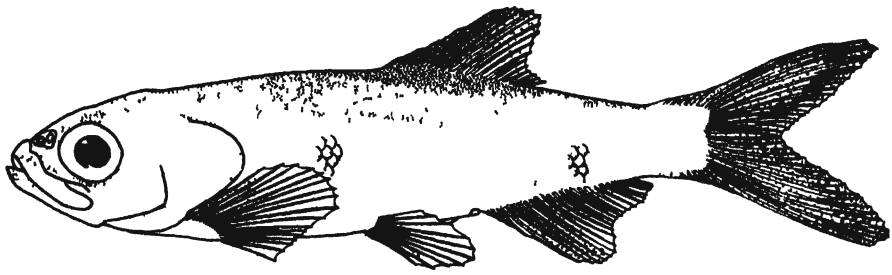


Text-figure 7.

*Megalops cyprinoides.* This 16.5 mm. specimen is post leptocephalus in development but has some characters of the younger stage. (× 5.5).

The 16.5 mm. specimen is post-leptocephalus in development and the body has lost the flat, band-like appearance of the younger and longer specimens. But this stage possesses characters of the larval and older fish. The pigmentation along the mid-line is still conspicuous and there is a general increase over all of the body and the fins which is shown in the accurate Text-fig. 7. There is a total of 65 myomeres; 33 from the head to the anterior of the dorsal fin and 22 from the head to the ventrals. This count shows a continued decrease in number to the dorsal fin but less to the ventrals. The rays of the paired fins are definite and the fins are proportionately larger than in the 15 mm. specimen. The ventrals remain in the center position of the body. The median fins show considerable growth. The dorsal is more anterior in position than in the 15 mm. specimen and the distance is shorter between the pectorals and the anterior margin of the dorsal fin. The intestine is not visible.

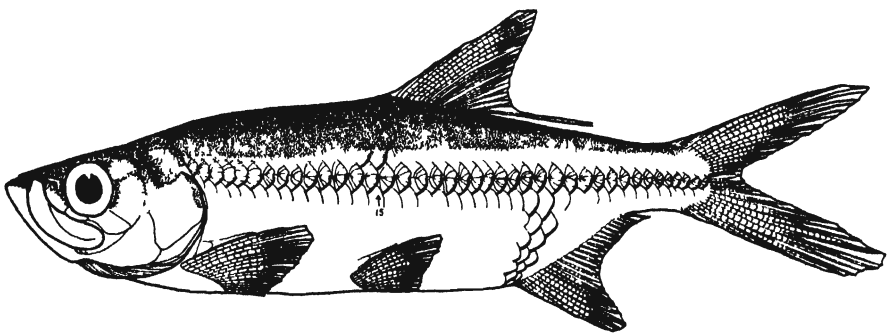
The 28 mm. fish resembles the adult in appearance and shape. The mid-line pigment spots are absent but there is dense pigmentation above the lateral line which is also present in the 300 mm. specimen. The accurate Text-fig. 8 of the 28 mm. fish shows the pigment over the whole body. Scales are present which are very thin and absorb no bone stain. In a larger



Text-figure 8.

*Megalops cyprinoides.* This 28 mm. specimen resembles in general the adult in appearance and shape. Delicate scales are present which absorb no bone stain (× 3.2).

specimen of 34 mm. the scales take a light stain. Myomeres cannot be counted but the distance between the head and the anterior of the dorsal is relatively shorter than in the 16.5 mm. fish. This is also true of the distance between the ventrals and the anal fins. The paired fins are proportionately larger than those of the 16.5 mm. specimen. The ventrals are in a central position. The median fins have also increased proportionately. The dorsal fin is more anterior in position than in the 16.5 mm. fish and, in cleared specimens, the anterior margin of the dorsal is almost directly opposite the base of the ventral fins. This is true in our 26 mm. cleared specimen and of all specimens larger and older.

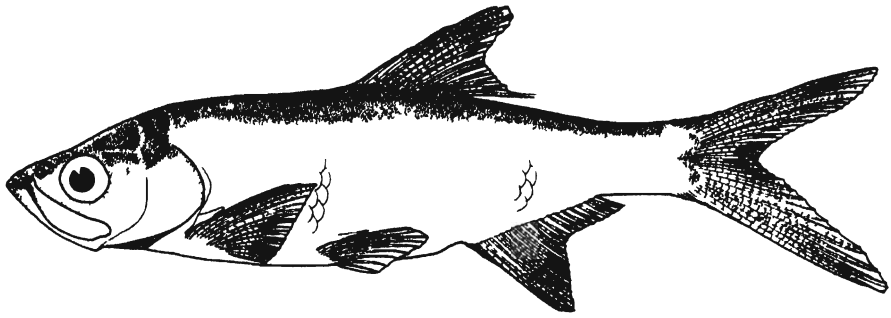


Text-figure 9.

*Megalops cyprinoides.* The 300 mm. specimen represents the adult form including secondary growth characters as the prolonged dorsal ray, axillary scales and well developed body scales. The marked 15th scale of the lateral line is enlarged in Text-figure 12. (× 1/3).

The 300 mm. *Megalops* has more pigmentation than smaller specimens as shown in Text-fig. 9. The scales are well developed and take a deep stain for bone. The 15th scale of the lateral line is shown in Text-fig. 12. The position of the fins is the same as in the 28 mm. specimen. The dorsal has developed the prolonged posterior ray, the growth of which is considered later. The axillary scales are also well developed.

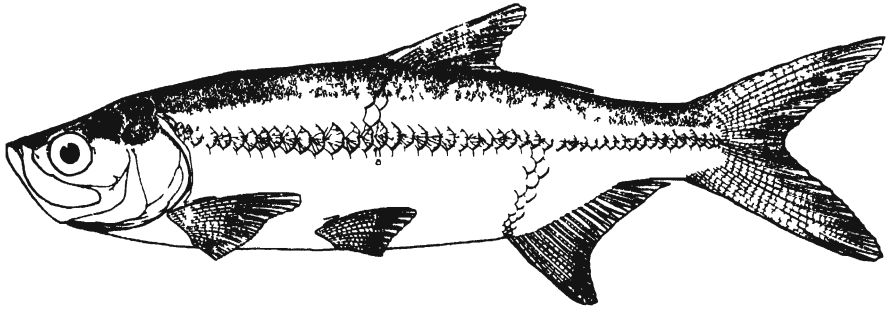
This series of specimens shows that the leptocephali *Megalops* shrink from 24 mm. to 15 mm. At this time the number of post-anal myomeres increases from 19 to 22. Also the myomeres from the head to the dorsal decrease from 45 to 40 and those from the head to the ventrals 27 to 23. The



Text-figure 10.

*Tarpon atlanticus.* The 78 mm. specimen is comparable with the 51 mm. fish which is the smallest *Tarpon* available for study at the time of writing. As compared to the 238 mm. fish the pigmentation is not as dense and the prolonged dorsal ray not as long as shown in Text-figure 11. The ventrals appear nearer the snout than the ventrals of *Megalops* as shown in Text-figures 8 and 9 (× 1.15)

myomeres from the head to the anal decrease from 48 to 44. Then the larval fish grows longer and begins to resemble the adult. The 16.5 mm. specimen has characters of the younger and older stages. This stage has a decrease of myomeres from the head to the dorsal fin of 40 to 33. The greatest shrinking occurs between the ventral and dorsal fins. In the 24 mm. young the number of caudal vertebrae is the same as that of older and larger fish, and the entire skeleton is well stained. In the 28 mm. specimen the shape of the body and the position of the fins is identical with older specimens. Other growth characters appear later as the body and axillary scales and the prolonged posterior dorsal ray.



Text-figure 11.

*Tarpon atlanticus.* The 238 mm. specimen represents the adult form including secondary growth characters as the prolonged dorsal ray, axillary scales and well developed body scales. The marked 18th scale of the lateral line is enlarged in Text-figure 13. (× 3/8).

In examining 22 *Megalops cyprinoides* in the collection of the United States National Museum which ranged from 34 mm. to 400 mm. it was found that the prolonged end of the posterior ray of the dorsal fin is only slightly elongated in specimens less than 56 mm. In seven fish the distance that the prolonged ray extends, beyond the margin of the rays immediately above, is 3 mm. in a 56 mm. fish; 10 mm. in an 82 mm. fish; 20 mm. in a 110 mm. fish; 30 mm. in a 140 mm. and a 145 mm. fish; 40 mm. in a 160 mm. fish; 50 mm. in a 210 mm. fish.

In 6 *Tarpon atlanticus* the posterior dorsal ray extends beyond the margin of the rays immediately above as follows; 2 mm. in a 59 mm. fish; 10 mm. in a 115 mm. fish; 15 mm. in a 120 mm. fish; 18 mm. in a 125 mm. fish; 30 mm. in a 170 mm. fish. In a 238 mm. specimen the ray extends 35 mm. but is broken at this length.

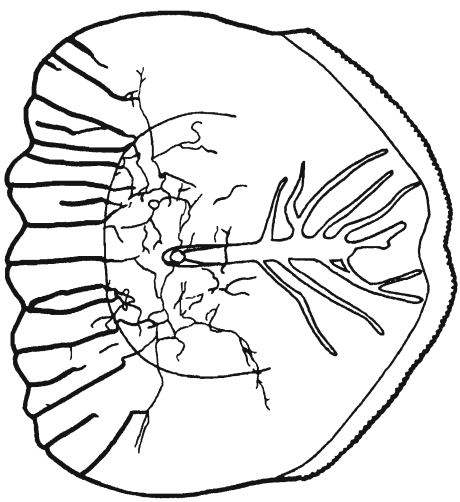
It has already been mentioned in the Taxonomic Discussion that the ventral fins of *Tarpon* are nearer the head than are the ventral fins of *Megalops*. This is shown in the comparative outline drawings of the two species by the lines lettered C. But the distances shown by the lines lettered A and B are the same in *Megalops* and *Tarpon*, and indicate the positions of the dorsal fins (Text-fig. 1).

In addition to these external measurements, it is found in cleared and bone stained specimens of *Megalops* that the anterior margin of the dorsal fin is above the 31st trunk vertebra in a 20 mm. specimen, and above the 29th vertebra in a 24 mm. specimen. In specimens 26 mm., 34 mm., and 56 mm., it is above the 27th trunk vertebra. The relative positions of the fins are constant in *Megalops* of approximately 26 mm. and larger (Text-figs. 8, 9). The ventral fins are also in line with trunk vertebra number 27 and therefore opposite the anterior of the dorsal fin.

In cleared and stained *Tarpon*, 51 mm., 55 mm., and 59 mm., the anterior margin of the dorsal fin is above the 27th trunk vertebra, which is the same as in *Megalops*. But the ventral fins are in line with the 22nd vertebra, which is anterior by five vertebrae than in *Megalops*. The ventral fins are nearer the head in all these specimens which is seen in detail in Text-figs. 10, 11.

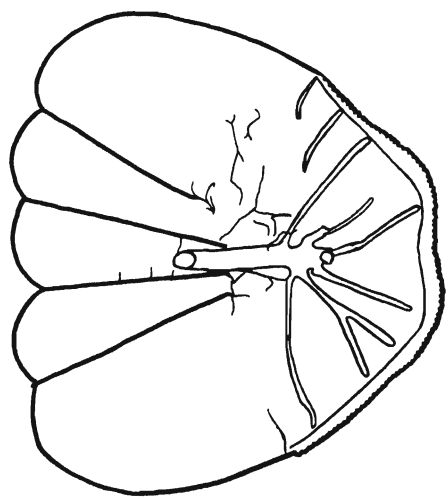
*Scales.*

Two lateral line scales taken from below the anterior margin of the dorsal fin of *Megalops* and *Tarpon* show differences in the two species. In *Megalops* this was the 15th scale (Text-fig. 12) and in *Tarpon* the 18th



Text-figure 12.

Scale of 300 mm. *Megalops cyprinoides* which is the 15th in the lateral line and taken from below the anterior margin of the dorsal fin as marked in Text-figure 9. (× 3.7).



Text-figure 13.

Scale of 238 mm. *Tarpon atlanticus* which is the 18th scale in the lateral line and taken from below the anterior margin of the dorsal fin as marked in Text-figure 11. (× 4.3).

(Text-fig. 13). In order to bring out variations in the two species all concentric lines have been omitted. The shape of the *Megalops* scale is rounder than the *Tarpon* scale and the former has many marginal scallops and lines radiating inward for a short distance. The *Tarpon* scale has only three marginal scallops with four lines radiating toward the center. These lines are much longer than in *Megalops*. The illustrations show that the architecture of the *Megalops* scale is more complex than the scale of *Tarpon*.

KEY TO CAUDAL FIN OF *Megalops* AND *Tarpon*.

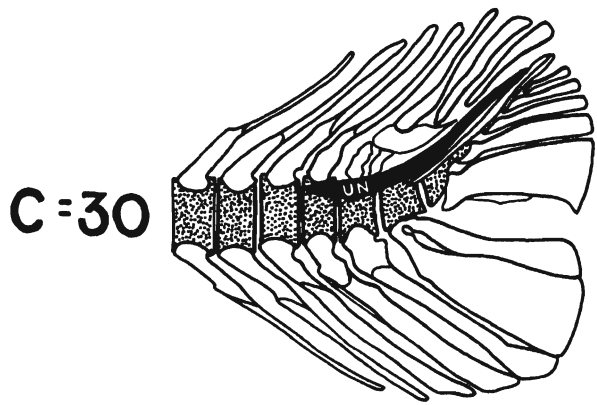
(Text-figs. 14, 15).

A. Position of the first or anterior pair of uroneurals: anterior end arises on centrum which is fourth from last and precedes centrum with reduced neural process.

Caudal vertebrae: 30. Total vertebrae 68: 38 trunk plus 30 caudal.

Caudal ray count: total 35 or 34. Dorsal 18, ventral 17 or 16.

Text-fig. 14.
*Megalops cyprinoides.*

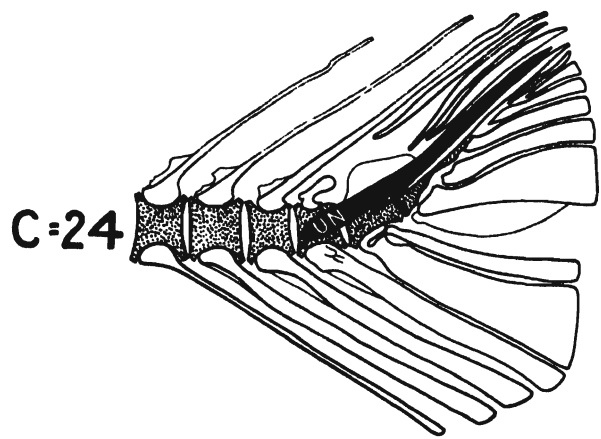



B. Position of first or anterior pair of uroneurals: anterior end arises on centrum which is third from last and has reduced neural process.

Caudal vertebrae: 24. Total vertebrae 57: 33 trunk plus 24 caudal.

Caudal ray count: total 31 or 30. Dorsal 17 or 16, ventral 15 or 14.

Text-fig. 15.
*Tarpon atlanticus.*



## Caudal Skeleton of *Megalops cyprinoides*, Including a Comparison with *Tarpon atlanticus*.

(Text-figs. 16-21).

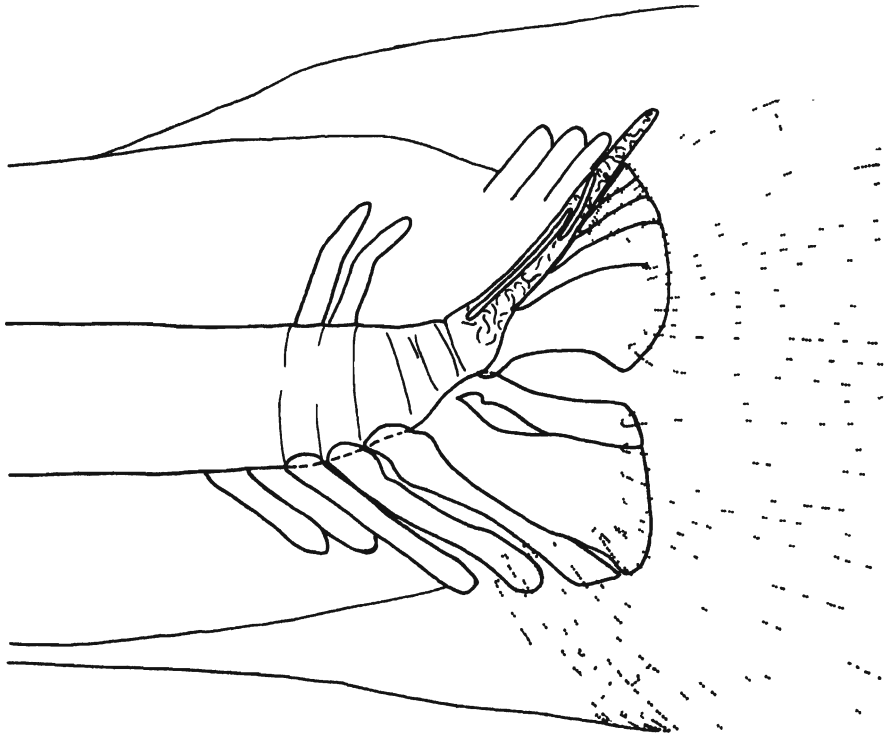
### *Material Studied.*

7 *Megalops* in the leptocephalus phase, 24 mm. to 22 mm., Cat. No. 28,903. Also 2 specimens, 22 mm. and 16.5 mm., KOH Cat. No. 2,288. 4 young fish, 20 mm., 24 mm., 26 mm., and 34 mm., KOH Cat. No. 2,288 and 2,295. 1 specimen, 55 mm., U. S. Nat. Mus., KOH Cat. No. 2,301. The specimens with the KOH numbers have been cleared and stained.

3 *Tarpon*, 51 mm., 55 mm., and 59 mm., KOH Cat. No. 2,302. In addition, specimens described in Hollister, 1936.2, pages 263 to 268. The drawing of the 140 mm. specimen is reprinted for comparison with *Megalops*.

### *Caudal Osteology.*

Ossification: In the 22 mm. and 16.5 mm. leptocephalus specimens there is no ossification but in the 20 mm. transitional specimen there is partial ossification of the column and other bones. The centra are thin, imperfect, bony rings which give rise to well ossified vertebrae of the older fish. Text-figs. 16, 17, show the column is continuous in these stages but Text-fig. 20



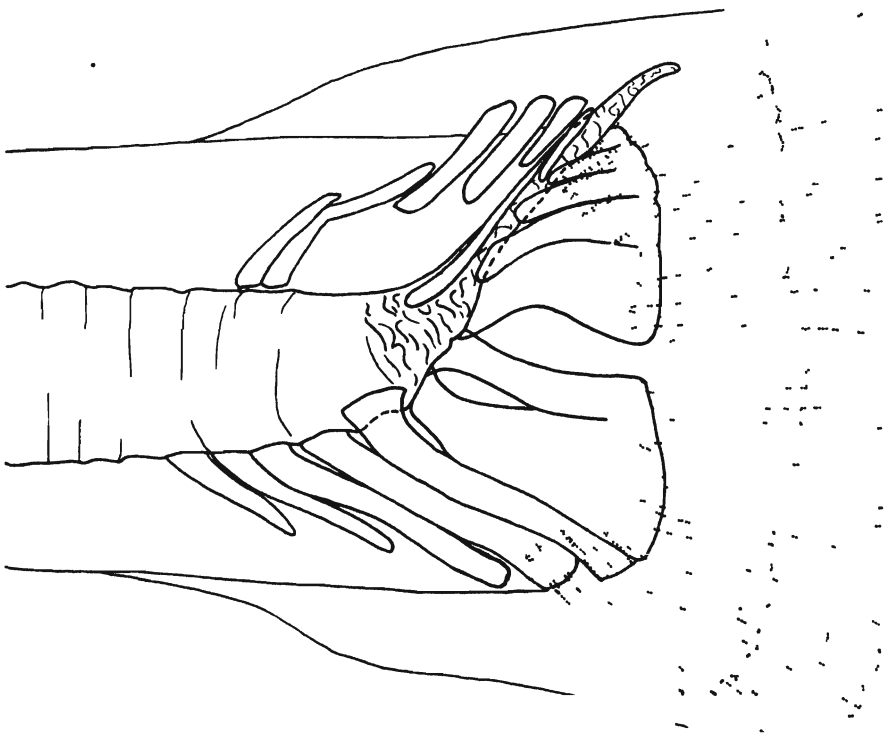
Text-figure 16.

*Megalops cyprinoides*. Tail of 22 mm. leptocephalus specimen which is unossified and the column unsegmented. The anterior and second pair of uroneurals are slender bones on the sides of the upturned distal end of the notochord. The illustration of the total fish in Text-figure 5 of a 21 mm. specimen shows the external form. (× 37).

shows the column is segmented in the 34 mm. fish. There is considerable increase in ossification in the 26 mm. specimen and also in the 34 mm. fish which resembles older stages. It has also been found in the young of other species that ossification appears suddenly at a youthful stage and develops rapidly.

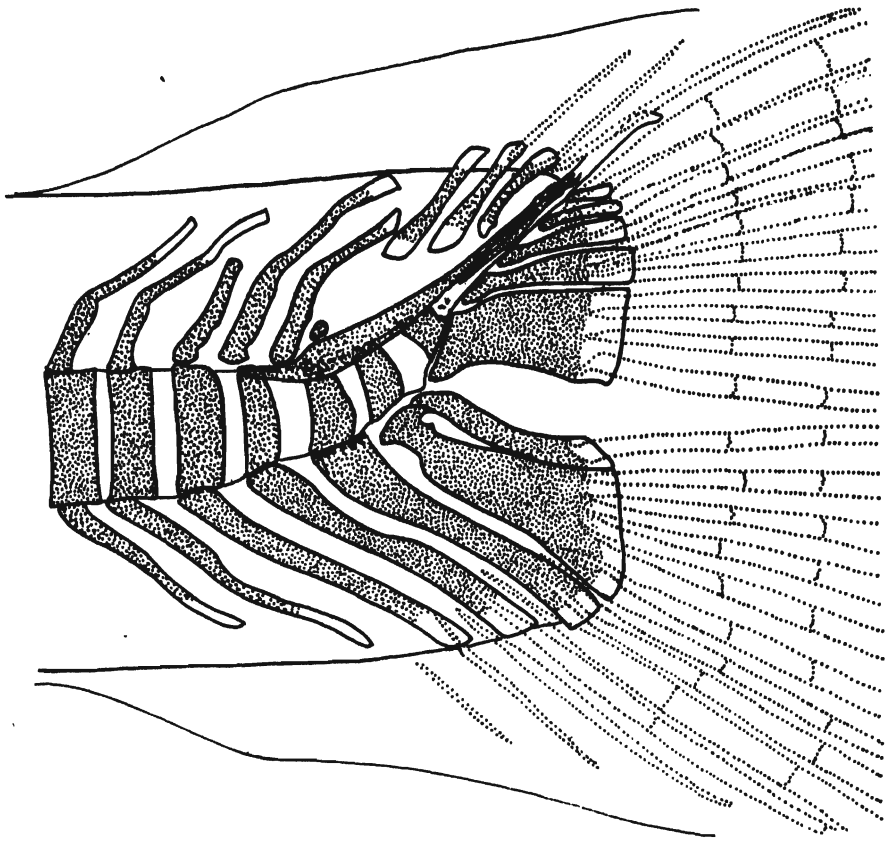
Urostyle: In the two larval specimens, 22 mm. and 16.5 mm., the urostyle has no definite segmentation and the cartilaginous notochord extends dorsally beyond the distal margin of the hypurals and the epurals (Text-figs. 16 & 17). In the 20 mm. transitional specimen, where partial ossification is present, three narrow centra form the urostyle (Text-fig. 18). In the 26 mm. and 34 mm. specimens the posterior terminal centrum is elongate and narrows distally to a rod-like end (Text-figs. 19 & 20). It is also seen in the Text-fig. 21 of *Tarpon atlanticus* that two complete centra and one elongate centrum form the urostyle.

Uroneurals: There are three pairs of uroneurals in the adult *Megalops* (Text-fig. 20). This is also true in *Tarpon* (Text-fig. 21). In the unossified 22 mm. *Megalops* only two uroneurals can be detected. These are slender bones lying on the sides of the notochord (Text-fig. 16). In the 16.5 mm. unossified specimen both pairs of the uroneurals have grown longer (Text-fig. 17). In the partially ossified 20 mm specimen the two pairs of uroneurals are considerably longer than those of the 16.5 mm. specimen. In addition, the



Text-figure 17.

*Megalops cyprinoides.* Tail of 16.5 mm. fish which is unossified. There is indication of later segmentation of the column by the incomplete vertical lines. The uroneurals are larger and the bones of the anterior pair longer than those of the 22 mm. fish. The illustration of the total fish in Text-figure 7 shows the external form which has changed more than the internal caudal structure (× 40).



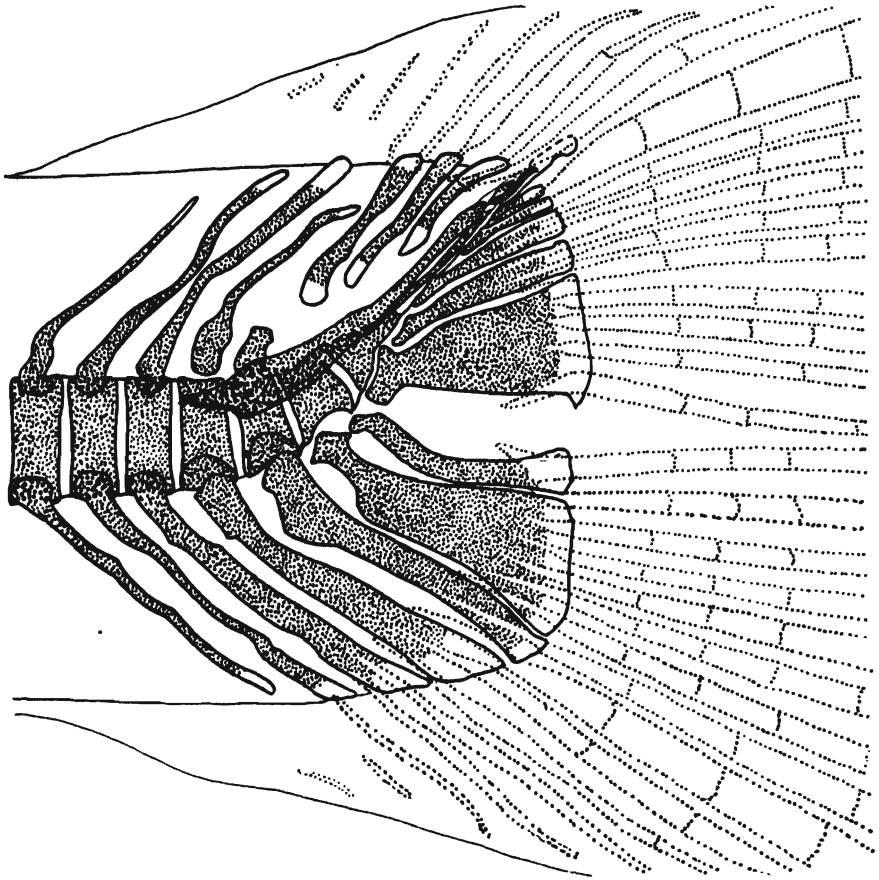
Text-figure 18.

*Megalops cyprinoides.* Tail of 20 mm. fish with considerable ossification but the column unsegmented. The anterior uroneural bones have lengthened considerably and the anterior tips appear on the same centrum as in all older stages. The diminutive third pair of uroneurals is present. The neurals are irregular in this specimen. (× 34).

third pair of uroneurals is present. These bones are very small and cross obliquely the distal tips of the other uroneurals. The third diminutive pair of uroneurals is elongated slightly in the 26 mm. and 34 mm. fish (Text-figs. 19 & 20).

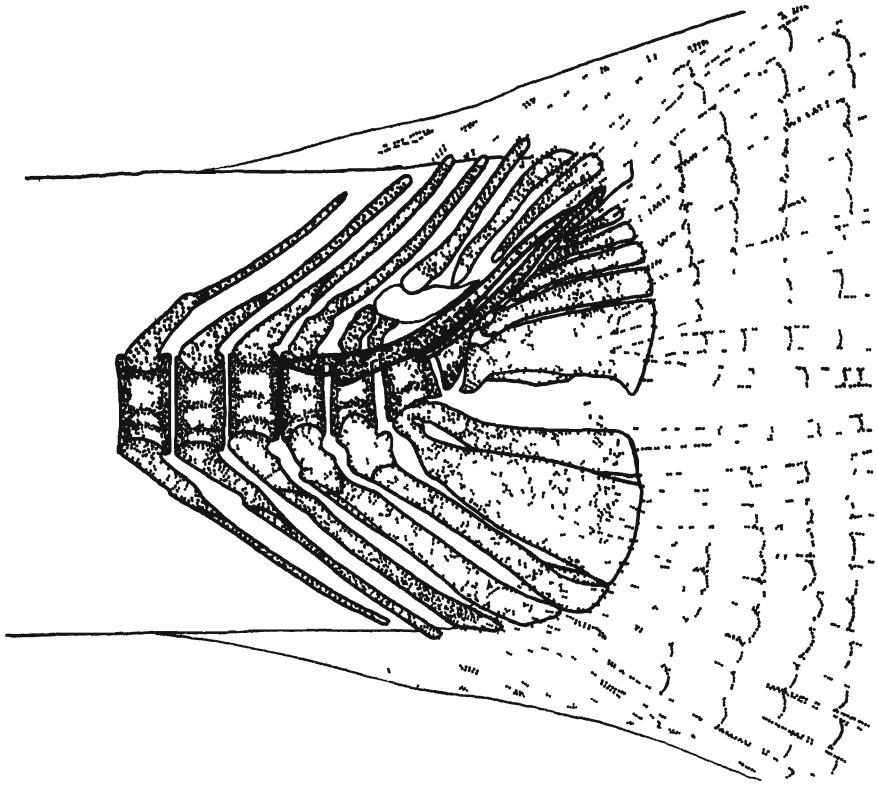
Hypurals: There are eight hypurals on the urostyle, three below and five above the median line (Text-fig. 20). This is also true in *Tarpon,* as shown in Text-fig. 21. Three additional long haemal spines project into the caudal contour with fin rays attached in *Megalops* and *Tarpon.* As in *Tarpon, Megalops* has two hypurals adjacent to a single urostyle centrum. In the 20 mm. and 26 mm. specimens the basal ends of the two hypurals are separate, although closely associated (Text-figs. 18 & 19). In the 34 mm. fish the basal ends appear as one (Text-fig. 20). This is true in the 51 mm. *Tarpon* and also in the 140 mm. fish (Text-fig. 21). This development takes place between the ages of 26 mm. and 34 mm. in *Megalops* (Text-figs. 19 & 20).

Epurals: There are three epurals present in all growth stages of *Megalops.* This is true of *Tarpon.* These bones are the last to ossify (Text-figs. 20 & 21).



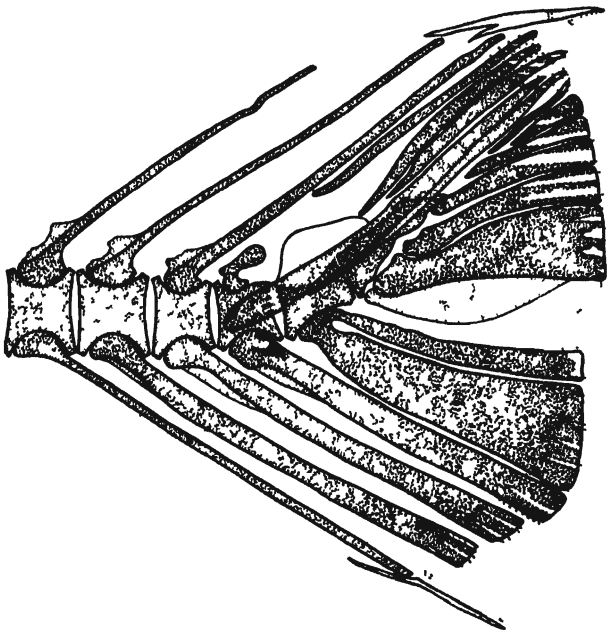
Text-figure 19.

*Megalops cyprinoides.* Tail of 26 mm. fish showing considerable increase in ossification but the column still unsegmented. The bones of the second pair of uroneurals have lengthened. For external development see Text-figure 8 of a 28 mm. specimen. (× 15).



Text-figure 20.

*Megalops cyprinoides.* Tail of 34 mm. specimen which has general increase in ossification and the column segmented The bones of the second pair of uroneurals have lengthened anteriorly and the tips are on the same centrum as in older fish. The cartilage plate is present between the urostyle and the epurals. This is present also in the 51 mm. *Tarpon* and shown in Text-figure 21. The double reduced neurals are irregular. (× 18 6)



Text-figure 21.

*Tarpon atlanticus* Tail of 140 mm. specimen reproduced for comparison with the caudal of *Megalops*. The tail structure of the 140 mm. fish is similar to that of the 51 mm *Tarpon* (× 4 75).

Caudal Fin Ray Count

*Megalops*.

| | | |
|---|---|---|
| 22 mm. fish | 10/11, 21 | No ossification. (Text-fig. 16) |
| 16.5 mm. fish | 10/12, 22 | No ossification. (Text-fig. 17). |
| 20 mm. fish | 13/13, 26 | Partial Ossification (Text-fig. 18) |
| 26 mm. fish. | 18/16, 34 | Ossification. (Text-fig. 19). |
| 34 mm. fish. | 18/17, 35 | Ossification. (Text-fig 20). |
| 56 mm. fish. | 18/16, 34 | Ossification. |

*Tarpon:*

| | | |
|---|---|---|
| 55 mm.<br>59 mm. fish. | 16/15, 31. | Ossification. |
| 115 mm.<br>120 mm. fish.<br>140 mm. | 16/14 or 15, 30 or 31. | Ossification. (Text-fig. 21). |

Specialized Ray-scales: There are no specialized ray-scales in *Megalops*. But *Tarpon* has well developed dorsal and ventral ray-scales as shown in Text-fig. 21. Regan (1910) made the following note: "In *Elops*, but not in *Megalops*, there is an oblong ray-scale above and below, partly covering the first upper and lower rays."

## ANNOTATED BIBLIOGRAPHY OF *Megalops* AND *Tarpon*.

In choosing authors for the bibliography an attempt has been made to bring together only references of importance pertaining to both the Pacific and Atlantic species. In most cases these are annotated. The subjects include the original and earliest authors, references to extreme geographical ranges where *Tarpon* have been reported, references concerning the osteology and anatomy of both species, and those describing *Tarpon* nurseries and very small *Tarpon*. The angler's interest has also been remembered. These references, together with their bibliographies, constitute most of the known literature of this nature on the two species of Megalopidae. The different groupings will be found following the alphabetical annotated list.

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Geographical reference for *Megalops* found on Natal coast, pp. 104-105.

BEAN, TARLETON H.

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1928. Beneath Tropic Seas. G. P. Putnam's Sons, New York-London, The Knickerbocker Press, 1928.

Translation of Van Kampen's original description of larva of *Megalops cyprinoides*, with illustration, pp. 228-229.

BEEBE, WILLIAM & HOLLISTER, GLORIA.

1935.1. The Fishes of Union Island, Grenadines and British West Indies, with a description of a new species of star-gazer. *Zoologica*, XIX, No. 6, p. 211.

Four Tarpon seen in twenty-five feet of water near shore off Medusa Islet, July 6, 1932, and on several other days. Only visible when below in diving helmet. Quite fearless, passing within ten feet, and all about the same size, six feet in length. Our expert tarpon fishermen could not persuade them to rise to any bait or lure.

BEEBE, WILLIAM & TEE-VAN, JOHN.

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Three-inch *Tarpon* taken in mid-January at Source Matelas, 15 miles from Port-au-Prince.

1933. Field Book of the Shore Fishes of Bermuda. G. P. Putnam's Sons, New York-London, 1933, pp. 33-34.

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Reference to two northern records, see Halkett & Radcliffe. *Tarpon* rare in Gulf of Maine.

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9 *Tarpon*, 7⅝ to 13⅜ inches, Andros Island, Bahamas. Natives reported many smaller ones.

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7 *Tarpon*, 6 to 10 inches, taken November 19, 1920, in Dauphin Bay, Gulf of Mexico.

CUVIER, M. LE B. & VALENCIENNES, M. A.

1846. Hist. Nat, Poiss., Vol. XIX, 1846, pp. 383-401. Description des Mégalopes.

*Megalops*, Commerson, pp. 383-388. Description Le Megalope Indien, *Megalops indicus*, nob., with colored plate, pp. 388-398. Description of type of Atlantic species, *Megalops atlanticus*, pp. 398-401. Type localities, Guadeloupe, Santo Domingo, Martinique and Porto Rico.

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DELSMAN, H. C.

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13 *Tarpon*, 2.25 to 3.25 inches. Taken in a small brackish pool, corner of mangrove swamp, separated from the sea, in February, 1900.

FOWLER, H. W.

1933. Notes on Louisiana Fishes. *Proc. Biol. Soc. Wash.*, Vol. 46, p. 58.

*Megalops atlanticus* Valenciennes. Lake Charles. Several exceeding 610 mm. taken during the past few years. May be seen most any morning feeding on mullet.

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Description of the 20 mm. *Tarpon* mentioned by Storey & Perry, which includes differences between *Tarpon* and *Albula*. Only known specimen of transitional *Tarpon* and one of smallest recorded. Taken at Core Creek, from very brackish water. Fish accidentally destroyed.

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LACÉPÈDE, B. G. E. DE LA V. (COUNT).

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Found in Buffon (G.L.L. De) Count. Hist. Nat. avec la description du Cabinet du Roi, 44 Tom. illust. Paris, 1749-1804. One of earliest authors to describe *Megalops*. See Cuvier & Valenciennes, p. 385.

MACPHERSON, G. A. HILL.

1935. A Record Tarpon from Nigeria. *The Field*, Vol. CLXV, No. 4288. The Field Press, London, England, March 2, 1935, p. 447.

A 156-pound *Tarpon* caught by Mr. J. N. Zarpas in Lagos Harbour, Nigeria. Good photograph which shows position of fins.

MARCGRAVIUS, GEORGIUS.

1648. Historiae rerum Naturalim Brasiliae. Lib. IV, Hist. Piscium, page 179. Published at Leyden, and Amsterdam.

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MEEK, ALEXANDER.

1916. The Migrations of Fish. London, published by Edward Arnold, 1916, pp. -XVIII and 1-427.

The spawning habits of Elopidae on pp. 64-65.

MEEK, S. E. & HILDEBRAND, S. F.

1923. Marine Fishes of Panama. *Field Museum of Natural History*, Vol. XV, Part I, p. 174.

Five specimens, 300 to 575 mm., preserved, caught at Gatun, Mindi and Colon.

MONOD, THEODORE

1927. Faune des Colonies Francaises, by Gruvel, A. Pages 643-742 = Contribution a La Faune Du Cameroun.

Page 654 = *Megalops* note: "Espèce non encore signalée au Cameroun. Ce poisson qui peut atteindre des tailles énormes est rare mais se rencontre cependant dans tout la région. Je l'ai observé personnellement à Souelaba et à Kribi. Les écailles si developpées de cette espèce obtiendraient des fabricants de fleurs artificielles des prix interessants. Malheureusement le Tarpon est trop rare pour que ce produit puisse être récolté au Cameroun."

*Megalops* found at Souelaba and Kribi, Cameroon.

MULLER, JOHANNES & TROSCHEL, FRANZ HERMANN.

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NICHOLS, J. T.

1929. The Fishes of Porto Rico and the Virgin Islands. *Scientific Survey of Porto Rico and the Virgin Islands, New York Academy of Sciences*, Vol. X, Part 2, 1929, pp. 161-535.

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PELLEGRIN, JACQUES.

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Page 44. *Megalops* found at the mouth of the Senegal and Congo.

RADCLIFFE, LEWIS.

1916. An Extension of the Recorded Range of Three Species of Fishes in New England Waters. *Copeia,* No. 26, January 24, 1916, pp. 2-3.

One of northernmost records, Provincetown, Mass.

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Good drawings of the caudal rays of *Megalops cyprinoides* and *Tarpon atlanticus.*

RIDGEWOOD, W. G.

1904. On the Cranial Osteology of the Fishes of the Families Elopidae and Albulidae, with Remarks on the Morphology of the skull in the Lower Teleostean Fishes generally. *Proc. Zool. Soc. London,* 1904, Vol. II, pp. 35-81.

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1916. Fishes of Australia and their Technology. Technical Education Series, No. 21. Technological Museum, Sydney, 1916, pp. -XVI, 1-296.

*Megalops,* pp. 11-12, plate I. Geographical reference and said to rank high in food value.

SENIOR, H. D.

1907.1. The Conus Arteriosus in *Tarpon atlanticus* (Cuvier & Valenciennes). *Biol. Bull. Woods Hole,* 1907, 12, pp. 146-151, 3 figs.

1907.2. Note on the Conus Arteriosus of *Megalops cyprinoides* (Broussonet). *Biol. Bull. Woods Hole,* 1907, 12, pp. 378-379, 2 figs.

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1906. Fishes of Australia. A Popular and Systematic Guide to the Study of the Wealth within our Waters. Sydney; William Brooks & Co., 1906, pp. -XII, 1-278.

*Megalops,* pp. 23-24. Systematic description.

STOREY, MARGARET & PERRY, LOUISE M.

1933. A Record of Young Tarpon at Sanibel Island, Lee County, Florida. *Science,* Vol. 78, September 29, 1933, pp. 284-285.

Mention of 20 mm. specimen in the Bureau of Fisheries, Washington; erroneously given as 25 mm. See Hildebrand, 1934, for description. Fish accidentally destroyed.

SUNIER, DR. A. L. J.

1921-1922. Contribution to the Knowledge of the Natural History of the Marine Fish-Ponds of Batavia. *Treubia,* Vol. II, pp. 159-405, illustrations.

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WALFORD, LIONEL A.

1937. Marine Game Fishes of the Pacific Coast from Alaska to the Equator. A Contribution from The Santa Barbara Museum of Natural History. University of California Press, Berkeley, 1937, pp. ix-xxix, 1-205, and 147 plates and figures.

Footnote on p. 166. "I have the following note from Walter D. Clark, of the Panama Canal Zone: 'Have definite proof of tarpon now on Pacific side in spillway at Pacific end of Canal. Do not know if they venture into the Pacific Ocean proper or not. Plentiful in the Lake area'."

WEBER, MAX & BEAUFORT, L. F. DE.

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| Hollister, Gloria | 1936. |

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| | |
|---|---|
| Fowler, H. W. | 1933. |
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Atchafaloya River, 150 miles from sea.

*Guatemala.*

Hubbs, Dr. Carl — Unpublished.
Rio de la Pasión, about 300 miles by stream to sea. Many adults.

*Panama Canal.*

| | |
|---|---|
| Hildebrand, S. F. | 1937 & 1939. |
| Walford, Lionel A. | 1937. |
| Whiton, Henry D. | 1928. |

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| Hubbs, Dr. Carl | Unpublished. |

Fortaleza, Ceará, Brazil. 1 specimen, 178 mm., Sept. 18, 1935

Marcgravius, Georgius — 1648.

*Africa, West Coast.*

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# 29.

## The Feeding and Grooming Habits of the Galago.

FLORENCE DE L. LOWTHER
*Barnard College, Columbia University*

(Plate I).

The peculiar arrangement in the lemur group of the six front teeth of the lower jaw, popularly known as the "tooth-comb," has long been considered a grooming apparatus with which the lemur combs his thick fur. These teeth, two pair of incisors flanked by two modified canines, project almost horizontally beyond the abbreviated lower jaw and form what seemed to be an ideal comb.

Dr. M. Russell Stein, in an article entitled "The Myth of the Lemur's Comb," (1936) challenges this long accepted theory. After observation of captive lemurs in the New York Zoological Park and a study of specimens which had died recently he came to the conclusions that (1) this incisor-canine complex is not a comb because the tips of the teeth converge so closely that fur cannot pass between them; (2) the tooth formation takes no part in the grooming operation so characteristic of the lemuroids. He suggests that the function of these teeth is probably that of cutting leaves and fruit, though he offers no evidence to substantiate his suggestion.

My contribution to this question of the use of the specialized teeth in feeding and grooming is based on observations of a galago, one of the African lemuroids. Though not a true lemur, the galago is closely related, and has the same tooth-complex and feeding habits as the Madagascan lemurs. My notes, therefore, have a definite bearing on the question of the use of the incisor-canine complex in the group as a whole.

In Africa, in 1936, I procured from a native in Mombasa a young, tame, *Galago crassicaudatus*. He was about the size of a small gray squirrel, with thick gray fur frosted over with light buff on the back; the ventral surface was almost white with buff on chest and sides of the legs. He was strictly an arboreal type, with hind legs much longer than his fore legs. The hind feet, more specialized than those of the lemur, were disproportionately long and gave adequate leverage for his huge leaps. The big toe, set apart and apposed to the others, also made the hind foot a powerful grasping structure. All the digits had flat, concave tipped (Hayman) nails with the exception of the index toe which bore the pointed claw characteristic of Lemuroidea. He possessed other features typical of the lemurs such as the long, thin tongue used for lapping and licking; the pointed nose with crescent-shaped nostrils extending beyond the lower jaw with its incisor-canine complex and canine-like first premolar. On the upper jaw were two pairs of small incisors and conspicuous canines. The galago tooth structure differs from that of the lemur in that (1) the first premolar of the lower jaw, though long and sharp, is not quite so caniniform as that of the lemur; (2) the molars of the galago have better grinding surfaces; (3) the last premolar of the upper jaw is more molarized. (Le Gros Clark).

The animal whose feeding and grooming habits I have studied was with me for fourteen months, until he made his escape into the tree-tops of the Connecticut hills. During this time he had complete freedom of action within the confines of the house and screened-in porch. He slept all day in some dark, high spot, with neck arched and head tucked between his hind legs. He became active at dusk and in the intervals between jumping, feeding or grooming he would look to me for companionship. He seemed to enjoy being fondled. He would jump from a curtain rod to my shoulder or drop from the top of the door into my lap, demanding attention by nibbling my fingers. I make these statements at this time in order to show how completely at home the animal seemed to be and how simple a task it was to make observations at close range.

## Feeding Habits.

The galago is an omnivorous feeder though he much prefers insects. Each evening during the summer months I set loose on the screened-in porch a dozen or more grasshoppers and moths. With eyes focussed intently the galago would watch, then leap to a perch close to the insect, grab it with one or both hands and put it in the side of the mouth. Jumping to a more comfortable perch he would sit like a squirrel holding the morsel in his hands while he consumed it with relish. He discarded wings and used his tongue to shove them out over the "comb," which thus appeared to be passively used as a trough. He ate everything but the wings, beginning at the head, chewing vigorously.

I also placed on a shelf each evening an assortment of food which included cut up bits of raw vegetables, fruit, bread and milk in a shallow dish to which I frequently added cod liver oil and now and then a little sugar. At intervals he would help himself, lapping up the milk with his long tongue, keeping his projecting nostrils out of the milk with difficulty. Other food he smelled carefully; if acceptable he would take a small piece directly into his mouth, jump away, and holding it in his hands, bite off what he wanted, using the upper canine against the caniniform first premolar of the lower jaw. As an animal in captivity eats what is provided for him, it is obvious that one cannot determine in what ways he might normally extend his diet. This galago once astonished me by leaping to my shoulder with a half consumed young mouse in his hands. I never saw him use the incisor-canine complex for seizing food. This does not mean that he could not do so. It may be, of course, that the type of food which would call for the use of this device was never offered to him. I am now making a study of the habits of a family of *Galago maholi* A. Smith, and I hope to have further observations to offer on feeding habits in this group.

It is well known that lemuroids are more primitive than the monkeys. Despite the fact that they are usually arboreal they still depend on their sense of smell as well as on their vision. The galago exemplified this by letting his nose tell him what he needed to know. He always cautiously smelled his food, except when it was food-on-the-wing; then he would grab first and smell afterwards. It was his sense of smell too that warned him not to land on a hot radiator or stand-pipe. I have watched him deliberately smell these surfaces.

## Grooming.

Although F. Wood-Jones (1929) and S. Zuckerman (1933) reaffirm the conclusion of earlier writers that the procumbent front teeth of the lower jaw are used in grooming the fur, Dr. Stein states that the captive lemurs in the New York Zoological Park groom themselves by the exclusive use of the index-toe claw and the tongue. He denies that the lower jaw teeth are employed in this operation. He further states that 85% of the entire groom-

ing time the lemur makes use of his index-toe claw, while the tongue completes the process. The grooming habits of the galago seem to be quite different. I find that (1) he does use the tooth complex, not, however, as a comb but as a scraper; (2) the tongue is used in grooming as in the case of the lemur; (3) the claw is not regularly employed as a grooming implement but only occasionally for scratching an irritated or otherwise inaccessible spot.

When the galago first awoke he would stretch his muscles and begin his toilet by scraping his fur. As in the true lemurs the individual teeth are probably not separated sufficiently at their tips to allow the fur to be pulled through them (Stein); scraper is, therefore, a better term than comb (Plate I). With this implement he would dig down to the integument, which he would scrape as well as his fur. I had frequent proof of this scraping action, when, as though I were a fellow galago, he would perch on my arm or hand and vigorously dig into my integument with this scraper. The intensity of the scraping made it clear that any dead skin or foreign objects lodged in the heavy pelt of the galago could be effectively removed in this way. After his energetic use of the scraper he would finish me off with a gentle but thorough licking with his long tongue, the same process with which he finished his own toilet.

Although I did not use a stop watch I saw repeatedly, at close range, scraper and tongue perform the operation of dressing the fur, briefly and with relative frequency; and I saw the claw used only in scratching, now and then. After scratching, the galago cleaned his claw by putting it in the side of his mouth.

Since the grooming habits of the galago seem to differ from those of the true lemur as recorded by Dr. Stein, it might be profitable if studies of other lemuroids possessing this scraper were made.

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## EXPLANATION OF THE PLATE.

Fig. 1. Lower jaw of *Lemur catta*. × 2.
Fig. 2. Lower jaw of *Galago* (sp?). × 2.
(Photographs from material in The American Museum of Natural History).

FIG 1

FIG 2

THE FEEDING AND GROOMING HABITS OF THE GALAGO

# 30.

## Parasites Obtained from Animals in the Collection of the New York Zoological Park during 1938.

CARLTON M. HERMAN, Sc.D.

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During the year 1938 parasites were collected from many of the animals exhibited at the New York Zoological Park. Most of these parasites were collected at autopsy, but a few are reported from examination of the blood or feces of living animals.

This report is not intended to represent the complete prevalence of parasites in the animals examined. For the most part only those parasites which appeared grossly during the routine procedure of an autopsy were collected, detailed examination being made in only a few animals. In some cases post mortem changes had progressed to a point such that the parasites could not be classified beyond class or family but an effort has been made wherever possible to identify the organisms to species.

Some of the parasites were classified at the Hospital and Laboratory of the Park but most of them were referred to specialists in some particular branch of parasite taxonomy, either for the original identification or for confirmation. Thanks are here extended to the following parasitologists for their cooperation in this work: Dr. J. Bequaert, Dr. F. C. Bishopp, Dr. H. E. Ewing, Mr. Howard R. Hill, Mr. J. T. Lucker, Dr. Irene McCulloch, Mr. A. McIntosh, Dr. O. Wilford Olsen, Dr. E. W. Price, Dr. C. R. Schroeder, Dr. E. W. Stafford and Dr. E. E. Wehr.

The infected animals and the parasites collected are listed in the two following tables. In Table I, the hosts are listed consecutively, while Table II contains a list of the parasites. The "Parasite No." in Table I refers to the "Parasite No." in Table II and shows what parasites were found in a particular host. Vice versa, the "Host No." in Table II refers to the "Host No." in Table I and shows what hosts were infected with any particular parasite.

TABLE I.

Animals from which parasites were collected.

REPTILIA

Squamata

| *Host No.* | *Host* | *Parasite No.* |
|---|---|---|
| 1. | *Acrochordus javanicus* (Karung) | 30 |
| 2. | *Agkistrodon piscivorus* (Water Moccasin) | 3, 41, 63 |
| 3. | *Bitis arietans* (Puff Adder) | 30 |
| 4. | *Bitis gabonica* (Gaboon Viper) | 3, 19, 29, 33, 67 |
| 5. | *Boa canina* (Green Tree Boa) | 63 |
| 6. | *Constrictor c. constrictor* (South American Boa) | 9, 23, 26, 68 |

| *Host No.* | *Host* | *Parasite No.* |
|---|---|---|
| 7. | *Crotalus adamanteus* (Eastern Diamond-back Rattlesnake) | 3, 33 |
| 8. | *Crotalus a. atrox* (Western Diamond-back Rattlesnake) | 3, 33 |
| 9. | *Drymarchon corais melanurus* (Gopher Snake) | 44 |
| 10. | *Epicrates cenchris* (Ringed Boa) | 65 |
| 11. | *Eunectes murinus* (Anaconda) | 7 |
| 12. | *Lachesis muta* (Bushmaster) | 69 |
| 13. | *Lampropeltis getulus floridana* (King Snake) | 35, 63 |
| 14. | *Notechis scutatus* (Tiger Snake) | 63 |
| 15. | *Pseudechis porphyriacus* (Australian Black Snake) | 63 |
| 16. | *Python regius* (Ball Python) | 25, 28, 36 |
| 17. | *Python reticulatus* (Regal Python) | 8, 21, 66 |
| 18. | *Spilotes pullatus* (South American Rat Snake) | 61, 62, 65 |
| 19. | *Tiliqua scincoides* (Blue-tongued Lizard) | 63 |
| 20. | *Tupinambis teguixin* (Tegu Lizard) | 32 |
| | **AVES** | |
| | Struthioniformes | |
| 21. | *Struthio camelus massaicus* (Masai Ostrich) | 60 |
| | Ciconiiformes | |
| 22. | *Ciconia c. ciconia* (European White Stork) | 46, 48, 49, 59 |
| | Anseriformes | |
| 23. | *Anas p. platyrhynchos* (Mallard) | 12, 13, 15, 42 |
| 24. | *Chloephaga melanoptera* (Andean Goose) | 57 |
| | Falconiformes | |
| 25. | *Pandion haliaëtus carolinensis* (American Osprey) | 54 |
| | Galliformes | |
| 26. | *Chrysolophus amherstiae* × *C. pictus* (Lady Amherst Pheasant × Golden Pheasant) | 24, 53, 55 |
| 27. | *Francolinus squamatus maranensis* (Kenya Scaly Francolin) | 39 |
| 28. | *Lophortyx c. californica* (California Quail) | 56 |
| 29. | *Ortalis v. vetula* (Northern Chachalaca) | 63 |
| | Gruiformes | |
| 30. | *Balearica p. pavonina* (West African Crowned Crane) | 20 |
| | Charadriiformes | |
| 31. | *Numenius a. arquata* (European Curlew) | 50, 51 |
| | Piciformes | |
| 32. | *Pteroglossus i. inscriptus* (Lettered Aracari Toucan) | 58 |
| | Passeriformes | |
| 33. | *Astrapia s. stephaniae* (Princess Stephanie's Bird of Paradise) | 2, 27 |
| 34. | *Cyanocorax cyanopogon* (Blue-bearded Jay) | 64 |
| 35. | *Monticola solitaria philippensis* (Japanese Blue Rock Thrush) | 64 |
| 36. | *Sarcops calvus* (Gray-backed Bald Myna) | 7 |
| 37. | *Seleucides m. melanoleucus* (Twelve-wired Bird of Paradise) | 10, 14 |
| 38. | *Turdus m. migratorius* (Eastern Robin) | 47 |
| | **MAMMALIA** | |
| | Primates | |
| 39. | *Ateles cucullatus* (Spider Monkey) | 45 |
| 40. | *Hylobates l. lar* (Black Gibbon) | 34 |

| *Host No.* | *Host* | *Parasite No.* |
|---|---|---|
| 41. | *Hylobates lar leuciscus* (White-handed Gibbon) | 7, 16, 22 |
| 42. | *Mandrillus sphinx* (Mandrill) | 7, 31 |
| 43. | *Oedipomidas geoffroyi* (Cotton-top Marmoset) | 27 |
| 44. | *Pongo pygmaeus* (Orang-utan) | 1 |
| | Carnivora | |
| 45. | *Canis dingo* (Dingo) | 37 |
| 46. | *Felis leo* (Lion) | 38 |
| 47. | *Lynx r. rufus* (Bay Lynx) | 11, 17, 38, 39, 43 |
| 48. | *Nandinia binotata* (Two-spotted Palm Cat) | 16, 25 |
| 49. | *Procyon l. lotor* (Eastern Raccoon) | 18 |
| | Pinnepedia | |
| 50. | *Zalophus californianus* (California Sea Lion) | 40 |
| | Rodentia | |
| 51. | *Erethizon d. dorsatum* (Canada Porcupine) | 52 |
| 52. | *Castor canadensis canadensis* (Canadian Beaver) | 40 |
| 53. | *Nyctomys sumichrasti* (Sumichrast's Night-mouse) | 2, 6, 26 |
| | Artiodactyla | |
| 54. | *Cervus elaphus* (Red Deer) | 5 |
| 55. | *Hippotragus niger* (Sable Antelope) | 7 |
| 56. | *Tragelaphus angasi* (Nyala) | 7 |
| | Marsupialia | |
| 57. | *Dendrolagus ursinus* (Black Tree Kangaroo) | 4 |
| 58. | *Macropus brunii* (Rock Wallaby) | 4 |
| 59. | *Macropus g. giganteus* (Great Gray Kangaroo) | 4 |
| 60. | *Macropus melanops* (Black-faced Kangaroo) | 4 |
| 61. | *Macropus robustus woodwardi* (Woodward's Wallaroo) | 4 |
| | Xenarthra | |
| 62. | *Dasypus novemcinctus texanus* (Texas Nine-banded Armadillo) | 5 |

## TABLE II.

### Parasites collected.

### PROTOZOA

| *Parasite No.* | *Parasite* | *Host No.* |
|---|---|---|
| 1. | *Endamoeba histolytica*[1] | 44 |
| 2. | Coccidia | 33, 53 |
| 3. | Haemogregarinidae | 2, 4, 7, 8 |
| 4. | *Pentatrichomonas macropi*[2] | 57, 58, 59, 60, 61 |
| 5. | Sarcosporididae | 54, 62 |
| 6. | *Trichomonas* sp. | 53 |

### CESTODA

| | | |
|---|---|---|
| 7. | Unidentified cestodes | 11, 36, 41, 42, 55, 56 |
| 8. | *Bothridium pithonis* | 17 |
| 9. | *Crepidobothrium gerrardi* | 6 |
| 10. | *Deltokeras multilobatus*, n. sp.[3] | 37 |
| 11. | *Diphyllobothrium mansonoides* | 47 |
| 12. | *Fimbriaria fasciolaris* | 23 |
| 13. | *Haploparasis* (*furciger* ?) | 23 |
| 14. | *Hymenolepis brevicirrosa* | 37 |
| 15. | *Hymenolepis collaris* | 23 |

[1] See Bibliography, Herman & Schroeder, 1939.
[2] See Bibliography, Herman, 1939.
[3] See Bibliography, Olsen, 1939.

NEMATODA

| *Parasite No.* | *Parasite* | *Host No.* |
|---|---|---|
| 16. | Unidentified nematodes | 41, 48 |
| 17. | *Ancylostoma braziliense* | 47 |
| 18. | *Ascaris columnaris* | 49 |
| 19. | *Capillaria* sp. | 4 |
| 20. | *Cyathostoma* sp. | 30 |
| 21. | *Dracunculus* sp. | 17 |
| 22. | *Enterobius vermicularis* | 41 |
| 23. | *Hastospiculum onchocercum* | 6 |
| 24. | *Heterakis gallinae* | 26 |
| 25. | *Kalicephalus* sp. | 16 |
| 26. | *Kalicephalus subulatus* | 6 |
| 27. | Microfilaria | 33, 43 |
| 28. | *Ophidascaris filaria* | 16 |
| 29. | *Ophidascaris* sp., probably *O. radiosa* | 4 |
| 30. | *Ophidascaris* sp. | 1, 3 |
| 31. | *Oesophagostomum* sp. | 42 |
| 32. | *Physaloptera retusa* | 20 |
| 33. | *Polydelphis* sp. | 4, 7, 8 |
| 34. | *Protospirura* sp. | 40 |
| 35. | *Rhabdias eustreptos* | 13 |
| 36. | *Spinicauda* sp. | 16 |
| 37. | *Toxacara canis* | 45 |
| 38. | *Toxascaris leonina* | 46, 47 |
| 39. | Trichiuridae (eggs in feces) | 27, 47 |

TREMATODA

| | | |
|---|---|---|
| 40. | Unidentified trematodes | 50, 52 |
| 41. | An undescribed species of styplodorid | 2 |
| 42. | *Echinostomum revolutum* | 23 |
| 43. | *Paragonimus* sp. | 47 |
| 44. | *Renifer* sp. | 9 |

ANOPLURA

| | | |
|---|---|---|
| 45. | *Pediculus* (*Parapediculus*) *chapini* | 39 |

MALLOPHAGA

| | | |
|---|---|---|
| 46. | *Ardeicola* (*Esthiopterum*) *ciconiae* | 22 |
| 47. | *Brüelia* (*Degeeriella*) *vulgata* | 38 |
| 48. | *Colpocephalum femoratum* | 22 |
| 49. | *Colpocephalum zebra* | 22 |
| 50. | *Cummingsiella testudinarius* | 31 |
| 51. | *Degeeriella numenii* | 31 |
| 52. | *Eutrichophilus setosus* | 51 |
| 53. | *Goniocotes crysocephalus* | 26 |
| 54. | *Kurodaia haliaëti* | 25 |
| 55. | *Lipeurus caponis* | 26 |
| 56. | *Menacanthus praecursor* | 28 |
| 57. | *Menopon loomisi* | 24 |
| 58. | *Myrsidea victrix* | 32 |
| 59. | *Neophilopterus incompletus* | 22 |
| 60. | *Struthiolipeurus struthionis* | 21 |

ACARINA

Ixodoidea

| | | |
|---|---|---|
| 61. | *Amblyomma dissimile* | 18 |
| 62. | *Ornithodorus* sp. | 18 |

Acarina other than Ixodoidea

| | | |
|---|---|---|
| 63. | Unidentified mites | 2, 5, 14, 15, 19, 29 |
| 64. | *Dermanyssus* sp. | 34, 35 |
| 65. | *Ophionyssus serpentium* | 10, 13, 18 |

PENTASTOMIDIA

| *Parasite No.* | *Parasite* | *Host No.* |
|---|---|---|
| 66. | Unidentified pentastomes | 17 |
| 67. | *Armillifer armillatus* | 4 |
| 68. | *Porocephalus clavatus* | 6 |
| 69. | *Porocephalus stilesi* | 12 |

## SUMMARY.

During 1938 autopsies were performed on 393 animals from the collection of the New York Zoological Park, including one amphibian, 103 reptiles, 159 birds and 130 mammals[4]. From these animals parasites were observed from 20 species of reptiles, 18 species of birds and 24 species of mammals. With the exception of the orang-utan and several of the kangaroos from which protozoa were diagnosed from fecal smears from the living animals, all material reported was obtained at autopsy. A few of the parasites reported here were observed in fecal smears in living animals and later confirmed at autopsy.

At least 70 species of parasites were collected, including at least 6 species of Protozoa, 9 Cestoda, 24 Nematoda, 5 Trematoda, 1 Anoplura, 15 Mallophaga, 5 Acarina and 4 Pentastomida. Protozoa were found in 14 species of animals, including 4 species of reptiles, 1 bird and 9 species of mammals. Cestodes were diagnosed from 11 species of vertebrates, including 3 species of snakes, 3 species of birds and 5 species of mammals. Nematodes are reported from 23 species of hosts, including 10 species of reptiles, 4 species of birds and 9 species of mammals. Trematodes were seen in 6 species of hosts, of which 2 were snakes, 1 was a bird and 3 were mammals. Anoplura were observed on only 1 mammal. Mallophaga were collected from 1 mammal and 9 species of birds. Ticks were collected from 1 reptile. Eight species of reptiles and 3 birds were parasitized with mites. Four species of snakes were infected with Pentastomida.

Some of the parasites collected during 1938 have been presented more in detail elsewhere. Reference is made in footnotes to Table II to these publications which are listed in the bibliography.

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# 31.

## On the Life History and Development of the Sponge Blenny, *Paraclinus marmoratus* (Steindachner).

C. M. BREDER, JR.
*New York Aquarium*

(Plates I-IV; Text-figures 1-3).

### INTRODUCTION.

This study of the life history and development of the sponge blenny, *Paraclinus marmoratus* (Steindachner), was carried on during February, 1939, as time would allow, while researches on the life history and habits of the tarpon were being undertaken at the research station of the New York Aquarium located at Palmetto Key on the west coast of Florida. This is west of Useppa Island, in Charlotte Harbor. See Breder (1939) for a description of the area. The bulk of the collecting was done by Mr. M. B. Bishop of the Peabody Museum, Yale University. Were it not for his persistence, it would have been impossible to examine so much material, both of adults and egg clusters. His vigorous field activity released the author for the necessary laboratory study of the living material. Also his subsequent collections up to June have given us an understanding of the post-breeding activity of these fishes and some idea of the rate of growth of the young. Dr. W. G. Van Name kindly identified the sponge through the good services of Dr. R. W. Miner. Mr. J Atz of the New York Aquarium was helpful with the manuscript. The photographs, Plate II, Figure 3, Plate III and Plate IV were made by Mr. S. C. Dunton of the Aquarium.

### THE MATURE FISH.

The taxonomy of this group of blennies (usually called *Auchenopterus* or *Cremnobates*) has long been confused. However, Margaret Storey (1940, in press) shows that the generic name *Paraclinus* must be used. The material with which we worked, incident to the present field studies, is the same that passed through her hands.

The physical appearance of these fishes, both male and female, is shown in Plate I, Figure 1. The adults ran between 60 and 80 mm. in standard length. The higher and differently appearing anterior dorsal spines and head form of the male is evident. There was no difficulty in sexing the living specimens, even in the case of recently spawned-out females, because of these evident and presumably permanent differences.

The life colors and patterns are rather difficult to describe briefly. The same Plate shows the pattern of the anterior part well enough, but its wide range of color and the shifts in detail which it underwent on slight provocation would take pages of descriptive detail. In the main the shades ran from light tan to Vandyke brown to almost black in some cases, or from

light tan to pale green and almost yellowish. Specimens sent to the New York Aquarium and placed against backgrounds of unaccustomed sorts exceed these general types found in the field. Some became almost brick red while others became so light as to appear almost white. This latter was clearly not a matter of failing health.

When newly placed in a collecting bucket or an aquarium and frightened, they would seem to huddle together, but as soon as they obtained their bearings their attitude would become that of the typical solitary or cryptic fish in that they strongly resented each other. Generally, if a fish was huddled into the angle formed by the bottom and side of an aquarium, which was perhaps its most usual choice, it would remain quiescent when a wandering specimen sidled up to it *if* he approached quietly from the rear. If, on the other hand, he happened to be coming the other way—that is, head on—the quiescent fish would become alert and take a stance not unlike that shown in Plate II, Figure 3. This would be accompanied by a great extension of the wide opening gape and a spreading of the large pectorals by both fishes, with what appeared to be intimidating gestures and motions. No damage was seen to be done, the intruder usually withdrawing after a sudden lurch forward with a vicious snap by the other fish. Apparently such is not always the result, for torn fins were sometimes seen which would seem surely to be the results of such encounters carried a little further.

As may be seen in the various illustrations, these fishes have a very great thigmotaxis and spend almost their entire time in crevices or cavities, apparently leaving them only when forced to do so by some untoward circumstance. They are not strong swimmers, their movements all being made by little jerks. Since they are very heavy in relation to sea water, they are as much a part of the bottom fauna as a heavy-bodied crab. Their ventral fins they use as props, sitting up tripod fashion on the tail and their pelvic apendages. The pectorals are wide and with heavy rays and have remarkable utility for wedging into crevices that are basically too large for the fish's body to fit into neatly. A peculiar trick of this species is to walk along the bottom on their delicate ventral fins, alternating them like little legs.

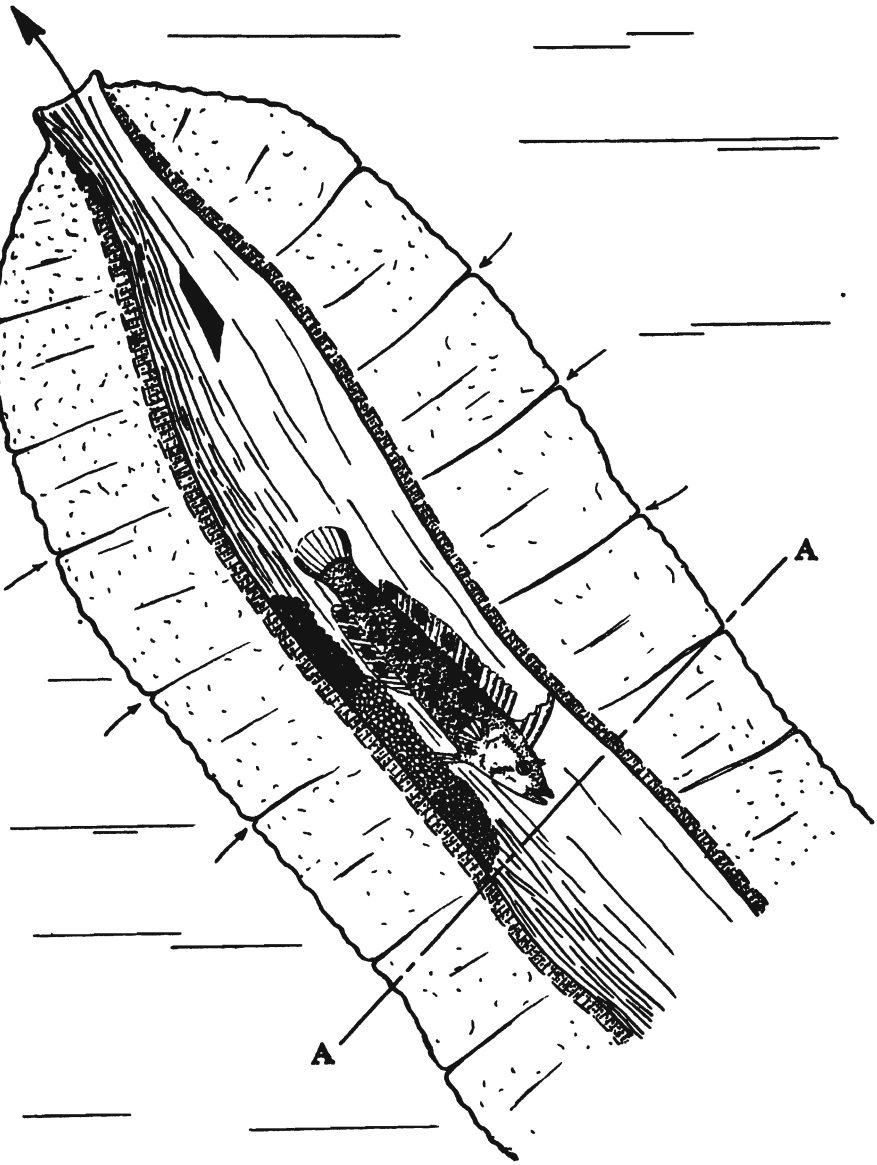
After a short sojourn in an aquarium, they fed freely on all manner of small organisms such as isopods, copepods, bits of fish, and so on. The large mouth enabled them to engulf surprisingly large objects and very likely they managed to catch a wide variety of invertebrates and smaller fishes without moving far from their normal lurking places.

## The Habitat.

All the material on which the present study is based was collected in Pelican Bay, a small body of water about one-half mile north of Palmetto Key. The collection area could be waded easily at low water, and both adults and eggs were taken by gathering up the very abundant yellow sponge, *Verongia fistularis* (Pallas). During the time of these collections, February, every fourth or fifth sponge would be found to contain one or more fish and a much lesser number to contain eggs, usually with an attendant parent.

Associated with them in the sponge cavities were *Opsanus beta* Goode & Bean, and *Bathygobius soporator* (Cuvier & Valenciennes). Other fishes did not seem to find these same refuges, but they were shared with a large number of invertebrates, including small octopi, various shrimps and prawns, small starfish, brittle stars and a large variety of other crustaceans and mollusks.

No very brisk tidal flow was noted but there was a good change of water, nevertheless, due no doubt to the open nature of the so-called bay, which was only enclosed by a scattering of the islands common to this region. This area was in clean, open water, well away from any mangrove stands and the associated turbidity frequently found in such places.




Text-figure 1.

Diagram of nest within the lumen of a sponge, in saggital section. Line **A-A** indicates region of transverse section shown in Plate III, Figure 5. The three clutches of eggs are indicated by progressive darkening. The arrows indicate direction of flow induced by the sponge. The exact position of the fish is hypothetical, based on observation in aquaria.

## THE NEST.

The nesting cavities selected by the fish were found to be exceedingly varied. Most frequently they were found in broken-open lumens of old sponges that had partly healed over. Such an instance is depicted in Plate

III, Figure 6. Only one was found in the central lumen of a vertical sponge. Whether deliberate or accidental, this nest certainly had the benefit of the flow induced by this sponge. It is to be noted in this connection that the flow from the oscula of these sponges is remarkably strong, so much so that the amount of water that passes through in an hour must run into many gallons. A diagram of this particular nesting site is given in Text-figure 1, and a photograph of it in cross section in Plate III, Figure 5. Portions of other sponges dissected away are given in Plate I, Figure 2; Plate III, Figures 5 and 6; Plate IV, Figures 7 and 8.

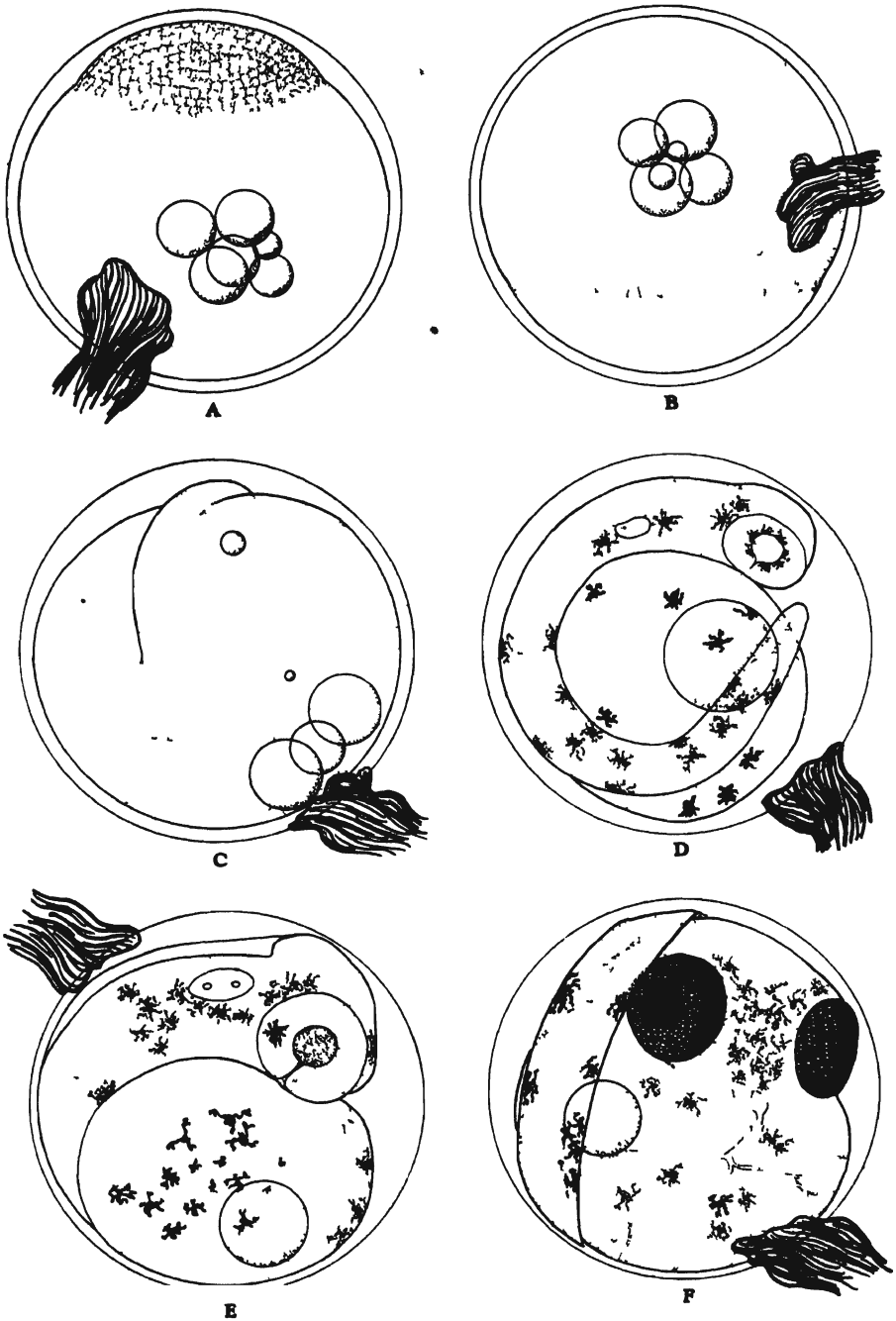
In many cases a fish was taken in company with the nests—a male in each instance. This indicates that this sex, as so common with fishes, at least guarded and probably fanned the eggs in their tightly compressed mass. Presumably in those cases in which there was no accompanying male, the fish slipped from the cavity as the sponge was removed from the water. This is further substantiated by aquarium observation. One male sent to the New York Aquarium established itself in a fork of a sea fan in one of the exhibition aquaria. It induced one female to spawn there. Since this activity was not observed, it is believed that spawning took place at night. The male was subsequently noted to fan the eggs, during which operation it exhibited a peculiar rocking motion. On the approach of an intruder it would open its mouth wide in a "threatening" attitude and spread its pectoral fins widely. Nevertheless, the eggs were found missing one morning, presumably successfully raided by some tank mate. Plate II, Figure 3, shows this male in a threatening attitude. When alarmed, this fish will erect the first dorsal spine so that it passes the vertical and actually leans forward. The male to the left in Plate 1, Figure 2, shows this posture.

Although actual spawning has not been observed, there are certain evidences from the eggs which indicated that once a male establishes himself he is ready to spawn with a succession of females. More frequently than not, the nests contained eggs in various stages of development, as well, in some instances, as hatched egg shells. Each batch of a single stage was found in one part of the generally agglutinated mass and represented a bulk about equal to the ovarian contents of a single female. Usually the stages of development to the number of four or five were in a linear series, forming in all an elongate mass flattened to the supporting surface. This naturally suggests that as each successive female came along with her contribution it was simply attached to one end of the already established cluster. Because of these considerations it would seem that while the male surely spawns with a succession of females, the latter may spawn their entire contents at one time. The grouping of the egg masses is indicated in Text-figure 1. The arrangement in another cluster may be seen in Plate IV, Figure 7. Sometimes the egg masses would be in massive groups as in this figure, but more commonly in linear series. Occasionally one could be found in the form of a flat, circular disc as shown in Plate IV, Figure 8.

The nests, many of which contained well advanced eggs, were first found on February 8. In all, twelve were carefully examined and many others handled that were in a fragmentary or partly destroyed state due to accidents in collecting.

## ONTOGENY.

*The eggs and their development.* The youngest eggs obtained showed the blastoderm in a many-celled stage as a cap on the yolk (Text-figure 2a). They ranged in size from 1.15 to 1.30 mm. in diameter with a mode at 1.20. As already noted, they are attached to each other by a cord of twisted strands which may be seen best in Plate II. Figure 4. This cord possesses a central stalk from which branch off smaller stalks to which the eggs are attached. In a general way these eggs seem to be attached to each other more like those of the Exocoetidae than of any others with which the writer



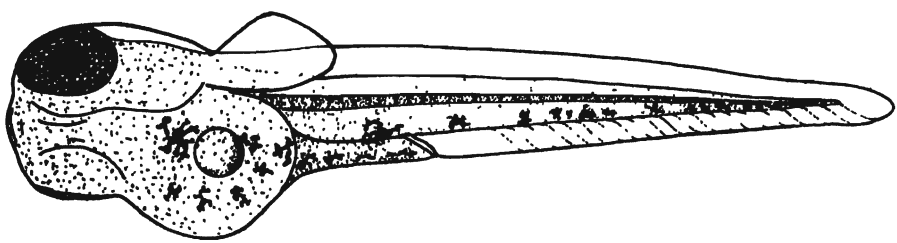

Text-figure 2.

Development of the eggs of *Paraclinus marmoratus*. A. Blastodisc in an advanced stage with many cells. B. Egg prior to the closing of the blastophore and before evident anterio-posterior differentiation C. Embryo with cephalization well advanced D. Chromatophores developing, the yellow ones indicated by stippling. E. Embryo well advanced, with circulation established. F. Egg shortly before hatching See text for full explanation Camera-lucida sketches from living material.

is personally familiar, see Breder (1938). In finger bowls at a temperature close to 70° F. they advanced to a condition shown in Text-figure 2b in which the developing cells partly invested the yolk, but in which the blastopore was not nearly closed, in a period of 13 hours. The yolk was a very pale amber and the oil droplets a deeper tint of the same color. The mass of cells presented a whitish appearance by reflected light. In 11 hours further the stage shown in Text-figure 2c had been reached. Cephalization had already reached an advanced condition. The condition shown in Text-figure 2d was reached in a further 45½ hours. The yolk was covered with a number of dark, nearly black, chromatophores and yellowish ones were placed at fairly regular intervals along the sides of the body and around the iris. The embryo at this time showed a considerable amount of movement and the beating of the embryonic heart was regular at about 33 beats per minute. By the time another 40½ hours had passed, the egg appeared as in Text-figure 2e. The eye was rapidly darkening and the dendritic chromatophores had somewhat rearranged themselves. Motion of the embryo was greater and the heartbeats had increased to about 37 per minute. In 20½ hours more the eyes had become fully pigmented and presented a bronzy appearance.. Vascularization was prominent and heartbeats had increased to about 150 per minute. This stage is shown in Text-figure 2f. Both blackish and yellowish chromatophores were present on body and yolk. At this time camera lucida drawing became exceedingly difficult on the living egg, not only because of the increasing activity of the embryo, but chiefly because of the increasing opacity of the egg membrane. All during incubation it had been slowly accumulating fine detritus. It would thus seem that the surface of the eggs continues to maintain an adhesive condition that does not disappear with the passage of considerable time. Two days later drawing of the living egg became impossible but the heartbeats remained the same, while the following day the latter became impossible to count. The following day hatching occurred. In all, a period of ten days passed for the hatching of this very slowly developing egg — February 10 to February 20.

Due apparently to the very close matting that these eggs show by virtue of their tangled adhesive threads, they were not easy to incubate in the standing water of a finger bowl. Only when a few were teased well apart could they be incubated at all. In clumps as found they died in a few days, the central ones first, with little doubt, from suffocation. Although these eggs are normally incubated in either absolute or semi-darkness, light as present on the laboratory table seemed to have no influence on them. They were incubated both in darkness and in light with equal success.

*The larvae.* On hatching, the larvae rested at the surface of the water in an inverted diagonal position. This was caused by the retention of a single relatively large oil globule. A specimen is shown in Text-figure 3 floating in this position as viewed directly from above. It measured 4.1 mm. in over-all length. Due to the necessity of leaving the laboratory at this



Text-figure 3.

Newly hatched larval fish shown from above in the typical floating position. Camera-lucida sketch from living material.

time, it was impossible to continue studies further. Hatched in a comparatively advanced stage and being notably buoyant, these fish should find themselves in the plankton soon after hatching. The coloration of the larval fish was essentially as described for the last stage of the egg figured. The melanophores were seen in an expanded stage and the xanthophores were contracted.

Specimens collected later, in April, by M. B. Bishop, of about 25 mm. in length, were clearly recognizable, appearing very like the larger females. Material at this time and all through the summer was absent from the sponge beds. There is a considerable faunal change in this bay with the seasons and whether these fish change their locale or mostly die after spawning is not entirely clear at this writing.

During July and August of 1938, Mr. Bishop reported finding both adults and young lurking about the marine growths on the piling at Palmetto Key, and during April and May, 1939, he found them in beds of eel grass. Apparently they are not present on the sponge beds of Pelican Bay in the warmer months, but move about in some kind of seasonal migration very likely associated with the temperature differentials in these shallow waters.

## Discussion.

Although there are hardly enough data on blenny reproduction to warrant an attempt to compare the various modes employed by these fishes, certain features are evident that are worthy of comment at this time.. The entire group comprising the Blenniodei is marked by a tendency to produce fairly large, heavy and attached eggs which may be attended by one or both parents. This is perhaps related to their mode of life, so closely associated with a sea floor well populated with marauding invertebrates of a large variety.

The related form, *Clinus argentatus* Cuvier & Valenciennes, lays adhesive eggs that are guarded by the male, according to Guitel (1892). This is also true of a wide variety of more or less related forms, as follows: *Blennius pholis* Linnaeus, *B. ocellaris* Linnaeus, *B. gattorugine* Bleeker, Lebour (1927) and Brown (1929); *Blennius sphynx* Cuvier & Valenciennes, Guitel (1893 a and b); *Chasmodes bosquianus* (Lacépède), Hildebrand & Schroeder (1928) and Hildebrand & Cabel (1938) *Hypsoblennius hentz,* (LeSueur) and *Hypleurochilus geminatus* (Wood), Hildebrand & Cable (1938).

In *Pholis gunnellus* (Linnaeus), on the other hand, according to Ehrenbaum (1904) and Gudger (1927), both parents guard the nest, but according to the first without much enthusiasm. The eggs are merely adhesive and in all of the above species no fanning of the eggs has been described. *Paraclinus,* however, is reproducing in water much warmer than that of *Pholis* but, on the other hand, not quite as warm as that of the others, none of which have eggs bound together with threads.

Schultz & DeLacy (1932) describe adhesive eggs for *Anoplarchus purpurescens* Gill, but found that the female did the nest guarding.

Certain other blennies have been described as having threads on their eggs and to this extent resemble our material much more closely. *Blennius montagui* Fleming, Guitel (1893 a and b), and *Heterostichus rostratus* Girard, Barnhart (1932). As in *Paraclinus* the male guards in *Blennius montagui.*

Other species found with eggs, sex not stated, include *Xerepes fucorum* (Jordan & Gilbert), Metz (1912), *Cebidichthys violaceus* (Girard), Schultz & Delacy (1932). The sexual difference of *Clinus superciliosus* (Linnaeus) is described by Gilchrist & Thompson (1911). The eggs and sexual differences of *Blennius pavo* Risso are described by Eggert (1932) and those of

*Salarias flavo-umbrinus* Ruppell by Eggert (1929). It would be pointless to go on to the other more distantly related blennoid fishes and it may suffice at this time to mention in passing that the above general pattern, with variations, apparently runs pretty generally throughout the entire group.

The period of incubation, while long, is in good agreement with that of other species in which data are available:

| | *Days* | *Temperature °C.* |
|---|---|---|
| *Paraclinus marmoratus* | 10 | 21.5 |
| *Hypsoblennius hentz* | 10—12 | 24.5—27.0 |
| *Hypleurochilus geminatus* | 6 — 8 | 26.0—28.0 |
| *Chasmodes bosquianus* | 11 | 24.0—27.0 |
| *Pholis gunnellus* | 42—70 | About 6. |

The size of the eggs is also comparable to other American blennies as is indicated below:

| | *Dia. in mm.* |
|---|---|
| *Paraclinus marmoratus* | 1.15—1.30 |
| *Hypsoblennius hentz* | 0.72—0.80 |
| *Hypleurochilus geminatus* | 0.60—0.75 |
| *Chasmodes bosquianus* | 0.93—1.10[1] |
| *Pholis gunnellus* | 1.90—2.20 |
| *Anoplarchus purpurescens* | 1.37—1.49 |
| *Blennius pholis* | 1.4 |

While we need not go into the details of the secondary sex characters in these fishes, there seems to be a general tendency for them to display differences analogous to those described herewith for *Paraclinus*.

## SUMMARY.

1. *Paraclinus marmoratus* deposits masses of adhesive eggs, usually in association with the sponge *Verongia fistularis*, sometimes within the lumen of the sponge, in which case they have the aerating advantage of the strong current which these sponges induce.

2. The males guard and fan the egg masses, which may be in several stages of development and on the basis of size of the individual clusters must be the product of several females which would seem to deposit their entire complement at one time.

3. The eggs, which are bound together by a tangled skein of threads, are of unusually slow development, taking at least ten days to hatch under the temperature of their environment, about 70° F.

4. The larvae are pelagic but by the time they are 25 mm. in length have taken up the residence on the bottom and already closely resemble their parents.

5. Sexual dimorphism is marked prominently in the form of the dorsal and head, and individual color and pattern variation is large and changes readily with background and emotional state.

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## EXPLANATION OF THE PLATES.

### PLATE I.

Fig. 1. Adult male and female *Paraclinus marmoratus* in an aquarium. The nearest fish is the female. The dorsal differentiation is evident.

Fig. 2. A male guarding its eggs after being removed to an aquarium. The full erection of the first dorsal accompanies alarm, in which case it is thrust anterior to a vertical. These eggs form a massive cluster in the central portion of the broken sponge and the fish sits on the bottom at the left of the sponge.

### PLATE II.

Fig. 3. A male guarding a small cluster (a single spawning) on a sea fan in a tank of the New York Aquarium.

Fig. 4. Photomicrograph of developing eggs. The egg in the upper right corner is more advanced than the rest. The cloudy mass in the center and left is one of the tangled skeins of threads that bind the eggs together.

### PLATE III.

Fig. 5. Eggs of *Paraclinus* in the vertical lumen of a sponge. This is the same example that is indicated diagrammatically in Text-figure 1.

Fig. 6. Eggs of *Paraclinus* in a horizontal connecting lumen of a sponge. The vertical portions may be seen in the background.

### PLATE IV.

Fig. 7. A massive cluster of eggs on the exterior of the base of a sponge. Several groups of eyed eggs may be distinguished among others not so advanced. This was an especially large cluster.

Fig. 8. A flat circular mass of eggs on the basal portion of a sponge. Such clusters were not common, the massive type being the most general.

FIG. 1.

FIG. 2.

ON THE LIFE HISTORY AND DEVELOPMENT OF THE SPONGE BLENNY, PARACLINUS MARMORATUS (STEINDACHNER).

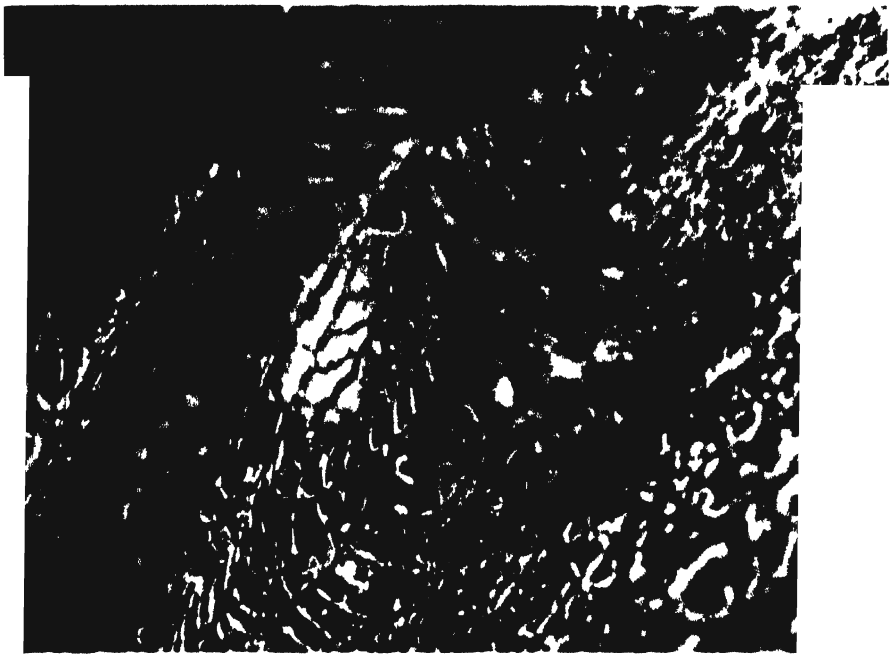

FIG 3

FIG 4

ON THE LIFE HISTORY AND DEVELOPMENT OF THE SPONGE BLENNY
PARACLINUS MARMORATUS (STEINDACHNER)

FIG. 5.

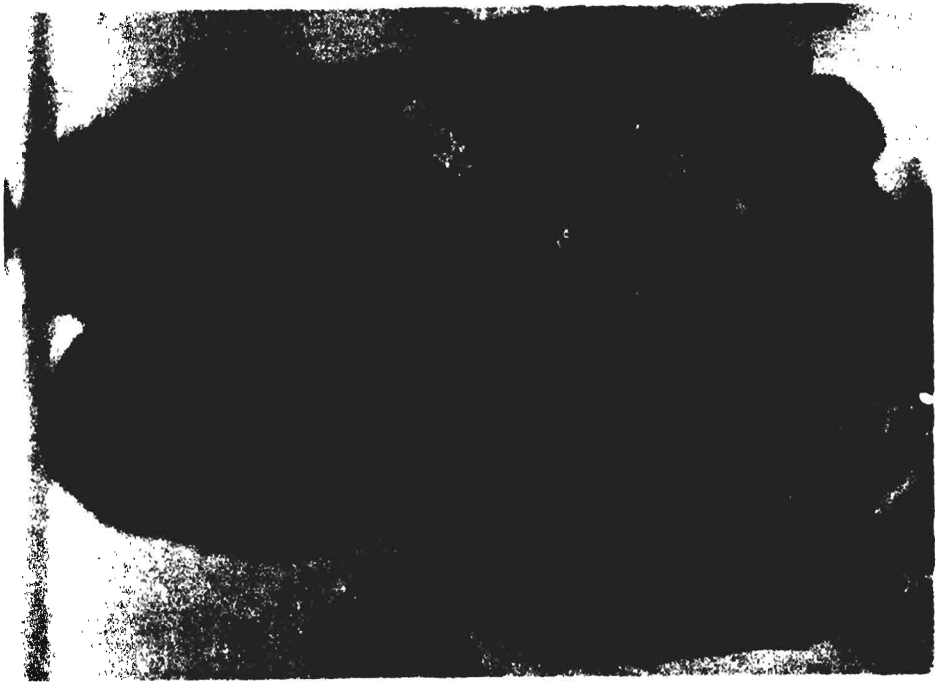

FIG. 6.

ON THE LIFE HISTORY AND DEVELOPMENT OF THE SPONGE BLENNY, PARACLINUS MARMORATUS (STEINDACHNER).

FIG 7

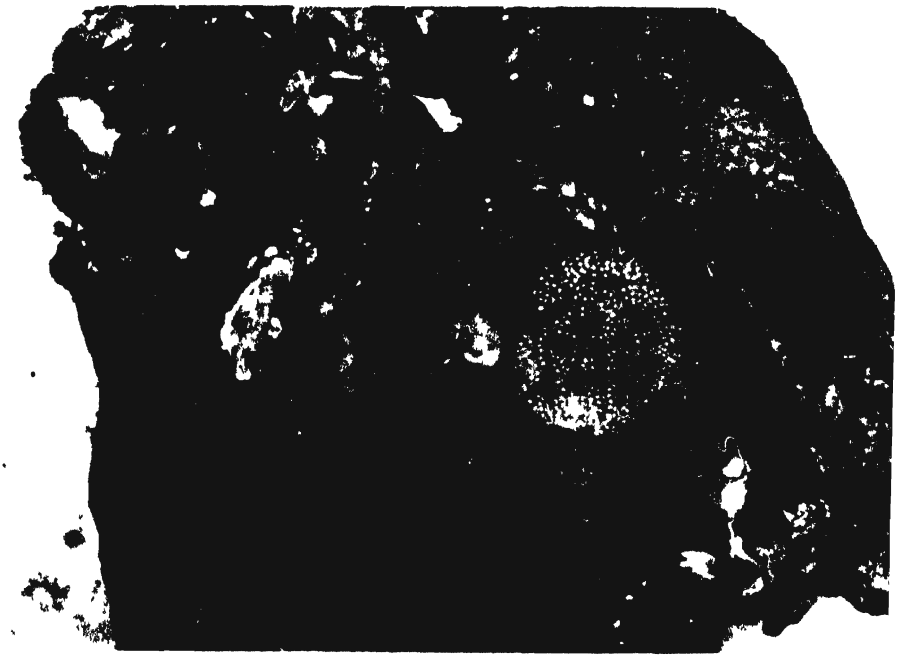

FIG 8

ON THE LIFE HISTORY AND DEVELOPMENT OF THE SPONGE BLENNY,
PARACLINUS MARMORATUS (STEINDACHNER)

# INDEX.

*Names in* **bold face** *indicate new genera, species or varieties; numbers in* **bold face** *indicate illustrations; numbers in parentheses indicate the paper containing the Plate numbers immediately following.*


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