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AGE AT MATURITY OF THE PACIFIC COAST SALMON OF THE GENUS ONCORHYNCHUS

By Charles H. Gilbert
Professor of Zoology, Stanford University

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AGE AT MATURITY OF THE PACIFIC COAST SALMON OF THE GENUS ONCORHYNCHUS.

By CHARLES H. GILBERT,
Professor of Zoology, Stanford University.

INTRODUCTORY.

During the past two summers (1910 and 1911) the writer has been engaged on behalf of the United States Bureau of Fisheries in determining the age at maturity of the five species of Pacific coast salmon, together with such other facts of their life history as can be inferred from the structure of their scales. The problem has a peculiar interest as concerns these species because of the fact, now sufficiently demonstrated, that all individuals perish when they have attained sexual maturity. They spawn but once and then die, whatever the age or size at which sexual maturity has been reached [a] and whatever may be their physical condition at the time of spawning. This peculiarity in their life history renders the question of their age at maturity an unusually important one, both from the scientific fish cultural and the purely economic standpoints.

Many attempts have been made to solve the problem for the two species commercially most important—the king salmon and the sockeye—usually by marking the artificially reared fry by clipping one or other of their fins before they are liberated, in the hope of recognizing the adult fish on their return at maturity. Unfortunately, these important experiments have lacked adequate supervision, and have furnished somewhat discordant and uncertain results. These have been supplemented, however, by the experiments in Tomales Bay, Cal., and in New Zealand, where fry were planted in streams not frequented by the species in question and the return of the adults was noted. Also, in the case of the sockeye, we have had as additional evidence the quadrennial increase in the Fraser River, which has been very generally accepted as demonstrating a four-year cycle for this species.

All the evidence available was considered by F. M. Chamberlain, in his highly valuable "Observations on Salmon and Trout in Alaska" (Bureau of Fisheries Document No. 627, 1907), with the resulting conclusion (p. 66):

> There seems to be sufficient reason for believing four years to be the usual term of life for the sockeye and the king salmon, but experiment has pretty conclusively shown that they may mature in less time or may be retarded beyond that term.

[a] With the possible exception of certain male king salmon fingerlings, which mature precociously in the streams during their first year, at a length of 3 to 7 inches. The fate of these has not as yet been determined.

This may be accepted as an adequate statement of our belief respecting these species up to the present time. It has lacked in definiteness and in detail. No conclusive evidence has been presented concerning the age of the markedly undersized fish or "grilse," which are conspicuous parts of the king salmon and sockeye runs. We have no knowledge concerning the extreme age which any species may attain, nor concerning the proportions in which different ages are represented in the spawning run. Furthermore, the question of size with relation to age has been wholly undetermined, the belief being yet widely entertained that no such relation exists, size being solely dependent on richness of feeding in the sea.

There remains to be noticed a recent attempt by Prof. J. P. McMurrich [a] to solve these problems by a consideration of scale and otolith markings. The figures of scales and otoliths presented in this paper show sufficiently that these structures present seasonal markings which when correctly interpreted will afford reliable indication of age. It is to be sincerely regretted that Prof. McMurrich's interpretations have been based on inadequate data, and these have misled him into announcing a series of conclusions so largely erroneous as to confuse rather than clarify the questions at issue. A further discussion of these matters will appear under each of the species considered below.

The present paper contains a purely preliminary statement of certain facts in the history of our salmon which can be substantiated through a study of scale structure. This method offers certain obvious advantages over that of determining the age by marking the young, although the latter method should be employed and rigidly supervised in corroboration of the former. But the scale method is of unlimited application. Any desired number of individuals can be investigated in connection with size and sex and other modifying factors. It thus becomes possible to analyze an entire salmon run into its age components, and each of these can then be the subject of further investigation and analysis. We can thus determine the range in size of each group and of the males and females separately for each age, and when definite events in the life history of the fish record themselves upon the scales—as we believe to be the case—corresponding categories can be formed and the possible effects of these events on growth and period of maturity can be determined. A very wide usefulness, therefore, attaches to this method, and for its proper elaboration discriminating study of many thousand specimens must be made.

While the method is new as regards Pacific salmon, it has been experimentally tested and fully approved by the Fisheries Board for Scotland in the case of the Atlantic salmon, and is now universally accepted as furnishing reliable data as to the age and many other facts in the life history of that fish. It has been shown to be applicable also to various species of trout, and its value has been demonstrated in fishes as widely divergent as the carp, the eel, the bass, the flounder, and the cod. Descriptions of this scale structure and its significance have appeared in a large number of papers, both scientific and popular. It will suffice here to repeat that the scale in general persists throughout life, and grows in proportion with the rest of the fish, principally by addi-

[a] The life cycles of Pacific coast salmon belonging to the genus Oncorhynchus, as revealed by their otolith and scale markings. Transactions Royal Society of Canada, 1912.

tions around its border. At intervals there is produced at the growing edge a delicate ridge upon the surface of the scale, the successive ridges thus formed being concentric and subcircular in contour, each representing the outline of the scale at a certain period in its development. Many of these ridges are formed in the course of a year's growth, the number varying so widely in different individuals and during successive years in the history of the same individual that number alone can not be depended on to determine age. For this purpose we rely upon the fact that the fish grows at widely different rates during different seasons of the year, spring-summer being a period of rapid growth and fall-winter a season when growth is greatly retarded or almost wholly arrested. During the period of rapid growth the ridges are widely separated, while during the slow growth of fall and winter the ridges are crowded closely together, forming a dense band. Thus it comes that the surface of the scale is mapped out in a definite succession of areas, a band of widely spaced rings always followed by a band of closely crowded rings, the two together constituting a single year's growth. That irregularities occur will not be denied, and this is natural, inasmuch as growth may be checked by other causes than the purely seasonal one. Also a considerable experience is requisite for the correct interpretation in many cases, and a small residue of scales of doubtful significance has always remained. This element is too small to affect the general results, and further investigation will almost certainly eliminate the doubtful cases altogether.

SOCKEYE OR RED SALMON (Oncorhynchus nerka).

[Pl. I–III; fig. 14, pl. VIII; fig. 22, pl. XII.]

The sockeye, red salmon, or blueback, as it is variously known, has been assumed to mature principally if not wholly in four years, on the basis of the constant four-year periodicity in the magnitude of its run in the Fraser River. Richardson is reported as having marked young sockeye at Karluk, Alaska, and observed their return at four years on the average. Chamberlain marked young hatched from 1902 eggs and planted the marked fry in the Naha River, Alaska. The return of adults bearing the appropriate mark was reported in 1906 and 1907, and has continued to be reported for each year since that date, including the summer of 1911. If these results are accepted, individuals may even reach the age of 9 years before maturing; but this is a conclusion so at variance with other evidence and with general probability that complete corroboration is required.

Finally, on the basis of scale and otolith structure, McMurrich announces 4 years as the age of adult Fraser River sockeye and 2 years for the undersized or grilse form. But as he frankly bases his investigation upon the a priori assumption that Fraser River sockeye must be 4 years old, and interprets scale and otolith structure in accordance with that assumption, it can hardly be claimed that his conclusion adds anything to our previous knowledge. This becomes the more apparent upon an examination of his figures, which indicate that he unfortunately chose for examination certain large specimens which were in reality 5 years old and not 4. Forced by this method to make an erroneous interpretation of the central area of the scale, all his conclusions are vitiated which

deal with the sockeye, the king salmon, and the coho. Thus the sockeye grilse is a 3-year and not a 2-year fish, a fact which we learn with some relief, in view of the very large numbers of grilse which regularly make their appearance three years after each quadrennial big run in the Fraser and the small numbers which can be observed in the intervening years. For reasons which will appear later, McMurrich's initial error did not to the same extent affect his interpretation of the scales of the humpback and dog salmon.

Our knowledge of the life history of the young sockeye is founded first on the important researches of Commissioner J. P. Babcock for the Fraser River (Report Fisheries Commissioner for British Columbia, 1903), and later of Chamberlain, for certain streams in Alaska. These investigators agree that in the early spring two sizes of young sockeye may be found together in the streams on their downward migration to the sea. The smaller of these comprise fry of the year hatched from eggs of the preceding fall, and are then about 1½ inches long. Those of larger size are yearlings, which instead of running out to sea the previous spring as fry, have remained in the lake during their first year and have grown during that time to a length of 3 or 4 inches.

The relative proportions of fry and yearling migrants in such streams as the Fraser and the Karluk are unknown. More fry have usually been captured in the fine-meshed nets employed for the purpose, but the superior strength and wariness of the larger yearlings have doubtless affected the result. It is also unknown whether in the same stream these two groups remain relatively constant in size or fluctuate widely from year to year in accordance with changing conditions of unknown nature. Chamberlain has pointed out that in the Naha River, Alaska, all the young remain in the lake during their first year, and migrate in their second spring as yearlings. It seems very probable that the chances of survival of yearling migrants is better than that of the fry, in which case a larger proportion of adults might be derived from that group, even in streams where considerable numbers migrate as fry. As will be shown below, the scales develop differently in the two groups. The history of each group can therefore be traced and the proportions which attain maturity can be determined.

In his interpretation of the sockeye scale McMurrich assumes that 13 of the 14 specimens which he examined belonged to the group which migrated as fry, the central close-ringed area of the scale having been formed during their brief life in fresh water. But, as a matter of fact, at the time when young fry migrate no scales whatever have made their appearance. In this group, therefore, the adult scales contain no record of life in lake and stream, even the innermost rings having been formed under marine or estuarial conditions. The close-ringed area which forms the center of the scale in McMurrich's specimens, as well as in the great majority of Fraser River sockeyes (pl. II, fig. 4), designates members of the second group, which have remained in their native stream or lake until their second spring. It presents, therefore, such record as we have of approximately the first year and a half of their life cycle. Plate III, figure 5, represents a scale, enlarged 40 diameters, of a yearling 3¾ inches long, taken in the Fraser River in April, 1903, by J. S. Burcham, working under instructions of Commissioner J. P. Babcock.

The scales in different yearlings captured at the same time and place differ considerably in size of scale and in the number of rings which they contain. Precisely similar variations are found in the nuclear areas of the adult scales, these being larger in some individuals than in others, and containing more numerous rings. Every variety of scale from migrating yearlings can be matched in the close-ringed centers of adult scales, both as regards actual size and in the number and arrangement of the rings. We can entertain no doubt, therefore, that the two have had an identical history. (See pl. II, fig. 4, with center of adult scale enlarged 40 diameters.)

The peripheral part of the scale seldom offers any difficulty. After life has begun in the sea, a regular alternation occurs of bands of widely spaced and of narrowly spaced rings, as shown in plate III, figure 6, the widely spaced rings representing the vigorous growth of spring and summer, the narrow rings the retarded growth of fall and winter. Finally, at the margin of the scale of the mature sockeye about to enter the Fraser are found a few widely spaced rings, indicating that the rapid growth of the summer in which maturity is attained early comes to an abrupt conclusion. This is true in the sockeye in greater degree than in other species of the genus, and may have its explanation in the earlier date at which mature sockeye discontinue feeding. All species of Pacific salmon (the steelhead is not here considered) cease to feed on entering fresh water at maturity, but the sockeye is extreme in this regard. Those bound for the Fraser are already fasting when first encountered along the Vancouver Island shore at the entrance to the Straits of Fuca, where other species are feeding greedily. The sockeyes are then over 100 miles from the mouth of the Fraser and are assuredly at that time not under the influence of fresh water. Fishermen are well acquainted with the fact that the sockeye, unlike the king salmon and the coho, are not to be taken by trolling, even when first they strike the coast.

With these facts in mind, we turn to plate II, figures 3 and 4, which represent a scale typical of a majority of the sockeyes of the Fraser River run. The nuclear area of finely crowded rings contains no record of the first winter after the eggs are laid, but represents the first summer and second winter which were spent in the lake. The broad band of widely spaced rings surrounding the nuclear area was formed in the sea and represents the second summer, thus completing the second year of the cycle. Then follow a narrow winter band of closely spaced rings and a second distinct summer band, constituting the third year of the cycle, and another winter band and the short marginal summer band of the fourth year.

While the majority of the Fraser River run are in their fourth year as shown by the evidence here adduced, a considerable number of them, including all the larger individuals, are just as evidently in their fifth year. The 4-year fish show, outside the nuclear area, three summers' growth and two winters' growth in the sea. The 5-year fish, as shown in plate VIII, figure 14, have just as distinctly, outside the nuclear area, four summers' growth and three winters' growth in the sea. As is given in a later table, there is a wide overlapping in size of the 4 and the 5 year fish, but all the smaller specimens are 4 years and all the larger are 5 years old. The specimens examined and

figured by Prof. McMurrich unfortunately were chosen from among the larger of those to be found on the cannery floor.

The great majority of the Fraser River sockeyes have scales of the type above described, the nuclear area being small, of crowded rings, and sharply set off from the widely spaced summer rings which surround them. As we have shown, these have all developed from fish which migrated seaward as yearlings. A different type is represented by plate XII, figure 22, in which it is seen that the nuclear area is much larger, the rings less closely crowded and widening gradually outward, until in extreme cases they merge almost imperceptibly with the succeeding summer rings. A scale of this type is figured by Prof. McMurrich (pl. III) and is interpreted by him as indicating a fish "which went to the sea as a yearling in the second spring after hatching." But the very reverse would seem to be the case. The large size and more widely spaced rings of the nuclear area indicate that growth in those individuals which spend their first year at sea is much more rapid than in those which remain in fresh water, and this is in accord with the few experiments which have been made with king salmon to determine that point. But more conclusive evidence of the history of these fish is found on comparing their type of scale with the scales of the humpback and dog salmon, which always migrate seaward shortly after hatching and while still in the fingerling stage. The nuclear area of humpback and dog salmon is exactly similar to the sockeye type last described, being comparatively large in size and of widely spaced rings. Furthermore, the king salmon, which migrates seaward partly as fingerlings and partly as yearlings, exhibits the same two types of scale shown by the sockeye, one with a small nuclear area of crowded rings, formed as can be demonstrated during the first year in fresh water, the other similar to the "sea type" of the humpback and dog salmon. While therefore we lack such direct demonstration as could be obtained by marking sockeye fingerlings on their seaward migration and observing on their return that the scales exhibit the "sea type" of nuclear area, there is yet sufficient evidence for the correctness of the theory to warrant us in accepting it.

The possibility of distinguishing throughout their lives those individuals which passed to sea immediately after hatching from those which migrated as yearlings has opened up a wide field of investigation, upon which we have thus far barely entered. A certain practical difficulty is encountered at the outset. In the majority of cases there is no question to which type a given scale belongs. But among those of undoubted "sea type," including humpbacks and dog salmon, as well as certain sockeyes and king salmon, there is found a tendency to the narrowing of a few of the rings immediately surrounding the nucleus, forming a sort of core to the nuclear area. (See pl. X, fig. 17.) The significance of this is in question, but we may perhaps hazard the conjecture that in such a case the individual tarried in fresh water or played back and forth on the tides for an appreciable time, during which growth was less rapid than in the majority which passed directly out to sea. Whatever the cause, this tendency to a slight central narrowing of rings of the nuclear area is of not infrequent occurrence in scales of the sea type, and is occasionally so pronounced as to simulate the smaller and least typical of what we may call for purposes of distinction the "stream nucleus." In a small proportion of

cases this may be the source of genuine doubt as to the early history of the individual and incidentally as to its age. For, if the nuclear narrowing be interpreted as indicating the first year spent in fresh water, the age will be greater by one year than if it be interpreted as the central narrowing of a large nuclear area of the "sea type." It is believed, however, that all doubt of this character can be removed by further investigation. For purposes of a preliminary discussion, like the present, as the doubtful cases are few in number, they can be omitted from consideration.

There is a fair indication—not to be taken as conclusive—that those individuals among the sockeyes which proceed to sea shortly after attaining the free swimming stage experience a mortality far in excess of those which pass to sea as yearlings, but that those of the first class which survive grow much more rapidly the first year than they would have done had they remained in fresh water. To a certain extent they seem to maintain this preponderance in size during succeeding years. In the Fraser River, as already indicated, only a very small proportion of adult fish have developed from young which sought the sea during their first year. Thus out of 625 individuals taken at random, without selection, from the cannery floor, only 35 belong to this group, while 590 had spent their first year in their native waters. So limited a number as 35 forms a wholly inadequate basis for generalizations, but it is worthy of note that 3 of these were grilse, maturing in their third year, 30 were in their fourth year, and only 2 in their fifth. If a larger series shall verify essentially the proportions here indicated it will demonstrate that early migration of the young accelerates growth and also the early coming to maturity, producing a larger proportion of grilse which mature in their third year, and a much greater preponderance of fourth to fifth year fish than occurs among those which migrate as yearlings. The increased size at the same age becomes evident on comparing the three "sea type" grilse above mentioned with "stream" grilse taken on the same date. The former were respectively 23, 23½, 23½ inches long and weighed 4¾ to 5¼ pounds. Sixteen grilse of the stream type taken on the same date (all that were secured) show the following lengths in inches: 17¾, 18, 18, 18⅛, 18½, 18½, 18½, 19, 19, 19¼, 19½, 19½, 19½, 20, 20½. Three of these, 18½, 18½, and 19½ inches long weighed each 2¾ pounds. It is further noticeable that 2 of the 3 grilse of the sea type were females, while among Fraser River grilse of the stream type females are so rare that we have thus far discovered but one among over a hundred grilse examined. This is a matter, however, which may be subject to wide variation in different streams. In the Columbia River, for instance, in 1910, grilse were numerous, and males and females in approximately equal numbers.

In discussing the commercial value of a run the grilse may be omitted from consideration, as ordinarily they are few in number and so small as to have practically no value. The valuable elements of the run are fish which are maturing in their fourth or in their fifth years. It was attempted during the season of 1911 to determine the relative proportions of these two generations, their range in size, and their average weight. In order to simplify the problem as much as possible we have omitted from our list the comparatively few individuals of sea type. In 500 fish of stream type, taken at random from the cannery floor, 271 were 4-year and 229 5-year fish. Of the 271 4-year

fish, 126 were males, 145 females; of the 229 5-year fish, 129 were males, 100 females. The total number of males (255) was but slightly in excess of the total number of females (245). Among 4-year fish the females were decidedly in excess, among 5-year fish the males.

As regards weight, 113 4-year fish taken without selection aggregated 709.25 pounds with an average of 6.27; 104 5-year fish weighed 776.25 pounds, with an average of 7.46. Extremes of weight among 4-year fish were 4.75 and 8, among 5-year fish 5.75 and 8.75.

The following table gives distribution in accordance with their length of the 500 individuals of the stream type in which age was determined, the 4-year males being compared with the 5-year males, and the 4-year females with the 5-year females.[a] At the time the measurements were taken the jaws in the males were seldom strongly hooked, but a preorbital elongation was apparent which accounts in part but not wholly for the greater length of males than of females. The fish were measured over the curve of the body from the end of the rostrum to the tips of the middle rays of the caudal fin. It will be noted that the range in size of the 4 and 5 year fish overlap widely, but the curves are characteristically distinct, the 5-year fish averaging at least 2 inches longer, out of a total range of 5 inches in length for each group. Examination of a larger series of individuals would unquestionably extend the limits of each group by the addition of the exceptionally large and the exceptionally small, but the table as presented doubtless gives correctly the range in size of the vast majority at the time the examination was made. It will be of great interest to compare similar curves prepared for the same river basin in successive years; also curves of the sockeye run in different basins.

FIVE HUNDRED FRASER RIVER SOCKEYES WHICH HAD MIGRATED TO SEA AS YEARLINGS, GROUPED BY SEX, AGE, AND SIZE.

Length in inches.	Males.		Females.		Length in inches.	Males.		Females.	
	4 years.	5 years.	4 years.	5 years.		4 years.	5 years.	4 years.	5 years.
21	.....	.....	.....	.....	26	21	25	2	27
21½	.....	.....	1	.....	26½	11	22	.....	15
22	.....	.....	1	.....	27	4	15	.....	12
22½	2	.....	2	.....	27½	.....	15	.....	4
23	4	.....	11	.....	28	.....	12	.....	2
23½	5	.....	19	1	28½	.....	2	.....	.....
24	13	.....	49	2	29	.....	.....	.....	.....
24½	20	4	27	3	29½	.....	1	.....	.....
25	23	13	22	13					
25½	23	20	11	21	Total..	126	129	145	100

Three-year fish, or grilse, were not included in the above table. During the summer of 1911 they were not numerous. Only a few (perhaps 3 or 4 on the average) could usually be found in each 1,000 fish brought in. It is the current belief among those who handle Fraser River sockeyes that all the grilse are male fish. As previously noted,

[a] Measurements were made August 2–4, 1911, in the cannery of the Pacific American Fisheries at Bellingham, Wash. To the management of this concern we desire to express our grateful appreciation of their uniform courtesy.

all those examined by us were males, with one exception, a female with well-developed ova. Examination of the scales (see pl. 1, fig. 1) shows that the final summer's growth is more extensive in grilse than in those which mature at 4 and 5 years, and the narrowing of the marginal rings to form the third winter band has often begun.

Much larger specimens than those included in the table were selected for examination in an attempt to find individuals older than 5 years. Several were found over 30 inches long, weighing 12 pounds, but all were 5-year fish. Examination of a larger number may possibly bring to light a rare individual which has not matured until its sixth year. Even this is doubtful and we assuredly do not anticipate finding older than 6-year individuals among the Fraser River sockeyes. The significance of the marking experiments of the Bureau of Fisheries in the Naha River, with the reported recovery of marked specimens up to 9 years old, remains to be determined.

If it be true, as indicated in our table, that relatively so large a proportion of Fraser River sockeyes mature in their fifth year, it may appropriately be asked how the enormously increased run every fourth year can be maintained in that river without its benefits becoming gradually distributed through five-year individuals over the intervening years. The great run of 1909 must have developed as 4-year fish from the superabundant eggs deposited by the great run of 1905. But if an almost equal proportion of those eggs should fail to mature until their fifth year, as was true in the 1911 run which we investigated, we should have expected a second great run, characterized by their relatively large size, in 1910. Such increased runs in the fifth years do not occur, and of this we have as yet no explanation to offer. There is some evidence that the fifth years of the cycle are characterized by fish of somewhat larger size than the other "off years," indicating, if true, a larger proportion of 5-year fish, but the total run is not appreciably increased. Certain it is that the fish of the big runs average smaller than those of the intermediate years. This might conceivably be explained by a limited food supply and sharper competition among the enormous schools of that year, but it is more probably due to the practical elimination of 5-year fish. Those 5-year fish present would have developed in their due proportion from the few eggs of an "off year," and would be too scattered to produce any effect among the vast hordes of 4-year olds. But these are matters for further investigation.

KING SALMON, OR CHINOOK (Oncorhynchus tschawytscha).

[Pl. IV–VII: fig. 15, pl. VIII: pl. IX; fig. 18, pl. X; fig. 25, pl. XIV.]

Speculation concerning the age of the king salmon (also called spring salmon, tyee, Chinook salmon, Sacramento salmon) has been encouraged by the enormous range in size which is exhibited by spawning fish. Adult females have been reported as small as 5 pounds, and adult sea-run males much smaller than this, while individuals of from 80 to 100 pounds weight occasionally are seen. No answer has heretofore been given to questions concerning the total range in years represented by these various sizes, nor as to the exact relation of age and size.

A detailed experiment to determine these points was undertaken by Superintendent Hubbard of the Clackamas (Oreg.), station, in 1896. Five thousand young, hatched

from eggs of the preceding fall (1895), were marked by removing the adipose fin, and were then liberated. In 1898[a] Columbia River cannery men reported the capture of some 375 of these marked fish, indicating their return in their third year. Thirty-two are reported, with details of sex and weight. Nineteen of these were females, ranging from 10 to 35 pounds; 13 were males, from 19 to 57 pounds in weight. The average for the 32 is 27.69 pounds, about 5 pounds above the average of all Columbia River salmon of this species.

The following year[b] between 40 and 50 were reported, the average weight said to be nearly 10 pounds greater than of those taken in 1898. And in 1900, by offering a small reward for marks saved and sent in, the Oregon commissioner received 72, with no indication of weight. No further record of the capture of marked fish is contained in the Oregon reports. According to this experiment, it would appear that both males and females may mature in their third year, and that very large fish (57 pounds) may appear among those returning thus early. These results have been accepted by Rutter and others, the evidence appearing on its face unimpeachable, but they are so wholly at variance with results obtained through a study of the scales that we have scrutinized the records with some care. Certain minor inaccuracies are obvious, but the dates are well attested, and the only criticism which seems pertinent is that the commissioner apparently relied wholly on reports from the canneries, and did not personally inspect any of those specimens reported in 1898 and 1899.

Other marking experiments on the Columbia River, made by the Washington Commission at Kalama and Chinook, indicate 4 and 5 years as the age of returning fish, none being recorded in the third year. In the well-known planting experiments in Tomales Bay, Cal., and in New Zealand, both of which resulted in establishing spawning runs in streams which hitherto had not possessed them, no run was reported until the fourth year. In view of these facts and others, we must hold in question the report of the Oregon experiment of a considerable return in the third year of both males and females of large size, in spite of a certain appearance of conclusiveness in the report itself.

The history of the king salmon is known principally from the work of Rutter and Scofield on the Sacramento River, and of Chamberlain in Alaska. The fact is well attested that large numbers of fry pass into salt water in spring or early summer as soon as possible after the absorption of the yolk. Many others, but in unknown proportion, remain behind in the streams and migrate the following spring as yearlings. Whether any of these, which have been somewhat unfortunately termed "summer residents," pass out during the late summer or on the high water of the fall remains unknown, but many if not all of them remain during the following winter. The center of the king salmon scale, which records their early history, is subject to more variation than in the sockeye, and will require longer investigation in connection with young salmon of known history.

[a] Sixth Annual Report Fish and Game Protector of State of Oregon, 1898, p. 48.
[b] Annual Report Department of Fisheries, State of Oregon, for 1899 (1900), p. 15.

In general, king salmon scales exhibit the same two types characteristic of the sockeye—a stream type, with close-ringed nuclear area, sharply set off from the enveloping wide-ringed summer band (pl. IV, fig. 7), and a sea type, of large nuclear area, with less crowded rings, which widen outwardly and usually pass gradually into the rings of the second summer (pl. VII, fig. 13). The nuclear area of the close-ringed stream type agrees with the entire scale of a yearling on its seaward migration in its second spring, and can be safely so interpreted. The nuclear area of the sea type is here interpreted as in the sockeye, as indicative of an early passing to salt water on the part of those individuals which migrate as young fry. A more extended inquiry into this matter must be made before offering data with full conclusiveness, but it may be offered in evidence that young king salmon about 4 inches long taken in Puget Sound in midsummer exhibited the wide-ringed sea type and were in their first year (pl. VII, fig. 12). It may also be noted that on examining a series of larger king salmon (9½ to 17½ inches long) taken in late summer in Puget Sound, all were found to be in their second year, the smaller individuals (9½ to 11½ inches) exhibiting the stream type of nucleus (pl. IV, fig. 7), and the larger members of the series (13½ to 17½ inches) the sea type (pl. VII, fig. 13).

Conspicuous in every spawning run of king salmon are the numerous undersized males, known locally as grilse, jack salmon, or sachems. Two theories have been held regarding these, according to which they have been considered either stunted individuals of equal age with the larger salmon, or younger fish which have matured precociously. The theory of precocious development has had wider currency of late, and is in entire agreement with the evidence from the scales, according to which the individuals are always in their second or third year. The mature second-year fish are smaller than those in their third year, and are usually little in evidence, as they escape readily through the meshes of the nets. None which were mature at this age have been taken by us in Puget Sound. But on the Columbia River, a considerable series of mature males in their second year, 9 to 18½ inches long, were secured from the seines and fish wheels. It will be noted that this range in size agrees with that already given for immature second-year fish from Puget Sound. It is further significant that in the Columbia River series, also, the smaller individuals, 9 and 9¼ inches long, are of the stream type, and the larger, 13 to 18½ inches, are of the sea type.

The larger grilse (19 to 26 inches) are in their third year (see pl. IV, fig. 8; pl. VII, fig. 11), and among them, again, the smaller individuals of the series are preponderatingly fish of stream type and the larger of sea type. But in the third-year fish there is more overlapping of the two types, as though subsequent inequalities in growth had partially concealed the initial advantage secured by those which had early sought the sea. This is a question which merits further investigation on a much larger series than has thus far been examined.

From salt water in Puget Sound we have secured immature third-year fish, both males and females, and also matured third-year males, taken by purse seines from the same school, and both feeding voraciously and equally on small sand lance and young

herring. There was no difference in size between the mature and the immature individuals, nor could they be externally distinguished, unless by a certain distention of the abdomen in mature specimens, due to the developed testes. It became evident from our observations: (1) That a very small proportion of the males of a given year develop precociously; (2) that precocity is apparently not caused by the influence of peculiar external conditions operating upon the individuals thus affected, but by some unknown factor; (3) that precocious development does not stunt the growth. No mature female king salmon less than 4 years old have thus far been encountered.

The commercially valuable portion of the king salmon run consists mainly of 4 and 5 year fish, with less frequent 6-year individuals. Plate V, figure 9; plate X, figure 18; and plate VI, figure 10, represent these three ages. On the Columbia River they are roughly grouped at the canneries as "half salmon" and "full salmon." The half salmon consist very largely of 4-year individuals and the full salmon those 5 and 6 years old, although there is a certain amount of overlapping, as in the sockeye. The 4-year fish include more females than males, and the 6-year fish are males in even greater proportion. It is thus seen that the females are much more uniform in the age at which they mature than are the males, being practically limited to their fourth and fifth years, while males may develop precociously at any age before the fourth year, or may be retarded beyond the usual period. A single male, weighing 67 pounds, observed by Mr. N. B. Scofield in the Sacramento River, was in its seventh year. None larger than this have been examined, although such are known to occur, so the total range of the species may even include 8 years. Anything beyond seven is problematical and beyond eight must be considered highly improbable.

Among the king salmon taken by purse seines in Puget Sound and those taken by trolling in the salt water of Monterey Bay, Cal., are found 4-year-old male and female individuals which are mature, and others of the same size and age which show no activity of the gonads and would not mature until a later year. The same is true of the 5-year-old fish, but the undeveloped individuals of this age are more largely males. It seems evident that the maturing individuals feed together in the same schools with those which are undeveloped and become segregated only when the period arrives for them to seek their spawning stream.

Prof. McMurrich announces, in the recent paper already referred to, that scale and otolith structure indicate mature king salmon to be always 4 years old and the grilse 2 years old. Such a conclusion is on its face highly peculiar and improbable. That certain males should mature in their second year as grilse and all others unanimously pass their third year without precocious development would be highly remarkable. Fully as improbable would be the corollary as regards size in relation to age. As is well known, the larger grilse equal or very slightly exceed the smaller salmon of the regular 4-year series. Prof. McMurrich's contention is again based on his erroneous interpretation of the nuclear area of the scale, taken in connection with the very limited amount of material which he examined. Plate V of his paper indicates a typical 5-year scale of the stream type, the nuclear portion which he designates fresh-water being

correctly so interpreted, but representing the first year and a half of the life cycle and not the first few months only. Plate VI, figure 1, is also a 5-year fish of similar type. Plate VII represents, however, a 4-year scale, the second summer showing an "intercalated check" wholly similar to that characterizing the sockeye scale represented on plate II. But whereas the sockeye scale presents three winter bands outside the "intercalated check," the king salmon scale presents but two, hence the necessity for the author's interpretation of the same structure in two opposite ways, in order that both may appear 4 years old. As already indicated, the sockeye scale presents five years' growth and the king salmon four.

We shall not here enter upon a detailed discussion of accessory bands formed by checks in growth during the summer, especially during the first summer in the sea. Such have been demonstrated by Johnston to occur in the Atlantic salmon and are abundantly represented in any series of Pacific salmon or steelhead scales. Their true nature can usually be recognized without difficulty—as in the specific cases mentioned—by the proportion of the bands in which they occur and often by a wide variation in their appearance in different scales from the same fish. Occasionally, however, they so closely simulate genuine winter bands as to occasion some difficulty and doubt, and may then constitute one of the more troublesome features in the interpretation of large series of scales. But the proportion of doubtful cases is very small and such can be eliminated from the series without danger of affecting disastrously the results.

McMurrich's plate VI, figure 2, represents a grilse in its third year. Here the nuclear area of the scale is abnormal and does not give satisfactorily the history of the first year. Other scales from the same fish would have given this in all detail. But we have to do apparently with a fish of stream type, which spent its third winter (marked second winter) in the sea, and was therefore toward the close of its third year. Its length (approximately 20 inches) is that which we have found uniformly characteristic of third-year grilse of stream type.

SILVER SALMON, OR COHO (Oncorhynchus kisutch).

[Pl. XI; fig. 21, pl. XII.]

The coho agrees with the sockeye and king salmon in having a dual habit during its first year. Certain of the young migrate to sea as soon as free-swimming, others, in unknown proportion, remain in the stream until their second spring. Fingerlings are present in all streams visited by this species throughout the summer, fall, and winter of the first year. If a seaward migration occurs in the fall, it has so far not been demonstrated. In the latitude of San Francisco yearlings are very numerous in all the smaller streams as late as March and April, and are often caught by trout fishermen during the early spring months. They remain in evidence several weeks after the appearance of the fry of the year, and may then be 3 to 4½ inches long, being of the same size and general appearance as yearlings artificially reared in aquaria. Rather suddenly, on some spring freshet, they disappear from the stream. Some in their downward migration are often left stranded in overflow pools along the lower course of the stream.

A scale taken from a migrating yearling (pl. XI, fig. 19) is entirely similar to those of the stream type in the case of the sockeye and king salmon. A few widely spaced rings in the center, representing the late spring or early summer growth of the fry, are followed by closely crowded rings of fall and winter. The outermost of these are often very slender and broken. The number of rings formed during the first year varies widely, perhaps from 10 to 25, the larger number being found in general in individuals of larger growth. In many migrating yearlings the more rapid growth of the new year is apparent around the edge of the winter band (pl. XI, fig. 19), but the rings thus formed in the stream are not nearly so wide as those formed during the same season after reaching the sea. There is thus, surrounding the first year's growth, often an intermediate zone which, together with the surrounding band of very widely spaced rings, represents the second summer's growth. (Pl. XI, fig. 20.) The outer rings of the intermediate zone may even be narrowed, as though a check to growth was experienced at the migrating period. Such an intermediate zone is by no means of universal occurrence.

The further fate of the stream type yearlings is well shown in a series secured in Puget Sound in the month of August, 1910 (pl. XI, fig. 20). These range in size from 6 to 14 inches and wholly parallel the series of yearling king salmon of stream type, 9½ to 11½ inches, with which they were found associated. As they were taken with purse seine in the open sound, the greater number of individuals were sexually undeveloped, but a few males were developed precociously. The precocious males later join the spawning run and have been found associated with it.

We are unable to give any satisfactory account of the fry which run to sea soon after hatching. Chamberlain has reported these in Alaska waters as more numerous than those which descend as yearlings. By analogy we should expect the same to be the case in Puget Sound and California. But neither among the yearlings of Puget Sound nor the adults of this and other regions do we find scales of the sea type in any considerable numbers. Three alternatives seem to confront us. Either (1) the young do not proceed to sea as fry in the southern part of the range of the species, or (2) the fry do not survive in salt water, or (3) unlike the sockeye and king salmon there is no difference in growth during the first year between those which proceed to sea and those which remain in the streams. As bearing on this last point it must be stated that a very few individuals of undoubted sea type have been examined. The matter is one in need of complete investigation. We are of the opinion that the spawning run in Puget Sound and in California is composed of those individuals which spent their first year in the streams, with exceptions so few as to possess no practical significance.

The spawning run has been examined by us in numerous individuals covering the range in size from 17 to 30¼ inches. All of these have been fish in their third year, the scale being shown in plate XII, figure 21. The closely crowded nuclear area represents here as elsewhere the first year and a half spent in fresh water. Outside this are seen the parts representative of the life spent in the sea, consisting of the bands of the second summer, the third winter, and the third summer. Larger specimens should be

examined than any to which we have had access in search of 4-year-old individuals, but such may not be found.

Experimental evidence is thus far largely lacking in Pacific salmon to corroborate inferences we draw from scale structure. But in the coho we have one piece of evidence conclusive as far as it goes. In the midwinter of 1910–11, with the assistance of Superintendent Frank A. Shebley and Mr. W. H. Rich, we marked a certain number of yearlings in Scotts Creek, Santa Cruz County, Cal., by excising both ventral fins. In the spawning run of the winter of 1911–12 several of these returned to the same stream as mature male grilse, with scales clearly in agreement with their known age, having formed a single summer band outside the close-ringed nuclear area and a marginal narrowing for the fall growth. Full-grown fish differ from these only in having completed the winter band and one additional summer band. A more detailed account of this experiment will be given later.

Prof. McMurrich announces the coho adult to be 2 years old. He has here again underestimated by one year the significance of the nuclear area.

DOG SALMON (Oncorhynchus keta).

[Pl. XIII; fig. 26, pl. XIV; pl. XV and XVI.]

Less is known of the life history of the dog salmon than of any of the species thus far considered. Our knowledge of the young is entirely due to Chamberlain, who secured them on their seaward migration as fry, some with remnants of the yolk still attached. They were not associated with larger individuals which could be considered yearlings. As stated by Chamberlain, "records of the occurrence of larger individuals in streams have not been authenticated, and, so far as known, all leave the fresh water as soon as they are able to swim." Records of yearling dog salmon have been made by the writer and by others in the streams of Washington, Oregon, and California, but all such have been founded on incorrect identification of the coho yearlings.

At the time of the seaward migration of the fry no scales have been formed. It is therefore obvious that even the inner rings of the nuclear area give the history of life in the sea and not in the fresh water.

In late April, 1911, we found the fry of this species about 1½ inches long, very numerous about the wharves and shores at Seattle, vigorously feeding on ostracods to the exclusion of other food. In midsummer, fingerlings are to be seen abundantly in the Puget Sound traps. In common with the young of other species they pass along the lead and into the heart of the trap, where they remain until forced to pass through the coarse meshes of the webbing.

The fingerlings of the dog salmon are then conspicuous among the others by their slender, graceful form, the dark blue of the back and the conspicuous black margins of the tail. Plate XIII, figure 23, represents the scale of such a specimen, 6 inches long, taken August 2, 1909, from a trap in the Gulf of Georgia. It will be noted that the rings are widely spaced, indicating much more vigorous growth than is commonly shown by such young of other species as spend their first summer in fresh water. The rings are

slightly narrowed from the center outward to about the twelfth, the outer rings showing again a decided widening. The significance of this midsummer check in growth during the first year is unknown. It is frequently wholly absent, may be present as a bare trace, or may become so well marked as to simulate the nuclear area of an individual of other species which spent its first year in the stream.

But little is known concerning the dog salmon in their second year. Fine-meshed purse seines in Puget Sound, which take so many 2-year-old coho and king salmon, are said now and again to capture dog salmon also, but none have been seen by us. A single mature male in its second year, 21 inches long, was secured at Bellingham August 3, 1910. As the habit of the species is to mature about equally during the third and the fourth years, this young male is properly to be designated a "grilse," precociously developed a year in advance. Plate XIII, figure 24, presents the scale of this specimen. The run of dog salmon has not been adequately observed, as it occurs late in the fall, when most investigators have left the field. Examination of a larger series may well show that precocious individuals (grilse) are as numerous in this species as in the others thus far considered. Whether females as well as males mature in the second year remains to be ascertained.

The series examined by the writer, exclusive of the fingerling and the grilse given above, consists of 58 mature individuals obtained at Bellingham August 2 and 3, 1910, ranging in length from 23 to 35¼ inches. They are so distributed as completely to cover this range in size. From the following table it will appear that the spawning fish are almost equally in their third and in their fourth years; or if there be any preference it is in favor of the third year. The two years overlap from the 26th to the 30th inches, inclusive, a size which seems to include the greater number of males in their third year and of females in their fourth. But the limited number of examples investigated is inadequate to decide this point. A single large male, 35¼ inches long, the largest specimen secured, was in its fifth year.

DISTRIBUTION OF MALES AND FEMALES, BY AGE AND SIZE, IN A NUMBER OF DOG SALMON, CHOSEN AT RANDOM.

Length in inches.	Third year.		Fourth year.		Fifth year.	
	Male.	Female.	Male.	Female.	Male.	Female.
23	1	3	.....	.....	.....	.....
24	1	0	.....	.....	.....	.....
25	2	4	.....	.....	.....	.....
26	5	2	2	0	.....	.....
27	3	0	0	4	.....	.....
28	2	0	3	4	.....	.....
29	5	1	2	1	.....	.....
30	2	0	2	0	.....	.....
31	.....	.....	4	0	.....	.....
32	.....	.....	1	0	.....	.....
33	.....	.....	3	0	.....	.....
35	.....	.....	.....	.....	1	0
Total....	21	10	17	9	1	0

AGES AND LENGTHS OF A NUMBER OF DOG SALMON, TAKEN AT RANDOM WITHOUT SELECTION.

Years.	Length in inches.												
First	6												
Second		21											
Third			23¾	23½	23½	23¾	24	25	25	25	25¼	25¾	25¾
Fourth													
Fifth													

Years.	Length in inches.												
First													
Second													
Third	26	26	26	26¼	26¼	26½	26½	27¼	27¼	27½			
Fourth			26		26¼					27½	27½	27½	27¾
Fifth													

Years.	Length in inches.												
First													
Second													
Third				28¼		28½		29		29½	29½	29½	29½
Fourth	28	28	28	28¼	28¼	28½	28¾		29¼				29½
Fifth													

Years.	Length in inches.												
First													
Second													
Third	29¾	30	30½		31¼	31½	31¾	31¾	32¼	33	33½	33½	
Fourth	29¾		30½	30¾									
Fifth													35¼

In the above table fractions of inches are included with the whole numbers. While the number of individuals under consideration is too limited for safe generalization, it may yet be noted that both third and fourth year females average distinctly smaller than the males of their own age.

In plate XIV, figure 26, and plate XV and XVI, figures 27 and 28, are presented scales respectively of 3, 4, and 5 year fish. The scales of the dog salmon are broader than in any other species, the rings being approximately circular, or even broader than long. The nuclear area is always large, as in the sea type generally, comprising roughly half the diameter of the scale in 2-year-olds. The central portion of the nuclear area is usually of the open wide-ringed type, the outer portion dense (especially so laterally) and ending in a perfectly defined margin, with abrupt transition to the summer growth which follows. Considerable variation is found in the outer half of the nuclear area, but seldom any which could cause confusion. The size of the area is little variable. Only in cases where it presents a double outer band can any question arise. A slight narrowing of rings in the middle of the nuclear area is not infrequently present. Occasionally this is emphasized until the median and the marginal nuclear bands are about equal in development. In such cases irregularities and fusions can usually be found, and the size of the total nuclear area and the subsequent growths can be relied on to determine.

There is usually no narrowing just outside the nucleus to form a "core," but this may be present in a faint form, or occasionally be more pronounced.

Subsequent years' growths are usually about equal, the well-formed winter bands about equally spaced and very strongly marked. Occasional exceptions occur, in which the second summer's growth has been unusually wide and the third summer's growth much less so, with the result that the second and third winter bands are more closely apposed than usual. Such cases must be distinguished from others in which a double second winter band occurs, or an "intercalated check," during the latter part of the summer. In instances of the latter class there are usually irregularities in the development of the redundant band in different scales, also fusions of the two bands here and there. There is also a lack of any very sudden break or change in character of the rings outside a redundant band, and no unconformity in the rings, characters which very generally accompany the new year's growth.

At the 1st of August, when our series of scales were taken, the rings of the outer summer zone had in all cases begun to narrow into the winter band. The great thickness of the winter bands in this species may be in part thus explained. They may represent more than half the year's growth, beginning perhaps in July and continuing until the new year's growth commences at some period in the spring. Material collected at Seattle the last of April, 1911, did not include this species, but in the king salmon smaller individuals had then produced from two to six broad rings of the new growth, and larger ones (from 18 inches up) contained usually no new growth. If this holds also in the dog salmon, the winter bands represent growth at ever-decreasing rate from July to May of the following year, the few wide summer rings representing sudden vigorous growth for but two or three months. This is of course insufficiently established.

Taking the great majority of specimens (in at least 90 per cent), the scales are perfectly typical and schematic, a glance with the aid of a simple lens being adequate to determine the age. This regularity and simplicity is also evident in the humpback salmon, and is in both species to be attributed to the fact that the young all have the same history, proceeding at once to sea, whereas in the other species, as has been shown, a dual habit is found.

Prof. McMurrich's contention that the dog salmon is a 4-year fish, with a nuclear area representing life in fresh water, has already been sufficiently answered. Plate VIII of his article has unfortunately the nuclear area so blurred in reproduction that its character can not be positively determined. If, however, this area was close-ringed "as in the sockeye and spring salmon, a central nucleus surrounded by a zone of fresh-water lines," the scale could hardly belong to the dog salmon. Such a description could not apply to plate IX, which represents obviously a 3-year-old scale, with the medial portion of the first winter band very narrowly divided but the two portions wholly fused at the sides. The significance of the so-called "spawning mark" we do not here discuss.

HUMPBACK SALMON (Oncorhynchus gorbuscha).

[Fig. 17, pl. x; fig. 29, pl. xvii.]

Available data concerning the habits of young humpbacks are derived almost wholly from Chamberlain's observations in Alaska. Like the dog salmon, the humpback young seek the sea as soon as they are able to swim. No yearlings have ever been reported from fresh water. In accordance with this habit, the nuclear area is consistently of the sea type, as in the dog salmon, being large in size and consisting for the most part of rings widely spaced. An inner nuclear core or region of narrowed rings is not infrequently present, and may here also simulate a close-ringed small nucleus of stream type. But the examination of a large series, taken in connection with the known history of the young, satisfies that such is never the correct interpretation.

No young humpbacks in their first year have come under our observation. Those listed by Chamberlain (op. cit., p. 55 to 57) were taken during the summer months and ranged from about 40 to 115 millimeters, the larger individuals being those of late summer. All were undoubtedly in their first year, and would yield interesting results on examination of their scales.

The possibility that the humpback salmon reaches maturity in less time than other species is considered by Chamberlain, who states: "The rapid growth of the young and the biennial occurrence of the species in Puget Sound may be noted in behalf of this belief." This suggestion that the species matures in its second year is wholly substantiated by the evidence of the scales (pl. x, fig. 17 and pl. xvii, fig. 29). A wide-ringed nuclear area of sea type, with its outer portion consisting of a definite winter band, is followed by the band of widely spaced rings representing the second summer's growth. Numerous individuals have been examined, representing all sizes readily secured in a spawning run, and all were uniformly in their second year. Statistics containing sizes of males and females have not been prepared.

Prof. McMurrich's inference from the humpback scales is correct, except perhaps that portion which recognizes in the central area of the scale a record of life in fresh water.

SUMMARY OF RESULTS.

The following conclusions can be drawn from data here presented:

1. The sockeye spawns normally either in its fourth or fifth year, the king salmon in its fourth, fifth, sixth, or seventh year, the females of both species being preponderatingly 4-year fish.

2. The young of both sockeye and king salmon may migrate seaward shortly after hatching, or may reside in fresh water until their second spring. Those of the first type grow more rapidly than the second, but are subject to greater dangers and develop proportionately fewer adults.

3. Coho salmon spawn normally only in their third year. The young migrate either as fry or yearlings, but adults are developed almost exclusively from those which migrate as yearlings.

4. Dog salmon mature normally either in their third, fourth, or fifth years, the humpback always in their second year. The young of both species pass to sea as soon as they are free swimming.

5. The term "grilse," as used for Pacific salmon, signifies conspicuously undersized fish which sparingly accompany the spawning run. They are precociously developed in advance of the normal spawning period of the species. So far as known, the grilse of the king salmon, coho, and dog salmon are exclusively males, of the sockeye, almost exclusively males, except on the Columbia River, where both sexes are about equally represented. The larger grilse meet or overlap in size the smaller of those individuals which mature one year later at the normal period.

6. Grilse of the sockeye are in their third year, of the king salmon in their second or third year, of the coho and the dog salmon in their second year.

7. The great differences in size among individuals of a species observed in the spawning run are closely correlated with age, the younger fish averaging constantly smaller than those one year older, though the curves of the two may overlap.

FIG. 1.—Sockeye scale, × 25. From male, 17¾ inches long, grilse in third year. Bellingham, Wash., July 31, 1911.

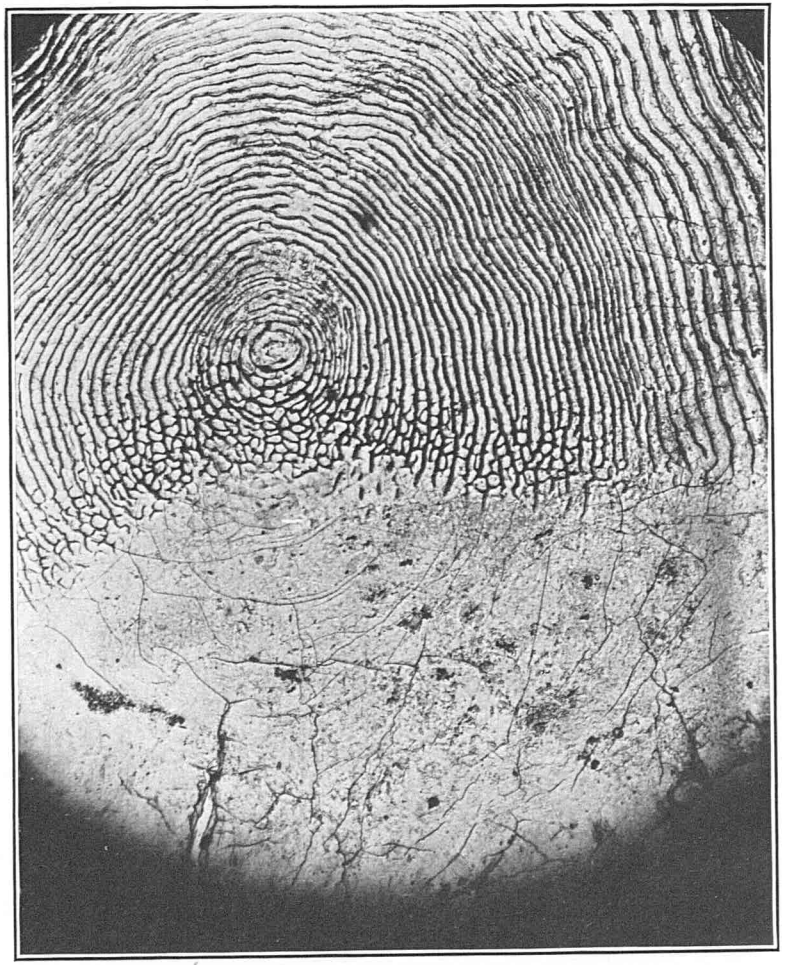

FIG. 2.—Center of scale shown in figure 1. × 40.

FIG. 3.—Sockeye scale, × 25. From male, 25 inches long, in fourth year. Bellingham, Wash., July 31, 1911.

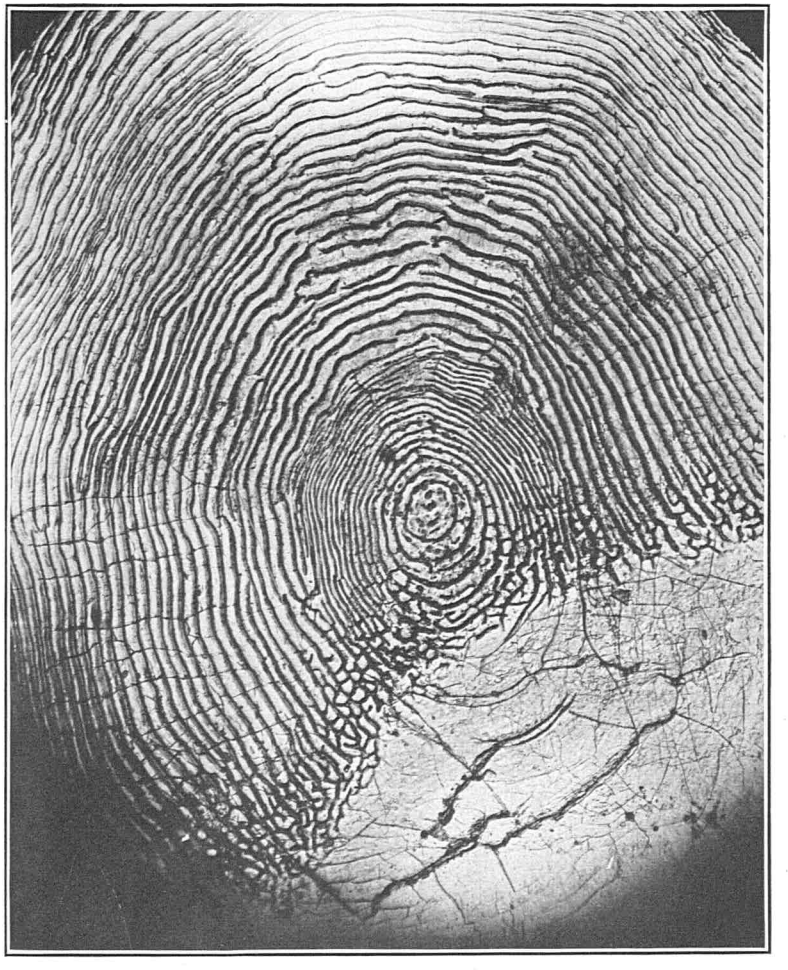

FIG. 4.—Same scale as in figure 3, × 40.

FIG. 5.—Sockeye scale, × 40. From yearling, 3¾ inches long. Fraser River, April 26, 1903.

FIG. 6.—Sockeye scale, × 25. From female, 19¾ inches long, in fourth year. Columbia River at The Dalles, Oreg., July 7, 1910.

FIG. 7.—King salmon scale, × 40. From immature male, 9 inches long, in second year. Everett, Wash., August 16, 1910.

FIG. 8.—King salmon scale, × 25. From male grilse, 21 inches long, in third year. Everett, Wash., August 16, 1910.

FIG. 9.—King salmon scale, × 25. From mature female, 35 inches long, in fourth year. Bellingham, Wash., August 5, 1910.

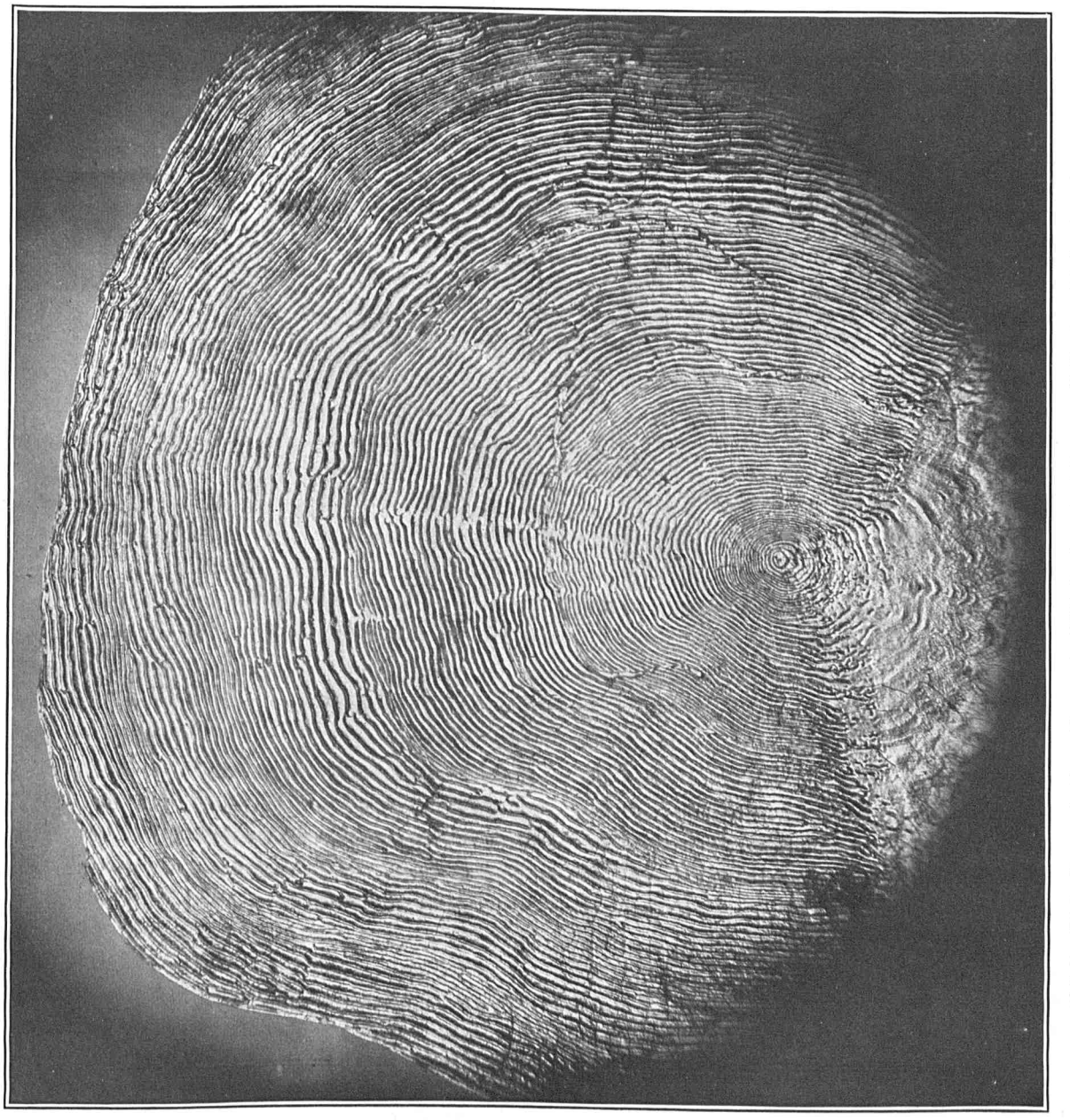

FIG. 10.—King salmon scale, × 20. From male, 48¼ inches long, in sixth year. Bellingham, Wash., August 3, 1910.

FIG. 11.—King salmon scale, × 25. From mature male, grilse, 20½ inches long, in third year. Everett, Wash., August 16, 1910.

FIG. 12.—King salmon scale, × 40. From fingerling, 3¾ inches long, in first year. Friday Harbor, Wash., July, 1909.

FIG. 13.—King salmon scale, × 40. From immature male, 17 inches long, in second year. Anacortes, Wash., August 15, 1910.

FIG. 14.—Sockeye scale, × 25. From male, 27 inches long, in fifth year. Bellingham, Wash., July 27, 1911.

FIG. 15.—King salmon scale, × 25. From mature male, 26 inches long, in third year. Columbia River at The Dalles, Oreg., July 9, 1910.

FIG. 16.—King salmon scale, × 40. Center of scale shown in figure 25.

FIG. 17.—Humpback salmon scale, × 25. From mature male, 25 inches long, in second year. Bellingham, Wash., August 2, 1910.

FIG. 18.—King salmon scale, × 25. From mature female, 39 inches long, in fifth year. The Dalles, Oreg., July 10, 1910.

FIG. 19.—Coho scale, × 40. From yearling, 4⅝ inches long, taken at Swanton, Cal., April 23, 1910, during seaward migration.

FIG. 20.—Coho scale, × 40. From immature female, 9¾ inches long, in second year. Everett, Wash., August 16, 1910.

FIG. 21.—Coho scale, × 25. From mature male, 23½ inches long, in third year. Monterey, Cal., July 3, 1911.

FIG. 22.—Sockeye scale, ×25. From male, 26½ inches long, in fourth year. Bellingham, Wash., July 31, 1911.

FIG. 23.—Dog salmon scale, × 40. From specimen 6 inches long, in first year. Bellingham, Wash., August 2, 1909.

FIG. 24.—Dog salmon scale, × 25. From mature male grisle, 21 inches long, in second year. Bellingham, Wash., August, 1910.

FIG. 25.—King salmon scale, × 25. From mature male, 26 inches long, apparently in third year. The Dalles, Oreg., July 9, 1909.

FIG. 26.—Dog salmon scale, × 25. From mature female, 25 inches long, in third year. Bellingham, Wash., August 3, 1910.

FIG. 27.—Dog salmon scale, × 25. From mature male, 31¼ inches long, in fourth year. Bellingham, Wash., August 2, 1910.

FIG. 28.—Dog salmon scale, × 20. From male, 35¼ inches long, in fifth year. Bellingham, Wash., August 3, 1910.

FIG. 29.—Humpback salmon scale, × 40. From mature female, 22 inches long, in second year. Bellingham, Wash., August 3, 1910.

A NEW SPECIES OF TROUT FROM LAKE TAHOE

By John Otterbein Snyder
Stanford University

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A NEW SPECIES OF TROUT FROM LAKE TAHOE.

By JOHN OTTERBEIN SNYDER,
Stanford University, California.

While engaged under the direction of the United States Bureau of Fisheries in an examination of the fauna of the various river basins that were at one time connected with the quaternary Lake Lahontan, a very remarkable species of trout was observed, which, although known to many sportsmen and fishermen, has entirely escaped the attention of ichthyologists. It is the purpose of this paper to record something of what is now known of its characteristics and present a preliminary description of the species.

Lake Lahontan, which in quaternary times was a large body of water very irregular in shape, extended over a considerable part of northern Nevada. By a shrinkage of the great lake, due to desiccation, a number of its tributary streams became detached and now remain as minor systems. Their waters ultimately disappear through evaporation or by sinking in the loose, dry sand of the deserts, which now cover the floor of the old lake, whose ancient terraces and gravel bars are plainly visible on every side. The largest and most important of these minor basins is that of the Truckee River, including Lake Tahoe and tributary streams, which form its source, and Pyramid and Winnemucca Lakes, into which the river flows, and where its waters are finally carried off by evaporation.

The rivers and lakes of the various basins which belong to the Lahontan system are well supplied with fishes, exceedingly abundant in number although representing but a few species. Of chief interest and value among these are the trout, which appear to have found the most advantageous conditions for growth and development in the Truckee River basin. A résumé of the information obtained from the more intelligent anglers shows that they here distinguish six varieties of native trout. Three forms are recognized in the lower portion of the basin, viz, the large redfish, which in early spring ascends the Truckee River to spawn; the Tommy trout, which is smaller, darker colored, and more conspicuously spotted, and which ascends the river at a later date than the redfish; and the greenback, a deep-water, silvery trout, which occurs in Pyramid Lake, presumably spawning there. Three varieties are distinguished also in the upper Truckee region: The Tahoe trout, dark in color, boldly and regularly spotted, ascending the tributaries to spawn; the silver trout, somewhat similar to the foregoing except that it is decidedly silvery in color, the spots are smaller and somewhat more elongate, and the body is deeper and heavier; and, finally, the royal silver trout, blue above, silvery on the sides, and almost entirely without spots.

In discussing the status of these forms anglers are found to differ considerably among themselves. Some distinguish two, three, or more of them, but none has been interviewed who recognizes all. Concerning the silver trout, it is difficult to find two men who entertain the same opinion. The writer first learned the name "royal silver trout" from Mr. Ralph Lowe, of San Jose, who caught a fine specimen and sent it to Stanford University. This was followed by another, which was presented to the university by Mr. F. K. Pomeroy, a graduate student in the department of medicine, and also by a third, caught by Mr. W. P. Lyon, of San Jose. Each of these was caught near Brockway, on the east side of Lake Tahoe. The collection was further enriched by another example, which had been sent to Dr. C. H. Gilbert by Mr. Charles A. Vogelsang, the fish having been caught somewhere near Tahoe City. It is with these specimens representing the royal silver trout that the writer is at present most concerned.

Ichthyologists themselves have not been altogether unwavering in their discussions of Lake Tahoe trout. It seems, however, to be generally admitted that the Tahoe trout and silver trout belong to the same species, *Salmo henshawi* Gill and Jordan. A recent examination of an additional number of specimens seems to strengthen that conclusion. For the present, at least, the redfish and the Tommy are considered as representatives of that species. The royal silver trout is, however, not to be confused with *S. henshawi*, for it evidently belongs to a distinct and well-characterized species, which may hereafter be known as *Salmo regalis*. This species does not appear to be closely related to either the cutthroat trout (*S. clarkii*, *S. henshawi*, and others) or the rainbow trout (*S. irideus*). The greenback trout of Pyramid Lake probably belongs to the same form.

Salmo regalis is distinguished above all else by its unusual color. A fresh specimen (the writer has not seen a living example) is of a beautiful deep steel blue on the dorsal surface, which in some lights seems to be tinted with olive, the blue extending downward on the sides to about the sixth row of scales above the lateral line, where it abruptly gives place to the most brilliant and highly burnished silver. The silver sheen grows dull on the ventral surface, the chin, throat, and abdomen being dead white. No dark spots are to be seen except on the dorsal and caudal fins, where they are very inconspicuous. No red or yellow color is to be found anywhere except on the cheek, where it glows faintly through the silver. Structurally the species differs from the other native trout, *S. henshawi*, in having a shorter head, a shorter and more rounded snout, a much smaller maxillary, larger scales, narrower and more pointed fins, perfectly smooth basibranchials without teeth, fewer gillrakers. It differs also in other respects, which, together with those enumerated, will appear in the following description:

Salmo regalis, new species.

Royal silver trout.

Head, 4.4 in length to base of caudal; depth, 4; depth caudal peduncle, 9.5; snout, 4.5 in head; length of maxillary, 2.1; vertical diameter of eye, 5.8; dorsal rays, 11; anal, 11; longitudinal series of scales above lateral line, 144; in series between lateral line and middle of back, 29; pores in lateral line, 120.

Body shaped as usual among trout, perhaps somewhat flatter than ordinary, the width contained 2¾ times in the depth near middle of body. Snout short and rounded; maxillary weak, narrow, and short, scarcely extending beyond a vertical through posterior edge of orbit. Opercles and branchiostegals rather thin and papery. Jaws weak; their teeth small and sharp; teeth in bands on vomer and palatines; 2 rows of 5 teeth each on the tongue; basibranchials smooth and without teeth. Branchiostegals, 11. Gillrakers on first arch, 7+12, slender and pointed. Lateral line almost straight from opercle to caudal. Scales very thin, not deeply embedded, moderate in size on the sides, extremely small on middle of back anterior to dorsal fin and on throat and abdomen. Fins all comparatively thin and frail, not like those of trout from mountain streams; pectorals and ventrals sharply pointed; dorsal and anal with slightly concave edges; caudal deeply cleft, the lobes pointed; adipose fin thin, narrow, and elongate.

Color in alcohol, dusky above, silvery on the sides, white beneath; dorsal and caudal fins dusky; anal somewhat dusky toward the border; pectorals and ventrals immaculate; no spots or bars on the head, body, or fins. On close examination the scales are observed to be silvery, those on the dorsal region closely speckled with black, those beneath with but little luster.

The type, which will be deposited in the United States National Museum, is a specimen measuring 323 millimeters in length, collected near Brockway, Lake Tahoe, Cal., August 23, 1912, by Mr. W. P. Lyon.

No external sex differences appear, a male and female being alike in all outward respects. Three of the specimens have 5 rows of small, elongate spots on the dorsal fin, some small spots on the caudal, and a few poorly defined spots on the dorsal part of the body. The latter did not become visible until the specimen had been in alcohol for some time. In the new species the maxillary averages 0.114 of the length to base of caudal; in *S. henshawi*, 0.145, as exhibited by 10 examples from Lake Tahoe, 0.141 in 10 from the Truckee River, and 0.14 in 10 from Pyramid Lake, the sexes being equally represented. The gillrakers differ as follows:

	S. regalis.			S. henshawi.			
Number on upper arch	7	8	9	9	10	11	.....
Number of specimens	1	2	1	10	18	2	.....
Number on lower arch	11	12	13	12	13	14	15
Number of specimens	1	1	2	2	9	17	2

The difference becomes more evident when the entire number on both limbs of the gill arch is taken into account, and this method of enumerating them is the better, as it is usually difficult to determine whether the one at the angle should be included with those above or below.

	S. regalis.			S. henshawi.			
Number of gillrakers	19	20	21	22	23	24	25
Number of specimens	1	1	2	4	11	13	2

Two examples of the new form have 42 and 57 cæca, respectively.

The measurements in the following table are recorded in hundredths of the length measured to the base of the caudal fin.

MEASUREMENTS OF SPECIMENS OF SALMO REGALIS.

Catalogue number	370	371	372	416
Length body ..... mm.	305	225	270	250
Length head	.23	.235	.225	.235
Depth body	.22	.22	.245	.23
Depth caudal peduncle	.095	.09	.10	.095
Length caudal peduncle	.175	.18	.19	.18
Length snout	.05	.05	.05	.05
Length maxillary	.11	.12	.105	.12
Diameter eye	.04	.045	.04	.04
Interorbital width	.07	.07	.075	.08
Depth head	.16	.16	.16	.155
Snout to occiput	.16	.15	.145	.146
Snout to dorsal	.49	.48	.48	.51
Snout to ventral	.56	.54	.52	.54
Length base of dorsal	.12	.12	.14	.13
Length base of anal	.11	.11	.10	.198
Height dorsal	.12	.12	.14	.14
Height anal	.13	.125	.13	.12
Length pectoral	.15	.15	.16	.15
Length ventral	.12	.12	.14	.125
Length caudal	.20	.20	.22	.22
Dorsal rays	10	10	11	10
Anal rays	11	11	11	11
Pectoral rays	14	14	.....	14
Scales lateral series	152	153	144	150
Scales above lateral line	30	31	29	29
Branchiostegals	12	13	11	12
Sex	♀	.....	♂	.....

Specimens of this species are not often taken, and they seem to be growing less common from year to year.

DESCRIPTION OF A NEW DARTER FROM MARYLAND

By Lewis Radcliffe and William W. Welsh

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DESCRIPTION OF A NEW DARTER FROM MARYLAND.

By LEWIS RADCLIFFE and WILLIAM W. WELSH.

There are about 15 known species of darters belonging to the genus *Hadropterus*. Of these only two (*H. peltatus* and *roanoka*) have been reported east of the Alleghenies and north of the Carolinas. In North Carolina, *H. evides*, which is common west of the Alleghenies, here occurs on the Atlantic slope. The range of *H. nigrofasciatus* extends from South Carolina to Louisiana. The remaining species are found in the Mississippi Basin, Great Lakes, and southwestern streams. The members of this genus are active, graceful, and usually of brilliant coloration.

The examples of the new species herein described were seined in Swan Creek, near Havre de Grace, Md., in water 6 inches deep, on a long, stony riffle, where the bottom was comparatively free from bowlders and the current so swift that one would not have expected to find fishes of any kind.

Hadropterus sellaris, new species.

Dorsal XI–11,i; anal II,8,i; pectoral 14; scales 5+6–46 (+3).

Head 3.66, considerably broader than deep, parietal region rather depressed; body slender, fusiform, not markedly compressed, greatest depth 5.09; caudal peduncle slender, as long as head, its depth 2.75 in its length; eye 3.67, subcircular, dorso-lateral; snout 3.14; interorbital very narrow, 2.4 in diameter of eye; mouth rather wide, terminal, lower jaw included; maxillary 2.82, reaching nearly to vertical from anterior margin of pupil, premaxillaries not protractile, the broad frenum connecting them with the skin of the forehead without groove; teeth small, vomerine and palatine teeth present.

Spinous dorsal low, fourth spine longest, 2.20 in head; second dorsal somewhat higher, second ray longest, 1.80; distal edge of caudal emarginate, anal low, sixth ray longest, 1.83; ventrals 1.21, rather widely separated at base, tips of spine and anterior rays expanded, adipose; pectorals broad, slightly longer than head, reaching to behind the vent, tips of lower rays expanded, adipose.

Opercle and cheeks to below middle of eye scaled, rest of head naked, back in front of dorsal, breast, and belly naked; scales large, regular in arrangement, about as deep as long, the free portion with a submarginal row of well-developed spinules; lateral line nearly straight, not arched anteriorly.

Color in alcohol: Ground color light smoke-gray, becoming white on ventral surface; back crossed by four black saddles with light margins, broadest dorsally, narrower than interspaces, the first extending across back in front of spinous dorsal downward to base of pectoral, the second, lying between base of next to last dorsal spine and origin of second dorsal, extends downward and forward below lateral line; the third, from sixth to last dorsal ray, extends downward and forward to within two scales of base of anal; the fourth, crossing back in front of base of caudal, extends downward and slightly forward to

ventral surface of caudal peduncle. Lying below the lateral line, and alternating with the black saddles are four black quadrate blotches, the last being on base of caudal. Several scales on either side of base of spinous dorsal between first and second saddle black. Dorsal spines with a few dusky or black markings; the soft dorsal crossed by three rows of blackish spots, these confined to the rays; caudal with dusky mottlings; anal and ventrals white; pectoral crossed by five more or less concentric rows of blackish spots; axil white. Opercle and top of head dusky, a black spot behind eye, a black bar in front of eye, a second below eye, and a third from upper margin of pupil to interorbital, apparently a continuation of the second.

In life the reddish-brown ground color and jet-black saddle markings present a very striking appearance.

Type: Catalogue no. 74346, United States National Museum, 4.9 cm. in length, from Swan Creek, Md., May 2, 1912.

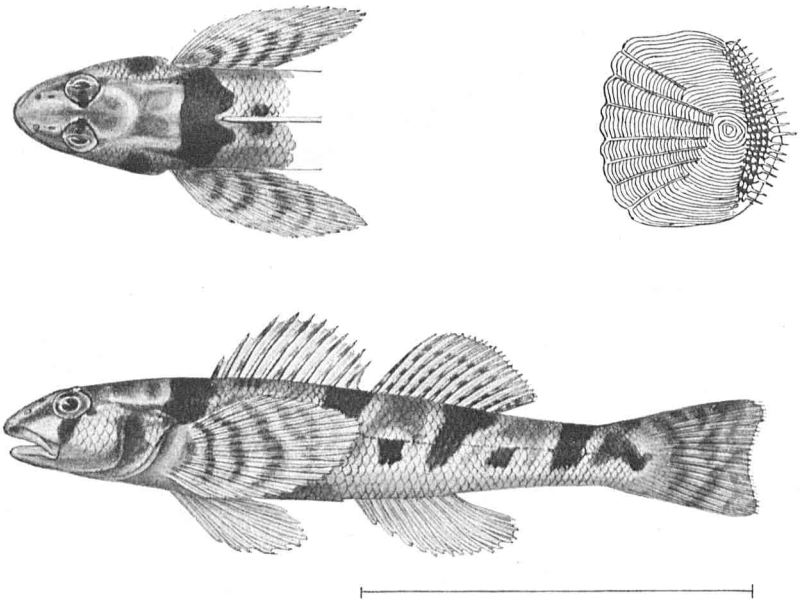
The cotype, 4.9 cm. long, agrees with the type in the form of fins, scaling, and coloration; and has dorsal X–II,i; anal II,8,i, pectoral, 14, scales, 5+9–50 (+3), head, 3.66; depth, 5.17; length of caudal peduncle equal to maxillary, 2.82, interorbital, 2.38 in eye.

The differences between *H. sellaris* and *H. peltatus*, the only other species whose range coincides, may be seen from the following comparative table, based on the type and cotype of the new species and on 6 specimens of *H. peltatus* from Mattapony River, Va. (No. 69716, U. S. National Museum).

COMPARISON OF MEASUREMENTS OF HADROPTERUS SELLARIS AND H. PELTATUS.

Items.	Hadropterus peltatus.						H. sellaris.	
Total length	6.55 cm.	5.5 cm.	5.0 cm.	5.0 cm.	4.9 cm.	4.7 cm.	4.9 cm.	4.9 cm.
Dorsal formula	XIV–12,i	XIII–13,i	XIII–12,i	XV–11,i	XIII–12,i	XIII–11,i	XI–11,i	X–11,i.
Anal formula	II,9	II,9	II,8,i	II,8,i	II,8,i	II,8,i	II,8,i	II,8,i.
Scales	6+9–56	5+8–57	6+10–52	6+10–53	5+9–55	6+8–57	4+6–46	5+7right[a]–50
Eye in head	3.47	3.47	3.12	3.37	3.31	3.43	3.67	3.55.
Snout in head	3.47	3.90	3.86	3.93	3.87	4.48	3.14	3.14.
Maxillary in head	3.12	3.20	3.05	3.11	3.05	3.22	2.82	2.82.
Interorbital in head	6.24	6.25	5.50	5.90	5.52	5.15	8.80	8.46.
Interorbital in eye	1.80	1.80	1.62	1.75	1.66	1.50	2.40	2.38.
Interorbital in snout	1.80	1.60	1.43	1.50	1.43	1.15	2.80	2.69.
Pectoral in head	1.27	1.10	1.16	1.12	1.16	1.03	.92	.92.

[a] Left side, 9.



Hadropterus sellaris, new species.

THE SENSE OF SMELL IN FISHES

By G. H. Parker and R. E. Sheldon

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THE SENSE OF SMELL IN FISHES.

By G. H. PARKER and R. E. SHELDON.

INTRODUCTION.

That fishes scent their food in the water much as many land animals do in the air is a belief that is held by many fishermen. This opinion has led to the practice of chumming or baiting up; i. e., of spreading bait in a region preparatory to fishing it, a practice that, in the case of sharks, mackerel, and bluefish, seems to be justified by the results. Such practice is based on the assumption that fishes have a sense of smell, but this opinion has been unsupported by physiological evidence, for up to the present time investigators of the subject have not been able to demonstrate any form of stimulation or reaction characteristic of the olfactory apparatus in water-inhabiting vertebrates. The observations of Aronsohn (1884, p. 164) that a goldfish which ordinarily will eat ant pupæ with avidity will not take these pupæ after they have been smeared with a little oil of cloves, are not conclusive evidence that the fish scents the oil, for it is entirely possible that this oil merely irritates the skin of the fish's snout and does not stimulate the olfactory apparatus at all. Nor is the discovery made by Steiner (1888, p. 47), that the spontaneous appropriation of food by the shark *Scyllium* ceases on the removal of the cerebral lobes or simply on cutting the connections between these lobes and the olfactory bulbs, satisfactory evidence that the olfactory apparatus in these fishes is an organ of smell rather than a receptor for taste or some closely allied sense.

Nagel (1894, p. 184) noted that the rostral portion of the head of *Barbus* was as sensitive to sapid substances after the olfactory tracts had been cut as before that operation, and Sheldon (1909, p. 291), studying the dogfish, demonstrated that the decided sensitiveness of the nostrils of this fish to weak solutions of oil of cloves, pennyroyal, thyme, etc., was not influenced by severing the olfactory crura, but disappeared on cutting the combined maxillary and mandibular branches of the trigeminal nerve. Evidently the nostrils of fishes, like those of the higher vertebrates, are innervated by fibers from the trigeminal nerve, and it is this nervous mechanism rather than the olfactory apparatus that is stimulated by the substances that have ordinarily been applied by experimenters. In fact, so far as the olfactory apparatus of the fishes and amphibians is concerned, we must agree with Nagel (1894, p. 61) that no one thus far has discovered anything positive concerning its function. It is, therefore, a matter of interest to record what seem to be unquestionable reactions dependent upon the olfactory apparatus of three of our common fishes: The fresh-water catfish (*Ameiurus nebulosus*),

the smooth dogfish (*Mustelus canis*), and the killifish (*Fundulus heteroclitus*). The work on *Ameiurus* and *Fundulus* was done by G. H. Parker, that on *Mustelus* by R. E. Sheldon.

EXPERIMENTS WITH AMEIURUS.

Ameiurus nebulosus is a bottom-feeding fish possessing fair powers of sight and unusual gustatory organs located not only in the mouth and on the general outer surface of the body, but especially on the eight barblets about the mouth (Herrick, 1903). It is a hardy fish, living well in confinement and undergoing operations with success. It possesses near its anterior end a pair of nasal chambers, each of which is provided with two apertures, one anterior, the other posterior. The anterior aperture is nearly circular in outline and is located on a slight conical elevation somewhat anterior to the root of the dorsal barblet. The posterior aperture is slit-like in form and lies immediately posterior to the same barblet. The anterior aperture is apparently always open; the posterior one seems capable of slight closure, but is usually freely open.

By keeping catfishes a few days without food they can be made most eager for it, and if into an assemblage of such individuals a few fragments of fresh earthworms are dropped, the excitement that ensues will last some time after the final piece of worm has been swallowed. During this period the fishes swim about actively in the lower part of the aquarium, now in this direction, now in that, and frequently sweep the bottom with their barblets. As can be noticed when feeding actually occurs, the fishes seldom seize a fragment of worm until their barblets have come in contact with it. Yet before they have thus touched any food they show a marked degree of excitement and it is this initial nervous state that would lead an observer to suspect that they scented their food. This phase of their activity was, therefore, taken as the one to be tested in connection with their olfactory organs.

The nasal chambers of the catfish contain ciliated epithelium, the action of which is to draw water in at the anterior olfactory opening and discharge it at the posterior one. As can be demonstrated with carmine suspended in water, the passage through the chamber is accomplished in 8 to 10 seconds.

As a preliminary step in testing the catfishes, five normal fishes were placed in a large aquarium over night that they might become accustomed to their surroundings. In this aquarium were then hung two wads of cheesecloth, in one of which was concealed some minced earthworm. The fishes, which were swimming about near these wads, were then watched for an hour and their reactions in reference to the wads were recorded. The wad without worms was passed by the fishes many times and did not excite any noticeable reaction. The wad containing the worms was seized and tugged at eleven times in the course of the hour, notwithstanding the fact that from time to time this and the other wad were interchanged in position. Not only did the fishes thus openly seize this wad, but when in its neighborhood they would often turn sharply as though seeking something without success, a form of reaction seldom observed near the wad which contained no worms. Two other sets, of five normal fishes each, were tested in this manner and with similar results. It was perfectly clear to anyone watching

these reactions that the fishes sensed the difference between the wad of cloth with worms and that without worms.

To ascertain what receptive organs were concerned in the reactions just described, two sets of 5 fishes each were taken from among the 15 normal fishes already tested, and each set was prepared differently by subjecting its members to a special operation. One set was etherized, and, through a small incision between the eyes, their olfactory tracts were cut, thus rendering their olfactory apparatus functionless. From fishes of the other set all the barblets were removed, whereby their external gustatory organs were partly, though not wholly, eliminated. After these operations both sets of fishes were liberated in the large aquarium, where they remained for over two days. At the expiration of this time, they were carefully inspected and tested. They swam about in an essentially normal way and members of both sets snapped bits of worm from the end of a hooked wire much as a normal fish does. Presumably they were in a satisfactory condition for experimentation.

The tests were begun by introducing into the large aquarium containing the 10 fishes a wad of cheesecloth within which were hidden some minced earthworms and recording the kind of fish that visited it and the nature of their reactions. During the first hour the wad was seized 34 times by fishes without barblets but with normal olfactory organs and, though often passed by fishes with cut olfactory tracts, it was "nosed" only once by one of these. A wad of cheesecloth without worms was next substituted for that with worms and the reactions of the fishes were recorded for a second hour. Though members of both sets frequently swam by this wad, none at any time during the hour seized it or even nosed it. These tests were repeated on the same fishes for two succeeding days and with essentially similar results. On the second day the wad with worms was seized 16 times during the test hour by fishes with normal olfactory organs and on the third day 54 times. On both these days the fishes with their olfactory tracts cut made no attempts on the wad with worms nor did any fish at any time nose the wormless wad. The movements of the two sets of fishes when in the neighborhood of the wad containing minced worms were characteristically different. The fishes with their olfactory tracts cut swam by the wads without noticeable change; those without barblets, but with their olfactory apparatus intact almost always made several sharp turns when near the wad as though seeking something, and then either moved slowly away or swam more or less directly to the wad and began to nose and nibble it. These reactions were so clear and so characteristic that when taken in connection with the conditions of the fishes, they lead inevitably to the conclusion that the olfactory apparatus of the catfish is serviceable in sensing food at a distance much beyond that at which the organs of taste are capable of acting; in other words, catfishes truly scent their food.

EXPERIMENTS WITH MUSTELUS.

The experiments here recorded were performed on the smooth dogfish, *Mustelus canis* (Mitchell). This was selected owing to its great abundance in Buzzard's Bay near Woods Hole, and also because previous experimentation (Sheldon, 1909) rendered many of its habits and reactions familiar.

Bateson, Nagel, and others believed that selachians recognize their food through the sense of smell; their evidence is, however, valueless in this connection owing to the fact that irritating substances were used as tests, or else no distinction between smell and other chemical senses was made. Mr. Vinal Edwards, collector for the Woods Hole Laboratory of the Bureau of Fisheries, states that it is the custom in fishing for dogfish to throw out in the tide lines baited with menhaden or alewives. For a time no dogfish will be seen, then they will appear in numbers, swimming around the bait in gradually diminishing circles until finally it is seized. Field (1907) finds that the dogfish carefully search the bottom for crabs. Finding one they turn on their sides to seize it, then dart off quickly, shaking the crab as a terrier would a rat. After swallowing the food, Field states that the dogfish keeps up its active swimming, often returning to the place where the crab was found.

Some experiments on the relation of the olfactory apparatus of the dogfish to its feeding habits were undertaken in the summer of 1908, but failed owing to the fact that the fishes refused to eat in captivity. These experiments and those of Field show that dogfish will not eat if kept in large tanks or even in the large cod cars of the station, even though they are kept in captivity to the point of emaciation. In order, therefore, to give them a habitat comparable to the normal, a portion of the large observation pool of the station was fenced off with meshed wire. This gave a pool 24 feet long, 8 feet wide at one end, and 10 feet wide at the other, with normal sea bottom, an irregular stone wall on three sides, and a depth of water of from 2 to 8 feet, depending on the portion of the pool considered and the height of the tide. Tufts of eelgrass, together with many other varieties of sessile marine life, grew on the botttom and sides. The pool, therefore, fulfilled to a reasonable degree the conditions of normal life, so far as the dogfish are concerned.

The individuals used were those caught in the traps from day to day and placed in the pool for a period of 10 days in order to bring about a state of hunger.

Spider or blue crabs were first offered the dogfish, but were always refused. The rock crab, *Cancer irroratus*, was next tried, with success, and used for all the experimental work. All experiments were conducted at low tide, when it was easy to observe the actions of the individual fishes. At first living crabs were used. These were found by the dogfish in from 10 to 15 minutes. Next, crabs were killed and a hole broken in the carapace, exposing the flesh. Such were found in from 2 to 5 minutes. These results suggest at the start that the food is recognized through the diffusion of animal juices into the water. Crabs killed, with the flesh thus exposed, were used for all further work.

In a total of about 40 experiments the method of feeding was the same in all cases. The dogfish spent most of the time swimming lazily around the pool, usually close to the sides. Now and then the direction was reversed, but at no time was there observed any search over the bottom or the rocks forming the sides of the pool. When a crab was placed in the pool, a few minutes was required, as noted, before any evidence of stimulation was to be seen. Then one of the dogfish which happened to be swimming within 3 or 4 feet of the crab seemed suddenly startled. It turned very quickly, and

swimming with quick, nervous motions, instead of the calm, lazy movement of the unstimulated fish, began a systematic search over the bottom, investigating particularly grassy or uneven spots. The head was moved rapidly from side to side as the fish swam slowly, coursing, in gradually diminishing circles, 2 or 3 inches from the bottom. When within 2 or 3 inches of the crab the dogfish seized it suddenly, making off in a swift rush. As remarked by Field, the crab is shaken violently from side to side for a moment, as the shell is crunched and broken by the powerful jaws of the fish, after which it is quickly swallowed. Occasionally, however, the crab is dropped during the process; when this occurs, a search similar to the first follows until it is found again.

At no time did the dogfish appear to make any use of the sense of sight in feeding. A crab hidden in eelgrass is found as quickly as one lying on the open bottom; moreover, one is found with equal promptness whether lying on its venter, exposing the dark carapace, or on its dorsum, with the light-colored venter showing conspicuously. A dogfish, dropping a crab, is apparently unable to find it again excepting by means of the same sense which enabled recognition of food in the first place. It was observed, however, that a dogfish with food is usually followed by others in the vicinity, which endeavor to secure possession of it. Moreover, the fish will frequent for some time thereafter the region of the pool in which food was found. This is probably due to olfactory stimuli, although sight may be brought into play to a slight extent. It was often noted that a dogfish would circle around the spot where a crab had lain, often biting into the bottom at the exact spot; probably some body juices had escaped into the ground. Now and then a crab was placed on the bottom near the screen separating the experimental from the larger pool. If no fish capable of finding food were present in the former, it would often happen in a few minutes that 8 or 10 dogfish from the large pool would be swimming rapidly back and forth along the screen, endeavoring to find their way through.

Some experiments were tried with a hook and line baited with the flesh of a rock crab tied in cheesecloth. The dogfish here follow the same procedure as when the crab lies on the bottom. On noting the proximity of food the fish begin to swim, as before, in circles, but for a time persistently search the bottom beneath the baited hook. At length they gradually rise, turning somewhat sidewise, as stated by Field, to seize the bait. When the food is lying on the bottom this sidewise turning was never observed

Observation of the feeding habits of the dogfish would indicate, then, that it recognizes its food through some chemical sense. To test this the following experiments were performed:

Some fresh eelgrass was secured and two packets, closely resembling each other, were made, one containing a small stone, while the other inclosed a crab. Both were so tied that when placed in the water a foot apart a portion of the grass rose toward the surface, giving an appearance similar to the grass of the pool. In three sets of experiments the presence of food was detected in an average time of three minutes, the packet found by the usual procedure, torn apart, and the crab eaten. At no time did the packet containing the stone receive the slightest attention.

Next two packets of white cheesecloth of a similar size and appearance were made up. One of these contained a stone, the other a crab. This experiment was repeated four times on different days. The packet containing the crab was found in each case in from 3 to 5 minutes, while the one with the stone was never molested. The two packets were placed from 10 inches to 3 feet apart. Once or twice a dogfish which had eaten a crab would return and, circling about the spot where the crab had been found, would approach the packet containing the stone in an inquiring sort of way but at no time touched it. The packet containing the crab was always shaken and bitten until the food could be removed and eaten.

A crab was killed and a piece of white cheesecloth saturated in its juices. This was then attached to a small stone. In two experiments the presence of a food substance was noted in two minutes. The stimulus was located by the usual circling method and the stone, with its saturated cloth, seized again and again and shaken violently. After a half hour the fish took no further notice of it, probably because of a complete diffusion of the juices in the water.

In all the above experiments a number of different sets of dogfish were used. There were usually from 6 to 8 fish in the pool at a time. Normally only one or two experiments a day were performed, in order that there be no interference between them.

These observations show beyond doubt that the dogfish obtains its food through the use of a chemical sense. Experiments were now undertaken to find out what part the olfactory apparatus plays in these reactions.

Four dogfish which had eaten readily when in the normal condition were removed from the pool and their nostrils stuffed with cotton wool; in two of the cases the cotton was covered with vaseline. When returned to the pool such fish rush about violently for a few minutes, as do all dogfish which have been out of water. They soon, however, quiet down and swim about the pool as do the normal fish. Twenty-four hours later three crabs were placed, an hour apart, in the pool, which now contained, in addition, four normal fish. All were found, in the usual manner and length of time, by the fish without cotton in the nostrils. At no time did any of the individuals with the nostrils filled show the slightest interest in the crabs, although such often swam within a few inches of the food. Moreover, these fish made no attempt to follow those which had secured one of the crabs, although the food was occasionally dropped. It was often observed that two dogfish, one normal and the other with the nostrils filled, would be swimming along the wall side by side when they approached the vicinity of the crab; the normal fish would then make the usual sudden turn to search for food, while the individual with the cotton continued on its way with no change in the lazy swimming movement. As it was noted that vaseline or a close packing of the nostrils with cotton caused suppuration in time, this experiment was repeated three times with the cotton loosely packed. Results similar to the above were secured in all cases. Two tests were made, also, in which there were no normal fish in the pool. In these cases the crabs were left untouched for 24 hours, although the dogfish on the opposite side of the screen became much excited.

Three of the dogfish, all of which had eaten readily before the use of the cotton, but which had refused to do so thereafter, although tested for three successive days, were removed from the pool and the cotton withdrawn from the nostrils. These were returned to the pool, which now contained no normal fishes. The following day one of these ate readily in the usual manner, although there seemed to be slightly more difficulty than usual in finding the crabs, both in the first place and after one had been dropped. A day or two later all three ate as usual. This experiment was repeated twice with the same results.

These experiments indicate that the dogfish normally recognize the proximity and location of food through the use of the olfactory apparatus. It may be argued, of course, that the mere presence of the cotton in the nostrils renders the fish so uncomfortable that it refuses to eat, even though it act otherwise in a perfectly normal manner. To obviate this objection four dogfish were removed and one nostril only stuffed with cotton. These four only were now placed in the pool. One of these, within an hour thereafter, caught a crab after the usual preliminary procedure, but lost it and then seemed to take no further interest in the matter. The following day all four ate as usual. It was noticed in this experiment, also, that the dogfish had rather more difficulty than normally in finding the food, but that this wore off in a couple of days. These four fish were removed after four days, and seven others, fixed in the same way, were substituted. The results were the same. These tests show that the presence of the cotton is not sufficiently irritating to interfere seriously with the normal feeding habits of the dogfish. As remarked earlier, individuals with the nostrils plugged act, except in so far as the feeding habits are concerned, just as do the normal fishes. As both kinds swim about the pool, such could not be identified by an uninformed observer.

The nasal apparatus of the dogfish consists of a pair of large capsules, partially divided into two parts by means of a superficial and inclosed flap of skin rostrally and a fleshy ridge caudally. There are thus two incompletely separated apertures, a rostrolateral and a caudomedian, the latter closer to the mouth. (See Sheldon, 1909, fig. 3.) The capsules contain a double row of lamellæ, extending laterally from a median ridge much as do the barbs from the rachis of a feather. This ridge extends from the more lateral to the more medial opening. The lamellæ are innervated by an enormous number of short olfactory nerve fibers which terminate in the large olfactory bulbs, closely apposed to the capsules. The nervus terminalis of Locy also sends a few fibers into the lamellæ, while the capsules, in general, are innervated for tactile and general chemical sensation by the nervus maxillaris trigemini.

During the ordinary movements of respiration, as water is taken into the mouth, a current is, by suction, drawn through the nostrils, entering the more rostral and leaving at the more caudal aperture, to be drawn farther, to some extent, into the mouth. This may be easily demonstrated by fastening a dogfish on its dorsum and expelling, from a pipette, a colored solution rostrally of the nostrils. The current, then, follows the median ridge, a part being diverted laterad between the lamellæ. The shape and

position of the fleshy ridge and flaps of skin are such, also, that a fish in forward locomotion forces water through the nostrils. A dogfish is, therefore, whether in motion or at rest, constantly receiving through its nasal capsules a current of water.

EXPERIMENTS WITH FUNDULUS.

The olfactory apparatus of the killifish, like that of the catfish, consists of a pair of sacs each provided with two apertures, one anterior, the other posterior. The anterior olfactory aperture is just above the upper lip and dorsal to the angle of the mouth. It is a small roundish opening not unlike one of the pores of the lateral line system and is on the summit of a low elevation. The posterior aperture is an elongated slit somewhat dorsal to the anterior limit of the eyeball. The mouth of the posterior aperture is partly occupied by a valve-like fold of skin.

If the quiescent head from a freshly killed *Fundulus* is examined in water, no motion is observable about the olfactory apertures. Suspended carmine is not carried into them nor discharged from them; in other words, there is no evidence of a ciliary current passing through the olfactory sacs such as is so easily demonstrated in the catfish. If a head in which the respiratory movements of the gills are still in progress is examined, well-marked currents can be demonstrated in the olfactory organs. Suspended carmine is taken in at the anterior aperture and discharged from the posterior one. With each respiratory movement, the valve in the posterior aperture opens, a small amount of water is discharged, and it then closes. This passage of water through the olfactory apparatus is apparently due to the changes of pressure produced by the rhythmic activity of the muscles of the gills probably acting in conjunction with valves within the olfactory sacs. The movement of the valve at the posterior aperture follows exactly that of the respiratory apparatus and its automatic character is obvious from the fact that if an anterior aperture in an active fish is closed by having its walls stitched together so that no current of water can enter the sac at that point, the posterior valve of the same side ceases to pulse, though that of the other side continues in normal activity. If, now, the closed aperture is reopened by removing the stitches, the valve previously quiescent begins again to pulse. Thus, though *Fundulus* has no continuous current through its olfactory sacs, such as the catfish has, it does have a well-developed intermittent current that is not inappropriately designated as respiratory, though this current is in no direct way concerned with the respiratory function. Apparently as long as the gill muscles of *Fundulus* carry out the respiratory movements, currents of water run through the olfactory sacs.

As a preliminary test to ascertain whether *Fundulus* could discover hidden food or not, packets of cotton cloth containing dogfish meat wrapped so as not to be visible and packets made of nothing but cotton cloth were hung in an aquarium in which there were a number of hungry *Fundulus*. After the packet had been thoroughly soaked in the sea water, the reactions of the fishes to them were watched. The packets without meat were occasionally approached and seized, but soon dropped. Those that contained meat were sooner or later surrounded by most of the killifish, which carried

on a vigorous competition as to which would have possession of the packet. Frequently the first comer would not only seize the packet and tussle with it, but would often attempt to drive off other fish that had approached the region, attracted apparently by the movements of the first fish. These preliminary tests showed quite conclusively that the normal killifish responds very quickly and in a characteristic way to hidden food.

It was also quite evident from these tests that the killifish, in strong contrast with the catfish and dogfish, uses its eyes as well as its chemical senses in seeking and retaining its food. If a small piece of dogfish flesh is dropped into an aquarium in which there are hungry killifish, one is almost sure to pounce upon the fragment and swallow it quickly. This action is so sudden and begins when the fish is at such a distance from the bit of flesh that it is evidently controlled through the eye. That it is not entirely so, however, is seen from the fact that if a small ball of filter paper is thrown into the water, this too is pounced upon and taken into the mouth but soon discharged. Thus the sight of an object must be followed by an appropriate stimulus of smell or taste, if the object is to be swallowed.

It is the eye, apparently, that leads killifish to swim to a packet of plain cloth and seize it, even though it contains no food. The fact that the fishes do not remain about such a packet long, however, shows how clearly they distinguish it from a packet in which meat is hidden and around which they will gather and tussle for long periods of time. The use of the eye in the preliminary steps of search for food is shown in the amusing habit that these fish have of chasing drops of water down the glass face of an aquarium as if they were bits of food. The eye, then, in *Fundulus* is serviceable in the initial stages of procuring food, but whether the material is to be persistently nibbled and finally swallowed depends, as the preceding tests show, on senses other than sight.

The part played by the olfactory organs in reactions to hidden food can be determined by first eliminating these organs and then testing the fishes. The olfactory apparatus can be rendered inoperative by cutting the olfactory tracts in a position where they are easily accessible as, for instance, between the eyes. In this situation a small incision can be made through the thin bony roof of the skull and the two tracts can be cut by a single movement of a narrow blade. Twenty-four hours after such an operation the fish were fully active, took food, and in all obvious ways seemed normal. When two packets of cloth, one with dogfish meat hidden in it and the other without this food, were suspended in the aquarium in which the operated fishes were, these animals nibbled temporarily both packets in a way that made it impossible for an uninformed observer to distinguish one packet from the other. When these two packets were transferred to an aquarium of normal fish, the one containing the food was soon surrounded by a vigorously contesting assembly of fishes, whereas the packet without food was only occasionally nibbled. The evidence from these experiments favors the view that the olfactory organs are necessary to *Fundulus* in sensing hidden food. The severity of the operation, however, renders this evidence not wholly conclusive.

In order to carry out tests in which the objection could not be raised that the results might be due to the shock of cutting nerves rather than to the loss of a sense organ, the following procedure was employed: By taking two stitches of very fine silk thread, one on either side of the external olfactory aperture, it was comparatively easy to close this aperture, and thus to prevent any passage of water through the olfactory sacs. Killifish which previous to the operation gave markedly different and characteristic reactions to the two classes of packets already described reacted to both kinds of packets after their anterior olfactory apertures were closed, as they had previously done to the packets that contained no food. That this reaction was not to be directly attributed to the operation of stitching up the apertures was demonstrated in two ways. If, after the stitches were taken, the thread was not drawn up and tied so as to close the aperture, but the ends were allowed to remain free, the fish would react as normal fishes do to the two classes of cloth packets, thus showing that the mechanical injury due to the stitches themselves did not influence the fish in any essential way. Further, if fishes whose anterior olfactory apertures had been closed by stitching and tying, and whose discrimination for the two classes of packets had thereby been lost, had their olfactory apertures reopened by cutting and removing the thread, they very soon regained their capacity to distinguish packets with food from those without food; in other words, they soon returned to the condition of normal fishes. For these reasons it is believed that stitching up of the anterior olfactory aperture is in itself not a disturbing operation for the fish and that the loss of the ability to recognize the presence of hidden food is in reality due to the loss of the olfactory function.

CONCLUSIONS.

Whether such olfactory reactions as those that have just been described are really due to smell or not is regarded by some authors as an open question. Nagel (1894, p. 56), who has discussed this matter at some length, concluded on rather theoretic grounds that fishes could not possibly possess a sense of smell and that their so-called olfactory organs act more as organs of taste than of smell. Possibly the whole matter is merely one of definition. With human beings smell differs from taste chiefly in the concentration of the stimulating solution and not, as was formerly supposed, on the state of the stimulating material, for, though we usually say that we smell gaseous or vaporous materials and taste liquids and solids, all these substances are in reality dissolved on the moist surfaces of whichever sense organ they stimulate. The most striking difference between smell and taste with us is that we smell extremely dilute solutions and taste only very much more concentrated ones. As a result we recognize the presence of many distant bodies by smell and not by taste, for the very minute amount of material that reaches us from the distant body will form a solution on our moist surfaces that will be stimulating for our organs of smell, but not for our organs of taste. Hence our olfactory organs as compared with our organs of taste are what Sherrington (1906) has called distance receptors, a designation justly emphasized by Herrick (1908). Although this distinction between taste and smell is one of degree rather than of kind, it seems to us

reasonably sound, and it certainly holds in the case of fishes much as it does with human beings, for these animals respond through their olfactory organs to solutions too dilute to affect their gustatory organs, and the nature of the response to olfactory stimulation (seeking food, etc.) is such that the olfactory organs in these fishes can be called appropriately distance receptors. We, therefore, believe that the fishes, although water-inhabiting animals, possess olfactory organs that are as much organs of smell as are the olfactory organs of the air-breathing vertebrates.

SUMMARY.

1. A current of water passes through the nasal chambers of many fishes in a direction from anterior to posterior. It may be produced by ciliary action (*Ameiurus*), by pressure due to the action of the respiratory muscles (*Fundulus*), or it may be a part of the true respiratory current (*Mustelus*).

2. By means of this current dissolved substances in the water are brought into contact with the olfactory surfaces.

3. Fishes distinguish packets containing hidden food from similar packets without food.

4. This power of distinguishing the two classes of packets is lost when the olfactory tracts are cut, when the anterior olfactory apertures are stitched up or when the apertures are plugged with cotton wool. It is revived on reopening the apertures by taking out the stitches or removing the cotton wool.

Mustelus and *Ameiurus* discover their food chiefly through the olfactory sense; *Fundulus* uses the eyes in addition to the olfactory organs for this purpose.

6. *Mustelus*, *Fundulus*, and *Ameiurus* use the olfactory organs to scent food much as land animals do; these organs are true organs of smell, i. e., distance receptors for the chemical sense.

POSTSCRIPT.

Since the preparation of this paper, confirmatory results have been obtained by Copeland (1912) on *Spheroides*, and our attention has been called to the earlier papers by Baglioni (1909, 1910) on *Balistes*, etc., in which, however, the reactions of the fishes are assumed, rather than proved, to be dependent upon the sense of smell.

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THE FISHES OF THE STREAMS TRIBUTARY TO MONTEREY BAY, CALIFORNIA

By John Otterbein Snyder
Stanford University, California

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THE FISHES OF THE STREAMS TRIBUTARY TO MONTEREY BAY, CALIFORNIA.

By JOHN OTTERBEIN SNYDER,
Stanford University, California.

INTRODUCTION.

The present paper deals with the fishes of the streams tributary to Monterey Bay, Cal. It contains a systematic record of the species, a discussion of their relationships, and an attempt to account for their present distribution. It involves some of the results of a prolonged investigation of western fluvial fishes which has been based primarily on material collected by agents of the United States Bureau of Fisheries. In connection with this study the writer has on several occasions visited the principal streams flowing into Monterey Bay, each time making observations and preserving specimens of the fishes. The early work was under the direction of Dr. Charles H. Gilbert, and assistance in the field was ably rendered by Dr. J. M. Stowell, Messrs. Wilfred H. Osgood and James A. Gunn. In the summer of 1909 the writer, assisted by Messrs. Willis H. Rich and Carl H. Gilbert, students of Stanford University, made a more complete survey of the system and collected large series of specimens. The well-preserved material obtained at this time has been most useful in determining the characteristics of the Pajaro species.

A microscopic examination of the scales has in some cases revealed reliable specific characters, and photographic illustrations are given. The proportional measurements of specimens are recorded in hundredths of the length from tip of snout to end of last caudal vertebra. They were made with considerable care by means of dividers and a proportional scale. The drawings of fishes are by Mr. W. S. Atkinson.

THE STREAMS TRIBUTARY TO MONTEREY BAY.

The streams that flow into Monterey Bay diverge from the coast like the fingers from the palm of one's hand. Beginning with the most northern, they occur in the following order: San Lorenzo River, Soquel Creek, Aptos Creek, Pajaro River, and Salinas River. Soquel and Aptos Creeks are of minor importance, as they drain very small basins and are subject to considerable desiccation during periods of long drought.

The San Lorenzo is a typical mountain stream. It drains a part of the moist western slopes of the Santa Cruz Ranges, flowing through canyons the steep sides of which are covered with trees and shrubs. Its water is clear and cool and is of large volume even during the dry season. Throughout its course the more rapid portions are broken by numerous quiet pools and broad, shallow areas with sandy or pebbly bottoms.

The Pajaro River receives the drainage from a large interior valley, flows through a narrow gorge which breaks transversely across a low range of the Coast Mountains, and enters the narrow valley which borders Monterey Bay. Its principal tributaries are Uvas and Llagas Creeks from the Santa Cruz Mountains on the northwest, San Felipe Creek from the dry Mount Hamilton Ranges on the east, and the San Benito River, which drains an elongate valley extending from southeast to northwest between the Mount Hamilton Ranges and the Gabilan Mountains. The upper courses of the Uvas and Llagas and parts of the San Benito flow through rather sparsely wooded mountain valleys. The San Benito is an uncertain and torrential stream, subject to great floods in the winter. It joins the Pajaro just before the latter enters the narrow gorge in the mountains, and brings in such quantities of sand and gravel that the Pajaro, unable to clear its channel, is so thoroughly choked up that there is no apparent current for several miles above the obstruction. Just above its junction with the San Benito, the Pajaro is from 12 to 15 feet deep, the submerged and dying branches of willows along its banks furnishing evidence of a recent rise in the water. There are indications that a shallow lake once covered an extensive area in the upper Pajaro Valley, Soap Lake, a mere pond being all that now remains of it. The lower Pajaro is a shallow stream, winding here and there over the sandy floor of a broad channel with high banks.

Salinas River flows through an elongate, narrow, and very deep valley which extends in the same general direction as the coast. Its course is parallel with that of the San Benito, from which it is separated by the Gabilan Mountains, a high and barren watershed. Between the valley of the Salinas and the ocean are the well-wooded Santa Lucia Mountains, from which the Salinas receives its principal water supply through the Arroyo Seco, San Antonio, and Nacimiento Creeks. The San Antonio and Nacimiento drain an extensive mountain area and pass down through deep canyons nearly parallel with the Salinas, presenting the very unusual case of tributaries flowing in a direction opposite to that of the main river. In their upper courses these creeks have a considerable volume of clear, cool water, which in summer is either largely consumed in irrigation or disappears in the parched sands and gravels of the valley below. The Salinas itself is an erratic and torrential stream. During the dry season its feeble current shifts here and there over broad stretches of wind-blown sand, entirely disappearing at times and again rising to the surface. After the advent of the winter rains, however, it presents a broad expanse of seething water which often threatens everything before it.

The streams tributary to Monterey Bay, which may be more briefly referred to as the Pajaro system, were described as diverging from the coast, when properly speaking they converge toward it. The mouths of the Pajaro and Salinas are in close proximity,

less than 3 miles of land separating them. The San Lorenzo flows into the bay at some distance north of the Pajaro, there being between their mouths more than 15 miles of coast, much of which is high, ascending rapidly to the foothills and the mountains beyond.

THE RELATIONSHIPS AND DISTRIBUTION OF THE FISHES.

The fishes of the Pajaro system may be said to belong to two fairly distinct groups. In the first of these may be assembled the anadromous forms and others which descend freely to salt water. They are the lampreys, trout, salmon, sticklebacks, and cottoids (*Entosphenus tridentatus*, *Salmo irideus*, *Oncorhynchus tschawytscha*, *O. kisutch*, *Gasterosteus cataphractus*, *Cottus asper*, *C. gulosus*, and *C. aleuticus*). Since the ocean presents no barrier to the dispersal of these species they have a wide distribution along the coast, occurring in all the streams of sufficient volume to support them.

To the second category belong the fresh-water fishes, the suckers, minnows, sunfish, and viviparous perch (*Catostomus mniotiltus*, *Orthodon microlepidotus*, *Ptychocheilus grandis*, *Hesperoleucus subditus*, *Lavinia ardesiaca*, *Agosia carringtoni*, *Archoplites interruptus*, and *Hysterocarpus traski*). These fishes are regarded as being strictly fluvial—not able to withstand long immersion in salt water. This assumption, though not based on experimental evidence, appears to be sufficiently established to accept without further discussion. Hence these species, living in isolated basins like those of the Pajaro or Salinas, occupy positions almost exactly analogous to those of reptiles or mammals inhabiting oceanic islands.

The present study shows that the fluvial fishes of the Pajaro system are all representatives of Sacramento River forms. In fact five of them, *O. microlepidotus*, *P. grandis*, *A. carringtoni*, *A. interruptus*, and *H. traski*, appear to be identical with Sacramento species, no distinctive local peculiarities having been observed among them. On the other hand, representatives of the Sacramento forms, *Catostomus occidentalis*, *Hesperoleucus venustus*, and *Lavinia exilicauda*, have become measurably differentiated, and so modified that they may be regarded as distinct species which are characteristic of the Pajaro system. The Pajaro basin alone contains a complete representation of the fluvial fauna of the region. The Salinas has six species, *C. mniotiltus*, *O. microlepidotus*, *H. subditus*, *L. ardesiaca*, *A. carringtoni*, and *H. traski;* the San Lorenzo three, *C. mniotiltus*, *H. subditus*, and *A. carringtoni*. Soquel and Aptos Creeks, which at times nearly dry up, have no fresh-water fishes at all.

If the relationships of the Pajaro fauna have been correctly determined, then one may safely pass to the conclusion that the Pajaro system received its species from the Sacramento,[a] and it may further be assumed that there was once an open passage between them, or an intermingling of their waters which enabled fishes to migrate from one basin to the other. The Sacramento, not the Pajaro, is thought to be the region from which the migration took place, as it contains not only a full representation of the

[a] There are no fluvial species in the coastal streams between the San Lorenzo River and the Golden Gate, nor are there any in the rivers immediately south of the mouth of the Salinas.

Pajaro fauna, but other species besides, and also because it is many times larger, and in the opinion of geologists it is considerably older.

In a recent study of the topography of a district including part of the Pajaro basin, Dr. J. C. Branner[a] discovered unmistakable evidences of a former shifting of the channel of Coyote Creek, a stream of the Sacramento drainage basin, whereby its upper portion was for a time transferred to the Pajaro drainage. Coyote Creek drains the upper (southern) part of Santa Clara Valley, which is prolonged for a considerable distance southward as the San Benito Valley, the two being separated by a low divide which crosses obliquely from the southeast to the northwest. The Coyote has its origin in the mountainous district south of Mount Hamilton and has attained considerable size when it breaks from the range through a narrow gorge to enter the valley from the east. It passes near the divide just mentioned, turns abruptly northward and continues its course directly to San Francisco Bay. On the southwest side of the divide Llagas Creek emerges from the mountains to the west, enters the valley and flows southward to the Pajaro. The relative positions of these streams are shown on the map, plate XIX. Speaking of Coyote Creek, Dr. Branner says:

From the mouth of the gorge where this creek debouches on the plain a great alluvial fan spreads out toward the south and west across the entire width of the Santa Clara Valley, at this place a distance of 2½ miles. This fan forms the watershed in the valley trough between the Bay of San Francisco and the Pajaro River or the Bay of Monterey.[b] The configuration of the materials of the alluvial fan at the mouth of the gorge shows that the Coyote has been shifting its channel of late. A terrace south of the stream, and approximately parallel with it, shows that it formerly flowed toward the west, while another and still higher terrace farther south shows that at an earlier date it flowed toward the southwest; and the general form of the alluvial fan shows that the whole fan was built by the Coyote. It is a characteristic feature of streams, in the building up of such deposits, that they swing from side to side, flowing down over their own deposits in every direction, and shifting their channels as they become choked up by the deposit of their excess of load. The depth and position of the channel through which the Coyote now flows after emerging from the hills show that there has been no recent discharge of its waters toward the Pajaro. The general topography of the region about the mouth of the gorge suggests that the alluvial fan was built up a long while ago, and at a period when the stream was much more active than it now is—possibly during or toward the close of the glacial epoch. During the glacial epoch the streams of the region were much more vigorous than they have been since, for the coast stood at an elevation of two thousand or more feet higher than it does at present. There was therefore a greater precipitation, and during the winter months the Mount Hamilton Range must have been covered with snow which accumulated more than it does now and went off rather suddenly with the warm rains of early spring, producing much greater floods than we now have. It follows from the form of the alluvial fan on the plain where the stream emerges from the mountains that the Coyote must have shifted from side to side in the usual fashion, especially in the early history of the alluvial cone and during the constructive period. It flowed sometimes toward the northwest, draining into the Bay of San Francisco, and at other times toward the southeast, draining through the Pajaro into the Bay of Monterey.

The fishes of the Coyote are like those of the Sacramento, the stream itself being a part of the Sacramento system, the salt water of San Francisco Bay not being a constant barrier to the free passage of fishes from stream to stream along its shores. If a portion

[a] Branner, J. C.: A drainage peculiarity of the Santa Clara Valley affecting fresh-water faunas. Journal of Geology, vol. XV, 1907, no. 1, p. 1–10, fig.

[b] This alluvial fan is indicated by dotted lines on the map, plate XIX.

of the Coyote was at one time turned into the Pajaro, it must have carried its species into that basin where, meeting no competitors, they probably multiplied and spread with great rapidity. This account may be accepted as an explanation of the presence of Sacramento species in the Pajaro Basin. It may also be invoked to explain the absence of a complete representation of the Sacramento fauna, as only such species as were present in the upper portion of the Coyote would have been introduced into the Pajaro. The capture of the upper Coyote does not of itself account for the occurrence of some or even any of these species in the San Lorenzo or Salinas, the basins of which are separated from that of the Pajaro by an apparently impassable barrier of ocean water. This difficulty is seemingly surmounted by a further consideration of the geological history of the region as pointed out by Dr. Branner in a reference to the work of Prof. George Davidson.[a] In his paper Davidson describes many submerged valleys that have been discovered by means of numerous soundings along the coast. After considering Monterey Bay and remarking that one would naturally expect the whole bay to be occupied by a 100-fathom plateau, he continues:

> Nevertheless a remarkable submerged valley * * * runs across this plateau and heads into a low-lying country immediately behind the 30 miles of shore line of Monterey Bay. It reaches into the middle of this low line of beach near the mouth of the Salinas River, and the 50-fathom line is within less than half a mile of the shore. The valley which runs east and west is narrow, and at 7 miles from the shore the 100-fathom curves are only 2 miles apart and the depth 350 fathoms where the 50-fathom would be normal. It broadens and at 11 miles has a depth of 615 fathoms. From its northern edge a short, deep valley reaches to the northwest, but the 50-fathom curve of this arm is 5 miles from the shore.

Attention may now be directed to a map constructed from a Coast and Geodetic Survey chart of Monterey Bay, plate XX, where various soundings have been connected by contour lines, thus outlining the great valley or gorge described by Davidson. Such a valley could have been formed only by stream erosion, and its presence plainly points to a time when the bed of Monterey Bay was entirely exposed and the shore line extended beyond the present 600-fathom contour. Dr. Branner believes that the formation of the alluvial fan by the Coyote was coincident with this period of elevation of the coast, which brought about a climate of greater humidity than we now have and a correspondingly large amount of stream activity. At this time the Salinas was probably the chief river of the system, and flowing down the great valley, received first the Pajaro and then the San Lorenzo from the narrow canyons which extended toward the northeast. There was then an open waterway between the rivers of the Pajaro system and any species which might chance to be introduced from the Coyote by a shift of its headwaters would soon extend its range throughout the system.

It will now be recalled that of the streams tributary to Monterey Bay, the Pajaro alone contains a full representation of the fluvial fauna of the system. The Salinas contains six species and the San Lorenzo three. The question at once arises, if these streams, being of similar character and of about the same volume, were once connected with the Pajaro, why do they not now contain all its species?

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[a] Proceedings California Academy Sciences, 3d ser., Geology, vol. 1, p. 73–103.

In attempting to present a plausible answer, reference is again made to the alluvial fan between the Santa Clara and San Benito Valleys. The growth of this great deposit, which swung the course of Coyote Creek from side to side, at one time into the Pajaro basin and at another into its former channel, was probably at the height of its activity near the time of the greatest coastal elevation, and then slowly ceased as the coast subsided. The lower course of the Coyote then, as at present, probably contained a fairly complete representation of the Sacramento fishes, it having direct connection with the river itself. The upper course would perhaps at no time harbor as many forms as the main channel, although any of its species might possibly be found there at periods of high water, and at the very time when a shifting of the channel would most likely occur.

The first transfer of the Coyote was presumably made when the shore of Monterey Bay was near the present 600-fathom contour, and the San Lorenzo was consequently a tributary of the Pajaro. This inflow of foreign water brought with it three species,[a] those which now inhabit the San Lorenzo and the Salinas, and all which at that particular time were contained in the captured portion of the Coyote. These forms eventually occupied the entire system, appearing in all its tributaries. The same cause which first turned the Coyote from its original channel would by its continued operation tend to shift it back again, leaving the Pajaro to itself as before. A subsidence occurring at this juncture drove the coast line back, submerging the lower part of the great valley, thus completely and permanently isolating the San Lorenzo with its three fluvial species. Again, the continued deposition of material on the plain where the Coyote emerged from the mountains turned its headwaters toward the Pajaro, bringing with it additional species, which easily reached the Salinas, but were barred from the San Lorenzo. Although the upper Coyote may have continued to swing back and forth over its growing alluvial fan, no other species succeeded in passing until by the continued subsidence of the coast and the consequent retreat of the shore line the Salinas was finally detached from the Pajaro. Further shifting of the stream over the alluvial fan enabled other species to enter the Pajaro, but the Coyote at last returned to its original channel before representatives of all its native fishes had succeeded in crossing the watershed.

It is especially significant that of the fishes which were presumably first transferred to the Pajaro, and which have consequently been longest isolated from the parent basin, three have become sufficiently differentiated to be regarded as distinct species.

[a] No account is taken of the possibility of the introduction of species which later became extinct, for the reason that the volume of the San Lorenzo and all other conditions of the river and its surroundings appear favorable to the support of at least some of the species not found there. It should be mentioned in this connection, however, that somewhat similar cases of unequal distribution do occur, in the streams tributary to San Francisco Bay, for example, for which no acceptable reason seems to present itself. The chance that species living in the basin have been overlooked is ignored also, because of the careful collecting that has been done in the region.

It is barely possible that a close connection may at one time have existed between the Pajaro and Salinas Rivers, which was not mentioned in discussing those streams. On an examination of the map, plate xx, or on an inspection of the coast between the mouths of the Pajaro and Salinas, evidence appears which seems to indicate that the mouths of both streams, and especially that of the Salinas, are subject, or have been subject, to considerable shifting. This shifting is due directly to the piling up of drift sand, which in the case of the Salinas has apparently been crowding the mouth of the river northward until it is now in comparatively close proximity to that of the Pajaro. It is conceivable that this same movement may continue until a union of the two streams takes place, and moreover one should not entirely overlook the possibility that such a union may have occurred before, and that the Salinas may even have received thereby a complete representation of the Pajaro fauna, certain species of which have since become extinct in that basin.

If the migration of these fishes from their native basin was accomplished during the glacial epoch or near its close, we have here a possible indication of the vast amount of time necessary for the appearance in nature of a slight amount of differentiation, for the Pajaro forms which have been described as distinct species differ only in a small degree from the parent forms of the Sacramento.

TABLE SHOWING DISTRIBUTION OF SPECIES IN THE PAJARO SYSTEM.

	Entosphenus tridentatus.	Catostomus rniotiltus.	Orthodon microlepidotus.	Lavinia ardesiaca.	Ptychocheilus grandis.	Hesperoleucus subditus.	Agosia carringtoni.	Salmo irideus.	Oncorhynchus tschawytscha.	Oncorhynchus kisutch.	Gasterosteus cataphractus.	Archoplites interruptus.	Hysterocarpus traski.	Cottus asper.	Cottus aleuticus.	Cottus gulosus.
San Lorenzo Basin:																
San Lorenzo junction, Kings Creek								X								
San Lorenzo junction, Boulder Creek	X							X								
San Lorenzo at Brookdale		X				X	X	X								
San Lorenzo near Felton		X				X	X	X						X		X
San Lorenzo near Big Trees		X				X		X						X	X	
San Lorenzo near Santa Cruz	X	X				X	X	X	X	X	X			X	X	
Soquel Creek								X			X			X		
Aptos Creek								X			X			X	X	
Pajaro Basin:																
San Felipe near San Felipe		X		X	X											
Pajaro between Sargent and San Felipe				X	X	X										
Pajaro at Sargent	X	X	X	X	X	X		X			X	X	X	X		
Pajaro above junction with San Benito			X	X	X											
Pajaro at junction with San Benito		X	X	X	X			X								
Pajaro below junction with San Benito		X		X												
Pajaro 3 miles above Watsonville	X	X		X	X			X			X		X			
Pajaro near Watsonville		X	X	X	X			X			X					
Pajaro at Watsonville		X		X	X		X		X				X	X		
Pajaro 1 mile below Watsonville		X		X	X		X				X		X	X		
Llagas Creek in mountains		X			X	X	X	X								X
Llagas Creek in mountains		X			X	X		X								X
Llagas Creek in mountains		X			X	X		X								X
Llagas Creek near mouth		X		X												
Uvas Creek in mountains		X			X	X		X								X
Uvas Creek in mountains					X	X		X								X
San Benito near San Benito		X				X	X									
San Benito near Erie		X				X	X									
San Benito near Hollister		X														
San Benito near mouth		X				X	X				X					
Tres Pinos Creek near Tres Pinos		X				X										
Tres Pinos Creek at Tres Pinos						X	X				X					
Salinas Basin:																
Salinas at San Miguel		X	X	X		X					X					
Salinas at Bradley		X				X	X				X					
Salinas at King		X														
Salinas between Soledad and King		X				X					X					
Salinas at Soledad		X					X	X			X			X		
Salinas at Gonzales		X		X		X					X					
Salinas near Spencers		X						X						X		
Salinas near Salinas	X	X		X		X	X	X			X		X			
Salinas near Spreckles		X		X		X	X				X		X			
Salinas near Blanco		X		X							X			X	X	
Nacimiento Creek in foothills						X		X					X			X
Nacimiento Creek in mountains	X	X				X	X	X								
Nacimiento Creek in mountains								X								
San Antonio Creek near Mission		X				X	X	X			X					
San Antonio in mountains		X						X								
Arroyo Seco 1 mile above mouth		X				X					X					
Arroyo Seco 2 miles above mouth						X		X			X					
Arroyo Seco 4 miles above mouth		X				X		X								
Arroyo Seco 6 miles above mouth		X				X	X	X			X					X

SYSTEMATIC DISCUSSION OF SPECIES.

Entosphenus tridentatus (Gairdner). *Three-toothed lamprey.*

Lampreys have been taken in the San Lorenzo, Pajaro, and Salinas Rivers. They appear in large numbers in the San Lorenzo during the month of March. Young examples may be found during the summer (May–July) burrowing like earthworms in the soil of the river banks below the water line. A dead adult specimen was found in Nacimiento Creek July 16.

Catostomus mniotiltus, new species. *Pajaro sucker.*

This form, a representative of *Catostomus occidentalis*, the coarse-scaled sucker of the Sacramento system, differs from the parent species principally in having larger scales in the anterior dorsal region of the body. This difference, visible on a careful comparison of specimens from both river systems, is well illustrated by enumerating the series of scales between the occiput and dorsal fin and also between the lateral line and middle of back.

Scales above lateral line	10	11	12	13	14	15	16	17
Specimens *C. occidentalis*	....	....	....	11	24	36	25	5
Specimens *C. mniotiltus*	13	66	31	6	....	....	....	....

Scales before dorsal	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
Specimens *C. occidentalis*	....	....	....	....	....	....	3	11	12	23	15	10	12	13	1
Specimens *C. mniotiltus*	2	6	16	18	27	23	16	7	1	....	....	....	....	....	....

The mouth is smaller and the lips narrower in *C. mniotiltus*, and the body appears to be more robust and stalky.

This species is not closely related to *C. microps* Rutter, of the Sacramento, the relationships of the latter being with the fine-scaled suckers *C. rimiculus* of the Klamath and *C. catostomus* of the Columbia.

Description of the type, no. 74465, United States National Museum, from Arroyo Seco Creek, Monterey County, Cal. Length, 208 millimeters.

Head 4.8 in length to base of caudal; depth 4.8; depth caudal peduncle 2.6 in head; eye 6; interorbital space 2.3; snout 2; dorsal rays 12; anal rays 7; scales in lateral line 57; between lateral line and middle of back 11; between lateral line and insertion of ventral 8; between occiput and insertion of dorsal fin 27.

The head is short and broad, the body deep and stocky; interorbital area very convex; width of mouth contained 5 times in head; upper lip with about 5 rows of papillæ; cleft of lower lip so deep that not more than 1 row of papillæ lies between it and the border of mouth; inner border of lips smooth and somewhat horny; about 4 rows of minute papillæ between valve and upper border of mouth. Length of fontanelle equal to diameter of orbit. Origin of dorsal midway between tip of snout and base of caudal; highest rays 1.5 in head, not nearly reaching tips of last rays in depressed fin. Ventrals inserted beneath middle of dorsal, their length 1.7 in head, the edges rounded. Anal 1.5 in head. Caudal lobes slightly shorter than head. Pectorals rather obtusely pointed, 1.4 in head.

Scales large and regular. Lateral line almost straight excepting a short curve immediately behind upper edge of gill opening. A row of mucous pores passes from near tip of snout, beneath and behind eye, then curves upward and turns backward to join the lateral line at upper edge of gill opening, from where it is connected with the opposite side of head by a similar row of pores across the occiput; another row of pores extends from occipital row forward above eye and near edge of nostril to near tip of snout.

Color in spirits, dark on the upper surfaces, growing lighter below the lateral line; the ventral area white. Scales of the dark areas with dusky basal spots and narrow dark margins. Dorsal, caudal, and pectorals suffused with dusky color; ventrals and anal immaculate. In life the upper parts are dark olive, the sides with brassy and silvery reflections. Young individuals have a dark spot on the

opercle, a similar one immediately behind the head, a third on middle of sides above base of ventrals, and a fourth on caudal peduncle. These spots enable one to identify young suckers at a glance when they are swimming among individuals of other species.

This appears to be the most widely distributed fluvial species in the Pajaro system. It is represented in each basin by large numbers of individuals which frequent all parts of the streams, living along with the trout in the cool, rapid creeks of the mountains, appearing in the warm, shallow ripples of the valleys, and thriving especially well in deep, turbid pools where algæ and diatoms are abundant. Specimens may be seen in the brackish water near the mouths of the rivers, and they survive to the last in the detached pools of a desiccating stream.

Measurements of 20 specimens follow.

MEASUREMENTS OF TWENTY SPECIMENS OF CATOSTOMUS MNIOTILTUS.

Arroyo Seco Creek.

Length of body.....mm..	200	220	205	198	148	152	128	124	123	122
Length head	0.24	0.245	0.25	0.245	0.24	0.25	0.25	0.25	0.25	0.25
Depth body	.25	.245	.25	.26	.22	.225	.25	.235	.25	.23
Depth caudal peduncle	.09	.095	.095	.095	.09	.09	.09	.09	.085	.09
Length caudal peduncle	.15	.15	.15	.16	.16	.15	.15	.165	.16	.15
Length snout	.12	.125	.12	.13	.12	.12	.12	.13	.12	.12
Diameter eye	.045	.04	.04	.04	.04	.045	.045	.045	.05	.045
Interorbital width	.10	.10	.10	.105	.10	.10	.10	.10	.10	.10
Depth head	.175	.18	.18	.185	.19	.18	.18	.18	.18	.18
Snout to occiput	.21	.21	.21	.21	.22	.22	.21	.23	.22	.22
Snout to dorsal	.52	.52	.52	.52	.515	.52	.53	.53	.54	.54
Snout to ventral	.565	.57	.59	.59	.585	.57	.57	.59	.58	.59
Length base of dorsal	.165	.17	.16	.17	.17	.17	.16	.16	.16	.16
Length base of anal	.08	.08	.075	.08	.075	.075	.075	.075	.075	.07
Height dorsal	.17	.165	.165	.17	.18	.17	.17	.17	.18	.18
Height anal	.18	.17	.165	.165	.16	.16	.16	.15	.17	.17
Length pectoral	.19	.20	.19	.18	.18	.19	.18	.18	.20	.20
Length ventral	.15	.15	.14	.145	.14	.14	.15	.13	.14	.15
Length caudal	.22	.22	.21	.22	.23	.23	.21	.23	.23	.24
Dorsal rays	12	12	12	12	13	12	11	12	11	12
Anal rays	8	7	7	7	8	7	7	7	7	8
Scales lateral line	60	61	60	57	62	61	60	58	57	63
Scales above lateral line	11	12	11	12	11	11	12	11	12	12
Scales below lateral line	8	9	9	9	8	8	8	8	8	8
Scales before dorsal	26	27	27	26	26	27	26	27	28	28

Pajaro River, Watsonville.

Length of body.....mm..	162	144	133	134	128	135	121	116	107	111
Length head	0.24	0.25	0.26	0.24	0.25	0.235	0.24	0.25	0.25	0.23
Depth body	.20	.21	.22	.245	.22	.20	.23	.20	.22	.21
Depth caudal peduncle	.09	.09	.09	.09	.09	.09	.09	.09	.09	.09
Length caudal peduncle	.15	.155	.15	.16	.15	.16	.16	.15	.15	.15
Length snout	.12	.11	.125	.12	.12	.12	.11	.12	.11	.12
Diameter eye	.04	.045	.045	.045	.05	.045	.05	.05	.05	.05
Interorbital width	.10	.095	.10	.10	.10	.09	.10	.10	.09	.095
Depth head	.17	.165	.17	.175	.18	.17	.17	.17	.18	.17
Snout to occiput	.22	.21	.22	.21	.22	.20	.21	.21	.22	.21
Snout to dorsal	.52	.51	.53	.51	.52	.51	.54	.51	.52	.51
Snout to ventral	.58	.57	.58	.56	.59	.575	.59	.59	.58	.59
Length base of dorsal	.17	.16	.17	.18	.16	.16	.16	.16	.17	.16
Length base of anal	.075	.07	.08	.085	.08	.08	.07	.07	.08	.08
Height dorsal	.18	.18	.20	.18	.19	.19	.20	.18	.20	.19
Height anal	.17	.16	.19	.18	.16	.17	.17	.16	.18	.17
Length pectoral	.19	.20	.21	.20	.19	.20	.20	.20	.20	.20
Length ventral	.16	.15	.165	.16	.16	.15	.16	.16	.17	.16
Length caudal	.23	.23	.245	.23	.23	.23	.24	.24	.25	.24
Dorsal rays	12	12	11	12	12	11	11	12	11	12
Anal rays	7	7	7	7	7	7	8	7	7	7
Scales lateral line	58	62	62	57	61	59	59	57	60	60
Scales above lateral line	12	11	12	11	12	12	13	12	12	12
Scales below lateral line	10	10	10	9	9	8	9	8	8	8
Scales before dorsal	26	27	27	25	28	29	29	28	29	29

Orthodon microlepidotus (Ayres). *Blackfish.*

This is a channel fish frequenting the deep pools and never appearing in the smaller creeks. In the Pajaro Basin it does not seem to occur in large numbers. It has not been seen in the San Lorenzo and it has been taken but once in the Salinas, Dr. Gilbert and Dr. Stowell having collected specimens near San Miguel.

The dorsal rays number from 9 to 11; the anal 8 or 9; scales in lateral line 94 to 102; below lateral line 12 or 13; above lateral line 23 to 25; between occiput and dorsal 49 to 54.

The following measurements are from specimens collected at Watsonville.

MEASUREMENTS OF SPECIMENS OF ORTHODON MICROLEPIDOTUS.

Length of body....mm..	184	190	200	195	202	185	189	182
Length head	0.25	0.26	0.27	0.26	0.26	0.26	0.255	0.27
Depth body	.245	.235	.225	.22	.22	.24	.23	.245
Depth caudal peduncle	.08	.08	.085	.08	.08	.08	.08	.09
Length caudal peduncle	.21	.21	.19	.21	.20	.21	.22	.21
Length snout	.08	.885	.09	.09	.09	.085	.085	.09
Diameter eye	.04	.045	.04	.04	.04	.045	.04	.045
Interorbital width	.10	.11	.115	.11	.11	.105	.11	.11
Depth head	.17	.17	.175	.165	.16	.17	.17	.175
Snout to occiput	.20	.19	.20	.20	.20	.21	.19	.21
Snout to dorsal	.52	.515	.535	.515	.52	.53	.53	.54
Snout to ventral	.52	.535	.535	.545	.54	.53	.535	.54
Length base of dorsal	.15	.17	.155	.145	.15	.15	.14	.135
Length base of anal	.11	.11	.10	.115	.10	.105	.10	.10
Height dorsal	.19	.185	.215	.19	.175	.20	.19	.205
Height anal	.16	.16	.165	.155	.15	.17	.16	.17
Length pectoral	.17	.18	.17	.19	.16	.21	.165	.175
Length ventral	.18	.17	.18	.18	.155	.185	.16	.17
Length caudal	.265	.26	.28	.26	.25	.28	.27	.27
Dorsal rays	10	11	10	9	10	10	10	10
Anal rays	8	8	8	8	8	8	8	8
Scales lateral line	94	94	100	102	101	95	100	102
Scales above lateral line	25	23	25	23	25	24	23	24
Scales below lateral line	13	13	13	13	13	13	13	13
Scales before dorsal	52	52	51	49	54	50	49	51

Lavinia ardesiaca, new species. *Silver minnow.*

Minnows of this type found in the Pajaro system differ from *Lavinia exilicauda* of the Sacramento River in having fewer dorsal and anal rays, a somewhat heavier and less compressed body, and in other peculiarities.

In *L. ardesiaca* the dorsal rays are usually 9 or 10 in number, most often 10, while in *L. exilicauda* they number from 10 to 12, most often 11. The anal rays of *L. ardesiaca* number from 8 to 13, the maximum number of examples having 10; the same rays of *L. exilicauda* number from 11 to 14 with 13 as the most usual. These differences are well illustrated in the tables of measurements annexed to the description of the species.

Description of the type no. 74459, United States National Museum, from the Pajaro River near Watsonville, Cal. Length 287 millimeters. (Fig. 1, text.)

Head 4.7 in length to base of caudal; depth 4.4; depth caudal peduncle 2.7 in head; eye 5.4; interorbital space 2.5; snout 3.4; dorsal rays 10; anal rays 11; scales lateral line 59; between lateral line and middle of back 14; between lateral line and base of ventral 7; between occiput and insertion of dorsal 38.

Body of symmetrical proportions, the head small and pointed, the caudal peduncle slender and round; dorsal outline rising in a nearly even curve to middle of back and then sloping gently to caudal peduncle. Eye located considerably in advance of middle of head, but not entirely above a median lateral line. Angle of mouth not reaching a vertical through anterior edge of pupil. Gillrakers on first arch, 19; each being a long, triangular, sharply pointed flap, the posterior edge of which is denticulate.

Pharyngeal teeth (cotype) 5–5, long and compressed; the tips hooked, the grinding surface well developed, though narrow. Lips with a sharp-edged, horny covering (more conspicuous in larger individuals). Lateral line with a gentle downward curve in its anterior fourth. Dorsal inserted midway between pupil and base of caudal; height of longest (first) rays 1.3 in head; edge of fin nearly straight. Height of first anal rays 1.5 in head, the last ray half as high. Ventrals rounded; 1.5 in head; not reaching vent when depressed. Caudal deeply incised, the lobes rather pointed; about an eye's diameter longer than head. Pectoral 1.3 in head, the edge rounded.

Color dark above, lighter on sides, immaculate beneath; the dark color more intense on edges of scales and forming definite dark borders on those below lateral line. In life, olive on upper parts, silvery on the sides and beneath, the silvery color especially brilliant when reflecting the sunlight in the clear water.

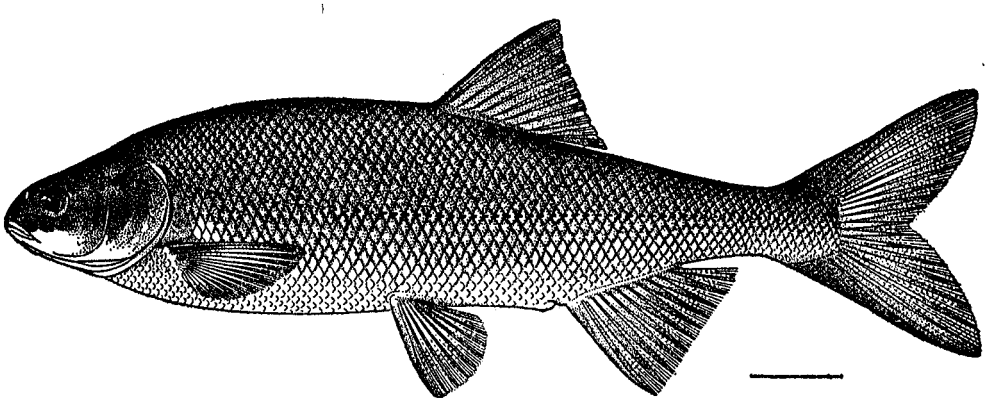

FIG. 1.—Lavinia ardesiaca, new species. Type.

NUMBER OF DORSAL AND ANAL RAYS IN SPECIMENS OF LAVINIA ARDESIACA AND LAVINIA EXILICAUDA.

Dorsal rays	8	9	10	11	12
Specimens *L. ardesiaca*	2	49	80	9	1
Specimens *L. exilicauda*	.....	.....	3	31	1

Anal rays	8	9	10	11	12	13	14
Specimens *L. ardesiaca*	1	20	51	38	29	1	.....
Specimens *L. exilicauda*	.....	.....	.....	1	8	25	1

The specimens of *L. exilicauda* referred to in the above tables are from Cache Creek and Putah Creek, tributaries of the Sacramento. However, the number of dorsal and anal rays here given appears to be fairly characteristic of examples of the species from various parts of its range, as is shown in a table published by Rutter[a] and here introduced.

[a] Rutter, Cloudsley: The fishes of the Sacramento-San Joaquin basin, with a study of their distribution and variation. Bulletin Bureau of Fisheries, vol. XXVII, 1907, p. 127.

VARIATION IN FIN RAYS OF LAVINIA EXILICAUDA.

Locality.	Number of specimens having—							
	Dorsal—				Anal—			
	10	11	12	13	11	12	13	14
Battle Creek hatchery	.....	1	1	.....	.....	.....	2	.....
Sacramento River:								
Red Bluff	.....	2	2	.....	.....	.....	4	.....
Chico	.....	1	1	1	.....	.....	3	.....
Jacinto	.....	7	3	.....	.....	.....	7	2
20 miles below Grimes	.....	1	.....	.....	.....	.....	1	.....
Feather River, Oroville	.....	.....	2	.....	.....	.....	2	.....
American River, Folsom	.....	.....	2	.....	.....	.....	1	1
Antelope Creek, Peryn	.....	.....	2	.....	.....	.....	1	1
Sacramento River, Rio Vista	.....	1	.....	.....	.....	.....	1	.....
San Joaquin River, Black Diamond	.....	1	.....	.....	.....	.....	1	.....
Merced River, Livingstone	.....	.....	5	.....	.....	.....	5	.....
China Slough, Centerville	.....	2	8	.....	.....	1	6	3
Kings River, Centerville	.....	2	8	.....	1	2	7	.....
Kaweah River, St. John Channel	.....	6	4	.....	1	1	7	1
Tule River, Porterville	2	2	1	.....	.....	.....	.....	.....
Total	2	26	39	1	2	4	48	8

With a decrease of the number of fin rays has come a consequent shortening of the bases of both dorsal and anal fins in *L. ardesiaca*.

DORSAL AND ANAL FIN MEASUREMENTS RECORDED IN HUNDREDTHS OF THE LENGTH TO BASE OF DORSAL.

Length base of dorsal	0.12	0.13	0.14	0.15	0.16	0.17	0.18
Specimens *L. ardesiaca*	1	6	30	43	19	3	.....
Specimens *L. exilicauda*	.....	.....	2	5	23	4	1

Length base of anal	0.11	0.12	0.13	0.14	0.15	0.16	0.17	0.18	0.19
Specimens *L. ardesiaca*	1	4	11	20	24	27	6	.....	.....
Specimens *L. exilicauda*	.....	.....	.....	.....	1	4	12	14	4

Examples of this species are comparatively heavy in appearance, the body being somewhat less compressed than that of *L. exilicauda*, the snout a little longer, and the head somewhat larger. These differences, though slight and not easily shown by measurements, appear when a considerable series of specimens of both species pass under one's observation.

The structure of the scales (fig. 26, pl. XXIV) does not appear to differ materially from that of *L. exilicauda*. They are more or less spatulate in outline, the nuclear area elevated, the basomedian and basolateral ridges high and rounded, the apicolateral ridges very weak or entirely absent. There are neither basal nor lateral radii. The apical radii number as follows, 50 scales from 10 individuals having been examined:

First year, 5 to 10, usually 7 to 9.
Second year, 6 to 16, usually 11 to 14.
Third year, 9 to 22, usually 14 to 19.
Fourth year, 11 to 26, usually 16 to 23.

The species is found in the Pajaro and Salinas Basins, but appears to be absent from the San Lorenzo. It frequents the lower courses of the streams, delighting in the shallow water of the ripples, where large schools may be seen moving about over the yellow sand of the bottom in the full glare of the sun. The larger individuals, which are darker in color and less silvery than the smaller ones, take

refuge in the deep pools. The species is not well represented where the current is very rapid and where the water, cool and clear, plunges over and around the rocks and bowlders. In the upper courses of the streams it is not found at all. It is seldom associated with *Hesperoleucus*.

The largest specimens caught measured 13 inches in length. They were taken with baited hook in the Pajaro. They do not appear to reach such proportions in the Salinas, the river being too shallow.

An examination of the scales of a number of individuals indicates that their growth is about as follows:

First year, 60 to 85 millimeters, about 3 inches.
Second year, 95 to 110 millimeters, about 4 inches.
Third year, 150 to 210 millimeters, about 7 inches.
Fourth year, 160 to 230 millimeters, about 8.5 inches.
Fifth year, —— to 280 millimeters, about 10 inches.
Sixth year, 285 to 320 millimeters, about 12 inches.

Measurements of 20 specimens of this species follow and for comparison similar measurements of 10 examples of *L. exilicauda* are also given.

MEASUREMENTS OF 20 SPECIMENS OF LAVINIA ARDESIACA, NEW SPECIES.

Pajaro River, Watsonville.

Length of body....mm..	162	166	133	118	112	114	100	86	84	93
Length head	0.235	0.235	0.23	0.24	0.245	0.24	0.24	0.24	0.25	0.25
Depth body	.28	.255	.27	.27	.265	.26	.25	.26	.275	.255
Depth caudal peduncle	.08	.075	.09	.085	.09	.09	.085	.08	.095	.09
Length caudal peduncle	.15	.16	.175	.15	.17	.16	.15	.165	.165	.17
Length snout	.07	.065	.07	.07	.07	.07	.065	.07	.075	.07
Diameter eye	.05	.05	.055	.055	.055	.05	.065	.055	.06	.055
Interorbital width	.085	.08	.085	.09	.085	.09	.08	.09	.095	.085
Depth head	.16	.155	.18	.18	.17	.17	.165	.18	.195	.18
Snout to occiput	.18	.175	.185	.19	.19	.185	.19	.20	.19	.20
Snout to dorsal	.575	.545	.56	.565	.57	.57	.56	.54	.58	.56
Snout to ventral	.525	.515	.51	.53	.51	.52	.50	.52	.53	.54
Length base of dorsal	.17	.155	.15	.15	.165	.15	.15	.17	.....	.15
Length base of anal	.16	.16	.155	.16	.145	.14	.16	.16	.15	.16
Height dorsal	.195	.195	.19	.21	.19	.20	.22	.21	.22	.21
Height anal	.18	.165	.17	.17	.165	.17	.18	.19	.185	.19
Length pectoral	.18	.17	.17	.17	.175	.17	.20	.185	.20	.18
Length ventral	.165	.16	.15	.165	.165	.16	.18	.16	.17	.17
Length caudal	.30	.275	.29	.30	.30	.29	.275	.31	.32	.32
Dorsal rays	11	10	10	10	10	10	11	10	10	10
Anal rays	11	11	11	11	11	11	12	11	10	12
Scales lateral line	60	54	55	55	54	54	54	55	57	54
Scales above lateral line	13	14	13	13	13	13	12	13	13	14
Scales below lateral line	6	6	6	7	6	6	6	6	6	6
Scales before dorsal	35	34	32	33	33	34	33	32	33	33

Salinas River, near Salinas.

Length of body....mm..	163	121	94	90	75	90	86	79	73	81
Length head	0.24	0.25	0.25	0.24	0.255	0.24	0.26	0.245	0.25	0.25
Depth body	.28	.265	.255	.25	.30	.25	.27	.275	.265	.275
Depth caudal peduncle	.08	.09	.08	.085	.09	.09	.09	.09	.10	.10
Length caudal peduncle	.16	.14	.14	.165	.17	.165	.16	.16	.16	.15
Length snout	.07	.065	.065	.065	.07	.065	.07	.07	.08	.07
Diameter eye	.05	.06	.06	.06	.065	.065	.07	.07	.065	.165
Interorbital width	.09	.09	.09	.09	.09	.08	.085	.085	.08	.085
Depth head	.185	.19	.175	.17	.185	.17	.185	.18	.18	.19
Snout to occiput	.18	.20	.185	.19	.21	.20	.20	.20	.20	.20
Snout to dorsal	.59	.585	.59	.57	.58	.56	.575	.58	.57	.58
Snout to ventral	.525	.55	.555	.52	.54	.51	.55	.54	.53	.54
Length base of dorsal	.14	.15	.16	.15	.14	.15	.15	.15	.16	.15
Length base of anal	.16	.17	.15	.16	.14	.17	.145	.16	.17	.16
Height dorsal	.175	.19	.21	.21	.20	.20	.22	.225	.21	.205
Height anal	.165	.17	.17	.17	.17	.18	.175	.18	.18	.19
Length pectoral	.165	.17	.17	.18	.18	.175	.19	.19	.18	.20
Length ventral	.155	.16	.17	.16	.16	.17	.17	.175	.16	.17
Length caudal	.275	.31	.305	.31	.30	.28	.31	.325	.31	.295
Dorsal rays	10	10	11	11	10	10	10	10	11	10
Anal rays	12	12	12	12	11	12	11	11	12	12
Scales lateral line	57	56	60	56	60	57	57	55	59	55
Scales above lateral line	13	12	13	13	13	12	13	13	12	12
Scales below lateral line	6	6	6	6	6	6	6	6	6	6
Scales before dorsal	34	31	34	34	32	33	31	32	32	33

MEASUREMENTS OF 10 SPECIMENS OF LAVINIA EXILICAUDA.

Cache Creek, tributary of Sacramento River.

Length of body....mm..	166	182	178	118	118	102	102	76	103	100
Length head	0.23	0.20	0.235	0.23	0.225	0.23	0.24	0.235	0.235	0.22
Depth body	.27	.24	.24	.265	.26	.27	.27	.26	.27	.26
Depth caudal peduncle	.08	.07	.07	.085	.08	.09	.09	.09	.08	.09
Length caudal peduncle	.155	.135	.17	.155	.155	.165	.16	.175	.17	.17
Length snout	.06	.055	.065	.065	.06	.065	.06	.06	.065	.055
Diameter eye	.05	.045	.05	.06	.06	.06	.06	.06	.065	.055
Interorbital width	.085	.075	.08	.08	.08	.08	.08	.08	.08	.08
Depth head	.17	.16	.16	.17	.16	.17	.16	.17	.17	.175
Snout to occiput	.17	.17	.18	.18	.18	.19	.185	.19	.19	.19
Snout to dorsal	.565	.59	.56	.58	.57	.57	.60	.58	.57	.55
Snout to ventral	.51	.54	.52	.515	.535	.52	.53	.51	.51	.50
Length base of dorsal	.16	.145	.16	.165	.16	.165	.16	.16	.16	.16
Length base of anal	.17	.175	.16	.17	.18	.17	.16	.165	.18	.175
Height dorsal	.20	.17	.185	.21	.21	.23	.21	.23	.20	.235
Height anal	.17	.16	.17	.185	.17	.19	.18	.20	.18	.195
Length pectoral	.17	.16	.155	.18	.18	.19	.185	.195	.185	.19
Length ventral	.16	.16	.16	.175	.17	.185	.17	.18	.18	.18
Length caudal	.29	.27	.30	.32	.33	.305	.32	.36	.32	.33
Dorsal rays	11	11	11	11	11	11	11	11	11	11
Anal rays	13	14	12	12	13	12	13	13	13	12
Scales lateral line	57	59	62	56	58	58	58	57	58	58
Scales above lateral line	14	14	13	14	13	13	12	13	13	13
Scales before dorsal	37	35	37	38	38	35	35	34	34	36

Ptychocheilus grandis (Ayers). *Sacramento pike.*

P. grandis[a] occurs in the Pajaro Basin, but is not found in either the San Lorenzo or Salinas. It is the largest of the Pajaro minnows. Specimens measuring 20 inches in length were caught in the deep pools. Although a channel fish, it appears to venture up the smaller tributaries farther than *Lavinia* or *Orthodon*, but is not able to extend its range with *Hesperoleucus* or *Catostomus*.

A table of measurements is appended.

MEASUREMENTS OF SPECIMENS OF PTYCHOCHEILUS GRANDIS.

Length of body....mm..	196	220	295	226	177	164	146	141	158	164
Length head	0.27	0.27	0.265	0.265	0.27	0.26	0.27	0.28	0.27	0.265
Depth body	.195	.205	.205	.195	.20	.22	.19	.19	.19	.20
Depth caudal peduncle	.09	.09	.095	.09	.09	.09	.08	.085	.08	.085
Length caudal peduncle	.195	.21	.19	.20	.19	.195	.19	.19	.18	.20
Length snout	.095	.09	.095	.095	.09	.09	.09	.09	.095	.095
Diameter eye	.04	.04	.035	.04	.045	.045	.045	.045	.05	.05
Interorbital width	.08	.075	.075	.075	.08	.075	.075	.08	.07	.08
Depth head	.14	.145	.135	.15	.14	.145	.14	.14	.15	.15
Snout to occiput	.21	.205	.20	.21	.21	.22	.21	.21	.22	.21
Snout to dorsal	.56	.56	.55	.56	.59	.59	.57	.58	.575	.57
Snout to ventral	.54	.545	.535	.55	.545	.55	.56	.555	.55	.54
Length base of dorsal	.105	.11	.115	.10	.12	.115	.11	.10	.11	.10
Length base of anal	.09	.95	.10	.09	.105	.95	.10	.10	.95	.95
Height dorsal	.175	.175	.165	.165	.175	.18	.175	.175	.18	.17
Height anal	.155	.16	.145	.155	.16	.16	.165	.15	.16	.165
Length pectoral	.15	.17	.14	.145	.15	.16	.15	.155	.16	.165
Length ventral	.13	.14	.14	.125	.14	.14	.135	.14	.145	.14
Length caudal	.24	.24	.235	.225	.24	.245	.24	.235	.245	.26
Dorsal rays	9	9	8	8	8	8	8	8	8	8
Anal rays	9	9	9	9	9	9	9	9	9	9
Scales lateral line	74	72	73	74	76	73	71	74	73	75
Scales above lateral line	15	14	14	14	15	15	13	14	13	14
Scales below lateral line	7	7	7	8	7	8	7	7	8	8
Scales before dorsal	36	40	36	38	39	36	38	41	39	41

[a] *Ptychocheilus rapax* Girard, said to have been collected at Monterey, Cal., is apparently a synonym of *P. grandis* and doubtless owed its assigned locality to a confusion of labels. A similar case is *Mylocheilus fraterculus* Girard taken by the same collector and also said to have come from Monterey. This is *M. lateralis* (*M. caurinus* of recent authors), the only known species of the genus, and does not occur south of the Columbia River.

HESPEROLEUCUS, new genus.

The generic name *Hesperoleucus* is here used for a small group of closely related cyprinoid fishes previously included with others in the genus *Rutilus* or *Myloleucus*. The species of *Hesperoleucus* have the insertion of the dorsal fin posterior to the ventrals, by which character they may be distinguished from *Myloleucus*. They also have a shorter head, more slender body, and a more nearly horizontal lower jaw. The pharyngeal teeth number 4–5, 4 on the right side, with a narrow but well-developed grinding surface. *Hesperoleucus symmetricus* may stand as the type of the genus.

Hesperoleucus is a genus peculiar to the Sacramento River fauna. Its species inhabit the smaller tributaries of the rivers that flow into the Sacramento and San Joaquin, some of the coastal streams north of the Golden Gate, the creeks tributary to San Francisco Bay, and the rivers flowing into Monterey Bay. They have been included in the species *Rutilus symmetricus* by recent authors, as were also several forms belonging to the genus *Myloleucus*. The latter is an assemblage of comparatively large lake and channel fishes which do not usually frequent the smaller creeks, but live mainly in the deep, sluggish pools of the rivers. They occur abundantly in certain lakes of the Great Basin, where they grow to a large size.

In a previous paper [a] the writer referred to three well-defined geographic races of *Hesperoleucus* (*Rutilus*) thus: "A minnow of this type occurs in the Navarro, Gualala, Russian, and Napa Rivers. Specimens from the Russian and Napa Rivers are alike in all respects, and they in turn agree closely with representatives from the streams tributary to San Francisco Bay. In a majority of cases the dorsal fin has 9 rays and the anal 8. The snout is rather pointed, the caudal peduncle slender, and the fins long, the whole body being trim and well proportioned. Examples from the Navarro and Gualala Rivers are distinguished from these by having generally 8 rays in the dorsal fin, a more robust body, with a deeper caudal peduncle, and a more rounded and shortened snout. The fins are also shorter and somewhat less acute. While examples from the Navarro and Gualala Rivers thus agree in differing from specimens taken in the neighboring basins, individuals from each of these streams bear a distinctive local stamp by which they may be recognized without difficulty, the Navarro examples having mostly one more ray in the anal fin, and larger scales in the series above the lateral line. It has been shown that individuals from the partly isolated rivers tributary to San Francisco Bay are alike in all points, and that these are scarcely to be distinguished in any particular from individuals from the Napa and Russian Rivers. Hence it appears that there are three well-differentiated forms of *Rutilus* in this somewhat restricted region, each of which occupies a distinct hydrographic basin or series of contiguous basins. When, however, the field is broadened and specimens from distant parts of the Sacramento and San Joaquin Basins are brought together, similar variations of a local nature are found to occur, but whether any geographical significance may be attached to these can not be known until more extensive observations have been made." Since then more material has been secured, including specimens of *H. symmetricus* from the type locality, and many examples of a well-differentiated form from the streams tributary to Monterey Bay. In order to deal intelligently with the latter it now seems best to restrict the name *symmetricus* to fishes of the genus inhabiting the rivers of the San Joaquin Valley, to recognize the form frequenting the streams in the immediate region of San Francisco Bay, and likewise that of the Navarro River, Gualala River, and of the streams tributary to Goose Lake, descriptions of which follow in the order indicated.

Hesperoleucus symmetricus (Baird and Girard)[a] is not to be confused with *Algansea formosa* Girard, *Algansea obesa* Girard, *Myloleucus pulverulentus* Cope, nor *Myloleucus parovanus* Cope. This species,

[a] Snyder, J. O.: The fishes of the coastal streams of Oregon and northern California. Bulletin Bureau Fisheries, vol. XXVII, 1907, p. 175.

[b] Jordan and Evermann: Fishes North and Middle America, Bulletin 47, U. S. National Museum, p. 246, synonymy of *Rutilus symmetricus*. Through the kindness of the National Museum authorities the writer has been permitted to examine the types of *Pogonichthys symmetricus* Baird and Girard, and also of *Algansea formosa* Girard. The latter, which is from Merced River, and in a bad state of preservation, appears to be indistinguishable from *Myloleucus thalassinus* of the upper Pit River and Goose Lake. It is a *Myloleucus*, not a *Hesperoleucus*, and if when better specimens from the Merced are examined no differentiating characters appear, *M. formosa* will stand in place of *M. thalassinus*, its known range extending from the lower San Joaquin to the northern tributaries of Goose Lake.

represented by specimens collected by Mr. Rutter near the type locality, San Joaquin River at Polasky, is a form characterized by large eyes, long head, and pointed snout, a symmetrical body with narrow caudal peduncle, and long fins. There are 9 rays in the dorsal, 8 in the anal.[a] The scales in the lateral line number from 47 to 53. A specimen 85 millimeters in length to base of caudal exhibits the following proportional measurements: Length of head, .27; depth of body, .24; depth of caudal peduncle, .10; length of snout, .09; diameter of eye, .07; interorbital width, .105; snout to dorsal, .585; snout to ventrals, .53; length of base of dorsal, .16; anal, .19; length of pectoral, .20; caudal, .32; scales in lateral line, 51; above lateral line, 13; below lateral line, 6; before dorsal, 30. Scales which appear to be typical are illustrated (fig. 1, 2, 3, and 4). The apical radii number from 13 to 22, 15 to 20 representing the usual number in individuals 2 or 3 years old. Lateral radii sometimes appear, but they are usually absent.

No exact data are at hand concerning the species of *Hesperoleucus* inhabiting the great rivers tributary to the Sacramento, and but little is known of those distributed throughout the valley of the San Joaquin.

Hesperoleucus venustus, new species. *Venus roach.*

This form inhabits the Russian River, the streams entering San Pablo, Suisun, and San Francisco Bays. It is characterized chiefly by long fins, a comparatively pointed snout, and slender caudal

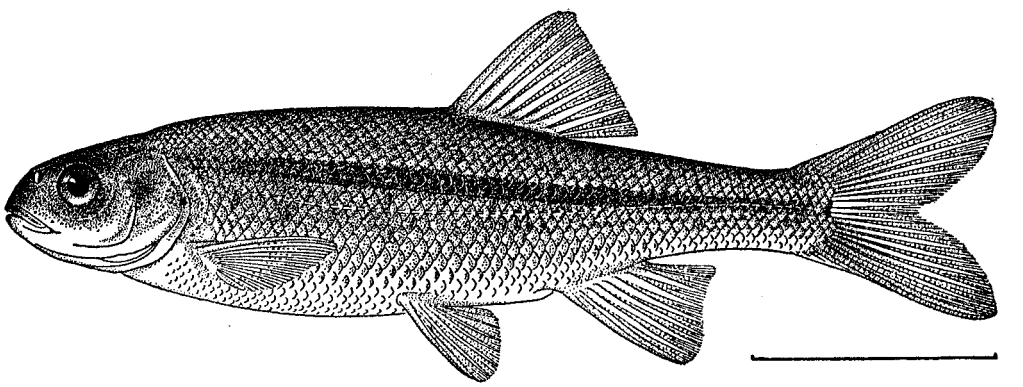

FIG. 2.—Hesperoleucus venustus, new species. Type.

peduncle, the whole body being trim and well proportioned. The dorsal and anal rays number 9 and 8, respectively.

Description of the type, no. 74476 United States National Museum, from Coyote Creek near Gilroy Hot Springs, Cal. Length, 107 millimeters (fig. 2):

Head 4.1 in length to base of caudal; depth 3.9; depth of caudal peduncle 2.5 in head; eye 4; interorbital space 2.7; snout 3; dorsal 9; anal 8; scales in lateral line 53; between lateral line and middle of back 13; between lateral line and origin of ventrals 7; between occiput and origin of dorsal 30.

Body slender, the caudal peduncle narrow, head small, snout short and rather bluntly rounded; eye not included in anterior half of head nor entirely above a median line through body; mouth reaching a vertical which passes a little anterior to orbit. Gillrakers on first arch 10, very short, pointed and widely spaced. Pharyngeal teeth (cotypes) 4–5, 4 on the right side, occasionally 5–5 or 4–4; grinding surface narrow, equal in width to the tooth; tips of teeth hooked. Lateral line with a gentle downward curve on anterior half. Origin of dorsal midway between posterior border of eye and base of caudal; anterior ray 1.3 in head, its tip when depressed not reaching as far posteriorly as that of last ray; edge

[a] Rutter (op. cit., Bulletin Bureau Fisheries, vol. XXVII, p. 138) records 10 rays in the dorsal and 9 in the anal, but an examination of some of his specimens shows that he is in the habit of enumerating the last ray as 2 when it is deeply cleft, i. e., branched.

of fin slightly concave. First anal ray 1.3 in head; edge of fin concave. Ventrals rounded, not reaching anal. Pectoral equal in length to height of dorsal; obtusely pointed. Caudal deeply cleft, the lobes acutely rounded.

Color in spirits dusky above, light beneath, the sides and under parts silvery; a narrow, light stripe extending from upper edge of gill opening to base of caudal; beneath this a conspicuous black stripe, narrow in front, somewhat wider behind, the color deepest above anal fin; several very indistinct, narrow, dark stripes beneath lateral line.

The scales are more or less quadrangular, rounded or spatulate in shape. (Fig. 5–10, pl. XXI and XXII.) The basolateral angles are prominant, and the apicolateral angles weak or entirely obliterated. There are no basal radii, and lateral radii are rarely present except in specimens from the Russian River. The apical radii number from 8 to 21, usually 10 to 18. There are from 50 to 61 scales in the lateral line, counts of a series of specimens resulting as follows:

Scales lateral line	50	51	52	53	54	55	56	57	58	59	60	61
Number of specimens	1	6	4	6	14	28	26	22	15	20	13	3

In this character it differs from *H. symmetricus*, which has from 47 to 53. It differs further from the same species in having smaller eyes and a shorter head. Measurements of many specimens have been made and published.[a]

At least one isolated basin, the Russian River, is included in the region occupied by this form, and specimens from it are somewhat peculiar. The trim, slender form characteristic of the species reaches its highest development here, and the scales usually have from 1 to 5 lateral radii. (Fig. 10, pl. XXII.) Specimens from Napa River also show slight local peculiarities, but neither these nor those from the Russian River appear to differ very much from individuals from the streams flowing into San Francisco Bay.

H. venustus appears to be the parent form of *H. navarroensis* and *H. parvipinnis*, they having become differentiated through the agencies accompanying complete isolation. It will be noted on referring to the descriptions of these species that lateral radii are present on the scales of both, and that in this respect they resemble individuals of *H. venustus* from the Russian River. The distribution of *H. venustus* in the Sacramento basin is unknown.

Hesperoleucus navarroensis, new species. *Navarro roach.*

This is a species inhabiting the Navarro Basin on the western coast of northern California. It is distinguished by its robust body, deep caudal peduncle, short snout, and rounded fins, and in having 8 rays in the dorsal and anal fins. This form is closely allied to *H. parvipinnis*, the one evidently derived from the other or both from one parent stock. *H. navarroensis* differs from *H. parvipinnis* in the number of anal fin rays and in having generally 1 less row of scales above the lateral line.

Description of the type, no. 74477, United States National Museum, from Navarro River near Philo, Cal. Length 90 millimeters.

Head 3.6 in length to base of caudal; depth 3.6; depth caudal peduncle 2.2 in head; eye 4.2; interorbital area 2.8; snout 3.1; dorsal rays 8; anal rays 8; scales lateral line 56; between lateral line and middle of back 13; between lateral line and origin of ventral 7; between occiput and origin of dorsal 30.

Body deep, particularly in the caudal region; posterior margin of eye behind a median vertical through head; lower border of eye somewhat below median line of body. Gillrakers on first arch 8, very short and stumpy. Pharyngeal teeth (cotypes) 4–5, 4 on the right side; a grinding surface equal to width of tooth; the tips slightly hooked. No material variation appears in the teeth of a number of

[a] Snyder, J. O.: Op. cit., Bulletin Bureau Fisheries, vol. XXVII, 1907, p. 176; Notes on the fishes of streams flowing into San Francisco Bay, Appendix to Report Commissioner of Fisheries for 1904, p. 332, *Rutilus symmetricus.*

individuals. Lateral line with a slight downward curve on anterior part of body. Origin of dorsal midway between center of pupil and base of caudal; height of longest rays contained 1.4 times in head; border of fin straight; rays all reaching an equal distance posteriorly when depressed. Ventrals inserted a little anterior to dorsal, the tips reaching anal opening, the edges rounded. Anal 1.7 in head, the edge straight. Caudal deeply incised, the lobes rather pointed, equal in length to head. Pectorals rounded, 1.2 in head.

Color in spirits, dark brown above, lighter and with a silver reflection below; a straight stripe about 2 scales wide extending from upper edge of gill opening to base of caudal, entirely above lateral line; below this a dark stripe, somewhat wider, and then a series of narrow, light and dark stripes which become less distinct ventrally and finally disappear.

Of 72 specimens examined, 68 had 8 anal rays, 3 had 7, and 1 had 9, while all had 8 dorsal rays. There are usually from 51 to 59 scales in the lateral line and 11 to 13 above it. The scales (fig. 11–13) are generally spatulate in form, mostly longer than broad; the apical edge very convex or even pointed, lateral edges usually sloping somewhat toward apex, basal edge double concave with a rather pronounced median prolongation which is the base of a strong median ridge; basolateral ridges prominent, apicolateral ridges more or less indistinct; apical region of scales located notably near the basal edge; basal slope abrupt; apical slope gentle. Basal radii absent; lateral radii weak and irregular, sometimes absent on one or both sides, numbering from 1 to 5; apical radii 14 to 24, usually 16 to 20.

Measurements of a series of 10 specimens of this species are given in "The Fishes of the Coastal Streams of Oregon and Northern California" (Snyder, Bulletin of the Bureau of Fisheries, vol. XXVII p. 177, *Rutilus symmetricus* near Philo, Cal.).

Hesperoleucus parvipinnis, new species. *Short-finned roach.*

This form, found in the Gualala River basin, is characterized by the robust body, deep caudal peduncle, short snout, short, rounded fins, and by having 8 and 7 rays in the dorsal and anal fins.

Description of the type, no. 74466, United States National Museum, Gualala River, Sonoma County, Cal. Length 83 millimeters.

Head 3.9 in length to base of caudal; depth 3.9; depth caudal peduncle 2.2 in head; eye 4.2; interorbital space 2.8; snout 3; dorsal 8; anal 7; scales in lateral line 59; between lateral line and middle of back 13; between lateral line and origin of ventral 8; between occiput and origin of dorsal 30.

Body deep, the caudal peduncle deep and heavy; eye not altogether in anterior part of head, and projecting a little below a median line alongside of body. Gillrakers on anterior arch 8, very short and stumpy. Pharyngeal teeth (cotypes) 4–5, 4 on the right side, the grinding surface no wider than the main shaft of the tooth; well defined hooks present. No variation appeared on an examination of the teeth of a number of specimens. Anterior third of lateral line with a gentle downward curve, the remainder straight. Origin of dorsal midway between posterior margin of eye and base of caudal fin; anterior rays highest, 1.4 in length of head, falling somewhat short of tips of posterior rays in depressed fin. Ventrals inserted anterior to a vertical through origin of dorsal, reaching anal opening when depressed, their edges rounded. Anal 1.5 in head; rounded. Caudal deeply emarginate, the lobes rounded; the length slightly less than that of head. Pectoral rounded, 1.2 in head.

Color in spirits dusky above, lighter below; a light lateral stripe two scales wide extending from upper edge of gill opening to base of caudal and entirely above lateral line; below this a somewhat wider dark stripe, which in turn is followed by several narrower and very distinct dark stripes which grow lighter ventrally.

In 80 specimens of *H. parvipinnis*, 70 had 7 anal rays, 9 had 8, and 1 had 6, all having 8 dorsal rays. There are usually from 54 to 59 scales in the lateral line, and 14 to 16 rows above it. The scales (fig. 14–16, pl. XIII) are rather small, usually somewhat longer than broad, generally quadrangular, the apical and basal edges not very strongly convex; lateral edges almost parallel. Spatulate examples are not rare. The apical slope gentle, basal slope abrupt; basolateral ridges prominent, the others well marked. No

basal radii present; lateral radii weak and few in number, 1 to 4; often absent; apical radii 11 to 24, usually 13 to 19.

Measurements of a series of specimens are recorded in the paper above referred to. (Snyder, Bulletin of the Bureau of Fisheries, vol. XXVII, p. 177, *Rutilus symmetricus*.)

Hesperoleucus mitrulus, new species. *Northern roach.*

This name is proposed for the form found in the streams tributary to the north end of Goose Lake, a basin properly belonging to the Sacramento system, but practically separated from it. This species has not been reported from the turbulent streams that flow into Goose Lake from the mountains on the eastern side, nor has it been taken in the lake itself. It is characterized by the short dorsal and anal, 8 and 7 rays, respectively, by having the fins lower and shorter than those of related forms, and in the peculiar cup-like shape of the scales.

Description of the type, no. 74474 United States National Museum, from Drew Creek, Lake County, Oreg. Length, 84 millimeters.

Head 4.7 in length to base of caudal; depth 4.7; depth caudal peduncle 2.4 in head; eye 4.6; interorbital area 3; snout 3; dorsal rays 8; anal rays 7; scales in lateral line 60; between lateral line and middle of back, 14; between lateral line and origin of ventral, 8; between occiput and origin of dorsal, 37.

Body rather deep and heavy, perhaps a little more slender than that of *M. navarroensis* or *M. parvipinnis;* snout short and rounded; eye entirely within anterior part of head, and not quite above a median lateral line of body. Gillrakers of first arch, 9; very small. Pharyngeal teeth (cotypes), 4–5, 4 on the right side; a grinding surface about equal in width to the shaft of tooth; small hooks at tips. Lateral line with a gentle downward curve on anterior half. Insertion of dorsal midway between center of pupil and base of caudal, the height about 1.6 in head, the edge rounded; ventrals inserted anterior to dorsal, the edges rounded, not reaching vent when fin is depressed. Anal rounded posteriorly; 1.8 in head. Caudal deeply incised, the lobes rounded; slightly longer than head. Pectorals rounded; 1.7 in head.

Color in spirits dark brown above, lighter beneath; no dark pigment on the ventral surface. A light stripe 2 scales wide passing from upper edge of gill opening to base of caudal, entirely above lateral line; beneath this a conspicuous dark stripe which is narrowed to a line anteriorly, nearly 3 scales broad posteriorly; sides anteriorly with several very narrow and indistinct dark stripes.

When examined under the microscope, the scales (fig. 17–20, pl. XXIII) are seen to be very convex, almost conical, usually though not always rounded, the basal edge scalloped. They are small in size, there being 54 to 61 in lateral series, 32 to 38 before the dorsal, and 12 to 15 above the lateral line. Basal radii are present in large number, and they are distinct and strong, occasionally entering the nuclear area of the scale. They number from 8 to 17, usually 12 to 15. The ridges of the scales being scarcely developed, there is no sharp line of demarkation between apical, lateral, or basal regions. The apical radii number from about 13 to 20, usually 15 to 18; lateral radii 3 to 9, generally 4 to 6 or 7. Measurements of 20 examples of this species were published in the paper previously referred to. (Snyder, Bulletin of the Bureau of Fisheries, vol. XXVII, p. 98, *Rutilus symmetricus*.)

Hesperoleucus subditus, new species. *Monterey roach.*

This species is related to *H. venustus* of Coyote Creek and other streams tributary to San Francisco Bay. It differs in having a somewhat more robust body, slightly shorter fins, fewer dorsal and anal rays, and a smaller number of scales in the lateral line.

Description of the type, no. 74475, United States National Museum, from Uvas Creek, Pajaro River basin, Santa Clara County, Cal. Length, 110 millimeters. (Fig. 3.)

Head 3.8 in length to base of caudal; depth 3.6; depth caudal peduncle 2.3 in head; eye 4.4; interorbital area 2.6; snout 3.1; dorsal rays 8; anal rays 7; scales in lateral line 53; between lateral line and middle of back 14; between lateral line and origin of ventral 7; between occiput and origin of dorsal 28.

Body markedly robust, deep and heavy, the caudal peduncle especially so; head rather blunt, the snout rounded; eye just within anterior half of head and entirely above median line of body; angle of mouth reaching a vertical which passes a little anterior to orbit. Gillrakers on first arch 9, very short and blunt. Pharyngeal teeth (of cotypes) 4–5, 4 on the right side; a narrow grinding surface on each tooth, a slight hook near the tip. An examination of 10 individuals shows no material variation in the character of the teeth. Lateral line curved downward to a point above insertion of ventrals from where it is more or less straight to base of caudal. Origin of dorsal midway between center of pupil and end of last caudal vertebra; the 2 anterior rays highest, 1.25 in head; their tips falling somewhat short of those of posterior rays when fin is depressed. Ventral inserted a little anterior to dorsal, the point of insertion being midway between nostril and base of caudal; edge of fin rounded; not quite reaching anal opening when depressed. Anterior rays of anal longest, equal to those of dorsal; reaching beyond tips of posterior rays in depressed fin. Caudal emarginate, the lobes broadly rounded and about equal; somewhat longer than head. Pectoral rounded, 1.3 in head.

Color in spirits, dark above, light below; a faint, light stripe about 2 scales wide extending from upper edge of gill opening alongside of body to base of caudal, the stripe being straight and lying entirely above the lateral line; beneath this a series of narrower and very indistinct alternating light and dark

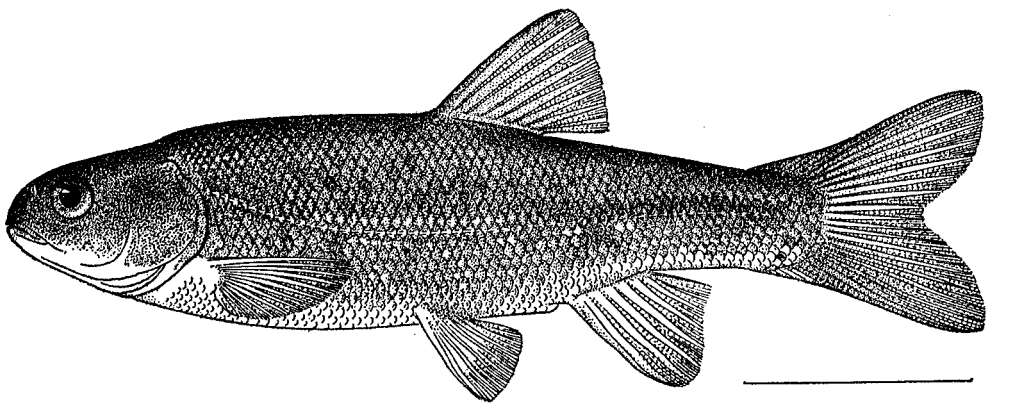

FIG. 3.—Hesperoleucus subditus, new species. Type.

stripes. In life deep olive above, whitish beneath, the transition appearing below the lateral line; a silvery pigment appearing on the lighter areas.

The number of dorsal rays is typically 8, the anal 7. Occasionally examples have 7 or 9 dorsal rays, and a few specimens have 8 anal rays. The following table will serve to illustrate the variation of fin rays:

Number of specimens examined.	Dorsal rays.			Anal rays.	
	7	8	9	7	8
205.....	9	194	2	187	18

Among the 18 examples tabulated as having 8 anal rays 13 were taken from the same pool in the Pajaro at Sargent.

The scales appear to be larger than those of *H. venustus*, and there are consequently a lesser number in the lateral series, the difference, an average one, appearing in the annexed table.

Lateral series of scales	48	49	50	51	52	53	54	55	56	57	58	59	60	61
Number of specimens, Pajaro system	1	2	14	10	14	26	28	18	16	8	1	1	....	....
Number of specimens, San Francisco Bay system	....	....	1	2	3	3	12	24	15	18	11	14	8	2

There is nothing distinctive in the shape of the scales (fig. 21–25, pl. XXIV), but on the contrary they exhibit a great variety of forms, none of which, however, is peculiar to any particular region. They are usually rather oblong, although rounded or quadrangular specimens may be found. Some are spatulate and others have the edges rather straight and nearly parallel. The nuclear area is distinctly basal in location, and the basolateral angles are pronounced. The apicolateral angles are usually weak or absent. The apical radii vary from 12 to 25, the usual number being from 15 to 21 in examples 2 or 3 years old, the radii increasing with age, as may be seen on examining the illustrations.

Number of apical radii	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Number of specimens	1	9	13	21	36	45	48	34	29	25	11	2	3	1

Lateral radii are present in nearly all cases, the scales in this regard differing markedly from those of *M. venustus*. The lateral radii number from 1 to 8, 1 to 5 or 6 being the most usual. There are no basal radii.

This species has about 36 vertebræ, in this respect not differing from related forms. Of 10 specimens from the Pajaro, 8 had 36 vertebræ, while the others had 35 and 37, respectively. In a similar series of *M. venustus* from Isabel Creek, Santa Clara County, 8 had 36 vertebræ and 2 had 37.

M. subditus is generally distributed in the Pajaro system, living in such portions of the streams as flow through the foothills and lower mountain ranges. It does not frequent the upper, turbulent parts of the creeks, nor is it often found in the low valleys where the water is shallow and the bed sandy.

MEASUREMENTS OF SPECIMENS OF HESPEROLEUCUS SUBDITUS, NEW SPECIES.

	Salinas Basin.									
	Salinas River near Gonzales.					Arroyo Seco Creek.				
Length of body....mm.	77	74	80	75	75	89	87	85	78	70
Length head	0.27	0.25	0.27	0.27	0.26	0.26	0.25	0.27	0.26	0.28
Depth body	.25	.24	.24	.26	.26	.26	.24	.26	.26	.27
Depth caudal peduncle	.11	.11	.11	.11	.11	.10	.10	.11	.11	.11
Length caudal peduncle	.23	.23	.22	.21	.22	.22	.21	.20	.21	.20
Length snout	.09	.085	.09	.09	.09	.08	.08	.09	.08	.08
Diameter eye	.06	.06	.06	.06	.06	.06	.06	.07	.06	.07
Interorbital width	.09	.09	.09	.09	.09	.08	.09	.085	.09	.09
Depth head	.185	.18	.18	.19	.19	.18	.20	.19	.18	.20
Snout to occiput	.22	.20	.22	.21	.21	.20	.20	.22	.21	.21
Snout to dorsal	.57	.55	.59	.55	.60	.58	.56	.58	.58	.59
Snout to ventral	.52	.51	.53	.54	.54	.52	.52	.54	.55	.52
Length base of dorsal	.11	.12	.12	.135	.115	.13	.12	.12	.12	.12
Length base of anal	.10	.09	.11	.11	.09	.10	.11	.10	.10	.10
Height dorsal	.21	.19	.16	.16	.20	.16	.17	.18	.19	.18
Height anal	.20	.18	.16	.17	.175	.16	.15	.16	.17	.15
Length pectoral	.26	.23	.19	.20	.20	.19	.18	.20	.19	.18
Length ventral	.18	.16	.14	.15	.16	.15	.13	.15	.14	.14
Length caudal	.30	.25	.26	.27	.29	.24	.25	.25	.24	.24
Dorsal rays	7	8	8	8	8	8	8	8	8	8
Anal rays	7	7	7	7	7	7	8	7	7	7
Scales lateral line	53	54	51	53	53	50	54	50	53	55
Scales above lateral line	13	14	12	14	13	13	14	14	13	13
Scales below lateral line	7	8	7	7	7	7	7	7	7	7
Scales before dorsal	29	31	30	28	28	27	30	30	31	28

MEASUREMENTS OF SPECIMENS OF HESPEROLEUCUS SUBDITUS, NEW SPECIES—Continued.

	Pajaro Basin.										San Lorenzo Basin.				
	Pajaro River at Sargent.					Uvas Creek.					San Lorenzo River.				
Length of body.....mm..	79	74	70	63	60	91	84	88	76	77	65	64	62	55	57
Length head	0.24	0.25	0.26	0.26	0.26	0.25	0.24	0.26	0.25	0.26	0.27	0.26	0.28	0.26	0.27
Depth body	.26	.25	.25	.26	.28	.26	.25	.27	.27	.26	.26	.24	.27	.27	.28
Depth caudal peduncle	.10	.11	.11	.11	.12	.12	.11	.12	.12	.11	.12	.11	.11	.12	.12
Length caudal peduncle	.22	.22	.21	.22	.23	.23	.22	.22	.22	.23	.22	.23	.22	.23	.22
Length snout	.08	.09	.09	.09	.08	.08	.08	.08	.09	.085	.08	.08	.09	.08	.09
Diameter eye	.06	.05	.06	.06	.07	.05	.06	.06	.06	.06	.06	.06	.065	.065	.065
Interorbital width	.10	.085	.085	.08	.09	.09	.09	.10	.10	.10	.10	.09	.09	.09	.10
Depth head	.18	.18	.18	.20	.20	.18	.19	.19	.20	.19	.20	.22	.20	.20	.20
Snout to occiput	.20	.21	.20	.21	.22	.20	.20	.20	.20	.21	.23	.21	.22	.23	.22
Snout to dorsal	.57	.54	.57	.57	.58	.57	.57	.55	.56	.57	.58	.57	.58	.59	.58
Snout to ventral	.53	.52	.51	.52	.52	.52	.52	.53	.51	.51	.53	.53	.53	.53	.54
Length base of dorsal	.13	.12	.13	.13	.12	.13	.13	.13	.14	.14	.12	.12	.12	.12	.13
Length base of anal	.12	.10	.12	.12	.10	.11	.11	.10	.10	.11	.10	.10	.10	.10	.10
Height dorsal	.19	.20	.20	.21	.19	.19	.20	.20	.20	.18	.18	.20	.18	.19	.20
Height anal	.17	.17	.17	.19	.18	.17	.18	.18	.18	.18	.16	.16	.16	.18	.19
Length pectoral	.19	.19	.19	.21	.23	.20	.20	.20	.19	.20	.18	.20	.19	.24	.21
Length ventral	.15	.15	.16	.16	.15	.16	.16	.16	.15	.16	.14	.14	.14	.15	.16
Length caudal	.28	.27	.27	.29	.27	.26	.28	.27	.28	.27	.25	.26	.25	.26	.27
Dorsal rays	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Anal rays	8	8	7	7	7	7	7	7	7	7	7	7	7	7	7
Scales lateral line	54	56	56	53	53	55	51	53	55	53	56	57	56	56	57
Scales above lateral line	15	15	14	14	13	13	14	15	15	15	14	14	15	14	16
Scales below lateral line	7	7	8	7	8	8	8	7	8	8	8	7	8	8	8
Scales before dorsal	32	30	31	31	30	29	30	29	32	32	31	32	30	30	32

Agosia carringtoni (Cope). *California dace.*

Specimens of *Agosia* taken in the Pajaro system do not appear to differ from those of the Sacramento.

Salmo irideus Gibbons. *Rainbow trout.*

The trout taken in the tributaries of the Pajaro system appear to belong to the native species, except a few specimens from the San Lorenzo River, which have larger eyes and a somewhat different color pattern. The native trout appear to agree in all details of structure and color with specimens from Coyote Creek and other streams tributary to San Francisco Bay. The young of other species have been introduced into various streams from time to time, but either none have been taken at the numerous collecting stations, or else the writer has failed to recognize them among the preserved specimens. It is possible, however, that the introduced forms of rainbow trout come to resemble the native species so closely that their identity would be difficult to detect. The dead bodies of large steelheads were occasionally seen in Uvas, Arroyo Seco, and Nacimiento Creeks. At high water they are said to enter all the streams in large numbers. They are frequently mistaken for salmon.

Small trout, beautiful in color and excellent in quality, abound in the upper courses of the creeks and rivers, and especially good fishing may be had in Nacimiento and San Antonio Creeks. The trout of the main channels of the rivers are apt to be rather poor in quality, and are usually light silvery in color. Occasionally a silvery specimen is taken among the darker colored examples of a tributary stream.

Oncorhynchus tschawytscha (Walbaum). *Chinook salmon.*

This species was reported from the San Lorenzo and Pajaro Rivers. No small salmon were taken with the seine at any collecting station.

Oncorhynchus kisutch (Walbaum). *Silver salmon.*

Silver salmon were said to have been observed in the San Lorenzo River at Santa Cruz.

Gasterosteus cataphractus (Pallas). *Stickleback.*

Sticklebacks appear in all the streams tributary to Monterey Bay. They usually have from 4 to 6 lateral plates, the sides being mostly naked and the caudal keel absent. Many fully plated examples were collected, however, these being found near the mouths of the rivers in close proximity to salt water.

An examination of the sticklebacks of this coast will scarcely bear out the conclusions of Mr. C. Tate Regan published in a recent paper.[a] He finds that a circumpolar species *G. aculeatus* extends downward along our coast to the Santa Clara River, Cal., and then gives place to *G. santa-annae*, a species inhabiting the Santa Ana River, which reaches the ocean a few miles to the southward of the Santa Clara River. The distinctive characters assigned to *G. santa-annae* are (compared with *G. aculeatus*) sides of body without bony plates (rarely with 2 or 3 anteriorly); dorsal rays 10 or 11; anal rays 6 or 7 (8); origin of first dorsal spine well behind base of pectoral and only slightly in advance of base of pelvics, 29 vertebræ.

Some time ago Rutter [b] showed that in the region between the Santa Ana River and San Francisco Bay all conditions of lateral armature from entirely naked to completely plated sides might be found. Rutter's notes show that of 111 specimens from the Santa Ana River at Riverside, 104 were naked, 4 had 1 plate, and 3 had 2 plates. Of 298 individuals from the Santa Clara River, 76 had no lateral plates, 41 had 1, 99 had 2, 67 had 3, and 15 had 4. These data seem sufficient to prevent differentiating the Santa Ana fishes on the character of lateral armature, and a perusal of Rutter's paper will demonstrate the futility of attempting to show that the sticklebacks of any locality on this coast may be distinguished by the number of plates on the sides of their bodies. The present writer [c] examined about 2,000 specimens taken in the rivers between San Francisco Bay and the Columbia, and became convinced that within that region at least but one form could be recognized. The data at hand simply show that a larger proportion of naked examples have been collected in the Santa Ana River, but judging from what is known of the lateral armature of sticklebacks in other streams it would not be very hazardous to predict that further collecting in the Santa Ana would result in securing specimens that are more fully armed. That the Santa Ana fishes are not distinguished by peculiar fin structure is shown in an examination of 20 specimens selected at random from a collection from Santa Clara River, where 3 examples have 10, 13 have 11, and 4 have 12 dorsal rays; 5 have 7, 11 have 8, and 4 have 9 anal rays. The position of the first dorsal spine and also the number of vertebræ are likewise variable. In brief, no one seems able to find any characters or set of characters that will serve to differentiate the Santa Ana sticklebacks, or in fact those from any other river basin along the west coast. Perhaps it may be said that individuals of the species generally attain a larger size and a more complete armature in the north, while they are usually smaller and more scantily armed in the south; and also that while such a geographic variation obtains a similar one seems to appear which is coordinate with habitat, i. e., heavily plated individuals are more generally found in or near salt water, while the more nearly naked ones usually occur in the rivers at some distance from the ocean.

It seems better to retain the name *G. cataphractus* for west American sticklebacks until sufficient evidence shows that it is not tenable.

Archoplites interruptus (Girard). *Sacramento perch.*

Small sunfish were collected in the Pajaro at Sargent and near the junction of the Pajaro and San Benito. This species has not been reported from Coyote Creek nor any of the smaller streams tributary to San Francisco Bay.

Hysterocarpus traski Gibbons. *Fresh-water viviparous perch.*

Frequently seen in the Pajaro and Salinas Rivers. Does not occur in the San Lorenzo.

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[a] Regan, C. Tate: The species of three-spined sticklebacks. Annals and Magazine of Natural History, ser. 8, vol. IV, p. 435.

[b] Rutter, Cloudsley: Notes on fresh-water fishes of the Pacific slope of North America. Proceedings California Academy Sciences, 2d ser., vol. VI, p. 245–254.

[c] Snyder, J. O., op cit., Bulletin Bureau Fisheries, vol. XXVII, 1907, p. 183.

Cottus asper Richardson. *Prickly bullhead.*

This species is a channel form, occurring in deep, quiet pools, and most often near the mouths of the rivers. It is easily caught with a baited hook. The following fin ray counts were made from specimens taken in the Pajaro River.

	Dorsal spines.			Dorsal rays.			Anal rays.		Pectoral rays.		
Spines or rays	7	8	9	19	20	21	16	17	15	16	17
Number of specimens	1	14	10	8	14	3	17	8	5	16	4

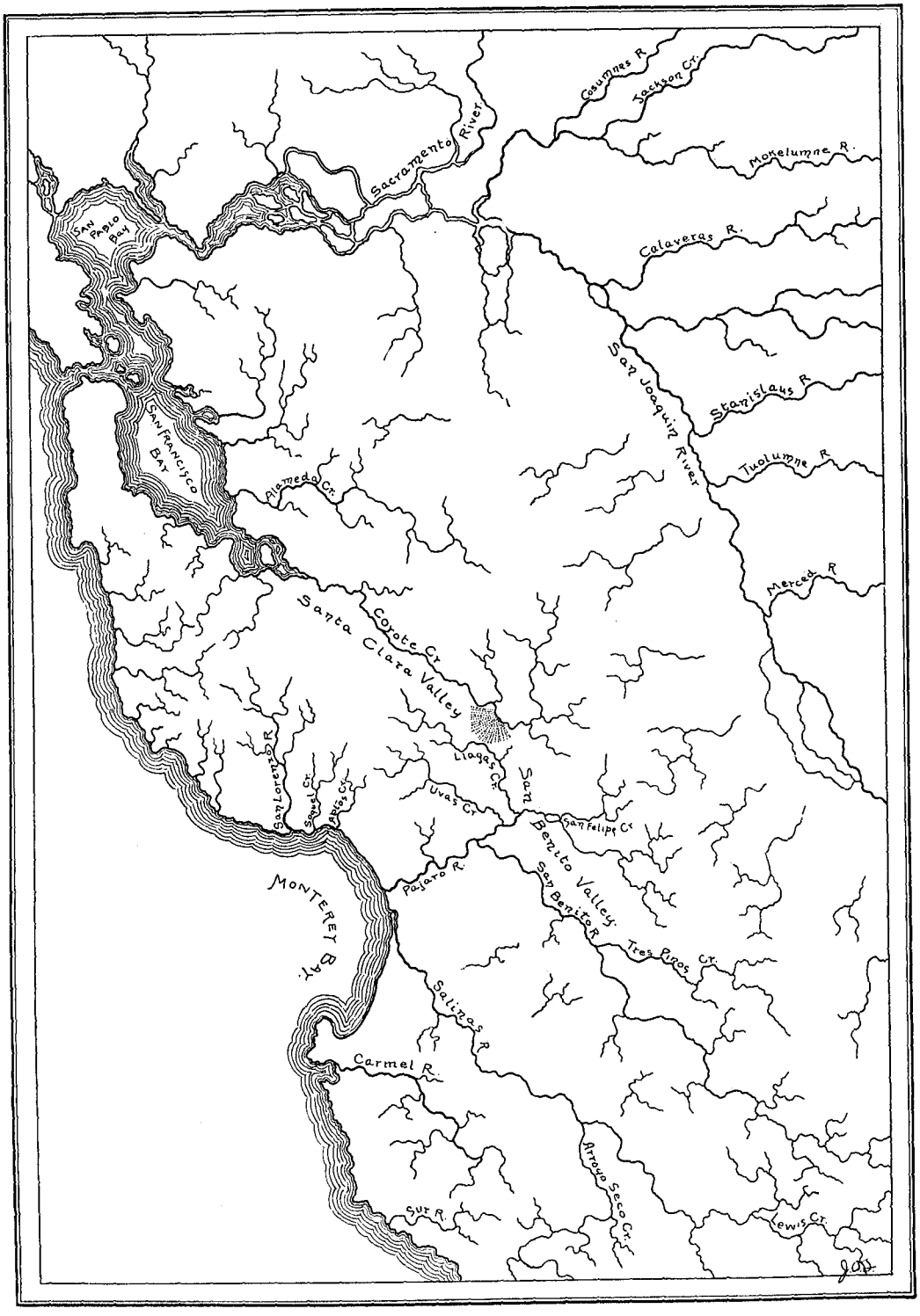
Cottus aleuticus Gilbert. *Aleutian bullhead.*

Cottus aleuticus appears to be associated with *C. asper*, often being taken in the same seine haul with the latter.

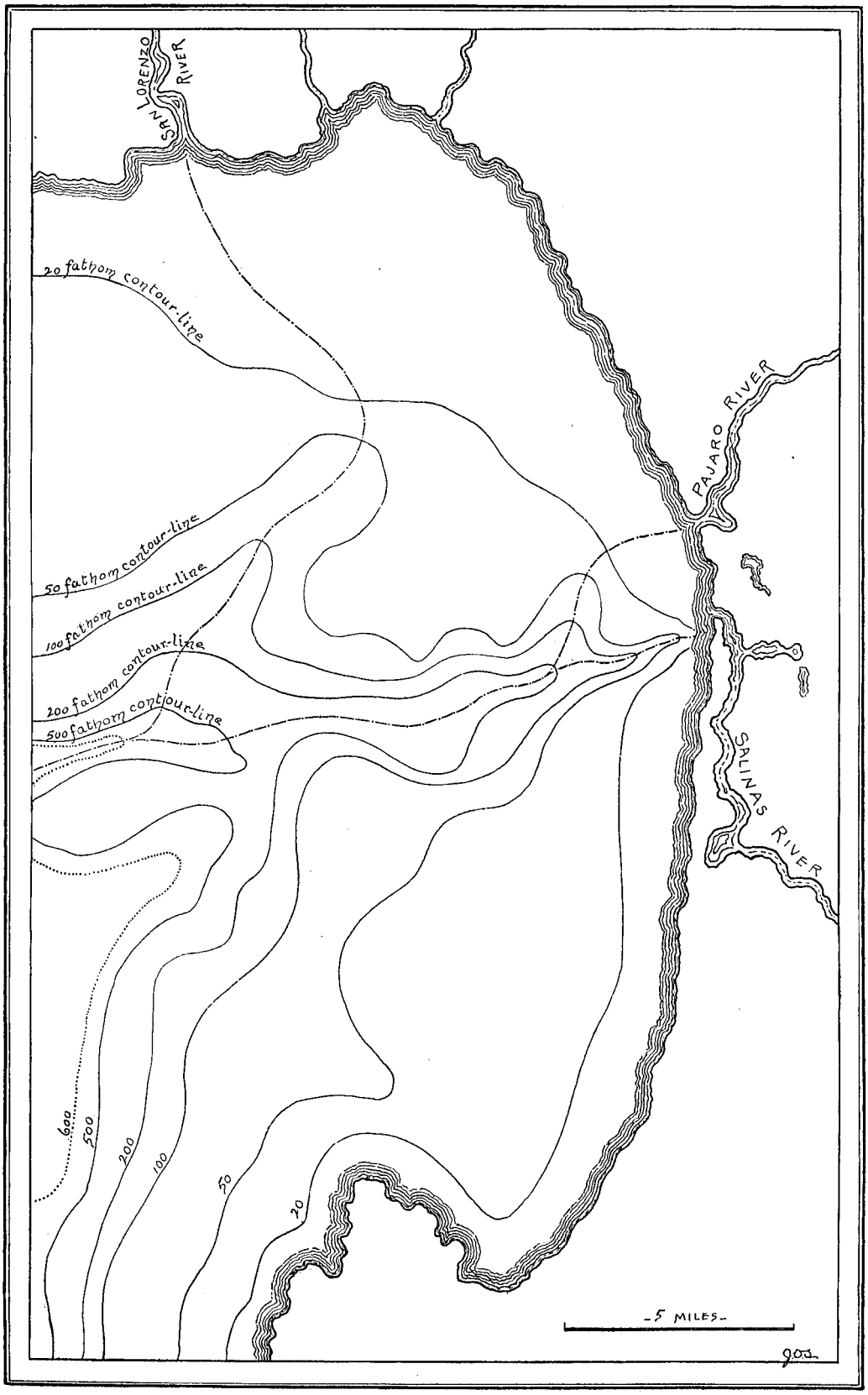
Cottus gulosus (Girard). *Rifflefish.*

Cottus gulosus inhabits the upper courses of the creeks, apparently preferring the clear, cool water of the ripples, where specimens may often be seen lying on the bottom near large pebbles or bowlders. They approach food with short, jerky movements, always keeping close to the bottom. They are difficult to collect, as they usually dart under the lead line of the net if it passes over the least obstruction.

	Dorsal spines.			Dorsal rays.			Anal rays.			Pectoral rays.		
Spines or rays	7	8	9	17	18	19	13	14	15	14	15	16
Uvas Creek	2	9	.....	1	9	1	.....	9	2	1	10	.....
Llagas Creek	2	16	2	2	12	6	1	16	3	1	18	1



Map of the Pajaro River system and contiguous basins.



Topographic map of Monterey Bay, showing submerged valley and probable ancient courses of Pajaro, San Lorenzo, and Salinas Rivers.

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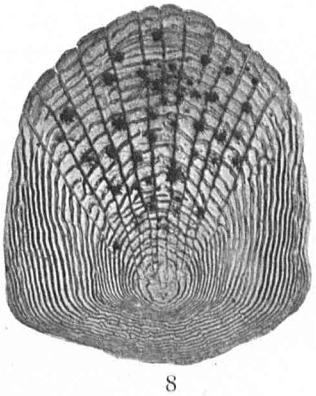

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FIG. 1 TO 4.—Scales of *Hesperoleucus symmetricus*, × 20; San Joaquin River at Polaski, Oct. 20; length, 90 to 108 millimeters.
FIG. 5 TO 8.—Scales of *Hesperoleucus venustus*, × 20; (5 and 6) Coyote Creek, July 25, length 85 millimeters; (7) Alameda Creek, June 15, length 94 millimeters; (8) Napa River, May 26, length 94 millimeters.

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FIG. 9 AND 10.—Scales of *Hesperoleucus venustus*, × 20; (9) Conn Creek, May 26, length 104 millimeters; (10) Russian River, June 17, length 95 millimeters.
FIG. 11 TO 13.—Scales of *Hesperoleucus navarroensis*, × 20; Navarro River, June 14; length 88 to 91 millimeters.

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FIG. 14 TO 16.—Scales of *Hesperoleucus parvipinnis*, × 20; Wheatfield Fork, Gualala River, June 6, length 74 to 79 millimeters.
FIG. 17 TO 20.—Scales of *Hesperoleucus mitrulus*, × 20; Drew Creek, July 11, length 84 to 87 millimeters.

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FIG. 21 TO 25.—Scales of *Hesperoleucus subditus*, × 20.

FIG. 21.—Uvas Creek, Oct. 15, length 110 millimeters.
FIG. 22.—Uvas Creek, Oct. 15, length 85 millimeters.
FIG. 23.—Salinas River, Oct. 10, length 95 millimeters.
FIG. 24.—San Antonio Creek, July 24, length 89 millimeters.
FIG. 25.—Nacimiento Creek, July 16, length 85 millimeters.
FIG. 26.—Scale of *Lavinia ardesiaca*, × 17, Pajaro River, Aug. 4, length 195 millimeters.

ANATOMY AND HISTOLOGY OF THE ALIMENTARY TRACT OF THE KING SALMON

By Charles W. Greene, Ph. D.

Department of Physiology and Pharmacology,
University of Missouri

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ANATOMY AND HISTOLOGY OF THE ALIMENTARY TRACT OF THE KING SALMON.

By CHARLES W. GREENE, Ph. D.,
Department of Physiology and Pharmacology, University of Missouri.

INTRODUCTORY.

In the older literature one finds discussions of the anatomy, histology, and embryology of a number of species of trout.[a] More recently a brief histological study was made by Gulland on the Atlantic salmon, *Salmo salar*.[b] This study of normal structures is very brief and is given by the author incidental to the presentation of certain degenerative changes in the digestive tract in the Scottish species. Gulland's paper covers only about six pages of printed matter, including both the normal and pathological findings. Previous to the work of Gulland, Miescher[c] published certain gross findings in the Rhine representative of the Atlantic salmon, but he does not offer histological details.

No studies presenting the details of the anatomy and histology of the alimentary tract of the king salmon thus far have been published. In my studies on the function of the digestive tract of this salmon, and in similar studies of the changes that occur during the spawning migration of the species, it was found necessary to examine the normal structural characteristics of this interesting fish. The facts determined in these studies are set forth in the present paper.

The digestive tract of the king salmon is, on the whole, quite similar in its gross anatomy to that of the Atlantic salmon, *Salmo salar*, and also is comparable to the anatomy of the species of trout. The alimentary canal of the king salmon has the relatively simple structure which characterizes carnivorous fishes in general. It consists of the usual parts, i. e., the mouth, esophagus, stomach, and intestine. Of special interest are the numerous diverticula of the small intestine attached to that limb of the intestine which immediately follows the stomach, and known as the pyloric cæca. Figure 3 presents a salmon in outline in which the anatomy of the alimentary tract is shown in its normal relations.

The anatomy of the mouth is not presented in this paper.

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[a] Oppel, Albert: Mikroskopische Anatomie, bd. 1, p. 28, 70, etc., bd. 2, p. 7, etc.

[b] Paton, D. Noël: Life history of the salmon. Article 3, by Gulland, "Minute structure of the digestive tract of the salmon, and the changes which occur in it in fresh water." Report of the Fisheries Board for Scotland, 1898, p. 13.

[c] Miescher, Friedrich: Statistische und Biologische Beiträge zur Kenntniss vom leben des Rheinlachses im Süsswasser. Schweizerischer Fischerei-Ausstellung zu Berlin, 1880, p. 154. Also reprinted in Die Histochemischen und Physiologischen Arbeiten von Friedrich Miescher, 1897, p. 116.

HISTOLOGY OF THE ESOPHAGUS.

The esophagus in the king salmon is a very short muscular tube extending from the posterior part of the pharyngeal cavity to the stomach. The length of the esophagus is only 3 to 5 centimeters, even in the largest salmon.

A cross section through the esophagus shows three coats, of which the thickest and most important is the muscular coat. The lining of the esophageal tube is composed of epithelium which is complexly folded and which rests upon a subepithelial connective tissue foundation.

EPITHELIAL COAT OF THE ESOPHAGUS.

The epithelial coat of the salmon esophagus consists of columnar epithelial cells. In the anterior portion this epithelial layer is supported by one or two irregular layers of deeper cells. This region represents the transitional stages between the stratified epithelium of the mouth and pharynx and the single layer of epithelial cells lining the rest of the alimentary tract. The smaller basal epithelial cells are represented for some little distance down the esophagus, though they are relatively few in number except in the region just described.

Most of the epithelial cells have clear outer margins with a stainable protoplasm and the nucleus crowded to the base of the cell. This is interpreted as meaning that these cells are chiefly concerned with the production of mucus, that they are in fact mucous cells.

The mucous coat is complexly folded. In microscopic cross section the folds are often cut in such a way as to simulate simple tubular glands. When the gross folds are unusually large then these simple tubelike appearances may be located on the sides of the larger folds. This is a mechanical condition which appears later, i. e., especially in the mucous epithelium of the intestine, and in simpler form in the cæca. In all the sections available the esophagus is strongly contracted so that the epithelial coat is thrown into unusually rich folds. The study of cross sections leads one to the view that if the esophagus were fully distended most of these epithelial folds would be eliminated. No differentiation among the epithelial cells of the esophageal mucosa could be discovered.

SUBEPITHELIAL CONNECTIVE TISSUE OR TUNICA PROPRIA.

This coat in the esophagus consists of a simple type of areolar connective tissue. The nuclei are small and oval, the connective tissue strands are open and especially loose in arrangement. Occasional blood vessels are noted in the sections. Just at the base of the epithelial coat the connective tissue is a trifle more dense and the fibers and nuclei are arranged parallel with the inner surface of the epithelial coat. No evidence of smooth muscle fibers or other specially differentiated cells was found in the tunica propria of the salmon esophagus.

MUSCULAR WALL OF THE ESOPHAGUS.

The muscular wall of the esophagus consists of a single circular coat. This is a thick, heavy muscular mass which is composed wholly of striated fibers. These fibers are about 15 μ in diameter. Their length was not determined, but they are relatively long. Numerous nuclei are found along every fiber, each nucleus lying just within the sarcolemma. The nuclei of the striated fibers are oval, but vary considerably in shape and size, averaging 6 by 9 μ. The total thickness of the circular muscle coat amounts to about 200 μ in a young salmon 7 cm. long in which these measurements were made. In the adult fish of course the total mass of the muscle is very much greater.

SEROUS COAT.

The posterior end of the esophagus where it passes over into the stomach is free and therefore covered with a serous coat. The serous epithelial cells covering this coat are very thin, and are of the usual stratified type. No thick subserous connective tissue which characterizes the intestine and cæca was noted in the esophagus. It was noted, however, that numerous blood vessels are present just under the serous coat. This vascular factor characterizes the esophagus in all the salmon studied.

THE STOMACH.

FORM AND DIVISIONS OF THE STOMACH.

The stomach of the king salmon is a U-shaped organ. The first limb of the U extends from the esophagus straight posteriorly a distance equivalent to one-fourth the length of the fish. At this point the stomach makes a sharp bend and extends directly back toward the head for about one-third the length of the first division. In the adult the lengths of these divisions of the stomach vary in proportion to the total length of the fish, but in an average-sized salmon, 80 cm., the length of the first, or cardiac division is from 20 to 22 cm., and of the second or pyloric division, from 6 to 7 cm.

There is great variation in the size of the stomach in feeding salmon from Monterey Bay. In the market there are always individual fishes in which the stomachs are empty and contracted until the gastric cavity is obliterated, i. e., until the mucous folds are in contact and the cavity is a potential one only. In the empty condition the cardiac division of the stomach is a regular cylinder in form and shape. The contracted walls are firm and resistant to the touch, and the total diameter is reduced to 1.5 to 2 cm. The pyloric division is also contracted, is firm to the touch, and its diameter is a trifle less in any given salmon than that of the cardiac division. The mucosa is compressed into great longitudinal ridges or folds. When the stomach wall is split open for its full length and the cavity opened out, then these folds appear as prominent longitudinal ridges.

If only a small amount of food is present in the stomach—for example, a single small fish or a squid—the mucous lining is pressed firmly against this food mass and the gross shape of the stomach is much the same as in the empty organ. But in these instances

the mucous membrane is quite red in appearance, as though filled with an unusual supply of blood.

When a large mass of food is present in the stomach and that in an advanced stage of digestion, then the muscular walls are greatly relaxed, the stomach is more flaccid, and its diameter is enormously increased. The mucous coat is then quite free from folds and the whole wall is relatively thin and pliable. In this condition the capacity of the stomach is at its maximum. In another connection I have called attention to the finding of as many as 18 squid besides several small fishes in one such dilated stomach. In such an instance the diameter of the stomach is greatly increased, but the length remains quite constant.

COATS OF THE STOMACH WALL.

The anatomical divisions that constitute the stomach wall are essentially the same in the king salmon as for carnivorous fishes in general, the details of the structure of the salmon comparing very closely with the carnivorous type. Beginning with the lining mucous membrane, one may record in their regular order the following coats:

I. Mucosa.
    1. Epithelium.
    2. Tunica propria.
    3. Stratum compactum.
    4. Stratum granulosum.
    5. Muscularis mucosa.
II. Submucosa.
III. Muscularis.
    1. Muscularis circularis.
    2. Muscularis longitudinalis.
IV. Serosa.

The stomach of the king salmon is characterized by the extensive differentiations of the mucosa, which possesses the five coats as outlined above. The structure is noteworthy for three features—first, the great differentiation of the gastric glands in the cardiac region; second, the strong development of the stratum compactum in this species; and, third, for the presence of a constant and definite layer of cells of special structure to be described more fully later as the stratum granulosum. This type of granule cell is present constantly, not only in the stomach but in all divisions of the alimentary canal. Its size and evident importance in the salmon physiology amply justify its description as a definite coat.

HISTOLOGY OF THE GASTRIC MUCOSA.

The epithelial coat of the salmon stomach presents a rather thick layer. A section through this coat will vary according to the location of the area in the stomach from which it is taken. In the cardiac region the coat is thickest, the thickness being due to the presence of the gastric glands. In the pyloric division of the stomach the structure is simpler, as will be described later.

Epithelium of the cardiac stomach.—The cardiac epithelial coat presents on the surface always a layer of slender cylindrical cells of the usual cylindrical or columnar epithelial type. Perhaps these cells are more slender than is noted in many animal species. Where the coat forms sharp folds the cylindrical cells will in cross section of the folds present great fan-shaped masses.

The cells are almost always slender at the base and somewhat broader at the apex of the cell. They vary in size, but average in thickness 3 μ at the base and 6 μ at the free end. The length of the cells of the free surface varies from 33 to 50 μ. The nucleus is in the basal third of the cell. It is a slender oval mass showing a rather close chromatin network. The normal size of the nucleus is on an average 2 by 6 μ. The outer fourth of the superficial epithelial cell is usually paler, contains less stainable protoplasm, and is relatively larger. This zone is one that takes a most active part in fat absorption. The cylindrical cells are not granular. Gulland's[a] figure 8 represents a view of the cells for *Salmo salar*. The whole gastric epithelium is thrown into deep folds in the empty stomach, folds which are more or less obliterated in the actively digesting organ. When the walls are not greatly distended then the folds are deeper and more pronounced, and the superficial epithelial coat and the deeper seated gastric glands are rather distorted in position and appearance. A more normal relation of the parts of the mucosa is presented in the distended stomach, and in such a stomach, moreover, the relations are most readily determined. The most superficial of the cylindrical cells, the ones that form the free surface bordering on the lumen of the stomach, are the longest and most slender. From this surface, extending down into and lining the mouths of the crypts, the cylindrical cells become gradually and uninterruptedly smaller. The only change in type, however, is one of relative size of the cells. The crypts themselves vary greatly in depth, forming longer or shorter tubes into the bottoms and sides of which the gastric glands open. (See fig. 3, pl. XXVI.)

The epithelial cells lining the tubes of the crypts nowhere present abrupt change in structure from the most superficial type. Where the tubes are relatively long the lining cells, presumably the neck cells of Gulland, become short, cubical, and of uniform size. In the bottoms of the crypts the cubical type of cylindrical cell changes quite suddenly to the secreting type. There is no intermediate structurally different type of neck cell in the king salmon as suggested by Gulland[a] for the Atlantic salmon. The term, "neck cell," when it is used, must refer merely to the fore-shortened type of cylindrical cell.

The point at which the transition takes place from the cylindrical to the glandular type is rather difficult to observe, since it seldom happens that a vertical section cuts through this critical region. Gulland presents a figure of such a transitional region for the Atlantic salmon and calls attention to the change in cell type. In figure 3, plate XXVI, I show the relation as it exists in the adult king salmon. The opening between the crypt and the gland duct is distinctly constricted and rarely cut exactly through its lumen, except in stomachs taken at a stage of digestion in which the whole wall is decidedly relaxed. Then the gland mouth may be more distended or relaxed.

[a] Paton, D. Noël, op. cit., p. 5, and fig. 9.

The superficial epithelial cells undoubtedly serve for the function of absorption throughout the full extent of their surface, even down into the depths of the crypts. This is proven in at least one instance, i. e., for the fats, as detailed in a later report of this series. Fat in process of absorption was found in the cylindrical cells down in the bottoms of the crypts, as well as in those cells on the free surface of the gastric epithelial coat.

The epithelial coat of the cardiac stomach is very thick because of the presence of the numerous gastric glands. The gastric glands are of the tubular type, though they are very irregular as to their position, size, and general arrangement. The glands are diverticula of the superficial crypts described above. Each crypt receives the openings from a number of the gastric glands. The openings are as a rule more numerous and more prominent over the bottoms of the crypts, but many glands open into the sides of and about the rims of the crypts. At the bottom of the average crypt there is a cluster of from three to six glands, the mouths of which open together or sometimes separately into the crypt. In the deeper lying crypts glands are more often to be found opening into the side of a crypt near its middle, or even near its superficial portion, than in those crypts located over the surface of a gross mucous ridge. These latter glands are very short and compact, and they are very irregular in shape and often oval in cross section.

The size of the gastric glands varies greatly, depending on their exact position. The more superficial glands are smaller and the deep ones larger and longer. The variation is due not so much to the size of the gland cells as to the number in the tube, yet there is greater variation in the size of the cells than noted for higher vertebrates.

The gland tubes are not always linear, on the contrary they are bent and very irregular in their extent. In the younger salmon the glands are more tubular as a rule, but older examples are often noted in which the tubes are bilobed at the blind end, or have one or more diverticula in the side walls. A cross section of such a mass of tubes presents very diverse and irregular outlines.

The gland cells are of a single type and are irregularly polygonal in shape, similar to the chief cells in the peptic glands of higher vertebrates. The cells are somewhat larger in the salmon, averaging 12 to 20 μ long by 9 to 18 μ in greatest width. In a cross section of a tube the cells do not approximate each other so closely as in the higher vertebrates, thus forming a wider lumen. (See fig. 4, pl. XXVI.)

The nuclei of the gastric secreting cells are slightly oval, almost spherical and rather large, with a nucleur diameter of from 5 to 6 μ. They are located near the bases of the cells. The cytoplasm of the gastric gland cells is highly granular, being filled with doubly refractive rather small zymogen granules. Special study has not been made of the chemical character of these granules. It has been noted, however, that the granules are relatively very small and that they stain in the characteristic way with eosin and with iron hæmatoxylin. The zymogen granules take these stains lightly and the technique must be followed with considerable care. The granules vary in numbers in the glands of different fishes from the feeding grounds, presumably, as Gulland suggests for *Salmo salar*, in relation to the stage of the progress of secretion and digestion. In certain

young salmon [a] taken early in the progress of an active stage of digestion these gland cells are charged with granules throughout their entire cytoplasm. The granules are smaller and less refractive than the granules of the "granule cells" described below.

The vascular supply of the mucosa of the cardiac division of the stomach has not been especially studied by the methods of injection. Enough has been learned, however, from the study of histological preparations to determine that there is a comparatively rich blood supply to the gastric mucous membrane. Small blood vessels are found in the tunica propria just at the bases of the gastric-gland cells, also between the glands themselves. Numerous capillaries are found about the bases of the glands and in the connective tissue supporting the superficial epithelium in the regions lying just under the superficial epithelium and between the crypts, where there is a relatively high content of supporting connective tissue. Numerous capillary nets are noted. Ofttimes in relatively thick sections capillary nets are noted which resemble somewhat the arrangement of smaller blood vessels as demonstrated by Mall.

Epithelium of the pyloric stomach.—In the pyloric division of the stomach the mucosa forms deep folds arranged in a general longitudinal direction. These folds are covered throughout with the cylindrical type of epithelial cell. Those portions of the cells of the folds bordering on the cavity of the stomach are only slightly different from the cells in the deeper grooves between the folds. This difference consists largely in the fact that the surface cells are more slender and somewhat more club-shaped, comparable to the superficial cells in the cardiac region of the stomach. There are no proper gastric glands in this division of the stomach. The pyloric epithelium forms counterfolds with a number of shallow epithelial pits in the first two-thirds of this division of the stomach. These shallow pits in the mucous epithelium are present occasionally on the sides of the walls of the larger longitudinal folds mentioned above. The many apparent pyloric glands, as seen in the transverse sections of the pyloric gastric mucosa, are in reality only transverse sections of the longitudinal folds. Near the pyloric valve, marking the boundary between the stomach and the intestine, the gastric mucosa consists of a series of simple longitudinal folds, and no suggestion of pyloric gland-like pits occurs. The longitudinal folds are permanent ones, a fact indicated by the somewhat longer and more slender cells present on the free borders of the folds. (See fig. 3, pl. XXVI.) This type of structure extends to the circular constriction, the pyloric valve, marking the boundary between the pyloric stomach and the pyloric intestine.[b]

Tunica propria.—The connective tissue of the stomach mucosa, on which the epithelial coat rests, is called the tunica propria. The term is here used to designate all that structure between the basement membrane of the epithelium and the stratum compactum. The tissue forms an open network varying in general outlines and in thickness according to the degree of stretching of the stomach walls. Folds of the tunica extend up into the grooves among the gastric glands, forming a supporting net-

[a] Salmon no. 45 and 46, Pacific Grove, July 10 and 11, 1911. These are the salmon that were artificially fed as described in later paper (now in manuscript).

[b] A view of the pyloric valve is given in a figure in the report dealing with the gross anatomical relations in the salmon. This transverse section is through the body at a plane just anterior to the pyloric valve.

work. This network in certain regions forms strong strands quite to the bases of the superficial epithelial cells. The connective tissue is of the compact areolar type, the fibers of which run in a general way parallel with the stratum compactum beneath. This tissue forms a proper support not only for the epithelial coat, including its glands, but also for its blood vessels and nerves. Numerous small arteries and veins are present in the thicker portion of the tunica, and branches from these form a capillary network in the meshes among the glands, as previously stated. The type of connective tissue cell present here calls for no particular comment, yet there are a number of cells of the type described below as granule cells present just within the stratum compactum. In the normal tissue of the tunica these granule cells are not numerous, though in the degenerated tissue, as will be described in a later report, they become more numerous in this region.

Stratum compactum.—A structure of peculiar type and significance because of the fact that it is not uniformly present in the walls of the alimentary canals of vertebrates is the stratum compactum of Oppel. In the salmon stomach this tissue forms a well-developed sheath. It is not in so compact a mass as in the intestine and in the cæca described below. Gulland [a] says of *Salmo salar*, "This layer in whatever plane the stomach is cut is always found as a compact hyaline band lying rather nearer the muscularis mucosæ than it does to the fundi of the glands. It is, of course, pierced by blood vessels, etc., but I have never seen muscle strands from the muscularis mucosæ passing through it. It contains no nuclei, and no structure can be made out in it by ordinary methods. Nuclei lie upon it, however, and the fibers of the connective tissue on either side are directly continuous with it (fig. 10)." This characterization of the *Salmo salar* stratum compactum applies very well to the stratum of the king salmon. In the king salmon there is the one thick sheath, very heavy and well marked and of wavy outline. This thicker sheath lies toward the inner or epithelial side of the gastric wall. However, in transverse sections it is always noted that the main portion of the stratum bears a network of strands and fibers of the characteristic staining reactions located both on its inner and outer surfaces. The network on the outer surface is of heavier strands and is about twice as extensive as that on the inner surface. This network of fibers runs in a general circular direction.

The substance of the stratum compactum takes a Mallory connective tissue stain. It is shown by this stain to be a homogeneous, compact, nonfibrous mass, evidently of collaginous material. Iron hæmatoxylin stain also fails to reveal fibrous structure. Lying on the surface of the strands one notes here and there connective tissue corpuscles. The surface is sharply marked by a substance or structure which takes certain stains somewhat more sharply than the central portion of the stratum. Occasional nuclei are embedded in this superficial layer.

In the open meshes of the stratum there are always found a number of cells of the type designated in this paper as granule cells. These cells form a part of a special coat, the stratum granulosum. (See fig. 3, pl. XXVI.)

[a] Paton, D. Noël, op. cit., p. 14.

Stratum granulosum.—There is present throughout the alimentary tract of the king salmon a special type of cell forming a distinct layer or coat. Throughout the preliminary studies this layer has been designated the granule cell layer, on account of the distinctive characteristic of the cells composing it. Oppel has described a stratum granulosum for the mucosa of certain animals, and while the homologies are not certain in the king salmon, I propose to use this designation as a permanent name for the structure in question present in *Oncorhynchus*.

The granule cell layer is a part of the mucosa. In the salmon stomach its cells lie between the stratum compactum and the muscularis mucosæ and in the meshes of the stratum compactum itself. The granule cells form quite a dense and well-marked coat, not only in the stomach but in the intestine and cæca. However, the boundaries of this coat are not sharp on either the inner or outer margin. On the inner margin cells of the coat are found scattered among the inner meshes of the network of the stratum compactum and occasionally in the tunica propria. The outer margin or boundary of the zone is sharper. The inner margin of the muscularis mucosæ marks this boundary. Yet a few scattered granule cells are found in the connective tissue of the submucosa outside the muscularis proper.

The arrangement of the cells about the surface of the layer, also the occasional displaced granule cells, suggest that these cells may be amœboid and migratory. This I believe to be true to a very limited extent. But I have not yet succeeded in observing amœboid activity in teased living cells. In fasting salmon, however, I find extensive migration of the cells into the tunica propria on the inner border and into the muscular coats on the outer border of the stratum granulosum. This observation is especially striking in the degenerating cæca. The granule cells, however, are never found far removed from the proper location of the stratum. They have not been observed in the blood vessels, in the liver, or in any skeletal muscle tissue.

The granule cells are supported by a delicate meshwork of fibrils of the histological type and staining properties of the stratum compactum. There is no distinct pattern or type of arrangement of the cells. That portion of the layer just within the muscularis is from four to eight cells thick. Many blood vessels pierce this coat on the way to the deeper structures. But ordinary histological methods do not reveal any definite vascular supply to this structure. It seems to derive its nutritive materials from the capillaries of the adjacent muscles and of the tunica propria.

The granule cells are irregularly oval in outline, varying in size between 6 by 9 μ and 7 by 12 μ in diameter. The nucleus is always eccentric in position and relatively small in size, 2.5 by 4 μ in diameter.

The special and characteristic feature of the structure of these cells is the presence of the cytoplasmic granules that always crowd them, uniformly filling the cell body. The only differentiation noted in this regard is that those cells most free and isolated from the stratum proper have somewhat fewer granules.

The granules stain deeply with a number of dyes, such as eosin, orange G, acid fuchsin, etc. The sharpest differentiation is obtained by staining with iron hæmatoxylin,

preferably after Bensley's corrosive bichromate fixative. The iron hæmatoxylin, differentiated to just the right degree, stains the granules an intense bluish black, while the rest of the cytoplasm is clear or may be counterstained with eosin. The cell granules are relatively uniform in diameter. In many preparations one can distinguish only a slight variation in the size of the granules. In certain preparations, however, there is considerable variation in the diameters of the granules within a single cell, a variation that is uniform throughout the cells of a given stomach. The size of the granules in a series of specimens measured varied around 0.8 to 1 μ in diameter. The extremes noted in these preparations were 0.4 and 1.2 μ, respectively. In several samples where the granules were especially uniform in diameter and in which the granules crowded the cell cytoplasm for its full extent the size ran from 0.4 to 0.5 μ in diameter.

The salmon pancreatic cells and the gastric gland cells also contain granules, zymogen granules. But the number and arrangement of granules in each of these two types of cells is characteristically different from that of the granule cells proper. Measurements show that the zymogen granules of the pancreatic cells also vary through a rather wide range. In sections from the same salmon from which the measurements of granule cells given above were taken the pancreatic zymogen granules measure from 0.6 to 1.5 μ in diameter. The number of granules in the individual cells was small and the granules were located chiefly on one side of the cell, presumably the side next the lumen. In another fish the granules of the cells of the pancreas measured from 0.4 to 1 μ in diameter. The loading of granules was somewhat greater in number than in the cells with the larger granules.

The granules of the granule cells take stains somewhat differently from the granules of either of the two types of secreting cells under comparison. The pancreatic cells and the granule cells of the pyloric cæca present in the same microscopic field are always in sharp contrast. The stain of the granules of the granule cells is sharper, more distinct and brilliant, and of a different shade of color when both are stained with the same dye.

Evidence of solution of the granules of these peculiar cells has been observed in the preparation of tissues by certain fixatives. Unfortunately this factor has not been investigated sufficiently for final report.

The character of the distribution of the cells, the staining properties of the granules, and the persistence of these cells during marked degenerative changes of much of the structure of the stomach and other portions of the alimentary canal all point to some function of special nature. This function, I believe, is that of internal secretion. The granules present are, therefore, true zymogen granules. In another connection I have presented the view that this function is one of lipase production. The absence of any tubular arrangement or ducts, and the apparent lack of an adequate capillary net would suggest that the granule cells must discharge their products directly into the surrounding tissue spaces from which distribution takes place.

The granule cells were observed by Gulland.[a] He figures a bit of the stratum compactum and adherent granule cells in its meshes. Gulland calls these cells "large

[a] Paton, D. Noël, op. cit., pl. 4, fig. 10.

eosinophile leucocytes." This identification will not apply to the cells of the king salmon for the following reasons: First, the salmon leucocytes are very much smaller than the cells in question. Also one never finds a cell of the granule-cell type inside a blood vessel, though diligent search has been made. Second, the granule cells form a distinct and persistent structure in a definite region of the stomach and alimentary tract. It is out of the question that the eosinophiles of the blood should form such a cell grouping in every animal of whatever age.

Muscularis mucosæ.—The muscularis mucosæ is present in the salmon stomach. It consists of a rather thick double layer of muscle fibers, relatively much thicker than the corresponding coat in the mammalia. The fibers run both in the circular and in the longitudinal direction. There is much irregularity in the direction of the fibers, due in part to the fact that the muscularis mucosæ follows the folds of the mucosa rather than the outlines of the outer and heavier coats of the stomach. There are many free bundles of fibers more or less irregularly disposed in the folds of the submucosa and on the external or outer surface of the muscularis.

In the contracted stomach, in which the mucosa is thrown into deep longitudinal ridges, a cross section shows that the muscularis mucosa takes a somewhat sinuous or wavy course in its position between the mucous epithelium and the outer muscular coats. In places the muscularis will be in contact with the inner or circular muscle coat, where its thickness is shown to be from 40 to 60 per cent as great as that of the muscularis circularis itself. In the loops of connective tissue between two such points of contact between the two muscular coats there are always found the free or isolated bundles of muscles mentioned above. These isolated bundles unquestionably belong to the muscularis mucosæ.

HISTOLOGY OF THE GASTRIC SUBMUCOSA.

The submucosa of the king salmon forms an irregular connective tissue coat between the muscularis mucosæ and the muscularis circularis. In places the submucosa seems quite obliterated and the two muscular coats are in contact. Under the deeper longitudinal folds of the mucosa the submucosa forms quite extensive masses of loose areolar connective tissue. Evidently in the salmon stomach this layer forms an adaptable coat for allowing the mucosa to slide over the inner surface of the muscularis circularis or vice versa.

The submucosa contains in its meshes numerous blood vessels of different sizes. There are also isolated bundles of muscle fibers from the muscularis mucosæ, and a sprinkling of granule cells that have wandered from the stratum granulosum.

HISTOLOGY OF THE GASTRIC MUSCLE COATS.

The proper muscle coats of the salmon stomach are two in number, the circularis and the longitudinalis. Between the two, and rather more deeply embedded in the longitudinalis, is the plexus of Auerbach,which should be mentioned in this connection.

Muscularis circularis.—The inner of the two muscle coats is the circular layer. It is a well-developed sheet of muscle in the salmon stomach, as shown in every cross

section of the gastric walls. It is about twice the thickness of the longitudinal muscle sheet.

The circular muscle is composed of smooth muscle fibers in the pyloric and lower three-fourths of the cardiac division of the stomach. Striated muscle cells extend down from the esophagus for some little distance, about one-fourth the length of the cardiac end. The point has been determined only in the young, where the striated fibers extend well below the esophageal boundary of the gastric gland region. There is no special peculiarity of structure of the gastric smooth muscle fibers. A rich vascular supply permeates this muscle coat, the blood vessels being for the most part small branches of the vessels lying between the two muscle coats.

Muscularis longitudinalis.—This is the outer of the two muscle coats of the stomach. It is well separated from the circularis by the numerous blood vessels and bundles of nerves of the Auerbach plexus, together with the connective tissue supporting these structures. These smooth fibers are rather less compact in arrangement than the circularis, perhaps due to the numerous blood vessels that are found in its substance. This coat is of course pierced by every vessel penetrating to the deeper structures. The striated muscle fibers of the upper end of the stomach are not found in the longitudinal muscle. This coat is very thin over the esophageal end of the stomach.

Plexus of Auerbach.—This nerve complex has not been sufficiently studied. It may be noted here, however, that the plexus is strongly developed in the king salmon stomach and in the other parts of the alimentary canal. Relatively large bundles of fibers are to be found between the two muscle coats and embedded in the longitudinal coat.

HISTOLOGY OF THE GASTRIC SEROSA.

The serosa of the salmon is formed by the single layer of plate-like epithelioid cells that is found in all the vertebrates of the higher series. Under certain conditions these cells become much thicker, i. e., quite cubical in shape. This form has been especially noted in the retrogressive changes that occur during the migration fast of the king salmon.

THE INTESTINE.

FORM AND DIVISIONS OF THE INTESTINE.

The intestinal portion of the alimentary tract of the salmon is, like the stomach, a U-shaped tube. In this case the first limb of the U is relatively short. It includes that portion of the intestine which has the numerous diverticula, the pyloric cæca. This limb begins at the pyloric valve which marks the limit of the pyloric end of the stomach. It extends anteriorly to about the level of the point where the esophagus and stomach join. At this level there is a sweeping bend in the intestine from the ventral to the dorsal position in the celomic cavity. The intestine here takes a position along the dorsal lateral side of the stomach and runs a straight posterior course to the cloaca and vent. This straight stretch of the intestine forms the second limb of the U, and is considerably longer than the first limb. In the adult salmon the two divisions of the intestine vary in length in proportion to the length of the fish. But for an 80-cm.

salmon the average length for the first limb is from 9 to 10 cm., that of the second limb from 28 to 30 cm. The last 4 or 5 centimeters of the intestine form a somewhat prominent enlargement, the cloaca.

There is a considerable variation in the size of the intestinal tube, even in fishes of the same length. This variation is greatest in the pyloric portion where the numerous cæca are attached. The variation in size is, however, dependent upon the degree of distension by food materials. It is largely an adaptation of the tube to its content, in so far as the diameter is concerned. If the tube be widely dilated the structural walls are correspondingly thin.

APPENDAGES OF THE INTESTINE.

Along the full length of the pyloric intestine there are numerous diverticula, the pyloric cæca. There is considerable variation in the number of cæca in different individuals of the genus *Oncorhynchus*. Jordan and Evermann, in "Fishes of North and Middle America," state that the number of cæca in the king salmon varies from 140 to 185. The larger number would seem to be more nearly the average.

The cæca are absent from the line of the wall of the pyloric intestine represented by the inner curvature. This line is marked by the attachment of intestinal blood vessels and of the gall and pancreatic ducts. All other portions of the wall of this limb of the intestine are studded thickly with pyloric cæca. The cæca, as a rule, arise as individual diverticula coming off at right angles to the surface and then bending posteriorly to lie like a fringe about the end of the pyloric stomach, and overlapping each other from this point for the full extent of the pyloric intestine. (See fig. 1.) The diameter of a cæcum at the base is usually somewhat less than in the main body of the diverticulum, averaging from 5 to 6 mm. Just outside the bases the cæca are somewhat larger—from 7 to 8 mm. in diameter. From this point to their tips they taper very gently to terminate in a blind sac.

The lengths of the cæca vary greatly in different regions of the pyloric intestine. The longest cæca are found at the origin of the intestine and just within the pyloric valve. At this point the appendages reach a length of from 6 to 8 cm., even longer in larger fishes. In any given segment those cæca that border on the line of the inner curvature are apt to be slightly shorter than the others in this segment. The lengths diminish progressively from the pyloric valve to the most anterior portion of the pyloric intestine. The last cæca are found on the ventral surface of the dorsal portion of the pyloric intestine, just where the anterior bend ceases and the straight limb of the intestine begins. These cæca are often 1 cm. or less in length, and the last two or three usually stand in a single row along the extent of the intestinal tube.

The pyloric cæca in their number, size, and arrangement form one of the most striking characteristics of the intestinal tract of this entire genus. In fact, the number is sufficiently constant to be given by systematists as a specific character. In the past the physiological function of these organs has been somewhat in doubt, but in the course of this work we have, fortunately, been able experimentally to establish certain points in their physiological economy to the salmon.

INTESTINAL COATS.

The coats of the intestinal tube are not so numerous as in the stomach. Certain parts present in the latter organ are not present in the intestinal tract, either in the intestine proper or in the pyloric cæca. Those structural coats that are present in the intestine are the following, beginning with the mucous membrane:

I. Mucosa.
   1. Epithelial coat.
   2. Tunica propria.
   3. Stratum compactum.
   4. Stratum granulosum.

II. Muscularis.
   1. Muscularis circularis.
   2. Muscularis longitudinalis.

III. Serosa.

HISTOLOGY OF THE MUCOSA.

Epithelial coat.—The epithelial coat of the intestinal mucosa is very simple as to structure, but rather complex as to its folding. A section at right angles through this coat will always show a single layer of columnar epithelial cells. I have been unable to show any differentiation in the structure of these cells in the different regions of the coat. The foldings of the mucous epithelium, however, are so complicated that it is difficult to secure right-angled sections through any great extent in any single section. In a cross section of the middle portion of the intestine which is uncomplicated by the origin of pyloric cœca, it will be noted that the mucosa is thrown into relatively complex longitudinal folds (figure 5). Occasionally in a widely distended intestine these folds are somewhat smoothed out, so that the arrangement seems less complex. If, however, the intestine be sharply contracted, then there are not only general longitudinal folds but many smaller collateral folds. Edinger [a] in one of his plates presents a series of figures to show the character of the folding of the mucosa in fishes. The type of folding that he figures holds for the intestine of the salmon. In another place [b] I have given a brief description of this folding as it appears in the pyloric cæca. There, however, the mucosa is more simple in its arrangement than in the intestine.

In a transverse section through a longitudinal fold in the intestinal mucosa the fold or ridge itself will have secondary pits or grooves on its lateral extent. Very often it happens that the section will present the appearance of definite tubes, or be through what looks like simple tubular glands, or sections of wide oval loops of epithelium will be shown. The tubelike structures do, indeed, suggest definite intestinal glands in the mucosa, but there is absolutely no histological differentiation between the cells of these narrow pitlike folds and the cells of the free epithelial surface. Although the folding of the epithelium is rather complicated one must accept the fact that the complexity of folding is not accompanied by histological differentiation of structure.

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[a] Edinger, L.: Ueber die Schleimhaut des Fischdarmes, nebst Bemerkungen zur Phylogenese der Drüsen des Darmrohres. Archiv für mikroskopishe Anatomie, bd. XIII, 1877, p. 651.

[b] Greene, Chas. W.: "The absorption of fats by the alimentary tract with special reference to the function of the pyloric cæca in the king salmon, Oncorhynchus tschawytscha." Transactions of the American Fisheries Society, 1911, p. 261.

The mucous epithelium is constantly marked by the presence of two common types of cells in addition to the typical cylindrical epithelium; first, mucous cells, and second, wandering cells presumably of the leucocyte type. In a normal epithelium the number of mucous cells varies through wide extremes. In certain sections they are relatively rare, and there are long stretches of epithelium without a single goblet cell. In other material the number of mucous cells is relatively great, and certain studies made on fasting salmon strongly support the view that the number of goblet cells is greatly increased during the early fasting period when the mucous membrane as a whole is just beginning its retrogressive changes. Certainly the number of mucous cells is greater if the fasting be somewhat prolonged. The observations on the salmon support the current view that cylindrical epithelial cells may be transformed into goblet cells.

The wandering cells are indicated by the small round nuclei interstitially arranged with reference to the normal epithelial cells. The nuclei are found chiefly near the basal portion of the epithelial coat, but they may also be found between the outer limbs of the cylindrical cells. In the normal digesting fish taken from among those feeding naturally on the banks at Monterey there are comparatively few of the wandering cells. This observation is of special significance in connection with certain theories concerning the part these cells are assumed to take in the process of absorption. Certainly in the salmon the small number present is strongly against the theory that fat absorption is accomplished by the wandering leucocytes. Indeed no evidence supporting this view of their function has been found in connection with numerous fat-absorption experiments.

I have been unable to show any particular differentiation in different limbs of the intestine, in so far as the mucous epithelium is concerned. The only differences noted are limited to complexity of the folding. In the pyloric intestine where the spaces between the cæca are small and limited, the intestinal epithelium has very simple folds. In the middle of the straight limb of the intestine these folds are more complex.

Tunica propria.—The tunica propria of the salmon intestine is defined as the connective tissue support extending from the bases of the epithelial cells to the stratum compactum. The tissue is composed of white fibrous connective tissue of the areolar type, carrying cells and nuclei of the connective tissue varieties. It is a very thin layer except in those places where the mucosa is folded into deep ridges. In the latter case the tunica propria extends into these ridges, forming a connective tissue foundation for the support of the epithelial coat.

The strands of the tunica propria support the blood vessels lying under the epithelium. These blood vessels consist of relatively small arteries penetrating from the muscle coat and forming a rich capillary network under the epithelium proper.

Stratum compactum.—This peculiar structure which has been described in some detail for the stomach is also present throughout the intestine. It forms a thick, heavy sheath, lying midway between the epithelium and the circular muscle coat of the intestine. The stratum compactum is not so complex as in the stomach in that it has a thinner mass of strands over the surface of the main sheet. A transverse section of the intestinal wall will usually show a heavy wavy line of dense nonfibrous connective

tissue, which stains the characteristic blue with Mallory's connective tissue stain. Its composition in the intestine is apparently the same as in the stomach. The inner surface of this stratum, that is, the surface toward the middle of the lumen of the intestine, is marked by a few smaller strands of the same peculiar type of connective tissue. The outer surface of the stratum has two or three times as many of these smaller strands. A distinct network is formed by the strands extending over to the circular muscle coat. In the intestinal region the number and complexity of arrangement of the strands composing the stratum compactum is about 40 to 50 per cent as great as in the stomach.

Nowhere does there seem to be any direct opening or break through the thicker portion of the stratum compactum, except where blood vessels penetrate this coat, a point which Gulland has made in his study of the stratum compactum of the stomach of *Salmo salar*. It may very well be, as Oppel suggests, that the stratum compactum is a protective supporting membrane. It certainly acts as such for the stratum granulosum in *Oncorhynchus*, whether or not it forms a supporting structure for the whole intestine.

Stratum granulosum.—The meshes of the stratum compactum directly support a layer of the special type of cells which has been described in connection with the stomach as the granule cells. This layer, the stratum granulosum, is most dense in its arrangement in the outer network of the stratum compactum There are a few cells more or less scattered, lying on the inner surface of the same connective tissue supporting membrane. The granule cells of the intestine are characterized by the same form and size and structural arrangements as described for the granule cells of the stomach. Here, also, they possess the uniformly distributed, highly refractive granules which take stains in the specific way already described.

These granule cells form a very definite and characteristic structure in the intestine and their appearance and presence indicate some function of a significance which one can not escape ascribing to the presence of the granules in the cells, a suggestion that has been briefly discussed in connection with the stomach.

There is no muscularis mucosæ present either in the intestine or in the pyloric appendages.

The submucous coat, which characterizes the structure of the walls of the stomach, is also absent in the intestine.

HISTOLOGY OF THE MUSCLE COATS.

The muscle coats of the salmon intestine consist of an inner circular and an outer longitudinal coat with the plexus of Auerbach and numerous blood vessels between.

Muscularis circularis.—The inner muscle coat of the intestine consists of fibers which run in a circular direction. It is a relatively well-developed muscle sheath about twice as thick as its fellow, the longitudinal muscle. It is composed wholly of smooth muscle fibers, the detailed structure of which does not vary in any particular way, so far as noted, from the usual type of smooth muscle. A rich vascular supply, consisting of smaller blood vessels and capillaries, is present in this coat, the capillaries coming quite largely from arterioles present between the two muscle coats.

Muscularis longitudinalis.—The outer intestinal muscle coat consists of longitudinal fibers. It is a rather thin coat composed of smooth fibers and carrying numerous small blood vessels within its mass or between it and the inner coat. The presence of the small blood vessels tends to break up to some extent the compactness of arrangement of the muscle fibers.

Plexus of Auerbach.—This nervous structure is quite prominent in all sections through the alimentary canal. It, however, has not yet been studied in detail for the salmon. The ganglia and the bundles of fibers of the plexus lie between the two muscle coats but rather largely imbedded in the inner wall of the outer coat.

HISTOLOGY OF THE SEROSA.

The serous coat of the salmon intestine is composed of a single layer of epithelia cells and the subserous supporting connective tissue. These cells are not so flat and attenuated as is usually the case for this coat in the intestines of mammals, but are more nearly cubical in shape, often quite cylindrical. Especially when the intestine is contracted are the cells of the serosa deeper than wide.

The subserous connective tissue is rather prominent in the salmon intestine. It consists of white fibrous connective tissue about twice as thick in total mass as the epithelial coat proper.

HISTOLOGY OF THE PYLORIC CAECA.

Oppel says, in volume II of Mikroskopische Anatomie, that "the pyloric cæca, when they exist, possess the structure of that portion of the alimentary tract on which they are attached." Gulland says of the cæca of the Scottish salmon that "in structure they exactly resemble the upper part of the intestine, so much so in fact that but for the difference in size it would be impossible to say whether a section came from one or the other." In the king salmon, too, the pyloric cæca are diverticula of the pyloric limb of the intestine, and one would naturally expect them to have a structure built on the same plan as the intestinal region from which they arise. This in general is true, though the pyloric portion of the intestine is so broken up by the origin of the numerous cæca that the intestinal structural constants are not altogether simple in this region.

The coats described above for the intestine are all present in the walls of the pyloric cæca. The only difference is one of relative complexity, or one might rather say simplicity, of arrangement. The parts enumerated from the lumen toward the outer wall are:

I. Mucosa.
   1. Epithelium.
   2. Tunica propria.
   3. Stratum compactum.
   4. Stratum granulosum.

II. Muscularis.
   1. Circularis.
   2. Longitudinalis.

III. Serosa.
   1. Serosa proper.
   2. Subserosa.

MUCOSA.

Epithelial coat.—The epithelium of the pyloric cæca is a coat of one uniform type throughout, and consists of a single layer of slender cylindrical cells with interspersed goblet cells and wandering leucocytes. The epithelial coat reaches its greatest development in the normal adult animal, in which its total surface extent is eight times the outer surface of the cæcum. This relatively enormous extent is secured by deep folds of the coat, which extend out into the lumen of the appendage. Cross sections of the pyloric appendages show all possible varieties of section of the epithelium. There are transverse sections of simple tongue-like folds extending from near the stratum compactum to approximately the center of the lumen. These are not villi, though they appear so. On the other hand there are regions where the epithelium is cut obliquely, or even in a plane parallel with the surface of the epithelial coat for some extent. There is in such a picture necessarily a great amount of irregularity in the boundary outlines of the epithelial surface.

The picture just described is due to the fact that the epithelial coat of the mucosa is built on a simple but extremely flexible plan. There are no projections of its surface comparable to the villi of the small intestine in the mammalia, but there are many clefts and folds. If a king salmon's cæcum were completely relaxed as to its musculature and distended from the inside to its maximum extent, both as to length and as to circumference, its epithelial coat would be greatly smoothed out and comparatively simple. Its irregularities of surface still observable would be chiefly low longitudinal ridges broken here and there by transverse furrows and partial clefts. Relaxation of the muscular walls and dilation of the cæcum to this extent probably seldom occur in nature though ofttimes closely approximated. In a maximally stretched cæcum the proportion between the surface extent of the mucosa and the outer wall should be lower than the minimum given in the preceding paragraph. If in such a case the cæcal wall should contract in diameter without changing its length the epithelial coat would be thrown into deep longitudinal ridges and clefts that would extend from the base of the mucosa to the center of the lumen of the cæcum. These ridges would appear in transverse section as simple uncomplicated folds, i. e., very long slender finger-like projections of mucous epithelium into the lumen of the cæcum. These projections show, as might be expected, a uniform type of cell from tip to base, as shown in figure 8, plate XXVIII.

Now if the cæcum contracted in length it would bend and twist these longitudinal folds, and at the same time interrupt their continuity by producing transverse ridges and pockets in the epithelial coat, giving rise to a net-like appearance as seen from a surface view, a view not unlike that presented by Edinger[a] in his figures 11 and 13b, and by Eggeling[b] in figure 156. A cross section of a cæcum in this state always shows an extraordinary complexity of section throughout the epithelial coat, a complexity that was found extremely confusing until interpreted in the manner presented above.

[a] Edinger, L.: op. cit., pl. 41.

[b] Eggeling, H.: Dünndarmrelief und Ernährung bei Knochenfischen, Jenaische Zeitschrift, bd. 43, 1908, p. 416.

In the young salmon of fingerling size or smaller the extent of epithelium is relatively less; therefore the folds are simpler than has been described for the adult above. This is shown in a number of colored figures illustrating the process of fat absorption in young salmon, presented in a paper to follow. A similar epithelial folding has been described for other fishes, i. e., for the herring, *Muræna*, and the sturgeon.[a]

The cells of the epithelial coat are of two types, and these are fairly uniformly distributed, i. e., the usual cylindrical cells, and the goblet cells. It is not desired to discuss here the question of the origin of goblet cells from the cylindrical cell, though the current views are supported by these observations.

The cylindrical cells are very slender in the adult, though less so in the younger fish, i. e., under 1 year old. Their size in a number of measurements made on paraffin sectioned material was from 45 to 63 μ long by 5 to 6 μ in diameter. They have slender oval nuclei located at the basal two-fifths of the cells. The cytoplasm of these cells presents no special structural features under ordinary conditions. If rapid absorption of fat is taking place it is shown by the special fat staining of fresh material to be present in the cylindrical cells. In paraffin preparations the fat is dissolved out and open empty spaces will appear in the cytoplasm (fig. 11, pl. XXVIII). No granules have been found and nothing comparable to the cells of Paneth have appeared in any of the sections.

The superficial borders of the cylindrical cells have a striated border marked by a homogeneous ground substance set with numerous fine striæ running vertical to the surface of the cell.

The goblet cells appear at tolerably regular intervals, though they are not numerous in the normal material. Their cell bodies seem a trifle larger on the average than the cylindrical cells. If the mucous of the goblet cell has not completely formed, then the striated border will be continuous over its surface. Many of these cells are present with the mucous content just beginning to discharge, in which state they are most prominent in appearance. The nuclei of the goblet cells lie nearer the bases of the cells than in the adjacent cylindrical cells. They also contain a greater amount of chromatin, hence stain more deeply with chromatin dyes.

The cells at the bottoms of the epithelial clefts or folds do not show any structural traits different from those on the folds projecting farthest into the lumen. This leads to the conclusion that there are no gland vestiges in the cæca of the salmon homologous with the glands of Lieberkühn, such as figured by Brass [a] for the human vermiform appendix. Neither have any rudiments of these glands of the type described by Kingsbury [b] for the small intestine of *Necturus* been found.

A certain number of wandering leucocytes are always found in the normal epithelial coat. In all the salmon material examined these white corpuscles are very small in size and are greatest in number in the basal region of the epithelial coat. They are not regularly distributed, but sometimes are present in groups of two or three. Their nuclei

[a] Brass, A.: Atlas der Gewebebelehre des Menschen, bd. 1, 1896, Göttingen. Reference from Oppel, Mikroskopische Anatomie, bd. II.

[b] Kingsbury, Benjamin F.: The histological structure of the enteron of Necturus maculatus. Proceedings American Microscopical Society, vol. 16, 1894, pp. 19–64.

are to be distinguished from the nuclei of the cylindrical epithelial cells by the fact that they are smaller in size and more round in outline and stain more intensely. The diameter of these cells is from 3 to 4 μ, while the long diameter of the oval nuclei of cylindrical cells is 5 to 6 μ, or even 10 μ in younger salmon. Occasionally through the epithelial coat scattered leucocytes are found in the outer third of the layer. In fact, these cells may be located at any level from the general nuclear region to the surface border of the coat. They do not appear to be, at least have not been observed, escaping from the epithelial coat into the intestinal cavity.

No eosinophile granule cells of any kind have been found in the alimentary epithelial coat of the king salmon. Such cells are described in this region for *Proteus* by Oppel. This observation is of importance in association with the fact that granule cells of a type already described above compose the stratum granulosum.

Tunica propria.—The tunica propria of the cæca extends from the epithelial layer to the stratum compactum. Its extent varies greatly, and its outlines are very irregular. On the epithelial surface the tunica must follow the irregularities of that coat, while next the stratum compactum it is equally sinuous, owing to the great irregularity of surface of the stratum. The whole outline is not unlike that in the intestine, though simpler.

The tunica propria is a connective tissue structure carrying numerous blood vessels and supporting a number of special types of cells in its meshes. The connective tissue fibrils form an open meshwork of the usual areolar type. (See fig. 9, pl. XXVIII.) At its epithelial boundary it forms a very definite limiting membrane, the basement membrane, on which the epithelial cell layer rests. From this basement membrane the more or less open meshwork of fibrils begins. Numerous oval nuclei appear in the ground substance. The compactness of the tissue and the relative number of nuclei vary extremely in the various specimens. Where the tunica propria extends up into a fold of epithelium its tissue usually appears somewhat more compact. Definite loops of small blood vessels and capillaries are present in these projections. Open tissue spaces are found both in the loops and in the broader expanses of the coat just within the stratum compactum, in the normal tissue these spaces being small in size. Beside the proper nuclei of the connective tissue there are relatively large numbers of nuclei of the white corpuscle type belonging to cells that have not yet been comparatively studied. These cells vary extremely in number in different areas and in different salmon.

The small arteries and veins, as well as the capillaries, are readily distinguished by the red corpuscles, which possess characteristic oval nuclei that take certain dyes in a differential way. Here and there are present certain large cells with a lightly stained cell body and a characteristic large nucleus, the identity of which has not yet been determined.

Lying just within the stratum compactum are scattered granule cells. These granule cells usually lie next the stratum compactum, sometimes in its loops, but occasionally may be found near the deeper loops of basement membrane, never in the epithelial coat. In fasting salmon this group of granule cells is more prominent.

Stratum compactum.—The stratum compactum is always present in the cæca of the king salmon. It is a striking structure and always stands out prominently in every microscopic section. Under the low magnification it appears as a broad wavy band extending around the circumference of the cæcum and lying within the muscular and external to the tunica propria coat.

The stratum is wavy in appearance, whether the section be transverse or longitudinal, but the extent of the folds which give rise to this phenomenon varies with the distension of the cæcum. Apparently the more contracted the organ as a whole the deeper the sinuosities of the stratum compactum. The stratum is a fairly uniform band, i. e., its thickness is relatively constant, varying between 12 and 16 μ.

Its structure has been described in other forms by several investigators, notably Mall.[a] Gulland[b] says that "a well-marked stratum compactum" is present in the Atlantic salmon. In the king salmon the stratum compactum is a homogeneous layer of fibrous connective tissue. It gives a characteristic staining with Mallory's connective tissue stain, but shows no fibrillar structure. On its surface the stratum of the cæca gives rise to a few smaller strands which extend out into the tunica propria on the one hand and form the network extending to the circular muscle coat on the other. These strands, especially in the latter case, form a supporting network for the special granule cells of the region. No nuclei are present in the body of the stratum compactum, but lying along its surface, especially on the surface next the tunica propria, a few nuclei are found. These nuclei are irregularly ovoid in shape, and appear to be embedded in a thin layer of tissue lying on the surface of the homogeneous portion of the stratum compactum. This layer stains a trifle more intensely than does the main body of the layer.

The stratum compactum is not present in the alimentary tract of all fishes, and why it should be so prominent a structure in the case of the king salmon remains a question. The coat is dense and it forms an uninterrupted layer (except where blood vessels penetrate from the outer to the inner structures of the cæcum). When a cæcum is widely distended the stratum is comparatively even and smooth in appearance. When the cæcum is contracted it is thrown into deep sinuous folds, no matter in what plane the section may lie. Its function is probably best explained by Oppel,[c] who suggests that this is the supporting membrane for the structures of the entire organ. The fact that the stratum compactum is a homogeneous uninterrupted sheet seems to have further significance than that assigned by Oppel. The fat studies described in a later paper suggest that this structure may be concerned in the process of the absorption of the food products by the cæcum.

Stratum granulosum.—The cæca have a characteristic layer of granule cells bearing the usual relations to the stratum compactum and its network, i. e., the relation described

[a] F. P. Mall: Reticulated tissue and its relation to the connective tissue fibrils. The Johns Hopkins Hospital Reports, vol. 1, 1896. Baltimore.

[b] Paton, D. Noël: Investigations of the life history of salmon, art. 3, The minute structure of the digestive tract of the salmon, and the changes that occur in it in fresh water, by G. Lovell Gulland. Report of the Fisheries Board for Scotland, 1898.

[c] Oppel, A.: Beiträge zur Anatomie des Proteus anguineus. I. Vom Verdauungstraktus. II. Von den Lungen, Archiv, für mikroskopische Anatomie, bd. 34, 1889, p. 511–572.

for both the stomach and the intestine. This layer of granule cells is very prominent in the pyloric cæca of the king salmon. Normally the layer is from two to four cells deep between the outer surface of the stratum compactum and the circular muscle coat. These cells are supported by the delicate strands of the outer surface of the stratum compactum. A few granule cells are located on the inner wall of the stratum compactum and occasional ones are found in the tunica propria, as mentioned above.

The numerous relatively large granule cells suggest Oppel's granule cells of *Proteus* in structural characteristics. The granule cells of the king salmon, however, have not been found in the epithelial coat, though under pathological conditions they undoubtedly do wander into other near-by regions. Gulland says, speaking of the pyloric appendages and the intestine: "In both structures the eosinophile leucocytes are numerous, but are to be found mainly in the connective tissue about the stratum compactum." In discussing these cells in connection with the structure of the stomach attention was called to the fact that Gulland figured cells of undoubtedly the same type as present in the king salmon. But I must again assert that these can not be blood leucocytes of the eosinophile or any other type.

The granule cells of the king salmon cæca have small round nuclei placed more or less eccentric with reference to the center of the cell. The cell body itself varies extremely in outline. In the majority of instances this outline is that of a broad oval, but where a cell is located in a restricted mesh its shape is adapted to conform to the space. This is especially to be noted in those cells present in the tunica propria.

In a section of a cæcum of a Monterey salmon taken June 23, 1911, the following measurements of granule cells are noted: 8 by 12, 8 by 10, 5 by 13, 8 by 14, and 9 by 14 μ. The special characteristic of the granule cells is the presence in the cytoplasm of large refractive granules. These granules stain with eosin, with Mallory's stain, taking especially the Bismarck brown but occasionally the acid fuchsin. They stain sharply with iron hæmatoxylin. The granules are very evenly distributed throughout the cytoplasm. The cells outside the stratum compactum seem more uniformly crowded with granules by whatever method of staining they be studied, and more densely granular than in the granule cells of the stomach. Those scattered cells that are present in the tunica propria are the ones that present the greatest irregularity in the distribution of the granules. A greater irregularity in outline suggests that the cells are amœboid. In one or sometimes both poles of these irregularly shaped cells the granules are fewer in number, though the difference is only slight. Also in the smaller cells there are on the average fewer granules than in the larger. The number of granule cells in the normal tissue is such that the connective tissue meshes seem about one-half filled with the cells. In the relatively distended cæcum the total thickness of the layer is less. These points are mentioned for comparison with the structural condition found in degenerated cæca in which the number and relations of the granule cells differ sharply from the normal Monterey salmon type, as will be described in a paper to follow.

MUSCULAR COATS.

The muscular coats are the inner circular and the outer longitudinal muscles. The two coats are not so thick as in the intestinal wall or in the thick muscular walls of the stomach. But they are on the whole very regular and uniform.

Muscularis circularis.—The circularis is thicker than the longitudinalis in the salmon cæcum in the approximate ratio of 3 to 2. The coat is composed of relatively long, smooth muscle fibers. When the cæcum is distended the number of fibers present in the total diameter of this coat in a transverse section is only from 8 to 10, often less. Numerous capillaries are always present. Very rarely in the normal animal will one find a granule cell in the spaces of the muscle fibers of the circular muscle coat.

Just at the base of the cæcum the muscle is a little thicker and the lumen usually smaller. The structure shows all the appearances suggesting a degree of valvelike action capable of influencing the filling or emptying of the cæcum from or into the cavity of the pyloric intestine out of which it originates.

Muscularis longitudinalis.—The longitudinalis is a thin sheet of smooth muscle, the outermost of the muscle coats. In the king salmon the longitudinal coat varies in thickness according to the distension of the tube, but on an average it is from 5 to 8 fibers thick.

This coat is chiefly distinguished by its vascularity. Relatively large veins are found at intervals in the coat and occasionally a section will show arterioles entering the cæcum from the exterior, penetrating this coat to distribute branches out in the space between the two muscle coats. In the neighborhood of these blood vessels there is connective tissue in relatively large amounts, an arrangement which tends to break up the continuity of the muscular sheet.

On the inner surface of the longitudinal muscle coat between it and the circular muscle fibers, sections reveal the presence of numerous nerve cells and fibers of the plexus of Auerbach. In the individual ganglia of this plexus there are only a few nerve cells.

SEROUS COAT.

The serous coat of the cylindrical cæca of the king salmon consists of a single layer of squamous epithelial cells resting on a subserous connective tissue base. In the normal tissue these cells are extremely thin and attenuated. Their boundaries are difficult to measure in transverse section, but the extent is from 10 to 12 μ. The nuclei are spindle shaped, having a diameter of about 1 μ and a length of about 5 μ. In many specimens the serous cells are more cubical in outline and the coat is correspondingly thicker.

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DESCRIPTION OF FIGURES.

The 11 figures presented in illustration of this paper were drawn for me by Mr. George T. Kline, biological artist of the University of Missouri, to whom I am indebted for skill and painstaking care in the interpretation of the specimens represented.

LIST OF ABBREVIATIONS USED.

Bl. v.....Blood vessel.	M. muc.....Muscularis mucosa.
Col. ep.....Columnar epithelium.	Neck c.....Neck cells.
Fat vac.....Fat vacuoles.	Str. comp.....Stratum compactum.
Gast. gl.....Gastric glands.	Str. gran.....Stratum granulosum.
Goblet c.....Goblet cell.	Submu.....Submucosa.
M. circ.....Muscularis circularis.	Tu. pr.....Tunica propria.
M. long.....Muscularis longitudinalis.	Wh. corp.....White corpuscle.

PLATE XXV.

FIG. 1.—This outline figure of the adult salmon is presented especially to show the external appearance of the viscera and the space relations of its parts. A segment of the left ventral wall is removed, exposing the organs in their natural position. The drawing is a semitransparency. The parts to which special attention is called are:

1. The liver, filling the anterior portion of the body cavity.

2. The cardiac loop of the stomach. The index figure is placed over the anterior portion of the posterior limb of the intestine shown as a transparency through the thickness of the stomach.

3. The pyloric limb of the stomach. The numeral is placed over the extreme anterior end and very near the constriction which is the location of the pyloric valve.

4. The pyloric intestine.

4′. The extreme posterior end of the intestine.

5. The pyloric cæca.

5′. Marks a cæcum that is almost surrounded by pancreas.

6. Pancreatic gland.

7. The spleen.

8. The long strap-like testes.

9. The ventricle.

Note that the pancreas is of the diffuse type of gland and is attached to the surfaces of, and lying among, the pyloric cæca. The gland is omitted over the cæca of the anterior loop. One-fourth natural size.

PLATE XXVI.

FIG. 2.—Cross section of a normal empty stomach from salmon no. 21, Monterey, Cal. This low-power figure shows the relation of the gross parts, also the compact folding of the glandular portion of the stomach into longitudinal rugæ when it is empty. Magnification, ×4.

FIG. 3.—A low-power drawing of a transverse section of the stomach wall, showing the histological relations of the various coats. For the interpretation of the abbreviations used to designate the parts, refer to the list of abbreviations above. Camera outlines. Magnification, Leitz ocular 1, objective 3.

FIG. 4.—A representation of a highly magnified gastric gland. To the left of the figure are three transverse sections of the gland tubes, one showing a deep oval. To the right of the figure is a longitudinal section of a short loop of gland cells just at the point where transition to neck cells takes place. The gastric-gland cells are loaded with granules from base to free margin. The granules vary considerably in size, as discussed in the text. The neck cells are free of granules. Camera lucida outlines. Magnification, Leitz ocular 2, objective 1/12.

PLATE XXVII.

FIG. 5.—A quadrant of a transverse section of the intestine taken from a salmon (no. 117) from Ilwaco, Wash. This salmon was in the first stage of the migration fast, hence the relative thickness of the different layers is undoubtedly somewhat different from the normal. However, it shows the relative position of the layers and the relative complexity of folding of the mucous epithelial coat. Camera outlines. Magnification, Leitz ocular 2, objective 3 (lower lens removed).

FIG. 6.—A superficial sketch of a single cæcum chosen from the longer group at the beginning of the pyloric intestine of a feeding salmon from Monterey, Cal. This cæcum is 8 by 160 mm. The smaller cæca have the same relative outlines as the larger. Magnification, ×1.

FIG. 7.—A transverse section of a normal cæcum from salmon no. 22, Monterey, Cal. This section shows the relation of the different coats, also is especially good to show the enormous extent and complex outlines of the mucous epithelial coat. The wavy band is the stratum compactum which characterizes not only the cæca, but the intestine and the stomach as well. Camera lucida outlines. Magnification, Leitz ocular 1, objective 3 (lower lens removed).

PLATE XXVIII.

FIG. 8.—A portion of the wall of the cæcum of a normal feeding salmon (1911 series, no. 11) from Monterey, Cal. The magnification in this figure is chosen to bring out the general histological relationships of the various parts. When the section is at exact right angles, as shown in the folds at the left, it presents an almost diagrammatic regularity. The folds to the right of the figure are complicated, hence many of the cells are cut at oblique angles. The muscular walls are relatively thin in this section, a condition that exists when the cæca are distended with food material. Magnification, Leitz ocular 1, objective 3.

FIG. 9.—A highly magnified section through the wall of a pyloric cæcum taken just at the bottom of a deep fold. The legend is sufficient to identify the parts. Particular attention is called to the relations of the stratum compactum. This dense connective tissue structure is marked on its external surface by a network of strands inclosing the cells of the stratum granulosum. These cells are characterized by the uniform and dense loading with highly refractive granules which usually completely obscure the small eccentric nucleus. Camera outlines. Magnification, Leitz ocular 1, objective 7.

FIG. 10.—A portion of the cylindrical epithelium and the substratum of the tunica propria highly magnified from a feeding salmon (no. 22) from Monterey, Cal. The figure presents a camera lucida outline of the cells, showing their relative size, structure, the relations of the nuclei, etc. Two goblet cells in different stages of maturity are shown. In the tunica propria there is a capillary in which lies the cross section of a red-blood corpuscle cut somewhat excentric to the nucleus. Camera lucida outlines. Magnification, Leitz ocular 4, objective 1/12.

FIG. 11.—Showing a highly magnified group of columnar epithelial cells from the pyloric cæcum of a Monterey salmon in the active stage of absorption. The fat vacuoles are relatively large and numerous in the outer third of the cells. They are present, but more scattered, in the inner limbs of the cells. In preparations made with a positive fat stain applied to fresh material these vacuoles are proven to contain fat droplets. Magnification, Leitz ocular 4, objective 1/12.

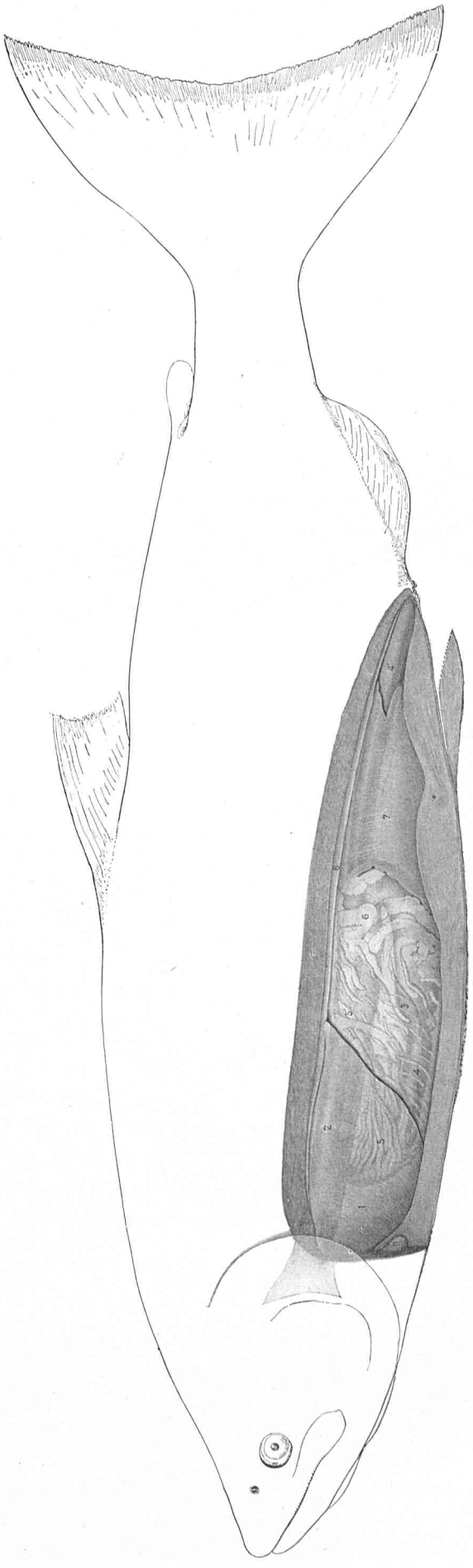
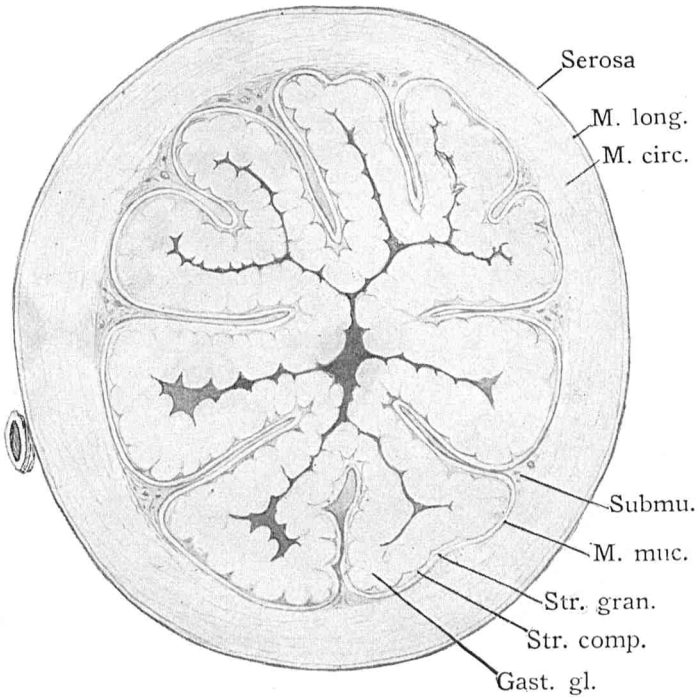


FIG. 1.



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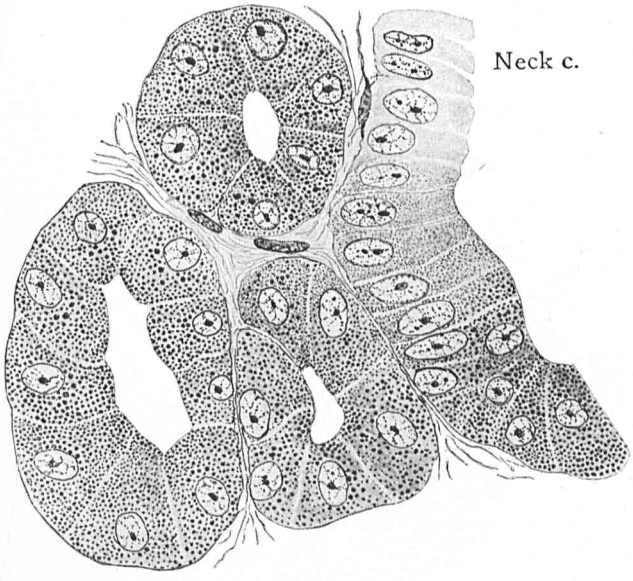
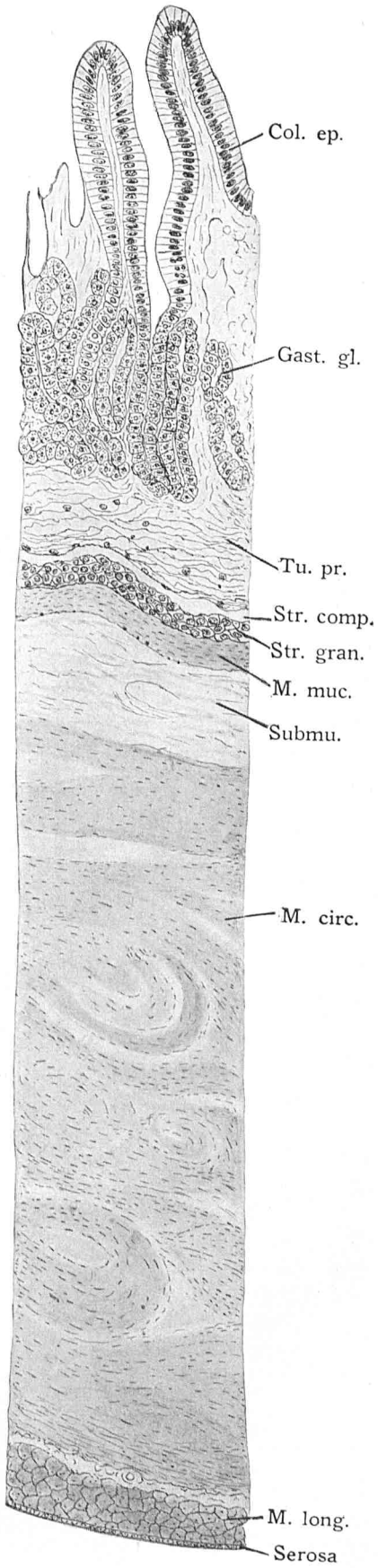


FIG. 4.



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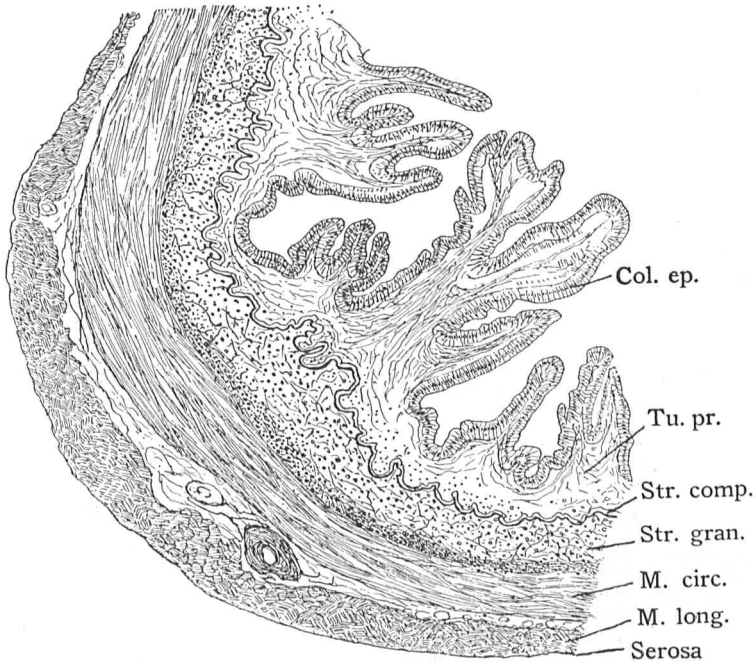

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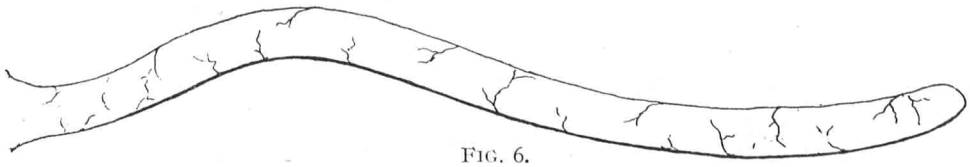

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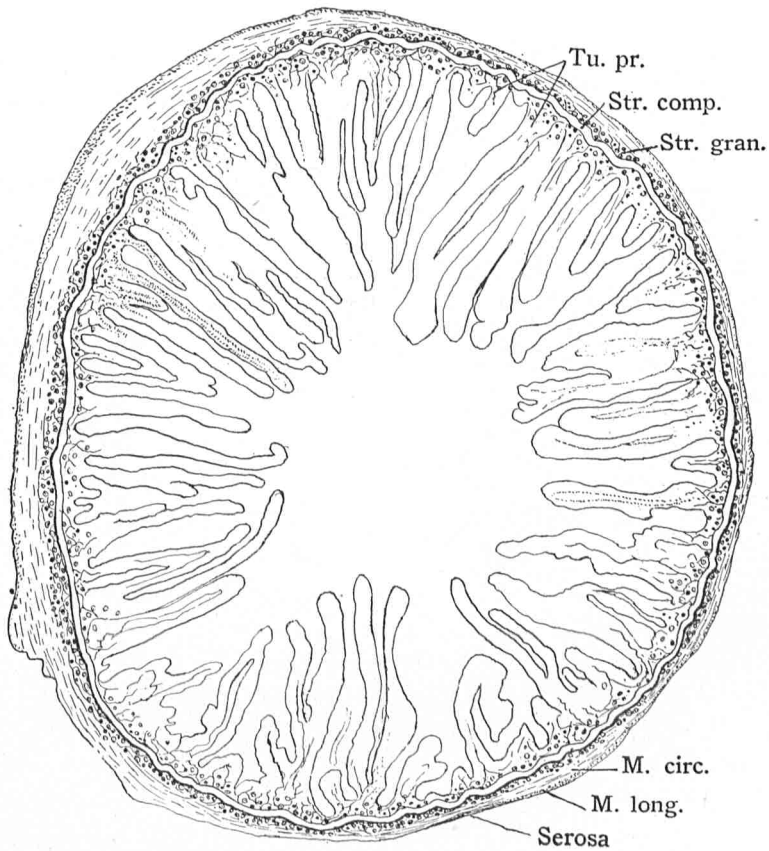

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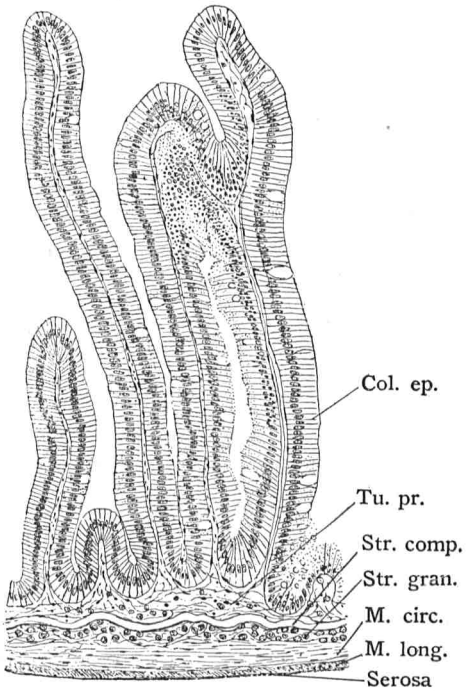

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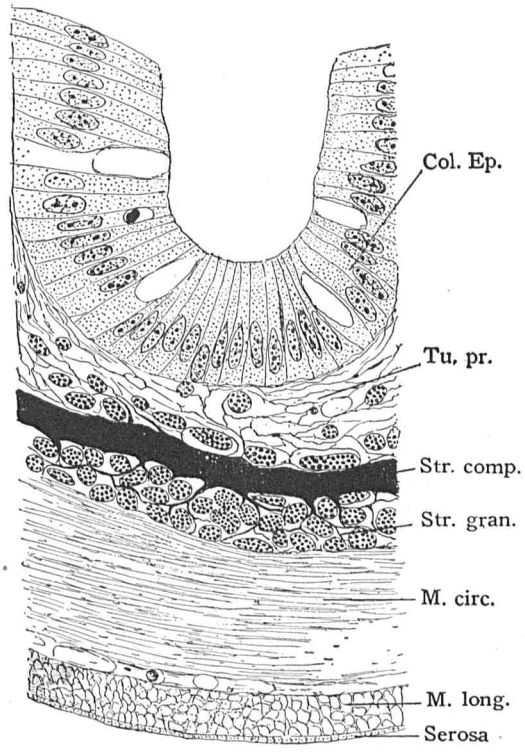

FIG. 9.

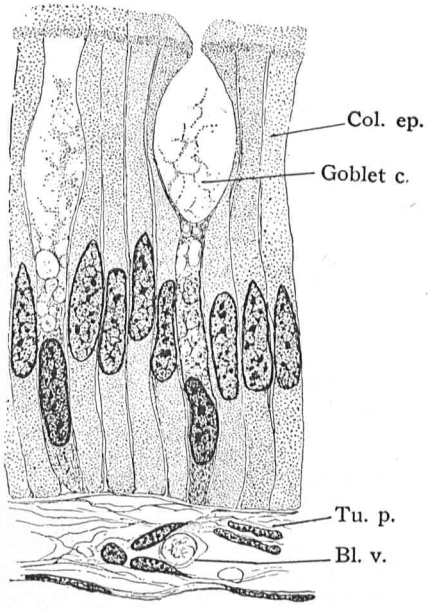

FIG. 10.

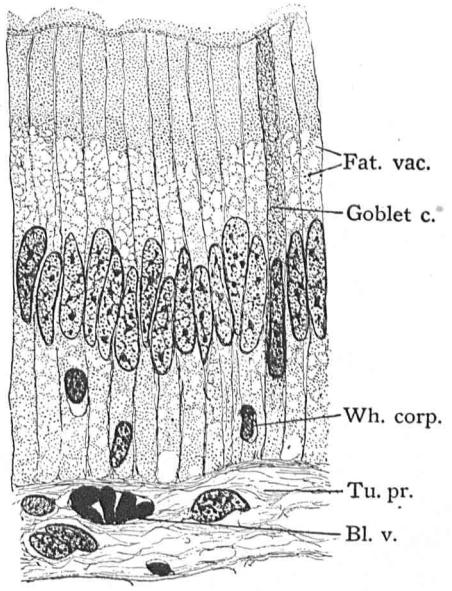

FIG. 11.

NOTES ON THE NATURAL HOSTS OF FRESH-WATER MUSSELS

By Thaddeus Surber

Assistant, United States Biological Laboratory, Fairport, Iowa

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NOTES ON THE NATURAL HOSTS OF FRESH-WATER MUSSELS.

By THADDEUS SURBER,
Assistant, United States Biological Laboratory, Fairport, Iowa.

A study of the conditions pertaining to natural infection of fishes with the larvæ of fresh-water mussels was begun by the writer, under the direction of Dr. R. E. Coker, at the Fairport laboratory in 1910, but was interrupted by assignment to other work, and, while an effort was made to resume the study in 1911, but little was done owing to more pressing duty demanding the time. From the last week in June till the close of November, 1912, however, work was pushed rapidly, 2,815 fish being critically examined, and considerable knowledge gained in regard to certain mussel species.

The observations given in this paper indicate that the natural hosts of our fresh-water mussels are divisible into two classes—i. e., specific distributors of particular species, and accidental or occasional hosts. To the first class belong the skipjack (*Pomolobus chrysochloris*), distributor of the niggerhead (*Quadrula ebena*); the sheepshead (*Aplodinotus grunniens*), distributor of the paper-shell (*Lampsilis lævissima*) and the deer-toe (*L. donaciformis*); and the shovel-nose sturgeon (*Scaphirhynchus platorhynchus*), distributor of the slough sand-shell (*L. fallaciosa*). The sauger (*Stizostedion canadense*) may belong here as distributor of another sand-shell (*L. higginsi*), but it would be unwise to conclude this on the strength of a single specimen. To the second class, in order of their importance, belong the crappie (*Pomoxis annularis*), which has been observed to carry six species; the sauger, carrying four species; two sunfishes (*Apomotis cyanellus* and *Lepomis pallidus*) each carrying three; the strawberry bass (*Pomoxis sparoides*), two species; and another sunfish (*Lepomis humilis*) and the white bass (*Roccus chrysops*), one each. A catfish (*Ameirus natalis*) carries a few glochidia of the *Quadrula* type, but I have not been able to identify the species, owing to accidental loss of material.

Upon consideration, the first class (specific distributors) will be found to agree closely in geographical range with the species of which it is the host, as might be expected. This, of course, is not an original theory, but was advanced years ago by Simpson,[a] and I am convinced that he was right in his conjecture, and to that end shall attempt to show that it is the case in at least three species of our mussels.

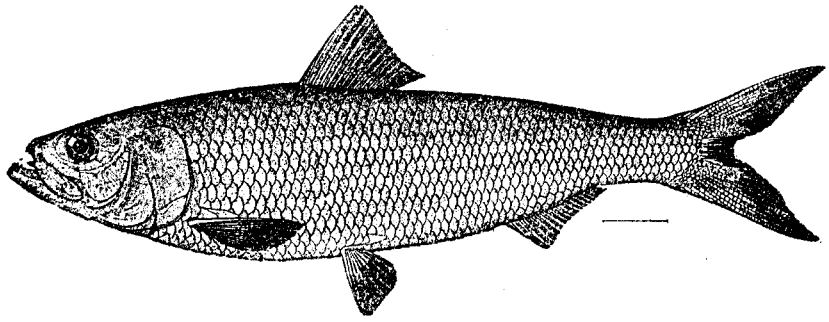
The second class of infections, accidental or occasional hosts, need not be taken up systematically at this time. Reference can be made to table II, however, which shows the species and number of fishes that were observed to be infected with the various species of mussels.

[a] Simpson, Charles T.: The pearly fresh-water mussels of the United States; their habits, enemies, and diseases, with suggestions for their protection. Bulletin U. S. Fish Commission, vol. XVIII (1898), p. 282.

HOSTS THAT ARE SPECIFIC DISTRIBUTORS.

SKIPJACK (*Pomolobus chrysochloris*).

This beautiful fish, variously known as "skipjack," "herring," and, at New Boston, Ill., as "nail-rod," is of rather erratic habits, being abundant at times at certain places along the Mississippi, and at others one of the rarest of fishes. The fishermen at New Boston tell me that at times it is very abundant there, usually in September, but at other times entirely absent. Mr. Will Morris, of Fairport, informs me that a number of years ago while in a flatboat lying off the point of an island in the Mississippi near Lansing, Iowa, he caught these fish nearly as fast as he could pull them aboard, using a common spoon hook. They take live minnows readily also, but the New Boston fishermen tell me are very rarely caught in a trammel net, most of those taken being secured by means of seines, or hook-and-line fishing in the vicinity of the wing dams. Frequenting the most rapid water in the river, particularly that having a rocky, gravelly bottom,



Skipjack (*Pomolobus chrysochloris*).

the skipjack is predaceous in habits, feeding mostly on minnows, and Forbes tells us the young feed on insects. I do not believe this fish is nearly so rare as we might infer from Dr. Forbes's records as given in his "Fishes of Illinois," but that the fishermen pay no attention to it at all, considering it a nuisance and immediately throwing overboard all that are caught.

The geographical range of this fish, as given by Jordan and Evermann, is "Mississippi Valley, etc., abundant and resident in larger streams; introduced into Great Lakes. Also in Gulf of Mexico."

The range of *Q. ebena* as given by Simpson is "Mississippi drainage generally except its western portion; Alabama and Tombigbee Rivers; northeast Texas(?)."

The importance of the skipjack to mussel culturists prompts the hope that it may be possible in the course of time to propagate this fish artificially, and in the meantime it is suggested to those who believe in the introduction of western forms into eastern waters to try one of its eastern congeners, *P. pseudoharengus* or *P. æstivalis* as an experimental host for this desirable mussel. The introduction of mussels into other waters by

transportation of the infected fish, entirely feasible with some fish,[a] would not be possible in this case, as the skipjack is very delicate and will not admit of handling during the warm summer months.

SHEEPSHEAD (*Aplodinotus grunniens*).

From its feeding habits we should expect to find this fish more often infected than any other species. In writing of it Dr. Forbes[b] says:

> This fish is of a sluggish habit, living on the bottom of muddy waters, where it feeds especially on mollusks, the shells first being crushed by the powerful, paved millstone-like, pharyngeal jaws. Often the stomach contains only the soft bodies and opercula of gastropod mollusks, the crushed shells having been thrown out. Crawfishes are also sometimes found in the food. Half-grown specimens feed largely on aquatic insects, especially the larvæ of May-flies, mingling larger and larger proportions of mollusks with this food as they increase in size, until they come finally to depend almost wholly upon water snails and the relatively thin-shelled clams.

As it is known to be the specific host for both *L. lævissima* and *P. donaciformis*, it is of rather more than usual interest.[c] It can no doubt readily crush the papery shells of *lævissima*, and, from their small size, swallow entire the shells of *donaciformis*, from which we can readily understand the enormous numbers that are attached to the gills of this fish.

The geographical range of the fish is given as "Great Lakes to Texas and Georgia; abundant in all lakes and large streams west of the Alleghanies and east of the plains" (Jordan and Evermann).

Simpson gives the ranges of the two mussels as follows:

L. lævissima: "Mississippi drainage generally; eastern Texas, southern Michigan, western New York."

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[a] Dr. Ortmann, in an interesting article in a recent issue of "The Nautilus" (vol. XXVI, p. 51), records the accidental introduction of the "pocketbook" (*L. ventricosa*) into the upper Potomac drainage in Maryland and West Virginia.

[b] Forbes, S. A.: Fishes of Illinois, Natural History Survey of Illinois, State Laboratory of Natural History, vol. III, p. 324.

[c] Since the above was written the author has had the opportunity to examine a number of fish taken by him in White and Cache rivers near Clarendon, Arkansas. During the first half of January (1913) 18 specimens of *Aplodinotus grunniens* were secured, eight of which bore natural infections, and from the number of glochidia borne by each fish I should accept it as the specific host of *Lampsilis* (*Proptera*) *purpurata;* five examples were infected on the gills and another both on gills and caudal fin. The cysts are very large and consequently very noticeable. While all are not of the same development the growth in the majority of cases is very marked; the infant mussels have assumed about the development indicated in the figure of *lævissima* shown in figure 2, plate XXIX. It is presumed these fish became infected some time during the autumn, but as many gravid mussels of this species, all with active glochidia, were taken during January, some may have become infected more recently. In these infections the number of infant mussels borne by individual fish varied from 68 to as many as 500 in two cases. The glochidium of *purpurata* resembles very closely that of *L.* (*Proptera*) *alata* both in shape and size, measuring 0.200 by 0.360 mm.; the hooks, however, are better developed than in *alata*.

A still more interesting discovery is the finding of a number of glochidia of *Quadrula heros*, heavily encysted and of considerable development, on the fins of two of these *Aplodinotus*. This glochidium being of the hookless type it was naturally supposed to be a gill parasite, but this does not seem to be the case, as none were found on the gills of the fish.

In the White River material is also a specimen of rock bass (*Ambloplites rupestris*) carrying on its gills six glochidia of *Arcidens confragosa* beautifully encysted and of considerable development. The hooked glochidium of *Arcidens* is closely related, in form at least, to the *Anodonta* group, one species of which (*cataracta*), according to Lefevre and Curtis (Bulletin U. S. Bureau of Fisheries, vol. XXX, p. 158), would not metamorphose on the gills of the carp. A crappie (*P. annularis*) was also secured bearing the same species on the gills; but this mussel is probably more frequently found on the fins of fishes, as two hickory shad (*Dorosoma cepedianum*) were taken bearing considerable numbers on the fin margins, particularly the caudal, where they are deeply embedded in the epithelium.

P. donaciformis: "Mississippi drainage generally; Alabama River area; southwest to the Trinity River, Tex.; Michigan."

In artificial infections this fish takes readily almost any glochidia of the *Lampsilis* group, but with indifferent results, more probably due to the difficulty of handling it in hot weather than from any other cause.

Shovel-nose Sturgeon (*Scaphirhynchus platorhynchus*).

Sturgeons as a rule are bottom feeders, and this species is no exception, so that we should expect to find it very frequently infected. Such, however, does not seem to be the case. The heavy gill filaments of this fish render difficult the detection of glochidia; therefore all that were obtainable were carefully gone over, and it is not believed any were overlooked which were carrying larvæ in any numbers. On October 15 and again on November 7 specimens were taken holding larvæ of *Lampsilis fallaciosa*, and these were in sufficient numbers to indicate that it is the specific host of this particular species.

While it is unsafe probably to consider this fish the only distributor of *fallaciosa*, it is interesting to note the known geographical ranges of the two species, which is as follows:

S. platorhynchus: "Mississippi Valley and streams of the Western and Southern States" (Jordan & Evermann).

L. fallaciosa: "Upper Mississippi drainage; south to the Cumberland River, Tennessee, and to Arkansas; Red River of the North?" (Simpson).

MUSSELS AS PARASITES.

We shall now consider the matter from another point of view, taking up in their order the various mussel species as parasites. It will be noted that all species considered in this study are gill parasites with one exception, *A. corpulenta*, and consequently nearly all of commercial value.

Slop-Bucket (*Anodonta corpulenta*).

But one fish has been taken bearing larvæ on the external parts, and this is found to be *corpulenta*. On November 10, 1910, along the river shore within the grounds of the biological station, a young skipjack about 3 inches in length was picked up which held 24 glochidia, mostly on the caudal fin, but a few on ventrals and pectorals. By reference to the accompanying figure (fig. 1, pl. XXIX) it will be noted that encystment is incomplete, though but a small portion of the dorsal edge of the shell protrudes, and that the infection is quite recent is further shown by the condition of development in the adductor muscle. This glochidium is saddled over the edge of the caudal fin and grasps two of the cartilaginous rays up almost to the adductor muscle; the other glochidia occupied relatively the same positions on the fins as shown in this figure.

YELLOW SAND-SHELL (*Lampsilis anodontoides*).

During the latter part of June and early in July this mussel was found on the two species of crappie and on *Apomotis cyanellus* and *Lepomis humilis*, but in such limited numbers that it is extremely doubtful if any of these fish are the actual host, as the greatest number occurring on any one species was six. As this time is the height of the spawning season of this particular mussel, and all the infections were recent, it is presumed they were more or less accidental.

Some sunfish infected artificially with glochidia of this mussel July 1, 1911, apparently took well and were deeply encysted at the end of three and three-fourths hours, but two days later not a single glochidium could be found on any of the fish, due probably to unfavorable conditions. On June 27, 1910, a lot of fish, chiefly *Pomoxis* and *Lepomis*, with a few *Micropterus*, *Aplodinotus*, and *Roccus* were infected and apparently took well, but the glochidia never completed their metamorphosis. However, on August 11, 1910, a few metamorphosed on a sunfish (*A. cyanellus*) in four days, about 1 per cent of those encysted.

SLOUGH SAND-SHELL (*Lampsilis fallaciosa*).

On June 27 a crappie (*P. annularis*) was taken holding 16 glochidia of this species, but it was not again found till October 15, when a sturgeon (*S. platorhynchus*) was taken holding 125. On November 7 another sturgeon was taken holding 56.

This glochidium does not, as a rule, take very near the tips of the filaments in the sturgeon, but rather deep, a great many as deep as the fork of the filament, and encystment is very heavy. The October infection indicates but very slight development, or none at all; cysts enormous. Examination of the November infection reveals the fact that the adductor muscle is dividing and traces of the foot are clearly discernible. It is believed these sturgeon become infected sometime during September or October, and the metamorphosis would, therefore, not be completed till some time during the following spring.

HIGGINS SAND-SHELL (*Lampsilis higginsi*).

The only fish so far taken which unquestionably holds this glochidium is a specimen of *Stizostedion canadense* taken October 4, 1912; it holds approximately 600 glochidia. The infection was recent and no development is clearly indicated; cysts very heavy.

PAPER-SHELL (*Lampsilis lævissima*).

For the past three years we have been taking sheepshead (*Aplodinotus grunniens*) bearing enormous numbers of young *lævissima*, generally in a high state of development. The sheepshead, from its habits, should be expected to be found more frequently infected than most any other species of fish, yet the percentage of infected fish is small.

Only 2 per cent of the fish taken during the period from June to November were infected with this larva, the number carried by each fish varying from 112 to 850. It was hoped that a critical study of the material would indicate the period of parasitism, but such is not the case, though I am of opinion that it covers a period of nearly a year.

The only fish so far taken carrying what is apparently recent infection is one taken October 21, but only a few, about 1 per cent, are of this stage, i. e., the glochidium still simple. The next stage is indicated in specimens secured October 15, where the growth is quite decided, the infant mussel having assumed a nearly circular form when viewed from the side; this phase is clearly shown in figures 2 (side view) and 3 (postero or antero ventral view). In figure 2 the larval mussel is on the extreme tip of the gill filament, while figure 3 is encysted about 3 mm. back from the tip and on the flat side of the filament. Another fish, taken October 30, holds larval mussels in a more uniform state of development, of a stage clearly shown by figure 4; by reference to this figure it will be found that the young mussel has apparently grown more rapidly in length than in height, and that in the region of the umbones, both anteriorly and posteriorly, it has not grown at all, except in thickness, giving it a curious depressed effect there. Figure 4 exhibits the sharpness of the ventral points of the glochidial shell on the upper side, caused by the growth of the shell of the young mussel expanding the glochidial shell; in figure 5 a dorsal view is given of another specimen of the same relative development to show increase in thickness.

The greatest development seems to be reached during October, when they have assumed the shape and size indicated in figures 6 and 7, where it has increased three to four times in length over glochidium and the inflation (thickness) is so marked as to suggest anything but the parent shell, when viewed dorsally (fig. 7). This stage has been shown before (Coker and Surber, Biological Bulletin, vol. 20, p. 179–182, fig. 5, 6, and 7). It is believed that at this stage the parasitism is completed, or nearly so, and this belief is strengthened by the fact that on November 2 a fish was taken holding comparatively few (120) mussels and a number of ruptured cysts which had probably held others a very short time previously, though it is of course possible that the ruptures may have been caused by other parasites, but this is not deemed probable. We might infer from this that the fish became infected either the preceding spring (1912) or during September of the preceding year (1911), the latter seeming the more probable. *Lævissima* with ripe glochidia has been taken in the vicinity of Fairport during April, June, and September.

So far, this mussel has been found on but one other species of fish, the crappie, in which the same development is indicated as occurs in the sheepshead.

TABLE I.—NUMBER OF LARVAL L. LÆVISSIMA CARRIED BY THE HOST.

Species of fish.	Date secured.	Number of glochidia.	Locality.
Aplodinotus grunniens	June 16, 1910	670	Fairport, Iowa.
	Oct. 18, 1910	375	Do.
	Oct. 15, 1912	325	Do.
	Oct. 17, 1912	112	Do.
	Oct. 15, 1912	850	Do.
	Oct. 30, 1912	200	Do.
	Oct. 21, 1912	240	Do.
	Nov. 2, 1912	120	Do.
	Nov. 9, 1912	540	Do.
Pomoxis annularis	Nov. 17, 1912	112	Do.
	Nov. 21, 1912	210	Do.

MUCKET (*Lampsilis ligamentina*).

On the 26th of September a rather large *Roccus chrysops* was taken holding upward of 200 glochidia of this species; cysts are heavy but glochidia show no development at all, so that it is presumed to be a recent infection.

A great many other fish were taken during September and October, principally crappie and sunfish, infected with this mussel, but as the crew of the station were at work infecting and liberating fish with this larva, all were presumed to be artificial infections. No *Roccus* had been artificially infected previous to September 26, so that the above record is deemed permissible.

BLACK SAND-SHELL (*Lampsilis recta*).

The only time this mussel has been found a natural parasite was July 2, 1912, when a *Lepomis pallidus* was taken bearing 35 glochidia. The infection was recent, deeply encysted, and I have no doubt would have metamorphosed in a very short time, the fish being extremely strong and robust.

DEER-TOE (*Plagiola donaciformis*).

This small mussel, so far, seems to be found almost exclusively on the sheepshead, the only exception being a sauger taken quite recently. Discovered first at New Boston, Ill., in August, 1910, it has since been found at frequent intervals, both there and at Fairport.

The number of young mussels found on a fish varies considerably, but is usually great, a fish taken October 30 holding about 2,800, which is the greatest number found. The duration of parasitism is problematical; no fish have been found recently infected, all infections so far found being highly developed. As we have secured gravid mussels of this species with fully developed glochidia only during the latter part of July, it seems probable, and is possible, that the enormous development indicated occurs in the short space of two months, but this of course can only be proved by artificial infection of the specific host. Specimens of least development, so far known, are some taken July 20, 1911, one of which is shown in figure 8 (postero-dorsal view); this would indicate one of two facts, either that it was an infection of the previous year, in which case growth is comparatively slow, or that it was very recent and growth correspondingly rapid. On a fish taken August 16 occur 1,495 young mussels, the development of which is very great, far exceeding that shown previously in *lævissima;* one in side view is shown by figure 9, which is found to have increased seven times in length, and about three and one-half times in depth over glochidial shell, yet all on this fish were not uniformly developed, as is shown in figure 10 (*a*). Figure 10 shows a portion of a filament with young mussels in situ, two of which are on the edge, while the other (*a*) is encysted on the flat side of the filament.

TABLE II.—NUMBER OF LARVAL P. DONACIFORMIS CARRIED BY THE HOST.

Species of fish.	Date secured.	Number of glochidia.	Locality.
Aplodinotus grunniens	Aug. 9, 1910	1,100	New Boston, Ill.
	Aug. 15, 1912	300	Do.
	Aug. 16, 1912	1,495	Do.
	.....do.....	1,200	Do.
	Aug. 15, 1912	76	Do.
	Aug. 22, 1912	2	Fairport, Iowa.
	Aug. 24, 1912	280	Do.
	Oct. 30, 1912	2,800	Do.
	Nov. 9, 1912	1,000	Do.
Stizostedion canadense	.....do.....	1,800	Do.

BUTTERFLY (*Plagiola securis*).

But a single glochidium, well encysted, has been found by the writer, this being found on a sunfish (*Apomotis cyanellus*) taken July 1, 1912; no development was indicated.

Experiments in artificial infection of the black bass, crappie, sunfish, and catfish with this larva have proved unfavorable, so that we must conclude the specific host is as yet unknown.

BULLHEAD, SHEEPNOSE (*Pleurobema æsopa*).

A sauger (*S. canadense*) was taken July 20, 1911, holding 17 glochidia of this mussel. As the anterior and posterior adductor muscles were clearly defined and the foot more or less conspicuous, indications are that this fish is at least an occasional host of this larva. As the mussel itself is not at all common, the sauger may eventually prove to be the specific host. An infection is shown in figure 17.

NIGGERHEAD (*Quadrula ebena*).

The discovery of the specific host of this mussel on August 13, 1912, was a great gratification, occurring as it did after almost three years' experimentation. Repeated failures in obtaining artificial infections with all the species of fish obtainable in the vicinity of Fairport led me to search for fish not previously taken, of which the skipjack (*P. chrysochloris*) was about the only one remaining. The taking of a specimen of this fish, June 18, 1910, by H. Walton Clark, was overlooked till after the August, 1912, material was identified, when his note was looked up and later the fish itself secured and found to be heavily infected. Mr. Clark, while recognizing at the time of taking that his 1910 specimen was carrying glochidia in great numbers, was unable to identify the species of mussel owing to lack of material, no glochidia of *Q. ebena* being available at that time for comparison. Owing to the great commercial value of this shell, which is exceeded by none, the final discovery of the host is of far-reaching importance.

During the season of 1912, 15 specimens of *Pomolobus* were secured in the vicinity of Fairport and New Boston, the 5 specimens secured during August all bearing glochidia in large numbers, ranging from 1,895 to 3,740 for each fish. During this month little development of the glochidia was shown which would indicate recent infection, but a

specimen taken at Fairport, September 11, had only 48 glochidia remaining, and two specimens out of a total of nine taken at New Boston, September 24, held 26 and 31, respectively, all the September material indicating much development. The same results are shown by some material from the upper Mississippi which Mr. W. B. Gorham secured while with the reclamation work of the steamer *Curlew*, when, on August 26, at La Crosse, Wis., he secured one fish holding 365 glochidia, well along in development, and another fish at Genoa, Wis., September 23, with development about completed. In the vicinity of Fairport *ebena* has been secured with well-developed embryos during the last week in May and during June, July, and August. This would indicate a comparatively rapid metamorphosis, which, in my opinion at least, does not much, if at all, exceed two months.

A study of the material shows us that *ebena* undergoes no important increase in size of shell, and consequently no change in form, during metamorphosis. Figure 11 shows a glochidium (side view) on the edge of a filament. By reference to the figure it will be noted that considerable development is indicated, the posterior adductor showing in place, and the foot considerably developed; this was taken August 13, and figure 12 shows dorsal and ventral views of the same development. In the specimens taken September 24, shown by figure 13, the development is very clearly defined, the foot having reached what might be considered normal size, while the position of the anterior and posterior adductors and the protractor pedis is distinct; it is believed this young mussel would have left its host in a very short time. In the specimens taken June 18, 1910, practically no development at all has occurred; the distal third of a gill filament of this infection is shown in figure 14.

Particular attention is called to figures 12 and 13, where the cysts are shown off to one side of the young mussel, a characteristic feature of those which have attained sufficient development. It seems the young mussel has shifted its position, migrating as it were from its normal position in the cyst to a new one among the delicate filaments, disarranging them as indicated in the figure (12) on the right side; this movement is preliminary to its ultimate freedom. The young mussels are now lying on the surface of the filament beneath the mucous membrane covering it, while the epithelial cells forming the cyst proper remain unbroken, so that it has evidently pushed along beneath the membranaceous covering to its present position, the membrane having now adapted itself to the new conditions and formed, as it were, a new cyst which covers the entire filament and gives to the parasite much increased freedom of movement. This condition is more clearly shown by reference to figure 18, where the distinctly swollen area comprising the new cyst is accentuated, though the magnification in this figure is much less than indicated in figures 12 or 13.

In the more recent infections—that is, the young still in the glochidial stage, as shown by figure 14—this remarkable condition does not exist, the development being such that the animal has no power of locomotion as yet. On the other hand, in specimens taken during September, there are many cysts having the appearance of these shown in figure 13, simple, hollow, globular areas suggesting small tumors, unmistakably the former abode of some young mussel which has completed its metamorphosis and departed with-

out apparent serious injury to the cyst. This condition is interesting, nothing like it having previously been noted in the parasitism of any of our mussels, so far as I know, and the causes leading up to it will bear careful investigation. This can be done only by a thorough study of the relations existing between host and parasite, in which connection it will be well to study in detail the structure of the gills of the host.

TABLE III.—NUMBER OF LARVAL Q. EBENA CARRIED BY THE HOST.

Species of fish.	Date secured.	Number of glochidia.	Locality.
Pomolobus chrysochloris	Aug. 13, 1912	2,100	Pearl Slough, Fairport.
	.....do.....	3,740	Do.
	Aug. 14, 1912	1,895	Buttermilk Slough, Fairport.
	.....do.....	2,700	Upper end Geneva Island.
	Aug. 17, 1912	3,200	New Boston, Ill.
	Aug. 26, 1912	365	La Crosse, Wis.
	Sept. 11, 1912	48	Fairport, Iowa.
	Sept. 24, 1912	26	New Boston, Ill.
	.....do.....	31	Do.
	Sept. 23, 1912	9	Genoa, Wis.
	June 18, 1910	2,570	Fairport, Iowa.

MONKEY-FACE (*Quadrula metanevra*).

During the early part of July five blue sunfish (*Lepomis pallidus*) and one green sunfish (*A. cyanellus*) were taken bearing a comparatively small number of glochidia of this mussel. The two heaviest infections are one of 50, the other of 69, and it is therefore probable the sunfishes may be found to be the specific hosts of this mussel. By reference to figure 15 it will be found that one of the infections, taken July 2, is developing, the adductors having become clearly defined and rudiments of the foot apparent. No change in form nor increase in size of shell is anticipated in this species.

TABLE IV.—NUMBER OF LARVAL Q. METANEVRA CARRIED BY THE HOST.

Species of fish.	Date secured.	Number of glochidia.	Locality.
Lepomis pallidus	July 1, 1912	6	Fairport, Iowa.
	July 2, 1912	50	Do.
	.....do.....	1	Do.
	.....do.....	6	Do.
	.....do.....	69	Do.
Apomotis cyanellus	.....do.....	15	Do.

BLUE-POINT; THREE-RIDGE (*Quadrula plicata*).

The only fish so far taken infected with this species was on June 28, 1912, when a sauger (*S. canadense*) carrying 28 and a crappie (*P. annularis*) 4 glochidia were secured. The development is decidedly progressing as indicated in figure 16, where the foot and both adductor muscles are clearly defined. The figure (16) is a glochidium attached to edge of gill filament of the sauger.

PIMPLE-BACK (*Quadrula pustulata*).

But two glochidia of this species have so far been detected and this on a crappie (*P. annularis*) taken September 12, 1912. While it is rather late in the season to expect to find this mussel still parasitic, it is not believed that the identification is wrong, yet the development should have progressed more rapidly than is the case in this instance.

PIMPLE-BACK (*Quadrula pustulosa*).

October seems extremely late to find any *Quadrulas* persisting, but the gills of a crappie taken the 17th of that month reveals a single glochidium of what I am compelled to regard as this species. No development whatever is indicated and the presence of the glochidium at this late season may be due to some freak physiological characteristic not easily understood.

QUADRULA SOLIDA.

Two sunfish (*Lepomis pallidus*) were taken July 1, 1912, bearing glochidia of this mussel, one having 50 present, the other only 6. The development is similar to that noted in *plicata*, the foot and adductors being clearly indicated. The shell itself is not at all common in this region, and one would naturally expect to find few fish infected. The glochidium of this species closely resembles that of *ebena* and might be mistaken for the latter by a careless observer, but may be recognized by its greater comparative depth and shorter, straighter hinge line.

PIG-TOE (*Quadrula trigona*).

From the frequency with which this shell is found in the vicinity of Fairport, it is surprising more infected fish are not taken, its spawning season being July and August. So far only a single black crappie (*Pomoxis sparoides*) taken June 25, 1912, has been found infected, and it held but three glochidia, none of which showed any development whatever, thus indicating recent infection.

SUMMARY.

In conclusion attention is directed to the table of fish examined (table V), following. The remarkably small percentage of fish infected in a state of nature will be apparent at once, even of those species known to carry glochidia, if we except the skipjack (*Pomolobus chrysochloris*). In the case of the sheepshead, known to be the specific host for two species of mussels, the percentage is about 3⅔, while in *Pomoxis annularis*, which carries more species of mussels than any other fish, it is only seven-tenths of 1 per cent. Out of a total of 38 species examined, numbering some 2,815 individuals, only 46 fish were infected, but of course only 11 species are apparently susceptible to natural infection. Further investigations will reveal much, the work having only begun. A summary of the present known hosts is shown in table VI.

By reference to table v the advantages of artificial infection can be readily imagined when the small percentage found infected in a state of nature is considered. Some one has long ago estimated that in the case of some fishes but 10 per cent of the eggs deposited naturally are even fertilized, whereas by artificial means it is now an established fact that fully 90 per cent, and even better, is not only possible, but a rule, in handling these same fishes. Now in the mussel the eggs are fertilized and the young developed ready for their parasitic life while still in the gills of the parent, so that all man has to do is find the specific host of a given species, procure that host, and load it to the limit, which may exceed the optimum infection of Lefevre and Curtis [a] in some cases. The simplicity of the proceeding is startling when we consider the ease with which the glochidia can be procured, a fair sized mucket (*L. ligamentina*), for instance, producing as many as 3,500,000 young and the niggerhead (*Q. ebena*) about 350,000.

TABLE V.—FISH CAUGHT AND EXAMINED FOR NATURAL INFECTION, JUNE TO NOVEMBER, 1912.

Species of fish.	June-July.		August.		September.		October.		November.		Total.	
	Examined.	Infected.	Examined.	Infected.	Examined.	Infected.	Examined.	Infetced.	Examined.	Infected.	Examined.	Infected.
1. Petromyzon castaneus							1				1	
2. Petromyzon concolor			2		1		2				4	
3. Polyodon spathula			2								2	
4. Scaphirhynchus platorhynchus			18		16		19	1	13	1	66	2
5. Lepisosteus osseus					7						7	
6. Amia calva			2		2				4		8	
7. Ictalurus furcatus					3						3	
8. Ictalurus punctatus			21		48		70		29		168	
9. Ameiurus natalis	6	1			2						8	1
10. Ameiurus nebulosus							1				1	
11. Ameiurus melas			4				2				6	
12. Leptops olivaris			44		18		4		1		67	
13. Carpiodes carpio							1				1	
14. Carpiodes velifer	18		7				3		13		41	
15. Cycleptus elongatus							2				2	
16. Minytrema melanops									1		1	
17. Moxostoma breviceps			1								1	
18. Moxostoma aureolum			3								3	
19. Hiodon alosoides					1						1	
20. Pomolobus chrysochloris			5	5	10	3					15	8
21. Dorosoma cepedianum					1				15		16	
22. Esox vermiculatus					1				1		2	
23. Anguilla chrisypa			1		2						3	
24. Pomoxis sparoides	7	1			104		144		3		258	1
25. Pomoxis annularis	30	5	195		640	1	278	3	12		1,155	9
26. Ambloplites rupestris							1		1		2	
27. Apomotis cyanellus	41	1	2		10		1		4		58	1
28. Apomotis symmetricus	1										1	
29. Lepomis humilis	42	1							1		43	1
30. Lepomis pallidus	35	4	30		137		43				245	4
31. Eupomotis gibbosus			3				1				4	
32. Micropterus dolomieu					3				1		4	
33. Micropterus salmoides			9		9		4				22	
34. Stizostedion vitreum							3		6		9	
35. Stizostedion canadense			5		20		32	1	38	2	95	3
36. Roccus chrysops			2		11	1	76		3		92	1
37. Morone interrupta			3		4				71		78	
38. Aplodinotus grunniens	30		141	6	27		104	5	20	4	322	15
Total	210	13	499	11	1,077	5	792	10	237	7	2,815	46

[a] Lefevre, George, and Curtis, Winterton C.: Studies on the reproduction and artificial propagation of fresh-water mussels. Bulletin of the Bureau of Fisheries, vol. xxx, p. 159.

TABLE VI.—NATURAL HOSTS OF FRESH-WATER MUSSELS.

Species of fish.	Species of mussel and number of fish infected.															
	Lampsilis anodontoides.	Lampsilis fallaciosa.	Lampsilis higginsi.	Lampsilis lævissima.	Lampsilis ligamentina.	Lampsilis recta.	Plagiola donaciformis.	Plagiola securis.	Pleurobema æsopa.	Quadrula ebena.	Quadrula metanevra.	Quadrula plicata.	Quadrula pustulata.	Quadrula pustulosa.	Quadrula solida.	Quadrula trigona.
Scaphirhynchus platorhynchus		2														
Ameiurus natalis																
Pomolobus chrysochloris										11						
Pomoxis sparoides	1															1
Pomoxis annularis	2	1		2								1	1	1		
Apomotis cyanellus	1							1			1					
Lepomis pallidus						1					5				2	
Lepomis humilis	1															
Stizostedion canadense			1				1	1	1			1				
Roccus chrysops					1											
Aplodinotus grunniens				10			9									

NOTE.—*Anodonta corpulenta* has been found but once, a young *Pomolobus chrysochloris* carrying a few on the fins; being an external parasite, it is not included in this table. *Ameiurus natalis* is included in the table because it was found to harbor one glochidium, the species of which was, however, indeterminable.

EXPLANATION OF PLATES.

PLATE XXIX.

FIG. 1. Glochidium of slop bucket, *Anodonta corpulenta*, on caudal fin of a young skipjack, *Pomolobus chrysochloris*.

FIG. 2. Young paper shell, *Lampsilis lævissima*, on gill of sheepshead, *Aplodinotus grunniens* (side view) in an early stage of development.

FIG. 3. Postero- or antero-ventral view of young *lævissima* of about the same development as figure 2.

FIG. 4–5. Another stage of development of *lævissima*, figure 4 representing side and figure 5 dorsal views.

FIG. 6–7. Side and dorsal aspects of *lævissima* upon reaching what is considered its greatest development as a parasite.

PLATE XXX.

FIG. 8. Postero-dorsal view of young deer-toe, *Plagiola donaciformis*, on gill of sheepshead, *Aplodinotus grunniens*.

FIG. 9. Side view of *donaciformis* on gills, the metamorphosis about completed.

FIG. 10. Portion of gill of *Aplodinotus* with young *donaciformis* in situ.

FIG. 11. Glochidium of niggerhead, *Q. ebena*, on gill filament of skipjack, *Pomolobus chryoschloris*, taken August 13.

FIG. 12. Dorsal and ventral views of *ebena* of same relative age as figure 11.

PLATE XXXI.

FIG. 13. *Quadrula ebena* presumed to have about completed its metamorphosis; a specimen taken September 23, 1912.

FIG. 14. Distal third of gill filament with glochidia of *ebena* in position.

FIG. 15. Glochidium of *Quadrula metanevra* on gill filament of sunfish, *Lepomis pallidus*.

FIG. 16. Glochidium of *Quadrula plicata* on gill filament of sauger, *Stizostedion canadense*.

FIG. 17. Glochidium of *Pleurobema æsopa* on gill filament of the sauger (*S. canadense*).

FIG. 18. Young *ebena* on gill filament, showing shifted position.

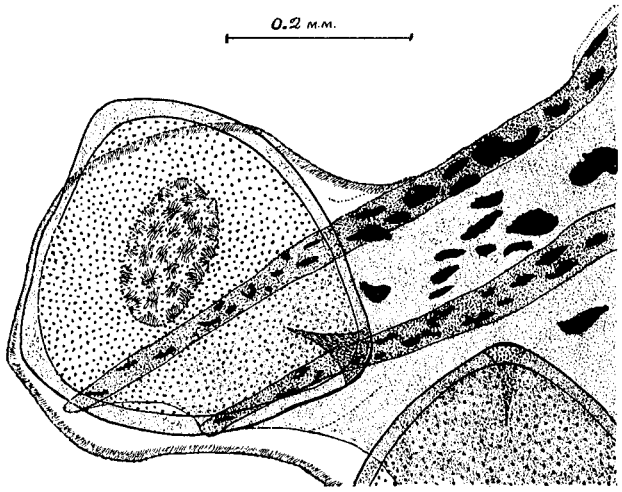


FIG. 1.

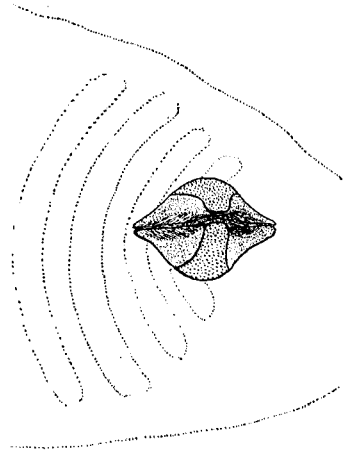


FIG. 5.

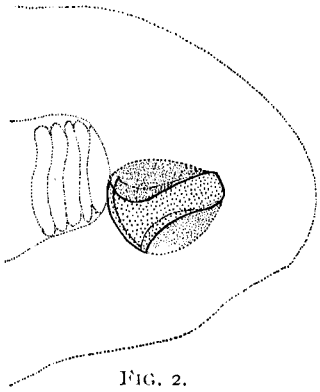
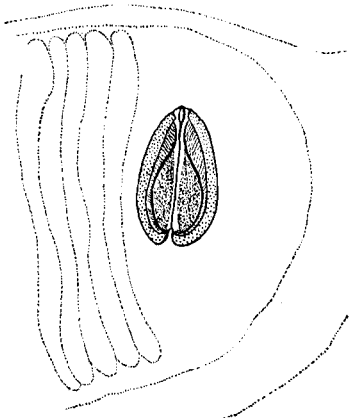


FIG. 2.



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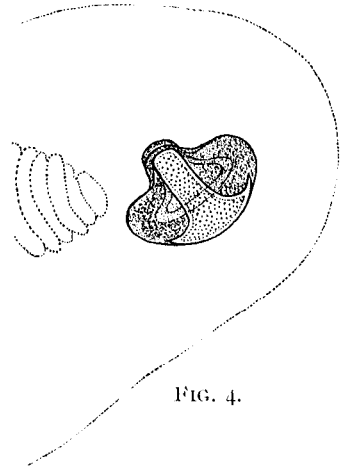

FIG. 4.

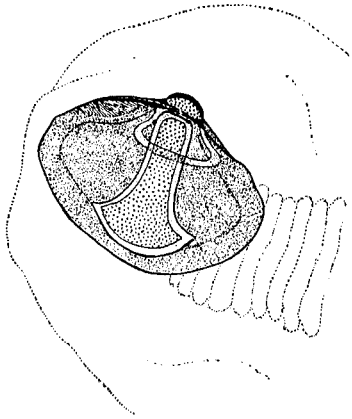

FIG. 6.

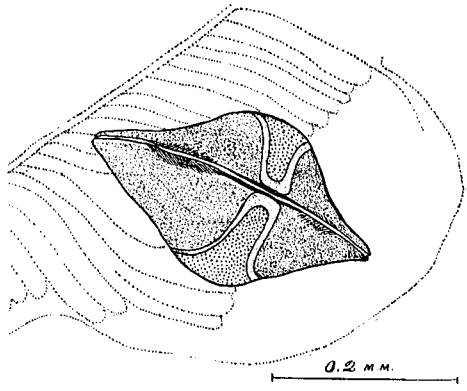

FIG. 7.

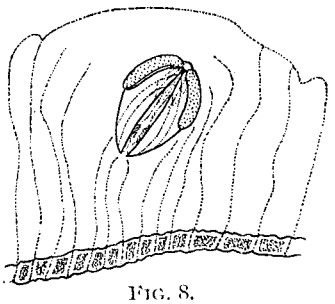

FIG. 8.

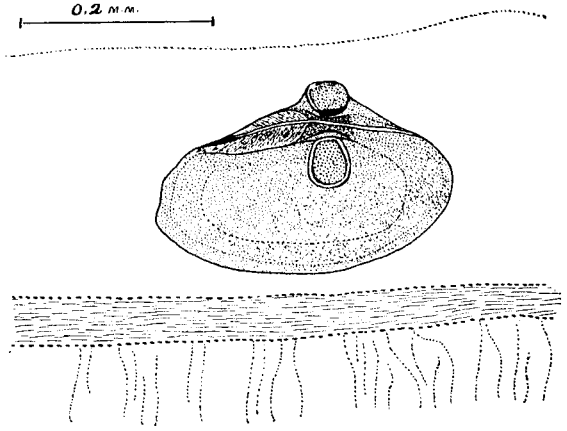

FIG. 9.

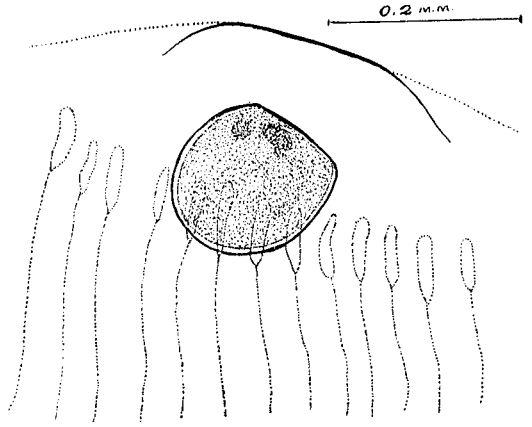

FIG. 11.

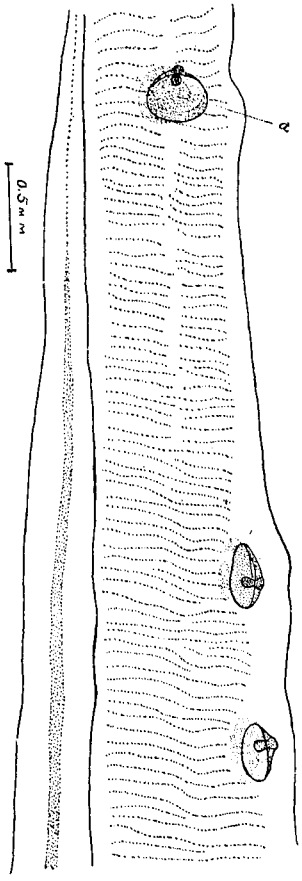

FIG. 10.

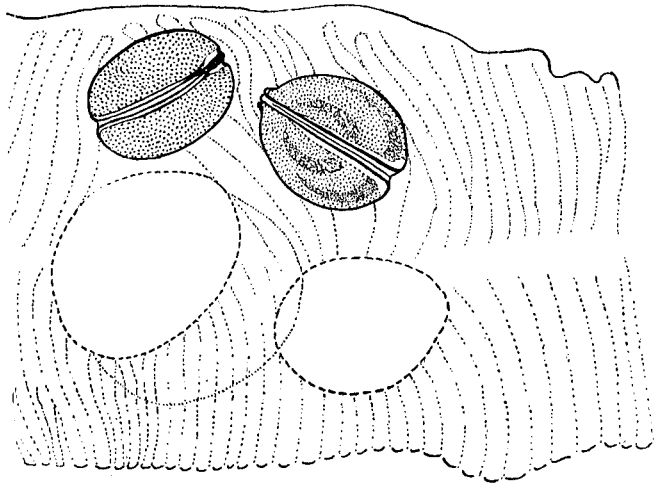

FIG. 12.

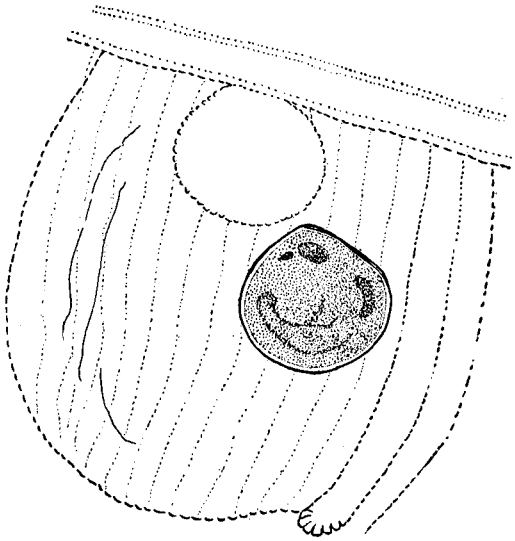

FIG. 13.

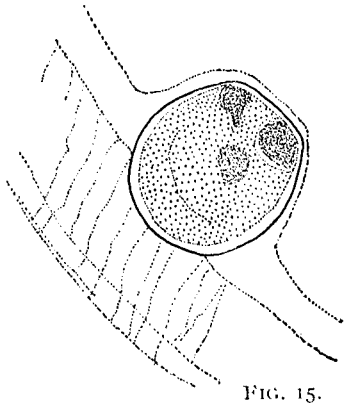

FIG. 15.

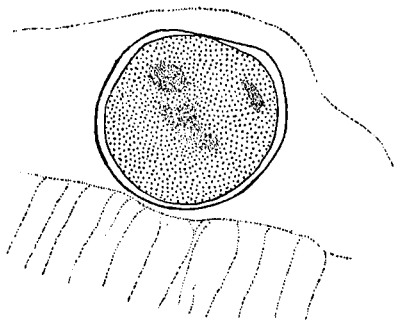

FIG. 17.

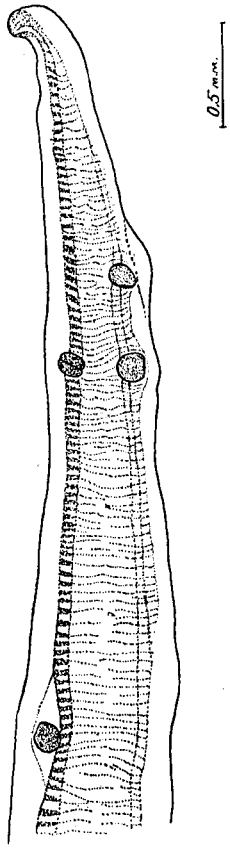

FIG. 14.

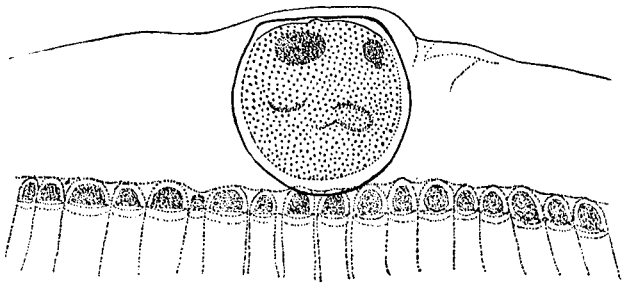

FIG. 16.

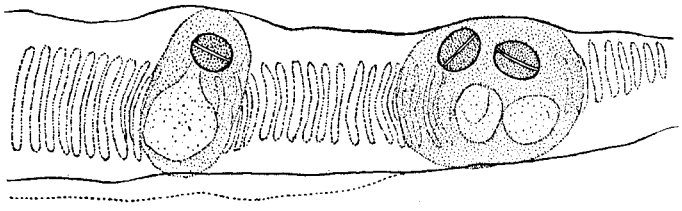

FIG. 18.

OBSERVATIONS ON FISH SCALES

By T. D. A. Cockerell

University of Colorado, Boulder, Colorado

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OBSERVATIONS ON FISH SCALES.

By T. D. A. COCKERELL,
University of Colorado, Boulder, Colo.

INTRODUCTION.

In a paper on "The Scales of Freshwater Fishes" (Biological Bulletin of the Marine Biological Laboratory at Woods Hole, Mass., vol. xx, May, 1911) I have given an account of the recent work on teleostean fish scales and have discussed some of the problems presented by the scales of freshwater fishes. Until recently it has been impossible to do much with the scales of marine fishes, owing to the difficulty of obtaining adequate materials. For the same reason very little was done on the spiny-rayed freshwater groups, the Percidæ, Centrarchidæ, etc. During the summer of 1911, however, I was enabled to continue the work in the laboratory of the Bureau of Fisheries at Woods Hole, where the director, Dr. F. B. Sumner, afforded me every possible facility and put at my disposal a large series of fishes representing many families. I have also been very greatly indebted to the Bureau of Fisheries, through Dr. Hugh M. Smith and Dr. B. W. Evermann, for numerous and important specimens from the collections at Washington. At the National Museum Mr. B. A. Bean and Mr. A. C. Weed gave me much help and supplied scales of some important genera, while other very valuable materials were secured from the Museum of Comparative Zoology, through the kindness of Dr. S. Garman. As in former years, I have been indebted to Dr. Boulenger for some of the rarest forms. With all this the outlook has been greatly enlarged; but of course the results here reported are quite insignificant compared with those which will doubtless be attained, mainly by other workers, in the future. The whole subject is still in a preliminary stage, and when it is considered that the ideal program is no less than the examination and description of the scales of every scaly fish, with figures of all the genera, it becomes evident that there is work ahead for an indefinite number of years.

A few years ago an eminent European ichthyologist expressed the opinion that the detailed work on scales was a waste of time; for, said he, "We have other excellent characters on which to classify fishes, so why bother with scales?" Possibly this particular authority will never be converted to lepidology, but I do not believe anyone could spend much time in the minute study of scales without becoming convinced of their great value for purposes of identification and classification. Like all other structures, they vary, and present characters of all degrees of significance and stability; in

the earlier work we made some mistakes because of poor judgment in these matters. The correct estimation of the importance of particular scale characters can only come with experience, and if through lack of it some unsound opinions are expressed in this paper, the fact should not be used as an argument against the study of scales.

I have adopted, for the purposes of the present paper, the classification given by Dr. D. S. Jordan in his recent (1907) work "Fishes," pages 757–771. It is only necessary to compare the classification in recent standard works by Jordan, Boulenger, and Goodrich, together with the essays of Regan, to perceive that there is still latitude for much difference of opinion in regard to fish taxonomy. Neither the authors cited nor anyone else would pretend to be able to present a classification which is nearly perfect, although many important matters are generally regarded as settled. In the slow approximation toward a system based on real relationship, lepidologists venture to think that they may have a part, and the present essay is written largely with this end in view.

The cost of the photographs used to illustrate this paper has been defrayed by a grant from the American Association for the Advancement of Science.

Two corrections which I have had to make in this paper since it was written may be worth citing, as illustrating certain dangers of error, and at the same time bringing out clearly the general reliability of scales for identification.

Under *Boleosoma nigrum* I had written that the scales from Osterville, Mass. (from the collection at Wood's Hole), were so unlike those from Indiana that I supposed them to be wrongly determined. Dr. Sumner has since very kindly looked up the specimens, and reports that they are really *Boleichthys fusiformis*. In the case of *Carpiodes velifer*, I used scales from the fishes forming the basis of Juday's record for Boulder County, Colorado, without making any study of the fishes themselves. I noted with surprise that they corresponded "very well with the scales of the common goldfish." Dr. Max Ellis, going over the collection, has discovered that the specimens are in fact wild, dark-colored examples of the goldfish, *Carassius auratus*.

Class TELEOSTOMI. The true fishes.

Subclass CROSSOPTERYGII.

Order ACTINISTIA.

CŒLACANTHIDÆ (Fossil).

Dr. A. S. Woodward (Catalogue of Fossil Fishes, pt. 2, pl. XIV) has figured the scales of *Cœlacanthus*. The figures are excellent, but unfortunately show only the apical (exposed) portion, which is ornamented with broad grooves running obliquely toward the middle line. Through the kindness of Dr. L. Hussakof, I have obtained the loan of several scales of *Cœlacanthus robustus* Newberry, from the Carboniferous of Mazon Creek, Ill. These show that the scale is elongate in form, with a large basal region wholly free from grooves, and consisting entirely of very fine longitudinal fibrillæ, exactly as in *Amia*. The scales are about 12 mm. long and 8 broad.

There is a striking resemblance between the apical (exposed) area of *Cœlacanthus*, with its grooved lines, and the same area in the South American characinid *Lebiasina bimaculata* Cuvier & Valenciennes.

Order CLADISTIA.

POLYPTERIDÆ.

The scales of *Polypterus endlicheri* Heckel from the White Nile (British Museum) are entirely of a dense bony consistence, the exposed surfaces rhombic or diamond-shaped with an enamel-like coating. The scales are produced into a long concealed process, and each has a peg or tooth fitting into a hole or socket in the next scale. Although *Polypterus* belongs to a very primitive group, its scales must be considered highly modified; the protection they afford may perhaps explain the survival of the genus. It is in *Cœlacanthus*, not in *Polypterus*, that we get the real clue to the affinities of the crossopterygians.

Subclass DIPNEUSTI. Lungfishes.

Order CTENODIPTERINI.

CTENODONTIDÆ (Fossil). Comb-toothed Lung fishes.

The large scales of *Sagenodus* from the Carboniferous of Mazon Creek, Ill. (American Museum of Natural History), almost entirely agree with those of the living *Neoceratodus*. Aside from the irregular radii, forming a network in the central part of the scale, both form and structure are very near to those of the bowfin, *Amia;* and both, except for the lack of grooves in the exposed region, approach *Cœlacanthus*. The one important feature in which all these agree is the large concealed area consisting of longitudinal fibrillæ. Among the Teleostei we find this retained only in the bonefishes, Albulidæ.

Order SIRENOIDEI. Sirenoid fishes.

CERATODONTIDÆ. Flatheads.

Neoceratodus forsteri, from Queensland (British Museum), has very large elongated scales with longitudinal beaded fibrillæ and a radial system of reticulation. (Science, May 26, 1911, p. 831.) The radial network and the tuberculate or beaded fibrillæ distinguish these scales from those of *Amia*.

LEPIDOSIRENIDÆ. Scaly sirenids.

The scales of *Lepidosiren* and *Protopterus* are briefly described in Science, May 26, 1911, page 831. Although these fishes come from widely separated regions (South America and Africa) and undoubtedly represent different subfamilies (Lepidosireninæ and Protopterinæ), their scales are almost exactly alike. There is a strongly developed radial network, as in the Osteoglossidæ, and the surface is minutely tuberculate, the tubercles derived from beaded fibrillæ. The scales are inclosed in the skin, and are circular or approximately so, not elongate as in *Neoceratodus* and *Sagenodus*.

Subclass ACTINOPTERI.

Superorder GANOIDEI.

In this case I prefer to write "superorder," rather than "series," as the term defines the rank of the category in relation to others.

Order GINGLYMODI.

LEPISOSTEIDÆ. Gar pikes.

The rhomboidal ganoid scales of the gar pikes *Lepisosteus* have a very close superficial resemblance to those of *Polypterus*, a case doubtless of convergence of type, due largely to the mechanical necessities of the situation. The scale of *Lepisosteus* is not so highly specialized as that of *Polypterus*, since it lacks the well-defined peg-and-socket arrangement. (For a further discussion of the scales of these genera, see Goodrich, Proceedings Zoological Society of London, November, 1907, p. 762–763.)

Order HALECOMORPHI.

AMIIDÆ. Bowfins.

I still write *Amia* and Amiidæ for the bowfin, being unconvinced that the rules of nomenclature require the change which has been proposed. The scale of *Amia* has been discussed in several of my earlier papers (e. g., Smithsonian Miscellaneous Collections, vol. 56, no. 1, p. 1). It has simple longitudinal fibrillæ, and no radial network. In its general structure it is not far from *Cœlacanthus*, or indeed very remote from *Neoceratodus* and *Sagenodus*. No comparison is possible between the scales of *Amia* and *Lepisosteus*, and it is *Amia* alone which points toward the *Teleostei*.

Superorder TELEOSTEI. The bony fishes.

Order ISOPONDYLI. The isospondylous fishes.

I would change Jordan's arrangement of families to the extent of placing the Albulidæ first among the living groups, as undoubtedly the most primitive. It alone has the strictly longitudinal basal

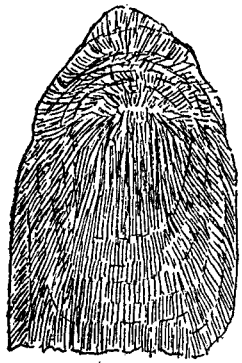

FIG. 1.—*Amia calva.*

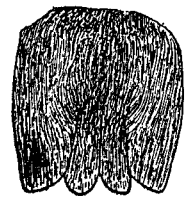

FIG. 2.—*Albula vulpes* (Albulidæ). Bureau of Fisheries.

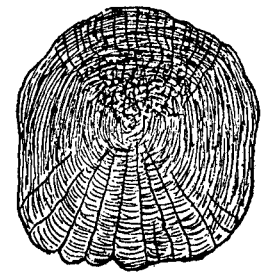

FIG. 3.—*Elops saurus* (Elopidæ). Bureau of Fisheries.

fibrillæ, which are tuberculate as in the Dipneusti. It alone, also, has two transverse series of valves to the bulbus arteriosus instead of one, another primitive character.

ALBULIDÆ. Bonefishes.

The scale of *Albula* is shown in text figure 2; that of *Dixonina* does not differ. In outline and general form these scales resemble those of *Synodus* and *Lucius* or *Esox* (pl. XXXV, fig. 19, 20), but these latter have transverse basal circuli.

ELOPIDÆ. Ten-pounders.

For a discussion of the scales of *Elops* see Smithsonian Miscellaneous Collections, volume 56, no. 3, page 3. Their structure shows nothing especially primitive; the basal circuli are very finely beaded, the lateral ones simple. The apical circuli, above the nucleus, break up into transverse labyrinthiform markings, the sculpture much coarser than that of the normal circuli.

MEGALOPIDÆ. Tarpons.

Jordan makes a separate family for the tarpons, although on an earlier page of the same book he follows the more usual custom of referring them to the Elopidæ. I am indebted to Mr. V. N. Edwards for a scale of *Tarpon atlanticus* (Cuvier & Valenciennes), from Woods Hole, Mass. It is of course very large (62 mm. long, and almost as broad), and is formed much as in *Elops*, differing, however, by having only three basal radii (12 to 20 in *Elops*), the basal margin broadly scalloped much as in *Synodus*. The

scale is indeed curiously similar in form and structure to that of *Synodus*, though the nucleus is not so far apicad. The region above the nucleus is minutely roughened or tuberculate, and the apical circuli are longitudinal. The basal circuli are finely beaded.

HIODONTIDÆ. Toothed herrings.

The scales of the moon-eye *Hiodon tergisus* are discussed in Smithsonian Miscellaneous Collections, volume 56, no. 3, page 3. They have much in common with *Elops*, but the wholly transverse fine circuli of the apical field are not at all modified above the nucleus. The basal radii are numerous and irregular, inclined to be divided into two groups, and the basal margin is undulate, not scalloped. The basal circuli are without distinct beading. The scale is of a cyprinoid type.

CHIROCENTRIDÆ. Long herrings.

The long herring, or dorab, *Chirocentrus dorab* (Forskål), from the Philippine Islands, has transverse circuli and radii, essentially as in Clupeidæ, the radii usually angled in the middle. There are also irregular basal longitudinal radii, few in number, much as in the anchovy *Stolephorus argyrophanus*. On page 113 of volume XXIII of the Proceedings of the Biological Society, Washington, for "*five* transverse circuli" read "*fine* transverse circuli," and it is the basal, not the apical field, which has these more widely spaced circuli. Upon minute comparison I find that the whole arrangement, both circuli and radii, agrees essentially with *Stolephorus argyrophanus*, and hence in its scales *Chirocentrus* is to be compared with the Engraulidæ rather than with the Clupeidæ. The scale is, in fact, wholly as in the engraulids.

ENGRAULIDIDÆ. Anchovies.

I alter Jordan's arrangement by placing these before the Clupeidæ, as being more primitive, at least as to the scales, and also nearer the chirocentrids. Dr. Max Ellis has prepared a paper fully discussing the available material. Some of the species show an evident reticular network, in one case so well developed that the scale looks like that of some osteoglossid.

CLUPEIDÆ. Herrings.

I here consider only the Clupeinæ, of which I have examined nearly all the American genera. Two tribes are indicated, Brevoortiini, for *Brevoortia*, and Clupeini, for the other genera. In the menhaden, *Brevoortia tyrannus* (Latrobe), the apical margin of the scale is produced into long parallel teeth with very slender ends. These teeth arise from a pellucid apical zone, and the intervals between them are prolonged basad as grooves for a distance about equal to the length of the teeth. Below these grooves are numerous small and short grooves looking like roots, the large grooves seeming to be the stems from which they arise. Below this the scale is entirely covered with very fine transverse circuli, and has in addition irregular pits and two transverse radii. The dentate scale margin is by no means peculiar to *Brevoortia;* it is quite distinct, for example in *Alosa* and *Clupea*, but the teeth are very irregular and by no means so long or tapering. In juvenile *Alosa* the margin is not dentate. The pitting seen in *Brevoortia* is also very strongly developed in some scales of the thread herring, *Opisthonema oglinum* (Le Sueur), from Woods Hole; it is evidently derived from evanescent transverse radii. In some scales of *O. oglinum* there are five transverse radii, all but the uppermost broken in the middle; there is then no pitting, but the well-pitted scales have only the upper radius. In the pilchard, *Clupanodon pilchardus*, from Palermo, Italy (Bureau of Fisheries), there are seven or eight transverse radii, all widely broken in the middle except the first, the lower ones oblique, the whole reminding one of the ribs of the human skeleton seen from in front. The extremely fine circuli are strictly transverse, meeting the lateral margins at right angles. I find essentially the same in the West Indian sardine, *Clupanodon pseudohispanicus* Poey, from Woods Hole (pl. XXXV, fig. 18), but in two scales I notice that the circuli curve upward on one side only.

Comparing *Clupanodon* with the sea herring, *Clupea harengus* (from Woods Hole and Sandy Island), two differences are at once apparent. In *Clupea* the transverse radii are commonly (though not uniformly) entire, or not interrupted in the middle, whereas in *Clupanodon* they are (except the first)

quite regularly interrupted; in *Clupea* also it is common to find a pair of irregular apical radii, joining basally to form a sort of U. In *Clupea* the lateral circuli, following the trend of the transverse radii, reach the margin obliquely, not at right angles as in *Clupanodon;* this seems to be in some degree a matter of age, yet the large scales from Woods Hole, in which the obliquity of the circuli is very strongly marked, show growth lines delimiting various younger stages, and when less than half grown the circuli were already moderately oblique. It is a curious thing that the scales from Sandy Island (Bureau of Fisheries) have the transverse radii more numerous, much less regular, and interrupted at intervals, the circuli more transverse, in the young very little oblique, and the lower limit of the hyaline apical area straight or almost, whereas in the Woods Hole scales it is concave or even broad V-shaped. Are there two types of herrings, or is this individual variation?

The large scale of the shad, *Alosa sapidissima*, has been figured in Smithsonian Miscellaneous Collections, volume LVI, no. 1, page 2, and discussed at length in the Proceedings of the Biological Society of Washington, volume XXIII, pages 61-62. It is shown that the transverse radii are derived from the apical radial system, all stages of transition being visible. The adult *Alosa* scale has the circuli and radii at the sides very oblique; in some scales the radial system is very highly developed, with very numerous apical radii, and those about the middle of the scale variously anastomosing, forming an irregular network. There is, however, no approach to the type of network seen in some Engraulididæ and better developed in Osteoglossidæ. So far as the scale goes, *Alosa* must stand at the base of

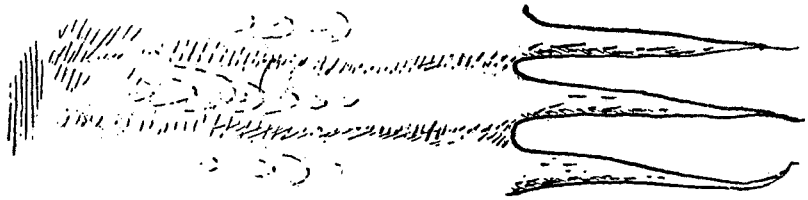

FIG. 4.—*Brevoortia tyrannus* (Clupeidæ). Apical teeth. Bureau of Fisheries.

the clupeine series, with *Clupea* close to it but a little more advanced. *Clupanodon* then represents a considerable further step in the direction of clupeine specialization, with the fixation of the more characteristic features.

In *Sardinella humeralis* (Cuvier & Valenciennes), from Tampa, Fla., the scales differ conspicuously from *Clupea, Clupanodon, Alosa*, etc., in being much broader than long, the lower corners obtusely almost rectangular. The circuli are strictly transverse, not oblique; there are two widely separated entire transverse radii, and part of a third one forming a small reversed broad V on the lower margin; the lower margin of the hyaline area is slightly concave. These scales are perhaps not adult; they resemble in many ways the immature scales of *Alosa*.

The scales of the alewives, *Pomolobus*, have the lateral circuli moderately oblique, except in the young; the undulating transverse radii distinctly rather widely spaced, often broken in the middle but not regularly or widely so, as in *Clupanodon*. Two species before me are rather easily distinguished:

Pomolobus æstivalis (Mitchill). Glut herring. Scales about as long as broad; lower margin of hyaline area concave.

Pomolobus pseudoharengus (Wilson). Branch herring. Scales conspicuously broader than long; lower margin of hyaline area straight. In a former paper I said I did not know how to distinguish young scales of *P. pseudoharengus* from young of *Alosa sapidissima*. However, in the *Alosa* the lower margin of the hyaline area is uniformly distinctly concave; in *P. pseudoharengus* it is straight or even convex, except in the very earliest stage, when the diameter is much less than a millimeter. Reviewing the Clupeinæ, it appears that we may place *Alosa* at the base of the series, and just above it *Clupea*. Then *Clupanodon* stands at the end of a branch, from the side of which springs *Opisthonema*, leading directly toward *Brevoortia*. From an earlier part of the same branch may arise *Pomolobus*, and somewhere near here *Sardinella*. All this is based on the scales, and must of course be modified when the structures are considered.

The character given in Jordan and Evermann's key for all the clupeines except *Brevoortia*, "scales with their posterior [apical] margins entire and rounded" is not accurate, although *Brevoortia* scales are readily separated from the others by their long weak teeth.

PHRACTOLÆMIDÆ.

Phractolæmus is a living African fresh-water genus; Jordan has the family printed by error in italics, as extinct. The scales of the only known species are described in the Proceedings of the Biological Society of Washington, volume XXIII, page 112, and figured in Biological Bulletin, volume XX, plate III, figure 17a. They strongly suggest certain of the Characinidæ.

OSTEOGLOSSIDÆ. Bony-tongued fishes.

There are at least two subfamilies, Osteoglossinæ (*Osteoglossum* and *Scleropages*) and Heterotinæ (*Heterotis*). The scales of this group, remarkable for their regular network and beaded circuli (primitive characters recalling the Dipneusti), have been discussed in the Proceedings of the Biological Society of Washington, volume XXIII, page 111, and volume XXIV, page 39; Science, May 26, 1911, page 831; and *Heterotis* is figured in Biological Bulletin, volume XX, plate III, figure 20. Mr. W. M. Mann has kindly sent me scales of the Amazon bone-tongue, *Arapaima gigas* (Cuvier), which Eigenmann makes the type of a distinct family, *Arapaimidæ*. They are about 78 mm. long and 55 broad, superficially like those of *Neoceratodus*. The exposed part has a very coarse labyrinthoid rugosity. The concealed part has elongated reticulations and beaded circuli; the reticulation very irregular and not nearly so well developed as in *Osteoglossum*. The scale is really very near to that of the Nile bone-tongue, *Heterotis*.

PANTODONTIDÆ. Pantodonts.

Living African fishes, only one species known. The scales are described in the Proceedings of the Biological Society of Washington, volume XXIII, page 112, and figured in Biological Bulletin, volume XX, plate III, figure 18. The circuli are strongly beaded.

NOTOPTERIDÆ. Finbacks.

Fresh-water fishes of the Ethiopian and oriental regions, considered by Boulenger to be nearest to the Hiodontidæ. The scales of the African *Notopterus afer* Günther are described in the Proceedings of the Biological Society of Washington, volume XXIII, page 112. In this place I have remarked on the resemblance of the scales to those of *Gadus*. This is certainly true as regards shape and general appearance, but on close comparison it is seen to be wholly superficial. In the gadines the numerous fine radii extend in all directions from the nucleus; in *Notopterus*, except for a series of striæ just below the apical margin, they are wholly basal, and only the central ones reach the nuclear region. In *Notopterus* these radii are only about half as dense (close) as in *Gadus*, but on the other hand the circuli are much denser. The circuli of *Notopterus* are not at all beaded.

SALMONIDÆ. Salmon, trout, etc.

Very good figures of *Salmo* scales have been published by Mr. J. Arthur Hutton in his pamphlet on "Salmon Scale Examination and its Practical Utility" (London, 1910). He shows that the life of the fish affects the growth of the scales, so that by examining the scales it is possible to determine the approximate age, the time spent in the river and in the sea, and other important facts. The salmonoid scales before me are the Atlantic Salmon, *Salmo salar* Linnæus, Woods Hole, Mass.; the golden trout, *S. rooseveltí* Evermann, cotype, Mount Whitney, Cal.; Coulter's whitefish, *Coregonus coulterii* Eigenmann & Eigenmann, cotype, Kicking Horse River, Field, British Columbia; the brook trout, *Salvelinus fontinalis* (Mitchill), Woods Hole, Mass.; the blueback or red salmon, *Oncorhynchus nerka* (Walbaum), Wallowa Lake, Oreg. (J. J. Stanley). I have figured the scale of the blackfin, *Leucichthys nigripinnis* (*Argyrosomus nigripinnis* Gill), in Biological Bulletin, volume XX, (1911), plate I, figure 2. The scales of *Salmo* are more or less oval, with well developed concentric circuli, which variously fail in the apical region; the radii are absent. Scales of *Salvelinus* and *Oncorhynchus* are essentially the same; with

the material before me I am not able to make any satisfactory table for their separation. *Leucichthys nigripinnis* is distinct by the evident laterobasal angles. *Coregonus coulteri* scales are about 1.5 mm. long by 2 broad, varying to approximately circular, but apparently never (at least on the middle of the side of the fish) longer than broad, as is usual in the *Salmo* group. The circuli are very widely spaced, and there are rather obscure indications of laterobasal angles. These *Coregonus* scales are perhaps immature. It is probable that the following characters are valid for the subfamilies:

COREGONINÆ, WHITEFISHES AND LAKE HERRING.—Scales as broad or broader than long, with laterobasal angles more or less developed.

SALMONINÆ, SALMON, TROUT, ETC.—Scales nearly always longer than broad, without laterobasal angles. Of these, the Coregoninæ must apparently be considered the more primitive.

ARGENTINIDÆ. Smelts.

Osmerus mordax Mitchill, from Menemsha Bight, Mass. (J. T. Field), has approximately circular scales about 2.5 mm. diameter, without radii. The circuli are very widely spaced except basally, where they are crowded; they are obtusely angled in the middle line above and on each side. The laterobasal corners are very obtuse but evident; the basal middle is broadly produced into a rounded lobe, which is usually emarginate. The nucleus is far toward the base of the scale, approximately on a level with the laterobasal corners.

This scale is in general related to that of the Coregoninæ, but is readily distinguished by the position of the nucleus.

SYNODONTIDÆ. Lizard-fishes.

Rather large semicircular cycloid scales; nucleus a little (*Trachinocephalus*) or considerably (*Synodus*) above the middle; very strong basal plicæ (2 or 3 in *Trachinocephalus*, 3 or 4 in *Synodus*); circuli normal, quite dense in *Synodus*, rather widely spaced in *Trachinocephalus*, the apical ones longitudinal; laterobasal angles evident but obtuse; apical marginal area broadly thin and sculptureless, in the manner of certain clupeids, but the submarginal area, or marginal area of the scale proper, sculptureless, except for scattered punctiform markings, its margin irregularly minutely dentate (more evidently in the *Synodus*), as if very irregularly broken. Scales of *Synodus* yellowish, of *Trachinocephalus* colorless.

The species studied are *Trachinocephalus myops* (Forster), the ground spearing, from Woods Hole, Mass., and *Synodus fœtens* Linnæus, the lizard fish (pl. xxxv, fig. 19), from Galveston, Tex. (Evermann). The apical structure seems to be prophetic of the acanthopterygian type of ctenoid scale; in the Gerridæ (*Xystæma cinereum* Walbaum) the apical margin is very thin, covered with minute shadowy diamond-shaped markings, the vestiges of the disappearing teeth; no such vestiges can be seen in the Synodontidæ, although the superficial appearance is similar. Jordan notes of Synodontidæ that the head is scaly, "a character rare among the soft rayed fishes," but usual among Acanthopterygians.

MAUROLICIDÆ.

Maurolicus pennanti (Walbaum), from Woods Hole, Mass., has easily deciduous, extremely thin scales, with widely spaced evanescent circuli. According to Jordan, the Maurolicidæ are scaleless, but no doubt the specimens examined had lost their scales. Dr. F. B. Sumner tells me that he carefully worked over the Woods Hole species and noted the presence of scales.

In the related family of Myctophidæ, the lantern fishes, the scales of *Myctophum resplendens*, as figured by Günther, are better developed; broad, cycloid, regularly circulate, nucleus nearly central, about six strong basal folds. They are rather like those of *Cypsilurus*.

Order APODES. Apodal fishes.

Suborder ENCHELYCEPHALI. The eels.

ANGUILLIDÆ. Fresh-water eels.

The scale of the common eel (*Anguilla rostrata* or *chrisypa*) is a remarkable structure, very unlike any of the scales discussed above. It is 2 mm. long, or slightly over, narrow, and with rounded ends, approximately sausage-shaped in outline. The nucleus is central, and on an extremely fine reticulated

framework are arranged concentric rings of oval elements, which are hyaline with narrow dense margins These oval bodies are actually capable of being detached, or more strictly speaking their surface layers are detachable, retaining their original form and appearance.

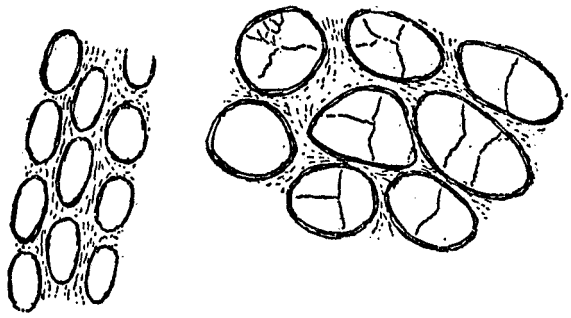

FIG. 5.—*Anguilla rostrata* (Anguillidæ). Details of sculpture. Bureau of Fisheries.

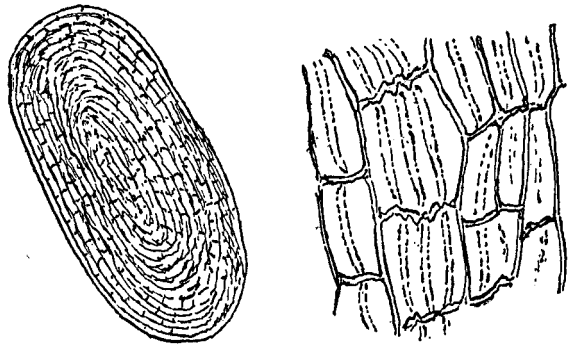

FIG. 6.—*Synaphobranchus pinnatus* (Synaphobranchidæ). Bureau of Fisheries.

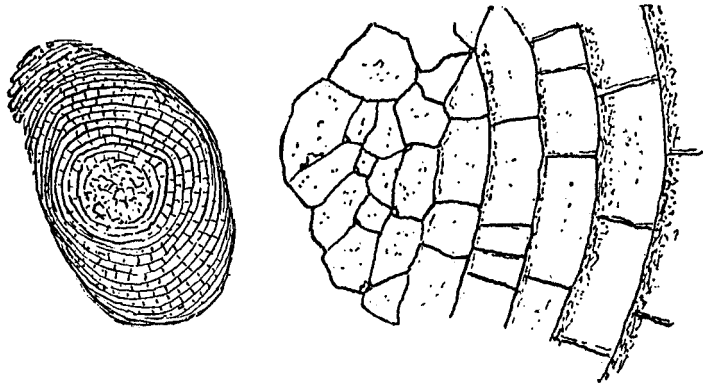

FIG. 7.—*Ichthyophis glutinosus* (Cæciliidæ). Amphibian scale. British Museum.

SYNAPHOBRANCHIDÆ.

In *Synaphobranchus pinnatus* (Gronovius), a deep-sea eel, the scales are shaped much as an *Anguilla*, but not so elongate, and very much smaller, the length about two-thirds of a millimeter. The general appearance and detailed structure are shown in the figure. In this scale we get a clue to the evolution

of the *Anguilla* type, the structure, with its upper and lower layers, being much the same; but the upper layer exhibits more or less quadrangular spaces, due to the crossing of the radial and circular systems. The specialization of detachable oval plates does not exist, but it is possible to see how it might arise from a type resembling *Synaphobranchus*.

Although I have found nothing among the primitive fishes which seemed to lead toward the eels, there is a distinct resemblance, I believe not altogether superficial, to be observed in the scales of the cæciliid amphibians. I am greatly indebted to Dr. Boulenger for material of *Ichthyophis glutinosus* (see text fig. 7). Here the elongate quadrangular spaces are arranged like bricks in a wall, but in concentric circles, while the center of the scale is reticulate and minutely tuberculate, quite closely simulating the condition in the Lepidosirenidæ. Thus in a remote and general way, *Ichthyophis* scales connect those of the eels with those of primitive fishes, suggesting that the eel type is really a very ancient one, not derived from any of the groups of fishes nearly associated with it in the classification.

In this connection the extinct Archencheli, considered primitive eels with isospondylous traits, become very important. I have never seen *Urenchelys*, but Dr. A. S. Woodward says of it, "scales rudimentary"; and under *U. avus* A. S. Woodward, he says of one specimen, "there are no traces of scales," but of another, "the brownish impression of the soft parts of the fish is curiously mottled, as if there were indications of small, rudimentary quadrangular scales." Looking in the opposite direction, we find an unexpected revival of the ichthyophoid type of scale, at least as regards the quadrangular areas, in the gadid *Brosmius brosme*, the cusk. The fine radii are broken so that, as in *Ichthyophis*, the bricklike spaces are largely laid in alternate fashion, not one directly above the other. In the pollocks, *Pollachius* and other genera, however, the radii are essentially continuous, and one can hardly doubt that the *Brosmius* scale was derived from a *Pollachius*-like type. In this connection it is worth while to note that *Sphyræna picuda* has a scale pattern practically identical with that of *Pollachius*.

All things considered, it must be admitted that the eel type of scale could have been derived from something of the *Sphyræna* or gadid pattern, and hence it is not necessarily primitive. The resemblances noted are, however, interesting, and may not be without some significance.

According to Boulenger, the scales of the Murænolepididæ resemble those of the Anguillidæ.

Order OSTARIOPHYSI.

Suborder HETEROGNATHI.

CHARACIDÆ (CHARACINIDÆ). Characins.

The scales of the African species have been discussed in Smithsonian Miscellaneous Collections, volume 56, no. 1. Those of the South American genera form the subject of a lengthy paper to be published by the Carnegie Museum. This also includes the Erythrinidæ.

Suborder EVENTOGNATHI.

CYPRINIDÆ. Minnows and carps.

The scales of this family have been discussed in numerous papers. I give here a list of the genera which I have examined, with references to literature and some additional information and figures.

(A) AMERICAN GENERA.

It is doubtful whether any genera of Cyprinidæ are common to America and the Old World, except, of course, those introduced by man.

Abramis auctt. Amer., the shiner=*Notemigonus*.

Acrocheilus Agassiz, the chisel-mouth. Proc. Biol. Soc. Wash., XXII, p. 210 (subfamily Chondrostominæ).

Agosia Girard, the western dace. Proc. Biol. Soc. Wash., XXII, p. 157. Girard, Ichthyology of the Mexican Boundary Survey, pl. XXVII, fig. 6–8 (*notabilis=oscula*); pl. XXVII, fig. 10–12 (*oscula*); pl. XXVIII, fig. 6–8 (*chrysogaster*); pl. XXVIII, fig. 2–4 (*metallica-chrysogaster*). Girard's figures show that the scales of the subgenera *Apocope* and *Agosia* are essentially of the same type, more or less elongate, with basal as well as apical radii. According to the figures, the scales of *A. chrysogaster* are distinctly different from those of *A. metallica*, the former rounded, the latter quadrate. Is it not probable that there are two species or races?

Algansea Girard. (Pl. XXXII, fig. 3.) Proc. Biol. Soc. Wash., XXIV, p. 213 (*A. sallæi*); Zoologischer Anzeiger, XXXVI, p. 476 (*tincella*); Biological Bulletin, XX, p. 373 (*tincella, affinis, stigmatura*). Girard figures the scales in Ichthyology of the Mexican Boundary Survey, pl. XXVII, fig. 2–4. They are of the same general type as those of *Agosia*, longer than broad, with basal as well as apical radii. According to the scales, *Algansea* does not seem near to *Hybognathus* (the scales of which are large and broad, without basal radii), but should be an herbivorous representative of the *Agosia-Rhinichthys* group, or related in some way to *Temeculina*. Among the herbivorous groups, it is by its scales nearer to the Chondrostominæ and Chrosominæ than to the Pimephalinæ. May we not regard it as a modified chondrostomine, pointing somewhat in the direction of the *Agosia* group? In any case the scale characters must be considered relatively primitive and indicative of affinity with Old World types.

Campostoma Agassiz, the stone-roller. Proc. Biol. Soc. Wash., XXII, p. 122. Girard, Ichth. Mex. Boundary Survey, pl. XXV, figures scales of *C. ornatum, anomalum* (as *nasutum*) and *formosulum;* they are all broad, with nucleus far basad of the middle, and apical radii only; the general type of *Notropis* and many other American genera. This genus is the type of a distinct subfamily, peculiar to America.

Chrosomus Rafinesque, red-bellied dace. Biol. Bulletin, XX, p. 370, pl. I, fig. 5; Proc. Biol. Soc. Wash., XXII, p. 121. Scale broader than long, with radii all around; the type that of the European *Phoxinus*. An isolated genus in America.

Cliola Girard. Proc. Biol. Soc. Wash., XXII, p. 189 (*C. smithii*). Girard, Ichth. Mex. Boundary Survey, pl. XXXI, fig. 22–24 (*velox=vigilax*). The scales are broad, with about 19 apical radii in *C. smithii*, about 8 or 9 (according to Girard's figures) in *vigilax*. The genus seems to stand between *Pimephales* and *Notropis*.

Cochlognathus Baird & Girard. Girard, Icth. Mex. Boundary Survey, pl. XXXV, fig. 15–17, shows very broad scales with subbasal nucleus, the radii only apical, about 10 or 12, not nearly reaching the nucleus. According to the figures the basal margin is strongly convex, not straight as shown in *Cliola vigilax*. Thus the base of the scale is practically as in *Lavinia*, while that of *C. vigilax* may be compared with *Ericymba* or *Phenacobius*.

Couesius Jordan, the chub-minnow. Proc. Biol. Soc. Wash., XXII, p. 159. Near to *Semotilus;* apical circuli angulate in the middle.

Ericymba Cope. Proc. Biol. Soc. Wash., XXII, p. 162, pl. III, fig. 1; Biological Bulletin, XX, p. 374, pl. V, fig. 28 (normal scale) and fig. 29 (latinucleate scale).

Exoglossum Rafinesque, the cut-lip. Proc. Biol. Soc. Wash., XXIV, p. 213. Scale resembling that of *Mylocheilus*.

Gila Baird & Girard, the bony-tail. Biological Bulletin, XX, p. 374, pl.V, fig. 30 (scale of young *G. robusta*); Girard, Ichth. Mex. Boundary Surv., pl. XXIV, fig. 10–12 (*grahami=robusta*); pl. XXXIII, fig. 8–10 (*emorii=elegans*). The mature scale is more or less elongate, with a distinct basal lobe, the base being in general like that of the shorter scale of *Lavinia*. A *Gila* about 9½ inches long, collected by Messrs. E. R. Warren and J. W. Frey in the Bear River at Lily, Routt County, Colo., June 30, 1909, appears to be *G. seminuda* Cope & Yarrow. The caudal peduncle is almost 13 mm. in depth, the base of the caudal fin 20 mm. The fish is a typical *Gila*, and *G. seminuda* appears to have been based on an immature specimen. The ventral surface is without scales. Peritoneum rather dilute black, not spotted. Posterior division of air bladder large and broad, its breadth 16 mm. Scales in lateral line about 96; the scales are elongate, with parallel, even concave sides;

laterobasal corners prominent though rounded; basal lobe very large; *Gila* seems to be a very good genus, a fact of some importance, since if it were united to *Richardsonius*, the name *Gila* would have priority.

Hybognathus Agassiz, silvery minnow. Proc. Biol. Soc. Wash., XXII, p. 122. Girard, Ichth. Mex. Boundary Survey, pl. XXVI, fig. 10–12 (*H. serena*); pl. XXVI, fig. 14–16 (*chrysitis=serena*); pl. XXVI, fig. 22–24 (*texensis=episcopa*); pl. XXVI, fig. 6–8 (*argentosa=?episcopa*); pl. XXVI, fig. 18–20 (*melanops*); pl. XXVI, fig. 2–4 (*couchi=melanops*); pl. XXVII, fig. 18–20 (*amara*); pl. XXVII, fig. 14–16 (*fluviatilis=amara*). A member of the Pimephalinæ, with scales of the type of *Notropis*, etc.

Hybopsis Agassiz, horny-head. Proc. Biol. Soc. Wash., XXII, p. 162 (species of *Hybopsis* s. str., and the subgenera *Erimystax* Jordan, *Yuriria* Jordan & Evermann, and *Macrhybobsis* Cockerell & Allison). Girard, Ichth. Mex. Boundary Survey, p. 50, briefly describes the scales of *H. æstivalis* (Girard).

Lavinia Girard. Proc. Biol. Soc. Wash., XXII, p. 161; Biological Bulletin, XX, pl. IV, fig. 23.

Lepidomeda Cope. Proc. Biol. Soc. Wash., XXIV, p. 213. Scales transversely oval.

Leuciscus auctt. Amer., dace=*Richardsonius*.

Mylocheilus Agassiz, Columbia chub. Proc. Biol. Soc. Wash., XXIV, p. 213. The species there called *M. caurinus* (Richardson) is *M. lateralis* Agassiz & Pickering, *caurinus* auctt., not of Richardson. The species of Richardson is to be called *Richardsonius caurinus*. *Mylocheilus lateralis* often enters the sea.

Myloleucus Cope. Proc. Biol. Soc. Wash., XXII, p. 161 (as *Rutilus*); XXII, p. 217. The aggregate called *M. symmetricus* is discussed in Biological Bulletin, XX, p. 374.

Mylopharodon Ayres. The scales of immature *M. conocephalus* (Baird & Girard) from Merced River, California, are broad-oval, and except that they are considerably broader in proportion to their length, closely resemble in form and structure those of *Orthodon microlepidotus;* the pattern, with few (about 8) radii, all apical and widely spaced, and the interradial circuli very widely spaced, is exactly as in *Orthodon*. The base is broadly rounded, and there are no laterobasal angles. The fish has a large forked caudal; scales small; gill lamellæ very obtuse; peritoneum marbled with light brown and speckled with black. Jordan & Evermann place this genus, with *Mylocheilus* and *Stypodon*, in a subfamily Mylopharodontinæ, said to contain comparatively primitive forms, allied to those of Asia. The scales of *Mylocheilus lateralis* differ conspicuously from those of *Mylopharodon*, having the apical radii quite three times as numerous, and the sides nearly straight, with obtuse but evident laterobasal angles, the basal margin strongly convex in outline. Except for the absence of basal radii, they very greatly resemble the scales of *Chondrostoma*. It seems probable that Mylopharodontinæ should be regarded as a tribe only (*Mylopharodontini*) of Chondrostominæ.

Nocomis Girard. Proc. Biol. Soc. Wash., XXII, p. 161–162. The scale is formed and sculptured much after the manner of that of *Richardsonius* (*Tigoma*) *pulchellus*, but is much broader, with the vertical sides considerably shorter. (Pl. XXXII, fig. 6.)

Notemigonus Rafinesque, shiners. Proc. Biol. Soc. Wash., XXII, p. 211–213. Girard, Ichth. Mex. Boundary Survey, pl. XIX, fig. 10–12 (as *Luxilus leptosomus*). On the same fish (from Falmouth, Mass.) the apical radii vary from 4 to 9; there are no traces of basal radii. The scales of *N. chrysoleucas* (pl. XXXIII, fig. 8), first seen by me were immature; obtaining mature scales, I find that they are almost identical in form and sculpture with those of the European *Abramis elongatus* Agassiz, both being extremely different from those of *A. brama*, the type of *Abramis*. According to the scales, *Ballerus* should be much nearer to *Notemigonus* than to *Abramis*. *Ballerus* is, however, separable from *Notemigonus* by the teeth and fins.

Notropis Rafinesque, minnows. Proc. Biol. Soc. Wash., XXII, p. 189–196; Biol. Bulletin, XX, pl. IV, fig. 25 (*galacturus*); Proc. Biol. Soc. Wash., XXII, p. 158, fig. 3 (*cornutus*); Girard, Ichth. Mex. Boundary Survey, figures *N. lutrensis* (*complanata, couchi, gibbosa, rutila*), *proserpina* (*aurata*), *macrostomus* (including *luxiloides*), *texanus, venustus, swaini* (*megalops*), *amabilis, socius, frigidus, formosus, ornatus*, and *aztecus* (*vittata*). Girard figures the scales of the two subgenera (*Aztecula* Jordan & Evermann and *Codoma* Girard) not studied by Cockerell & Calloway in 1909. *Aztecula*

(*N. aztecus*) has scales which are narrower than those of most *Notropis*, with about 9 to 11 apical radii. *Codoma* (*N. ornatus*), a fish remarkable for its vertical dark bands, has very ordinary scales of the *Notropis* type, the apical radii 9 or 10. The subgeneric name *Coccogenia* Cockerell & Calloway gives way to the earlier and long-forgotten *Coccotis* Jordan, as Fowler has pointed out. Two new descriptions are added:

Notropis lermæ Evermann & Goldsborough. Cotype; Lake Lerma, Mexico (J. N. Rose). Scales about 1.5 mm. long and 1.75 broad, rounded, not at all triangular, with 18–21 apical radii.

Notropis horatii Cockerell. Type; Julesburg, Colo. (H. G. Smith). Scales slightly over 1 mm. long and 1.5 broad, with rounded margins and 7 to 9 apical radii; circuli very widely spaced.

Opsopœodus Hay. Proc. Biol. Soc. Wash., XXII, pl. III, fig. 3. Scale broader than long, with few radii.

Orthodon Girard. Proc. Biol. Soc. Wash., XXII, p. 209–210, fig. 1. Scale oval, longer than broad.

Phenacobius Cope. Proc. Biol. Soc. Wash., XXII, p. 159; Biol. Bulletin, XX, pl. IV, fig. 24. Scale broader than long; radii few; apical circuli angulate in middle (*P. mirabilis*). In *P. mirabilis* the skin is thin, and the sculpture of the scales is clearly visible; in *P. scopifer* (from Longmont, Colo.) the skin is very thick, and the sculpture of the scales is not visible until it is removed.

Pimephales Rafinesque. Proc. Biol. Soc. Wash., XXII, p. 122; Biological Bulletin, XX, pl. V, fig. 26.

Platygobio Gill, flathead chub. The scales of this genus have not been described, but I have examined a specimen of *P. physignathus* (Cope) from Salida, Colo., May, 1908 (Warren). There are 49 scales in the lateral line, covered by thick skin. Characteristic of the genus are the flatness of the head above and the falcate pectoral fins. Barbels distinct; gill filaments not fimbriate; peritoneum clear silvery. In the relatively large scales and small eyes it is like *Nocomis* rather than *Couesius;* the large vertically elongate nostrils are distinct from either, but rather nearer *Couesius;* the pigmentation and tuberculate middle of head above resemble *Couesius*. Scales about 3 mm. long and 4 broad, approximately semicircular, the basal outline gently convex, laterobasal corners distinct though obtuse; nucleus subbasal; circuli crowded basally, rather widely spaced laterally; interradial circuli irregular and very widely spaced, more or less inclined to be angulate in middle, radii apical only, 11 or 12. The skin is densely very minutely tuberculate.

Pogonichthys Girard, split-tail. Zoologischer Anzeiger, XXXVI, p. 479. An isolated genus in the American fauna. Scales quite large, about 5½ mm. long and 5 broad; nucleus about 1½ mm. from base; radii all apical, very numerous and close together, about 35; apical circuli not at all angled; laterobasal corners distinct; basal outline strongly convex. This is based on *P. macrolepidotus* (Ayres) from San Francisco (Dr. W. O. Ayres); the specimen in the British Museum, labeled *Leucosomus inæquilobus*.

Ptychocheilus Agassiz, squawfish, Proc. Biol. Soc. Wash., XXII, p. 159, pl. III, fig. 2; Girard, Ichth. Mex. Boundary Survey, pl. XXXIV, fig. 2–4. Girard's figures show the more mature scales, in which the base is very distinctly produced.

Rhinichthys Agassiz, black-nosed dace. Proc. Biol. Soc. Wash., XXII, p. 157. In *R. cataractæ dulcis* from the Rio Grande in Colorado there are about 12 apical radii and five distinct basal ones. In *R. atronasus* from Spring Creek, Tenn., I found about 20 apical radii, but the outermost of these strictly lateral; the basal radii were only imperfectly indicated. In most respects the scales of *dulcis* and *atronasus* are essentially alike. This is closely related to *Agosia* (*A. oscula, A. nubila*), in which there are radii all around, the basal well developed.

Richardsonius Girard. Proc. Biol. Soc. Wash., XXII, p. 159–160 (as *Leuciscus*); t. c., p. 216–217; t. c., p. 186, fig. 1 (*R. thermophilus*); Biological Bulletin, XX, pl. II, fig. 14 (*orcutti*), pl. III, fig. 15 (*pulchellus*), fig. 16 (*carletoni*), fig. 17 (*thermophilus*); Girard, Ichth. Mex. Boundary Survey, pl. XXXIV, fig. 6–8 (*pulchellus*), pl. XXXIII, fig. 2–4 (*gibbosus*), pl. XXXII, fig. 2–4 and 6–8 (*nigrescens* and *pulchra*= *pulchellus*). *R. orcutti* (Eigenmann & Eigenmann) is the type of the subgenus *Temeculina* Cockerell; *R. pulchellus* (Baird & Girard) represents the subgenus *Tigoma* Girard; *R. thermophilus* Evermann & Cockerell represents *Richardsonius* s. str.; *R. carletoni* (Kendall) is provisionally referred to subgenus *Cheonda* Girard.

Richardsonius gibbosus is figured by Girard as having radii all around the scale, apical, lateral, and basal, and a scale from the abdominal region has a polygonal pattern in the nuclear field. According to the scales, therefore, this fish agrees with *Temeculina*. Placed in *Richardsonius*, the name *gibbosus* (*Gila gibbosa* Baird & Girard 1854) has priority over *nigra* Cope 1876, and *intermedia* Girard 1856, the latter said by Gilbert & Scofield (1898) to be identical. The name *gibbosus* is not a homonym if the fish is not placed in *Leuciscus*. According to Girard's figures, *R. pulchellus* has occasional poorly defined basal radii, but the whole appearance is very different from that of *R. gibbosus*. The scale of *R. intermedius* (there regarded as distinct from *gibbosa* or *nigra*) was briefly described in Proceedings of the Biological Society of Washington, volume XXII, page 159, and was found to fall in the same immediate group as *R. pulchellus* (*nigrescens*); this does not agree with Girard's figures of *gibbosus*, but certainly his scales came from a much older fish. It remains to be seen whether *R. intermedius* is really distinct from *gibbosus*, but in view of the facts stated it will probably be best to follow Jordan & Evermann in so treating it. There is, however, a further complication arising from the publication of *Gila gracilis* Baird & Girard 1853, which Gilbert & Scofield (1898) say is not *G. robusta*, but is "*Leuciscus intermedius*." The name *gracilis* is not a homonym if the fish is not referred to *Leuciscus*, and it has priority even over *gibbosus*, so that in any event *Richardsonius gracilis* (Baird & Girard) must be a valid specific name. Another change of nomenclature is required in the case of *Richardsonius aliciæ*. The name *Tigoma gracilis* Girard 1856, is not available; but *Squalius copei* Jordan & Gilbert 1880 is and the species becomes *Richardsonius copei* (Jordan & Gilbert).

Rutilus auctt. Amer.=*Myloleucus*.

Semotilus Rafinesque, chub. Proc. Biol. Soc. Wash., XXII, p. 162, pl. III, fig. 4 (*S. corporalis* and *S. atromaculatus*). A western form of *S. atromaculatus*, obtained by Mr. H. G. Smith at Julesburg and Sterling, Colo., appears to be subspecifically distinct and may be known as *S. atromaculatus macrocephalus* (Girard). In its scales it approaches *S. corporalis*.

Siphateles Cope. Proc. Biol. Soc. Wash., XXII, p. 161 (as *Rutilus olivaceus*); t. c. p. 217.

Tiaroga Girard. Girard, Ichth. Mex. Boundary Survey, pl. XXVIII, f. 12–14. The scales have radii all around, and are *transversely* oval in form, altogether in the manner of *Chrosomus*.

Although there is still much to be learned about the scales of American Cyprinidæ, the facts discussed above indicate very well that our fauna is essentially distinct from that of the Old World, with, however, the nearest allies of Old World types mostly in the far West; also, I believe that any fundamental separation of our genera into an herbivorous group with long intestine and a mainly carnivorous one with short intestine is artificial. The herbivorous group is to be divided into several which seem to be properly associated with corresponding groups in the carnivorous series.

(B) OLD WORLD GENERA.

My material representing Old World Cyprinidæ is almost wholly from the British Museum, which is herein abbreviated to B. M.

Abramis Cuvier, breams. Proc. Biol. Soc. Wash., XXII, p. 211–213; Zool. Anzeiger, XXXVI, p. 478, fig. 3 (*A. elongatus*).

Acanthorhodeus Bleeker. *A. tænianalis* is a very deep-bodied fish from Shanghai (Swinhoe, B. M.); the scales, as usual in the Rhodeines, are extremely broad; length a little over 5 mm., breadth fully 8. The basal circuli are dense, those at the sides more widely spaced; the very numerous radii, all apical, are wavy, or more or less zigzag. The region of the radii is finely striate with lines of growth, and in the interradial spaces are spots due to a kind of pitting. (Pl. XXXII, fig. 2.) Zool. Anzeiger, XXXVI, 477.

Alburnus Heckel, bleak. Zool. Anzeiger, XXXVI, p. 477. (*A. lucidus* and *filippii*.)

Amblyrhynchichthys Bleeker. *A. truncatus* from the Menam River, Siam (Royal Siamese Museum; B. M.), has subquadrate scales with very thin apical margins; length about 3½, with slightly over

4 mm.; nucleus well basad of middle; laterobasal corners very distinct; basal margin thrown into two or three prominent folds; basal radii few, delicate and irregular; apical radii about ten, very slender, the outer ones broad outward; apical area with growth striæ, but free from circuli (here agreeing with *Gobio*, *Saurogobio*, etc.); circuli very numerous, the lateral ones more widely spaced. The outline of the scale, especially the basal part, is practically as in *Barbus mahecola* (Biol. Bull., XX, pl. III, fig. 19), but the sculpture more resembles that of *Gobio* and its allies.

Aspidoparia (Heckel) Bleeker. Zool. Anzeiger, XXXVIII, p. 87, fig. 5.

Ballerus Heckel. Proc. Biol. Soc. Wash., XXII, p. 212–213.

Barbichthys Bleeker. Zool. Anzeiger, XXXVI, p. 252, fig. 2 and 3. The scale of *B. lævis* from Siam is large, about 10 mm. long and 8 broad, with prominent though rounded laterobasal corners; basal margin thrown into two broad wave-like lobes; a single, median, basal radius; numerous apical radii, but only about four, which are strong, reaching the nuclear area, whereas in the marginal region there are over 30; apical field with the circuli broken up, forming pustules; lateral and basal circuli dense and regular. The figures in the Zoologischer Anzeiger show the relation of the circuli to the pustules.

Barbus Cuvier & Valenciennes, barbel. Proc. Biol. Soc. Wash., XXII, p. 157–158; XXIII, p. 145–148, pl. III, fig. 1 (*B. chrysopoma*), fig. 3 (*batesii*), fig. 4 (*barbus*), fig. 5 (*ksibi*), fig. 6 (*pleurotaenia*), fig. 9 (*grahami*); Zool. Anzeiger, XXXVI, p. 479; Biol. Bulletin, XX, pl. III, fig. 19 (*mahecola*); Boulenger, Catalogue Freshwater Fishes of Africa, vol. II, p. 2, fig. 1 (*bynni, pleurogramma, perince*). The *Barbus compressus* mentioned in Proc. Biol. Soc. Wash., XXIII, p. 146, is from Fort Stedman, Shan States, 3,000 feet (E. W. Oates; B. M.). This is *B. compressus* Boulenger, Ann. Mag. Nat. Hist., ser. 6, XII, 1893, p. 202; not *B. compressus* Day, Proc. Zool. Soc. Lond., 1869, p. 555. With Dr. Boulenger's permission, I alter *B. compressus* Boulenger to *B. compressiformis* n. n.

Barilius Hamilton Buchanan. Proc. Biol. Soc. Wash., XXIII, p. 143–144, pl. III, fig. 10 (*B. loati*).

Barynotus Günther. I believe this generic name is preoccupied in Coleoptera. *B. luteus* from Schiraz (Marquis Doria; B. M.) has very large reddish quadrate scales, about 13 mm. long and broad; nucleus about 5 mm. from base; circuli very fine, about 10 or 12 basal radii and about 35 apical ones, the latter wavy and many of them imperfect. In size, color, and form this is like the scale of *Semiplotus macclellandi*, except that the latter is considerably broader than long. In detail there are rather important differences, though of degree rather than of kind. In the *Semiplotus* the basal radii are very few and weak, while there are numerous delicate but distinct lateral radii, represented only by a few irregular lines in *Barynotus*. In both the apical radii are wavy and the interradial spaces are tuberculate, but the tubercles are more prominent in *Semiplotus* and extend almost to the nucleus, whereas in *Barynotus* they do not go beyond the skin-covered area.

Capoeta Valenciennes. (Pl. XXXIV, fig. 13.) Proc. Biol. Soc. Wash., XXIII, p. 149. According to Berg, *C. steindachneri* Kessl is a synonym of *C. heratensis* Keyserling.

Carassius Nilsson, goldfish. Zool. Anzeiger, XXXVI, p. 480.

Catla Cuvier & Valenciennes. *Catla catla* (*Cyprinus catla* Hamilton Buchanan; *Catla buchanani* Cuvier & Valenciennes) from Calcutta (F. Day; B. M.) has large elongate scales with rectangular basal corners; length 11, breadth 8 mm. The nucleus is about 4½ mm. from the base; the base has five or six irregular but prominent radial folds; apical radii about 16, delicate, straight, many incomplete; lateral radii variable, when distinct similar to those of *Semiplotus;* basal circuli irregular and not so dense as usual; apical circuli distinct, longitudinal, the inner ones directed more or less mesad, approaching the condition so well developed in *Cirrhina jullieni*, but not nearly so extreme. According to Day, *Catla catla* reaches a length of at least 6 feet; my material is from a much smaller fish.

Chanodichthys Bleeker. *C. pekinensis* from Shanghai (Swinhoe; B. M.) has rather large broad-oval scales, about 10 mm. long and slightly over 8 broad; nucleus nearly central, circuli finely evanescent in the apical region, which is somewhat rugose; no basal or lateral radii, but about 21 apical, some incomplete. The scale examined is not symmetrical and probably not quite normal.

Chela Hamilton Buchanan. (Pl. XXXII, fig. 4.) Proc. Biol. Soc. Wash., XXIII, p. 142, pl. III, fig. 12 (*C. argentea*).

Chelæthiops Boulenger. Proc. Biol. Soc. Wash., XXIII, p. 141–142, pl. III, fig. 11 (*C. bibie*).

Chondrostoma Agassiz. (Pl. XXXII, fig. 5.) Proc. Biol. Soc. Wash., XXII, p. 210; Zool. Anzeiger, XXXVI, p. 477.

Cirrhina Cuvier. Proc. Biol. Soc. Wash., XXIII, pl. III, fig. 8 (*C. jullieni*). The scales of four species of *Cirrhina*, obtained from the British Museum, are so distinct as to suggest that they can not all be truly congeneric.

Scale much longer than broad (length 9, breadth 7 mm.) with broadly rounded apex and squared base; circuli fine, wanting in the apical field, where they are replaced by coarse tubercles; basal radii about a dozen, delicate, many incomplete; apical radii few and irregular; nucleus a short distance basad of middle (Cutch, F. Day).....*C. mrigala* Hamilton Buchanan

Scale slightly longer than broad, or about as broad as long.

Scale 9 mm. long, 8½ broad; laterobasal corners distinct; nucleus considerably basad of middle; no basal radii; apical radii over 20, mostly well formed; circuli replaced by transversely elongate tubercles in the apical region covered by skin, but in the central region below this by vermiform markings .....*C. chinensis* Günther (Haslar collection).

Scale 5¼ mm. long, 4¾ broad; laterobasal corners distinct; nucleus very far basad; a few weak submedian basal radii; apical radii about eight, distinct, wide apart; apical circuli very distinct, wide apart, sloping toward the middle (Stung-Strang, Paris Museum).
C. jullieni (from type lot)

Scale conspicuously broader than long (length 2¾, width 3½ mm.); nucleus far basad; basal radii about 20, very short, submarginal; apical radii over 20, not or hardly converging; circuli absent in apical region, but a small amount of tuberculation; broad nuclear area with fine very irregular reticulation; probably latinucleate scales (Kushk, Afghan Boundary Commission.
C. afghana Günther

The scales of *Cirrhina* are in general (excepting *C. afghana*) much like those of *Osteochilus* or *Labeo*. Thus, as regards the sculpture of the apical field, *C. jullieni* may be compared with *Labeo chrysophekadion*, while *C. mrigala* and *C. chinensis* may be compared with *Labeo sindensis*, etc. May we not suppose that the groups of *Osteochilus* and *Cirrhina* have arisen from different groups of *Labeo*?

Cosmochilus. I have a lateral line scale of *C. falcifer*, a very large fish from Sarawak, Borneo (C. Hose; B. M.). The scale is of the quadrate type, strongly orange tinted, about 20 mm. long and broad; lateral line canal bifid at the apical end; nuclear field extremely large, granular; basal radii very numerous, but wholly marginal and submarginal; apical radii very numerous, irregular, wavy; no circuli in apical field. *C. harmandi* from the Menam River, Siam (Royal Siamese Museum; B. M.) is represented by much smaller, pallid scales, about 7 mm. long and 6 broad, but of the same subquadrate form. Both basal and apical radii are fewer and more irregular, the basal longer, the apical wavy. Except for the size and minor details, the scales of the two species are wholly of the same type.

Crossocheilos Bleeker. (*Crossochilus* auctt.) I follow the British Museum labels, but Day refers *C. latia* and *C. reba* to *Cirrhina*. The scales before me are separable as follows:

Scales large and elongate (length about 11½ mm., breadth about 6½), parallel-sided; circuli dense, those of the apical field transformed into tubercles in part, but toward the nucleus into vermiform lines, and in the extreme apical region wholly wanting; nucleus only about 3 mm. from base; three or four distinct basal folds; apical radii numerous, more or less wavy, converging toward the middle; lateral radii delicate, variable, usually distinct (Madras, F. Day; B. M.).
C. reba (Hamilton Buchanan)

Scales smaller and much less elongate.....1

1. Scales evidently longer than broad.....2
   Scales not or little longer than broad.....3
2. Basal margin gently convex, not wavy; laterobasal corners more rounded; basal radii very few and feeble; apical radii numerous, parallel; scale (not adult) about 5½ mm. long and 4 broad (Simla, F. Day; B. M.).....*C. latia* (Hamilton Buchanan)
   Basal margin wavy or broadly crenate; laterobasal corners sharper; basal radii very irregular, but distinct; apical radii numerous, many imperfect; nucleus about 1¼ mm. from base; scale about 7 mm. long and 6 broad. (Java; B. M.).....*C. oblongus*
3. Nucleus less basad (1¾ mm. from base in scale 5 mm. long and 4½ broad); middle interradial (apical) region strongly tuberculate (Ningpo, F. W. Styan; B. M.).....*S. styani* Boulenger
   Nucleus more basad; middle interradial region not tuberculate (Cashmere, T. C. Jordon; B. M.)
C. barbatulus

C. reba seems to stand apart from the others. Day says of *C. latia*, "this fish has much the character of a loach or of a *Discognathus*, adhering to stones in the beds of rivers." Superficially the scales of *C. reba* look like those of *Rohita lineata*, but they are very different in detail, having a different apical field and the nucleus very much more basad than in *Rohita*.

Culter. This genus has rather small (about 4 mm. diameter) circular scales, with a central nucleus, rather few and weak apical radii, and no basal. The basal circuli are very dense. I have two species from the British Museum; *C. ilishæformis* from Kiu Kiang (Styan) and *C. erythropterus* Basilewsky from the River Keroulen, Mongolia (Chaffanjon). They are very much alike, but in *erythropterus* the apical radii are more distinct, and the apical margin is crenate. (Pl. XXXIV, fig. 14.)

Cyprinus Linnæus, carp. Zool. Anzeiger, XXXVI, p. 480, fig. 2 (p. 478). The figure represents the hybrid *C. kollarii*.

Dangila Cuvier & Valenciennes. From the British Museum I have the scales of three species:

Scales large, much longer than broad (length 16 mm., breadth 10); strongly orange-tinted; parallel-sided; nucleus far basad; weak radii all around; middle apical region strongly tuberculate (in a deep place in the cavery, Salem, Capt. Mitchell)..... *D. leschenaultii*
Scales much smaller, not longer than broad; not orange-tinted.....2
1. Apical field distinctly tuberculate; scale about 5 mm. long and broad. (Deli, Sumatra, Moesch.) *D. kuhlii* (cf. Zool. Anzeiger, XXXVI, p. 478, where for *gobiiform* read *gobioniform*.)
Apical field merely striate; scale about 7 mm. long and broad (mouth of Patani River, Annandale & Robinson)..... *D. cuvieri*

Danio Hamilton Buchanan. Type of subfamily Danioninæ. Zool. Anzeiger, XXXVIII, p. 85, fig. 1, 2; (*D. devario* and *D. æquipinnatus*.)

Diptychus Steindachner. *D. maculatus* Steindachner from Nepaul (F. Day; B. M.) was examined, but no scales were found; the skin is very thickly beset with small spots of ferruginous pigment. According to Day, there are small scattered scales, which I evidently overlooked.

Discognathus Heckel. Proc. Biol. Soc. Wash., XXIII, p. 149–150. The species described belong to the subgenus *Garra* Hamilton Buchanan.

Engraulicypris Günther. *Neobola* Vinciguerra is now regarded by Boulenger as a synonym. Proc. Biol. Soc. Wash., XXIII, p. 143 (*Neobola*) and 144.

Gnathopogon Bleeker. I have examined *G. gracilis* (*Capoeta gracilis*) from Superghan, Nalzow Chai River (R. T. Günther; B. M.), and have given some account of it in Proc. Biol. Soc. Wash., XXIII, p. 149. The scales are about 4⅓ mm. long and 3¾ broad; nucleus well basad of middle; laterobasal corners prominent; basal radii irregular, few and very feeble; apical radii distinct, about 15, with strong tubercles between.

Gobio Cuvier, gudgeon. Zool. Anzeiger, XXXVI, p. 477–478; Biol. Bulletin, XX, pl. V, fig. 27.

Gymnocypris Günther. I examined *G. waddellii* Regan (Yamdok Lake, Tibet, 14,800 ft., L. A. Waddell; B. M.) but found no scales. The skin is sepia brown with darker, reddish dots.

Hemibarbus Bleeker, Proc. Biol. Soc. Wash., XXIII, p. 146–147 (under *Barbus*). According to L. S. Berg, *H. barbus* or *schlegeli* is to be called *H. labeo* (*Cyprinus labeo* Pallas), with *maculatus* (Bleeker) as a variety.

Hypophthalmichthys Bleeker. In Günther's Catalogue this is considered typical of a distinct section or subfamily, Hypophthalmichthyina, or as we should now say, Hypophthalmichthyinæ. I examined *H. nobilis* from Shanghai (Swinhoe; B. M.), but by an unfortunate accident the scale was lost when in the hands of the photographer.

Ischikauia Jordan & Snyder. Zool. Anzeiger, XXXVIII, p. 86, fig. 3.

Labeo Cuvier. Proc. Biol. Soc. Wash., XXIII, p. 150–151, pl. III, fig. 2 (*L. fimbriatus*), fig. 7 (*L. senegalensis*); Biol. Bulletin, vol. XX, pl. I, fig. 8 (*L. sladoni*).

Leptobarbus Bleeker. *L. hoevenii* (Tinjar River, 200 miles from the sea, C. Hose; B. M.) is a fish with terminal mouth, having very large quadrate scales, my specimen 18 mm. long and 14 broad. The basal radii, about 14, are very delicate and irregular; lateral radii more or less developed; apical radii about 33; circuli evanescent apically. (Pl. XXXIV, fig. 15.)

Leptocypris Boulenger. Proc. Biol. Soc. Wash., XXIII, p. 144.

Leuciscus Cuvier, dace, chub, etc. Proc. Biol. Soc. Wash., XXII, p. 215–216 (including not only *Leuciscus* proper, but also *Rutilus* Rafinesque, *Pigus* Bonaparte, *Cephalus* Bonaparte, *Idus* Heckel, and *Scardinius* Bonaparte); Zool. Anzeiger, XXXVI, p. 479–480; Biol. Bulletin, XX, p. 371, pl. I, fig. 7 (*L. illyricus*), pl. II, fig. 10 (*L. rutilus*), fig. 11 (*L. friesii*), fig. 12 (*L. hakuensis*), fig. 13 (*L. jouyi*).

Leucogobio Günther. I have *L. mayedæ* (Jordan & Snyder) from Lake Biwa, Japan (Jordan & Snyder). The scales are much broader than long (length about 3½ mm., breadth 5⅓), but otherwise entirely of the type seen in *Gobio*, with the same radii, circuli, etc.

Luciosoma Bleeker. I have three species from the British Museum. The scales are large and subquadrate; basal, lateral, and apical radii distinct, the lateral oblique, not or hardly at all directed toward the nucleus, except when the lower end is abruptly bent and turned inward; circuli very fine, but absent in the granular or striate apical field; laterobasal corners distinct. The species are separated thus:

Nucleus central or nearly; scale 13 mm. long and 10 broad; about 10 apical radii; fish with dorsal fin very far back (W. Siam, Carl Bock).....*L. harmandi*
Nucleus conspicuously basad of middle..... 1
1. Scale reddish, 11 mm. long, 10¼ broad; about 14 apical radii; fish with dorsal far back (Kapit, Rejang district, Sarawak, C. Hose).....*L. pellegrini* Popta
Scale white, 8 mm. long and 7 broad; about 14 apical radii; fish with row of large spots down side (Upper Baram River, C. Hose).....*L. trinema*

In scale characters the genus is very compact and except for the difference in the position of the nucleus the characters cited may not be specific. Scales of *L. trinema* are figured on plate XXXIII, figure 7.

There is a rather strong resemblance between the scales of *Luciosoma* and *Leptobarbus hoevenii*, but in *Luciosoma* the apical radii are spreading, fanlike, in the *Leptobarbus* they are parallel.

Macrochirichthys; see *Chela macrochir;* Proc. Biol. Soc. Wash., XXIII, p. 142. Fowler (1905) treats *Macrochirichthys* as a distinct genus.

Myloleucus Günther. Cope published a genus of the same name at about the same time, but I believe the American genus has priority.[a] *M. æthiops*, from Kiu-Kiang (Styan; B. M.), has large scales, approximately circular, but with more or less evident laterobasal angles; length 12, breadth 11 mm.; nucleus central; area covered by skin unusually large, extending to nucleus, skin densely speckled with red-brown pigment; basal circuli quite dense; slight basal folds, but no radii; apical radii about a dozen, feeble; apical circuli strong, longitudinal, converging toward the middle, where they meet at very acute angles. A scale approaching the type of *Cirrhina jullieni*.

Neobola Vinciguerra; see *Engraulicypris*.

Opsariichthys Bleeker. Zool. Anzeiger, XXXVI, p. 252, fig. 1 (*O. morrisonii*); XXXVIII, p. 87. The species figured is now to be referred to *Zacco*.

Oreinus McClelland. (Pl. XXXIV, fig. 16.) A genus of mountain fishes with small scales, circular or broad-oval or (*grahami*) sometimes subtrigonal, with nucleus central or nearly, circuli not very dense and rather widely spaced radii all around. They are therefore of the general type of *Chrosomus* and *Phoxinus*. The genus on scale characters is quite compact. Three species have been examined in the British Museum:

O. grahami. Tongchuenfu, Yunnan (J. Graham). Scales 2 to 2¼ mm. diameter.

O. plagiostomus (Heckel) Assam (F. Day). Scales about 1 by ¾ mm.

O. richardsonii (Gray & Hardwicke) Nepal (B. H. Hodgson). Scales a little smaller than those of *O. grahami*. This genus is referred to the Schizothoracinæ.

Osteobrama Heckel. Day calls this genus *Rohtee*. Dr. G. A. Boulenger writes (litt., May, 1910): "*Rohtee* Sykes and *Osteobrama* Heck. are synonyms. Both genera were established in the same year. I don't know which has really priority." I have four species from the British Museum.

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[a] Dr. D. S. Jordan kindly informs me that Cope's name has about a year's priority. *Myloleucus* Günther may be changed to *Myloleucops* n. n., our fish becoming *Myloleucops aethiops*.

Scales elongate (8 mm. long, slightly over 3½ broad), parallel sided, nucleus 2 mm. from anterior end; posterior end broadly and shallowly emarginate; circuli fine and dense; a single delicate radial line runs down the middle of the scale from the nucleus to the posterior margin, but otherwise there are no basal radii; apical field rugose, with very weak radii (Sittang River, E. W. Oates).....*O. microlepis*

Scales circular or nearly; nucleus nearly central; no basal radii, but the basal region more or less undulate..... 1

1. Scales broader than long; only feeble rudiments of basal radii; about 13 wavy apical radii (Sittang River, E. W. Oates).....*O. alfrediana*

Scales larger (diameter 4½ mm.); apical radii few, strong but very irregular and broken, wavy; a very deep-bodied fish (Sittang River, E. W. Oates)..... *O. feae* Vinciguerra

Scales smaller (diameter about 3 mm.), apical field without circuli, but with weak and broken wavy radii (Sittang River, E. W. Oates).....*O. cotio* (Hamilton Buchanan)

The last three seem closely allied, but *O. microlepis* is very different and is probably not truly congeneric. In Günther's Catalogue *Osteobrama* stands next to *Chanodichthys*. The scale of *Chanodichthys*, without basal radii, is in fact of a similar type, but much larger, with the numerous apical radii not distinctly wavy.

Osteochilus Günther. Zool. Anzeiger, XXXVI, p. 253, fig. 4 (*O. kahajanensis*). I have seven species from the British Museum, which are separable thus:

Apical interradial area striate with longitudinal converging circuli..... 1

Apical interradial area evidently tuberculate, the circuli broken up..... 2

1. Scales about 7 mm. long and 5½ broad (Menam River, Siam; Royal Siamese Museum)..*O. schlegelii*

Scales about 4 mm. long and 3–3¼ broad (Menam River, Siam; Royal Siamese Museum). *O. melanopleurus*

2. Scales very large, 14 mm. long and 13 broad; apical radii wavy, basal radii very few and irregular (Baram River, Sarawak; C. Hose).....*O. hasseltii* (Cuvier & Valenciennes)

Scales smaller; apical radii essentially straight..... 3

3. Lateral radii few, reaching nuclear area; scales about 7 mm. long and 6 broad (Sittang River; E. W. Oates).....*O. neilli* (Day)

Lateral radii numerous, all or most failing to reach nuclear area..... 4

4. Basal margin strongly trilobed (Deli, Sumatra; Moesch).....*O. waandersii*

Basal margin weakly undulate..... 5

5. Scale about 10 mm. long and 9 broad; skin pale with dark dots. (Baram district; C. Hose). *O. kahajanensis*

Scale about 7 mm. long and 6 broad; skin brown (Tinjar River, 200 miles from sea; C. Hose). *O. vittatus*

All are broadly rounded apically, essentially truncate basally, with evident laterobasal corners; nucleus far toward the base (least so in *O. neilli*); apical radii well developed, basal very poorly, feeble and irregular. The genus is a compact one on the scales, and the specific distinctions given are probably not all valid. (See also remarks under *Cirrhina*.)

Paracheilognathus Bleeker. Proc. Biol. Soc. Wash., XXII, p. 157; Zool. Anzeiger, XXXVI, p. 477. Scales of *P. rhombeus* are about 2¾ mm. long, 4¾ broad; circuli not at all dense.

Parapelecus Günther. *P. argenteus* from Kiu-Kiang (Styan; B. M.) is a remarkable fish, with the scales inserted obliquely, and the lateral line abruptly bent. The scales are about 4 mm. long and 6¾ broad, covered with thin skin to the base. There are fine basal circuli, but no basal radii; in the apical field the circuli are wanting, but there are numerous irregular delicate radii. Thus the scale combines the shape of the Rhodeines with the sculpture of the *Gobio* group. Except for the larger size and covering of pinkish skin, the scales are extremely like the broader ones of *Leucogobio mayedæ*.

Phoxinellus Heckel. Proc. Biol. Soc. Wash., XXII, p. 216. The locality given as Oued el Mahd should be Oued (or Wed) el Mahdi; the printer took the i for a semicolon. The two lots of scales represented *Phoxinellus chaignoni* (Vaillant) and *P. callensis* (Guichenot), which Boulenger now regards as distinct, though very closely allied. I fail to find any difference in the scales of the two.

Phoxinus Rafinesque. Proc. Biol. Soc. Wash., XXII, p. 186 and p. 216; Zool. Anzeiger, XXXVI, p. 476.

Pseudogobio Bleeker. Zool. Anzeiger, XXXVI, p. 478, fig. 1 (*P. esocinus* Schlegel).

Rasbora Bleeker. Proc. Biol. Soc. Wash., XXIII, p. 144.

Rhinogobio Bleeker. Biol. Bulletin, XX, p. 371, pl. II, fig. 9. Scale elongate, with broad truncate base.

Rohita Valenciennes. *R. lineata* from the Sittang River (E. W. Oates; B. M.), has elongated scales, about 10 mm. long and 6½ broad, the truncate base with a broad median lobe, bounded by the basal radii, which are two or three in number. Nucleus a short distance basad of center; gently curved delicate lateral radii; apical radii evanescent or extremely feeble; skin-covered area strongly tuberculate. The shape of the scale is very like that of *Labeo fimbriatus*. (Pl. XXXIII, fig. 9.)

Saurogobio Bleeker. Zool. Anzeiger, XXXVI, p. 478. Scales elongated; those of *S. dumerilii* much like those of *Rhinogobio typus;* both species collected by Styan at Kiu-Kiang.

Scaphiodon Heckel. Scales broader than long, with small subbasal nucleus; apical radii numerous, but no basal ones; interradial area tuberculate. I have two species from the British Museum, very much alike, but separable as follows:

Base with a very prominent rounded lobe; laterobasal corners very distinct; skin pallid, speckled with light brown (Sind; F. Day).....*S. watsoni* Day
Basal margin convex, but not lobed; laterobasal corners indistinct; skin brown, speckled with darker (Muscat, Arabia; A. S. G. Jayakar).....*S. muscatensis*

Except for the broader scales and denser sculpture there is an evident resemblance to *Capoeta*. This resemblance doubtless extends to other than scale characters, for Cuvier and Valenciennes included species of *Scaphiodon* in *Capoeta*. *S. muscatensis* is figured on plate XXXIII, figure 10.

Scaphiodontichthys Vinciguerra. My two scales of *S. burmanicus*, from Mount Mooleyit (Fea; B. M.), are both latinucleate; the scale is broader than long (about 7 by 8 mm.), considerably larger than that of *Scaphiodon*, with numerous apical radii but no basal; the basal margin is convex, without any lobe, and without laterobasal corners. The scale is structurally close to that of *Scaphiodon*.

Schizopygopsis Steindachner. I microscopically examined the skin of *S. stoliczkae* (Seistan, Helmund River, Col. McMahon; B. M.) and *S. younghusbandi* (Lhasa, Tibet, H. J. Walton; B. M.), but found no scales. The skin in *S. younghusbandi* is clear, profusely dotted with lichenoid spots of dark brown pigment.

Schizothorax Heckel. Biol. Bulletin, XX, pl. IV, fig. 22 (*S. biddulphii*); Zool. Anzeiger, XXXVI, p. 476. In *S. intermedius* (Kashgar; B. M.) the scales are elongate as in *S. biddulphii*, and the sculpture is in all respects the same, except that it is less dense. (Pl. XXXIII, fig. 11.)

Semiplotus Bleeker. In *Semiplotus semiplotus* (*Cyprinus semiplotus* McClelland, *Semiplotus macclellandi* Bleeker) from Assam (F. Day; B. M.) the scales are quite large, reddish, broader than long (length 13, breadth 15 mm.); nucleus a short distance below the middle; basal radii 3 or 4, feeble; slender curved lateral radii; apical radii very numerous, wavy; apical field coarsely tuberculate. The scale is of entirely the same general type as that of *Barynotus luteus*, but shorter, with much less prominent laterobasal corners, and fewer and feebler basal radii. The color is the same in both, and the differential characters cited are doubtless more or less variable. (Pl. XXXIII, fig. 12.)

Squaliobarbus Günther. Biol. Bulletin, XX, p. 371, pl. I, fig. 6 (*S. curriculus*).

Tinca Cuvier. Zool. Anzeiger, XXXVI, p. 476; Biol. Bulletin, XX, p. 373, pl. IV, fig. 21.

Tylognathus Heckel. Day treats this as a synonom of *Labeo*. I have five species from the British Museum. They agree in having numerous apical radii and the apical field tuberculate. So far as the material goes, they appear to be separable as follows:

The subquadrate scale broader than long (about 7 mm. long and 8 broad); laterobasal corners very prominent; basal radii very numerous, but fine and irregular; apical radii strong, more or less wavy, the interradial tubercles very strong .....*T.* ("*Lobocheilus*") *lehat*
The subquadrate scale a little longer than broad (about 8 mm. long and 7½ broad); general characters like the last, but apical radii scarcely wavy, and interradial tubercles weaker (Pata R.; C. Hose) .....*T. hispidus*
Scale conspicuously longer than broad, parallel-sided, shape like that of *Labeo fimbriatus*..... 1
1. Scale about 12 mm. long and 8 broad (Bowany R.; F. Day).....*T. ariza* (Buchanan)
Scale about 7 mm. long and 4 broad, but fish not adult (Madras; F. Day)..*T. boga* (Buchanan)
Scale about 5⅓ mm. long and 3½ broad (Poona; Lieut. Col. Playfair).....*T. striolatus*

The following Asiatic *Labeo* have scales of the *Tylognathus* type, or approximating it; *L. sindensis*, *L. falcatus*, *L. bicolor*, *L. sladoni*, *L. ricnorhynchus*, *L. kontius* (nearly shape and size of *T. ariza*, but less

elongate), *L. leschenaultii* (looks like *T. ariza*, but differs by strong basal radii, which are entirely absent in *T. ariza*), *L. bata* (quite like *T. ariza*, with no basal radii), *L. pangusia*, *L. nigripinnis*, *L. kawrus*, *L. microphthalmus*. Several others approach the same type quite closely, and it is evident that so far as the scales go, *Tylognathus* can not be separated from *Labeo*.

Varicorhinus Ruppell. Proc. Biol. Soc. Wash., XXIII, p. 148.

Xenocypris Günther. Zool. Anzeiger, XXXVI, p. 253, fig. 5 (*X. argentea*). I have two species from the British Museum, both having pale subcircular scales.

Scale about 5½ mm. long and 5¾ broad; laterobasal corners rounded; no basal radii; circuli in interradial (apical) region strong, transverse; nucleus almost central (Kiu-Kiang; Styan). *X. microlepis*

Scale about 3⅔ mm. long and 3¼ broad; laterobasal corners more evident; no basal radii; apical radii 7 or 8, the interradial circuli transverse, strong, widely spaced; nucleus far basad of middle (mountain streams near Kiu-Kiang; Styan).....*X. argentea* Günther

In the apical field there is a strong resemblance to *Chondrostoma*, but that genus has well-developed basal radii. See also Zool. Anzeiger, XXXVIII, p. 86.

Zacco Jordan & Evermann. Zool. Anzeiger, XXXVIII, p. 86, fig. 4.

CATOSTOMIDÆ. Suckers and buffalo-fishes.

The scales of the Catostomidæ are usually quite large, and resemble those of the Old World Cyprinidæ in most respects. For figures see Proceedings Biological Society of Washington, volume XXII, page 158, figure 2 (*Catostomus griseus;* the figure is printed upside down); Biological Bulletin, volume XX, plate 1, figure 3 (*Moxostoma aureolum*), and figure 4 (*Pantosteus santa-anæ*). In every case the basal radii are well developed. The scales of *Moxostoma cervinum* Cope, showing two types, one reticulated, are described in Science, July 28, 1911, page 126.

Subfamily ICTIOBINÆ. Buffalo-fishes.

In the carp sucker, *Carpiodes velifer* (Rafinesque), the scales from just below the front of the dorsal fin are broader than long, but those from between posterior end of dorsal and lateral line are longer than broad. The scales studied are from a fish about 4⅞ inches long, from the Wabash River, Indiana (Bureau of Fisheries). Apical margin broadly rounded; laterobasal angles distinct; base rounded, forming a single broad lobe, between which and the laterobasal angles the margin is concave; circuli very distinct, in the apical field only about half as closely set as laterally and basally; apical radii few, usually three, one median, and a curved one on each side, but sometimes five are present; basal radii numerous, about 30, or more counting imperfect ones, close together; nucleus central or almost. Latinucleate scales are coarsely and irregularly reticulate in the middle. Compared with the Catostomine series, this falls with *Catostomus commersonii*, from which it is at once separated by the character of the apical radii.

Subfamily CATOSTOMINÆ. Suckers.

Scales very small; oval, oblong, or subcircular, without laterobasal corners..... 1
Scales larger, often very large, with evident laterobasal corners..... 4

1. Radii all around; nucleus more or less apicad of middle (Boulder County, Colo.). *Catostomus griseus* (Girard)

   Radii apical and basal, the lateral basal ones usually not pointing to the nucleus, but when complete strongly crooked above, the bent basal end then pointing to the nucleus; nucleus central or basad of center..... 2

2. Nucleus nearly central, or moderately basad of middle..... 3
   Nucleus far basad of middle of the very small scales (Russian River, Cal.; Stanford University. *Catostomus occidentalis* Ayres

3. Scales often broader than long, but variable (Oregon).....*C. macrocheilus* Girard
   Scales longer than broad, but little different from the last (California)..*C. humboldtianus* Snyder
   Scales closely resembling the last, but with lateral circuli more developed, so as to approach *C. griseus*, except for the more basad nucleus (California).....*Pantosteus santa-anæ* Snyder
   (The tubercles in the upper lip are much more numerous in the *Pantosteus* than in *Catostomus macrocheilus*.)

4. Lateral and apical (interradial) circuli about equally far apart, strictly transverse..... 5
   Apical circuli conspicuously more widely spaced than lateral..... 6
5. Scale subcircular, about 4½ mm. diameter, with about 4 to 6 apical, and 17 to 20 basal (no lateral) radii (Little South Fork, Cumberland River, Ky.; P. H. Kirsch),
   Lagochila lacera Jordan & Brayton
   Scale smaller, rather more quadrate, with very prominent laterobasal angles; radii very strong, apical 4 to 6, basal 6 to 8 (Cherokee, Iowa; S. E. Meek).*Placopharynx duquesnii* (Le Sueur)
6. Basal radii very numerous, 12 in young scales, up to 20 or more in adult; center reticulated in latinucleate scales.....*Catostomus commersonii* (Lacépède), including *C. teres* Mitchill
   Basal radii less numerous..... 7
7. Basal radii more than 12; scale hardly differing from *C. commersonii*, but interradial circuli more arched.....*Erimyzon sucetta* (Lacépède)
   Basal radii about 7 to 9 in normal scales..... 8
8. With many incomplete apical radii.....*Moxostoma cervinum* (Cope)
   With at most one or two incomplete apical radii.....*Minytrema melanops* (Rafinesque)

The scales of several of the above, but especially those of *Lagochila*, are quite of the type of *Chondrostoma*. It is evident that the scales of the American Catostomidæ can be practically matched among the Palæarctic and Oriental Cyprinidæ, excepting only the western small-scaled group of *Pantosteus* and *Catostomus griseus, occidentalis*, etc. Even this exception is doubtful, for these smaller scales are certainly extremely like those of *Oreinus*, from Yunnan, Nepal, Assam, etc. It thus seems entirely impossible to find a scale character separating the Catostomidæ from the Old World Cyprinidæ. *Decactylus* Rafinesque, type *Decactylus commersonii* (Lacépède), or if Lacépède's fish is considered dubious, *Decactylus teres* (Mitchill), seems to be a valid genus, but *Catostomus occidentalis, macrocheilus*, etc., must be excluded from it.

COBITIDÆ. Loaches.

Subfamily COBITINÆ.

The scales of this subfamily have been discussed in Proceedings of the Biological Society of Washington, volume XXII, pages 205–206. The following genera are available for examination:

Cobitis Linnæus. T. c., p. 206 (*C. tænia*).
Misgurnus Lacépède. T. c., p. 206 (*M. fossilis, M. anguillicaudatus*).
Somileptes (Swainson) Bleeker. T. c., p. 206 (*Cobitis gongota*).
Lepidocephalichthys Bleeker. T. c., p. 206 (*L. berdmorei* and *L. guntea*).
Acanthopsis Van Hasselt. *A. chœrorhynchus* (Bleeker) from Meetam, Tenasserim (Fea; B. M.) has scales which are much broader than long, with radii all around; transverse diameter less than half a millimeter. The scales are of the same general type as those of *Cobitis tænia*, and entirely different from the elongated scales of *Somileptes* and *Lepidocephalichthys*.

Subfamily HOMALOPTERINÆ. East Indian loaches.

For *Gastromyzon* and *Homaloptera* (pl. XXXIV, fig. 17) see Proceedings Biological Society of Washington, volume XXII, pages 206–207.

KNERIIDÆ.

Proceedings Biological Society of Washington, volume XXIII, page 113; Biological Bulletin, volume XX, plate V, figure 31. (*Kneria cameronensis* Boulenger). This family falls here in Jordan's list, but in his two-volume work no justification for this position is found. Boulenger, having examined the skeleton of *K. cameronensis*, places the family between Phractolæmidæ and Cromeriidæ. Regan (1911) places it near to Chanidæ, or milk fishes. It is an isolated type, and its scales are very peculiar.

Suborder GYMNOTI. Electric eels.

Dr. Max Ellis has in preparation a detailed paper on the scales of this group. He has very kindly allowed me to examine his series of slides in order to state the principal characters. Greatly to my surprise I find the scales to be quite different from those of the characinids known to me, but very similar

indeed to those of such cobitids as *Misgurnus* and *Lepidocephalichthys*. They may also be compared with the small-scaled catostomids, as *Pantosteus*, or in Cyprinidæ with *Oreinus*. This general type of scale, with radii all around and a sort of latticework pattern, is, I believe, really primitive, with characters not very distantly approaching those of the amphibian *Ichthyophis*. It appears, therefore, that the gymnotids are not "degraded characinids" (Boulenger), but rather specialized pre-characinids. The fully developed radial pattern is found in the small-scaled gymnotids, the scale being nearly circular (*Gymnotus carapo*), or elongated (*Sternopygus macrurus*), or transversely oval (*Hypopomus artedi*). In *Eigenmannia virescens* more than half the scale is without radii, and if they all disappeared we should have a scale not very unlike that of the characinid *Serrasalmo*.

In the larger scales of *Porotergus* and *Sternarchus* the radii are very fine and the basal ones converge to the middle line, curiously simulating the condition found in some Gadidæ, as *Urophycis*.

Order SCYPHOPHORI.

For the Mormyridæ (including Gymnarchidæ) see Smithsonian Miscellaneous Collections, volume 56, no. 3. In Jordan's list the Haplochitonidæ and Galaxiidæ appear as Scyphophori, but this reference is opposed to the treatment in the earlier part of the book, and according to Regan (1911) they are salmonoids.

Order HAPLOMI.

ESOCIDÆ. Pikes.

Esox (or *Lucius*) *lucius* from Toledo, Ohio (Rutter), has oblong scales about 3.5 mm. long and slightly over 2.5 wide; nucleus anterior to the middle; no apical radii, but two or three very strong basal radii or plicæ, ending between the large lobes of the basal margin. The circuli are dense, the apical ones distinct and transverse, with no approach whatever to any ctenoid structure. The base of the scale is nearly as in *Synodus*. (Pl. XXXV, fig. 20.)

UMBRIDÆ. Mud Minnows.

Umbra limi (Kirtland) from Milwaukee County, Wis. (Grænicher), has peculiar subquadrate or oblong scales, the largest about 3 mm. long, wholly unlike those of *Esox*. There are no radii, nor is the basal margin at all lobed. The very coarse circuli are essentially longitudinal, extending from one end of the scale to the other, but the innermost slant toward the middle line, meeting those of the opposite side at an extremely acute angle. In the largest scales the apical circuli are not angled in the middle, but normally arched, becoming transverse in the middle; the basal circuli in the same scales converge to two or three points, producing a transversely zigzag appearance. In *Kneria* the system of circuli is very much the same, though differing in detail. Much more noteworthy and surprising is the great resemblance in structure to the scales of *Urophycis regius*. So far as the scales go, *Umbra* and *Urophycis* might be imagined to belong to closely allied genera. Dr. Gill (Smiths. Misc. Coll., vol. 45, p. 297) has given a rather unsatisfactory figure of an *Umbra* scale.

PŒCILIDÆ. Killifishes. (Pl. XXXV, fig. 21, 22; pl. XXXVI, fig. 23.)

Scales broad, more or less semicircular, cycloid, with the nucleus apicad of middle and strong basal radii. No apical radii; circuli not, or not very, dense. *Tilapia* (Cichlidæ) has the same sort of scale, thus quite different from that of Pomacentridæ (*Eupomacentrus* and *Abudefduf* examined), which is ctenoid, of the ordinary Acanthopterygian type.[a] Compared with *Esox* or *Lucius* the Pœciliid scale differs by its broad form (the scale of *Lucius* is longer than broad), numerous basal radii (two or three in

[a] Many Cichlidæ have ctenoid scales, and no doubt *Tilapia* is secondarily, not primitively, cycloid; a parallel development to that of the Embioticidæ. In fact, it is not quite correct to say that *Tilapia* is cycloid, since extremely minute marginal teeth can be detected with the compound microscope.

Lucius), and much less dense circuli. On the other hand, the scale of *Dallia pectoralis* does not essentially differ from the smaller pœciliid scales, though the sculpture is less regular. Latinucleate scales are common in the pœciliid material examined.

The following rather unsatisfactory key is based on normal (not latinucleate) scales:

Scales larger, more than 3 mm. across 1
Scales smaller, less than 3 mm. across..... 4

1. Apicolateral outline a regular even curve, or without angles; nucleus a short distance apicad of middle; basal radii about 17, only about the 10 midmost complete.
Cyprinodon carpio Günther. Tarpon Springs, Fla. (Evermann & Kendall).
Apicolateral outline evidently bent or angled, the apical margin thus separated from the lateral.. 2
2. Nucleus less than a third of length of scale from apex; apicolateral angles pronounced, but apical margin convex; basal radii about 13 to 16.
Gambusia puncticulata Poey. San Antonio, Pinar del Rio, Cuba (Eigenmann & Riddle)
Nucleus more than a third of length of scale from apex..... 3
3. Scale larger, very broad (lat. pr. 6 mm.), apical margin hardly elevated.
Fundulus heteroclitus (Linnæus), Woods Hole, Mass.
Scale smaller, not so broad (lat. pr. 4 mm.) apical margin more elevated.
Mollienisia latipinna Le Sueur, Gordon's Pass, Fla. (Henshall).
Differing from the above two in having the scale longer than broad.
Fundulus majalis (Walbaum).
4. Nucleus far above middle of scale; basal radii about 10 or 11.
Pœcilia butleri; Jordan; fish about 40 mm. long; Salina Cruz, Mexico (C. C. Deam).
Nucleus about middle of scale or even below..... 5
5. Scale subquadrate, with more or less evident anterolateral angles.
Fundulus diaphanus (LeSueur), Osterville, Mass.
Scale broad, not subquadrate, without anterobasal angles..... 6
6. Scale less than 1½ mm. diameter..... *Lucania parva* (Baird & Girard), Woods Hole, Mass.
Scale more than 1½ mm. diameter.
Gambusia affinis (Baird & Girard), Myakka River, Florida (J. A. Henshall).

Dr. Max Ellis has kindly allowed me to examine scales of *Anableps anableps* (Linnæus) the four-eyed fish, and *A. microlepis* Garman, which he collected at Georgetown, British Guiana. They are quite large, those of *A. anableps* much broader than long, with a width of about 8 mm., those of *A. microlepis* smaller, and not so broad. In all respects they are quite typical pœciliid scales, much like those of *Cyprinodon*, but with considerably denser lateral circuli.

Order XENOMI.

DALLIIDÆ. Alaska blackfish.

Dallia pectoralis Bean, from Nushagak, Alaska (Albatross collections) has small scales about 1½ mm. diameter, with coarse circuli and numerous (about 15) basal radii, the basal margin finely scalloped. There is nothing in these scales which might not be expected in the Pœciliidæ. Regan has recently proposed to include the Esocidæ, Umbridæ, and Dalliidæ in Haplomi and to recognize a new order, Microcyprini, for the Pœciliidæ and Amblyopsidæ. So far as the scales go, the following arrangement would seem natural.

1. Umbridæ.
2. . . . . A. Esocidæ.
B. . . . . a. Dalliidæ.
b. Pœciliidæ,

the last showing a close approach to the acanthopterygian type.

Order ACANTHOPTERI. Spiny-rayed fishes.

THE ACANTHOPTERYGIAN TYPE OF SCALE.

The serranid *Centropristes striatus* (Linnæus), the black sea bass, from Woods Hole, Mass., may be taken as a type for the definition of the acanthopterygian scale. This scale is more or less quadrate, with the nucleus subapical, the basal circuli fine and transverse, the basal radii strong, spreading out like a fan, and the apical area covered with fine dentiform structures which can be counted in rows obliquely or transversely, and on the margin form a series of fine teeth. The *Centropristes* scale described is atypical in one respect—the marginal teeth are truncate instead of pointed. The toothed or ctenoid feature appears to be derived from the longitudinal apical circuli which become modified and segmented, the terminal segments especially taking the form of teeth. It is this segmentated arrangement which gives the apical area in acanthopterygians its special character, resembling very much the arrangement of bracts in the heads of some composite flowers. In the pœciliid scale we have a structure resembling much that of the acanthopterygians, but the ctenoid character wholly undeveloped; in some cichlids we attain a superficially similar condition, the ctenoid character having been lost.

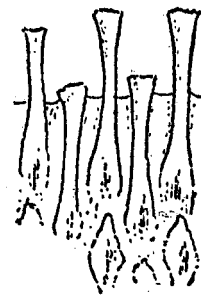


FIG. 8.—*Centropristes striatus* (Serranidæ). Ctenoid structures. Bureau of Fisheries.

At first sight the scales of the various acanthopterygian families Hæmulidæ, Lobotidæ, Serranidæ, Lutianidæ, Percidæ, Centrarchidæ, Anabantidæ, Sciænidæ, Mullidæ, Polynemidæ, and Mugilidæ appear so much alike that classification seems extremely difficult. There are, however, some good distinctions visible on close comparison and brought out more or less in the following table. This does not apply to latinucleate or lateral line scales.

Basal margin broadly emarginate in middle, the basal radii (about 4 or 6 distinct) nearly parallel, converging toward the margin; teeth of apical margin very small, not different from the submarginal structures..... *Mugil curema* Cuvier & Valenciennes (Mugilidæ)

Basal radii spreading..... 1

1. Middle of basal margin deeply emarginate; radii one in the middle, and usually three (closer together than the innermost to the middle one) on each side, not deeply impressed; apical modified area reaching nearly to nucleus; apical marginal teeth very small, sharp; subapical pattern composed of elements resembling phalanges, but grooved or bicarinate.[a] *Polydactylus octonemus* Girard (Polynemidæ)

Basal margin deeply lobed between the five of six widely and often irregularly spaced basal radii; large scales with extremely fine circuli; modified marginal area not approaching nucleus; marginal teeth sharp; submarginal elements phalangiform, flattened, looking like bricks placed on end, without grooves or keels, though some of the basal ones may have broken vermiform markings. Surmullets (Mullidæ)..... 2

Not like the above (in *Perca* the basal margin is strongly lobed, but then the basal radii are regular and very deeply impressed, and the apical region is differentiated into two parts)..... 4

2. Subapical marginal elements longer, many about four times as long as broad. *Mullus auratus* Jordan & Gilbert, Woods Hole, Mass.

Subapical marginal elements shorter, none about four times as long as broad..... 3

3. Elements of apical area in 5 or 6 transverse rows (only two in latinucleate scales). *Upeneus dentatus* Gill. Clarion Island (Albatross)

Elements of apical area in 8 or 9 transverse rows. *Mulloides samoensis* Günther. Honolulu, Hawaii (Jordan & Evermann)

4. Apical area beset with linear, spine-like structures (the marginal teeth not differing), the lateral ones often continuous at base with the circuli; apical circuli very widely spaced, meeting at about a right angle above nucleus; basal radii about 15 (Anabantidæ). *Anabas scandens* Linnæus. Lake Buhi, Philippine Islands

Apical area not thus..... 5

5. Scales conspicuously longer than broad; margin with about 7 or 8 prominent teeth or projections, to the ends of which the basal framework of the scale is carried; apical area with much reddish brown pigment; scale suggestive of *Achirus*, but the subapical structure different. *Epinephelus niveatus* (Cuvier & Valenciennes). Katama Bay, Mass. (Serranidæ)

Apical margin with many teeth..... 6

[a] In *Mugil* these structures are dentiform, like pointed scales, thus very different.

6. Marginal teeth truncate, often (except in *Micropogon*) broader at end than in middle..... 7
Marginal teeth sharply or rather obtusely pointed..... 12
7. Circuli above the nucleus broad and sublongitudinal, so that the nucleus and adjacent circuli suggest a section of an onion..... 8
Circuli above the nucleus transverse (concentric) or (in *Orthopristis*) evanescent..... 10
8. Scales much larger (about 8 mm. long and broad); elements of apical area with the median *oblique* rows about 12 or 13, but the inner ones poorly developed; basal radii about 9 or 10.
Centropistes striatus (Linnæus). Woods Hole, Mass. (Serranidæ)
Scales smaller (less than 4 mm. long), longer than broad; inner elements of apical area distinct (Serranidæ)..... 9
9. Scales 3 to nearly 4 mm. long.
Paralabrax maculatofasciatus (Steindachner). Guaymas, Mexico (Albatross)
Scales 1½ to 1⅔ mm. long....*Paralabrax clathratus* (Girard). San Diego Bay, Cal. (Albatross)
10. Circuli above the nucleus lost, the surface finely roughened.
Orthopristis chalceus (Günther). Guaymas or Clarion Island (Albatross). (Hæmulidæ)
Circuli above the nucleus distinct..... 11
11. Scale larger, up to over 10 mm. broad; elements of apical area in middle about 16 in a longitudinal series.....*Micropogon undulatus* (Linnæus). (Sciænidæ)
Scale smaller; elements of apical area in middle 8 or less in a longitudinal series.
Leiostomus xanthurus Lacépède. Florida. (Sciænidæ)
12. Apical teeth very short, for the most part hardly so long as their distance apart..... 13
Apical teeth well developed..... 14
13. Apical teeth more or less bifid at tip; sculpture of apical area strong.
Morone americana (Gmelin), fish nearly 8 inches long. (Serranidæ)
Apical teeth not bifid; sculpture of apical area weak.
Micropterus salmoides (Lacépède). Falmouth, Mass. (Centrarchidæ)
14. Scales large, colorless, very broad (a well developed one about 11 mm. broad and 8 long), often inequilateral; basal radii very numerous (about 40) and close together; elements of apical area longitudinally ridged or keeled.
Cynoscion regalis (Bloch & Schneider). Woods Hole, Mass. (Sciænidæ)
Scales very large, quadrate, equilateral (a well developed one about 16 mm. long and 15½ broad), orange-fulvous; basal radii very numerous (about 37, but many only in the peripheral area); circuli puncticulate; submarginal elements of apical area much longer than broad .....*Lobotes surinamensis* (Bloch). (Lobotidæ)
Scales smaller and otherwise different; many very small..... 15
15. Base of scale very deeply crenate, many of the lobes as long as broad; basal radii 5 or 6; apical area with a marginal band in which the elements are very distinct, but mesad of this they are indistinct, the transition abrupt.
Perca flavescens (Mitchill). Falmouth, Mass. (Percidæ)
Base of scale not thus deeply crenate..... 16
16. Scales larger, fully 5 mm. long and broad; basal radii very numerous (about 28–32) and close together; basal circuli puncticulate.
Roccus lineatus (Bloch). Woods Hole, Mass. (Serranidæ)
Scale much smaller; basal radii less than 20..... 17
17. Basal radii about 18.
Hypohomus spilotus (Gilbert). Hector Creek, Kentucky. (Woolman). (Percidæ)
Basal radii usually less than 10 (9 to 11 in *Neomænis*)..... 18
18. Submarginal elements of apical area much longer than broad..... 19
Submarginal elements of apical area mostly or all broader than long..... 20
19. Lateral circuli strongly curving inward above.
Morone americana (Gmelin), fish 3 inches long. (Serranidæ)
Lateral circuli (except the innermost) hardly curving inward above.
Neomænis analis (Cuvier & Valenciennes). Katama Bay, Mass. (Lutianidæ)
20. Scales very small; apical teeth broad at base, rapidly tapering to very slender sharp points; basal radii 6 to 9.....*Boleosoma nigrum* (Rafinesque). Osterville, Mass. (Percidæ)
Apical teeth conical, more regularly tapering..... 21
21. Lateral circuli (except the innermost) directed obliquely outward above, so that if they were continued in a straight line below until they met, they would form a broad V; basal radii 7 to 8.....*Brachydeuterus leuciscus* (Günther). San Juan Lagoon, Rio Ahoma, Mexico (Albatross). (Hæmulidæ)
Lateral circuli (except the innermost) directed upward above..... 22
22. Submarginal elements of apical area appearing distinctly concave below (helmet-shaped); basal radii 8..... 8
Hæmulon steindachneri (Jordan & Gilbert). Gulf of California (Albatross). (Hæmulidæ)

Submarginal elements of apical area not appearing concave below..... 23
23. Submarginal elements of apical area hat-shaped.
Cottogaster shumardi (Girard). Wabash River, Ind. (B. W. Evermann). (Percidæ)
Submarginal elements of apical area quadrate.
Menticirrhus saxatilis (Bloch & Schneider). Woods Hole, Mass. (Sciænidæ)

Suborder SYNENTOGNATH.

BELONIDÆ. Marine gars.

The houndfish, *Tylosurus acus* (Lacépède) has irregular elongate (broad) scales with conspicuous concentric circuli, but no radii whatever. They thus recall the scales of Salmonidæ.

EXOCŒTIDÆ. Flying-fishes.

Cypsilurus heterurus (Rafinesque) has large broad thin scales, about 10 mm. broad and 8 long; nucleus a short distance below middle; circuli strong, concentric, in some scales much more widely spaced laterally, and then often angled; margin wholly cycloid; about 4 or 5 strong basal radii (more in latinucleate scales), none apical. Except for the presence of radii, this is very similar to *Tylosurus*. It seems also to lead toward the scombrid type.

HEMIRHAMPHIDÆ. Halfbeaks.

Hyporhamphus unifasciatus (Ranzani), from Woods Hole, Mass., has very broad scales, about 5 mm. long and 8, or slightly over, broad; apical margin broadly rounded; laterobasal corners rounded but evident; middle of base with a broad median lobe, which may be bilobed; basal radii two or three, widely diverging; nucleus near middle, but indistinct; apical field entirely covered with very fine transverse circuli, except a slender sculptureless submarginal band; basal field with transverse more widely spaced circuli, bending upwards and still more widely spaced in the lateral fields, and ultimately, when not reaching the margin, forming acute angles with the adjacent circuli of the apical field. The transverse dense apical circuli remind one of *Xystæma* (Gerridæ), but in *Xystæma* there is no sign of lateral angulation, and the apical marginal region is entirely different.

The scale of *Hyporhamphus* is evidently a further development, much more extreme, of the type of *Cypsilurus*. It also seems to point clearly in the direction of the scombrids.

SCOMBRESOCIDÆ. Saurles.

The billfish, *Scombresox saurus* (Walbaum) represents a still more extreme development along the lines of *Hyporhamphus*. The thin scale is about 5 mm. long and 8 broad, without angles or radii. The circuli are everywhere completely transverse, denser on the apical than the basal half, the two halves separated in some cases by more or less of an interval about the middle. At each extreme side is a thin zone, sculptureless except for a few irregular lines. The scales are of the same general type as those of the Scombridæ and Cheilodipteridæ.

So far as seen, the synentognathous families may be separated thus:

Apical and basal circuli about the same..... 1
Apical circuli transverse, denser than basal..... 2
1. Radii absent.....Belonidæ
Basal radii strong.....Exocœtidæ
2. Without radii.....Scombresocidæ
With radii.....Hemirhamphidæ

If doubt should arise owing to the apical circuli of Scombresocidæ not being much denser than the basal, the family will still be easily recognized by the completely transverse character of the circuli, so that the effect of lateral angulation is lost. Dr. Jordan states that Regan (1911) recognizes an order Synentognathi, with one suborder for the belonids and scombresocids, and another for the hemirhamphids and exocœtids. The scale characters would not have suggested this arrangement.

Suborder PERCESOCES.

ATHERINIDÆ. Silversides. (Pl. XXXVI, fig. 25.)

For a general account of the scales of this family, see Proceedings of the Biological Society of Washington, volume XXIII, pages 47–48. The genera *Kirtlandia* and *Menidia* are discussed, and the resemblance to the scombrids is noted. All the scales except *Kirtlandia* have distinct basal radii, with the lower margin usually scalloped; the laterobasal angles are distinct, and there are distinct apical radii in some forms, as *Chirostoma*. The following key separates the species before me:

Lateral and apical circuli alike and continuous, the circuli very widely spaced; scale very small, less than 1½ mm. broad, strictly cycloid; no apical radii; basal radii well developed, about 5 or 6; laterobasal angles rectangular.
Atherinops regis Jenkins & Evermann. (Algodones Lagoon, Mexico; Albatross)

Lateral circuli strongly differentiated from apical, or the latter modified or partly suppressed... 1

1. Apical margin scalloped or lobulate..... 2
   Apical margin entire..... 3
2. Scale much broader than long; basal margin undulate, with a single large lobe; apical margin irregularly lobed, with traces of radii; basal radii reduced to one or two broad folds, no true radii; apical field without sculpture, but across the middle of the scale, apicad of the regular circuli, is an area of very fine longitudinal lines, in the middle on the apical side breaking into very fine labyrinthiform markings.....*Kirtlandia laciniata* (Swain). (Chesapeake Bay, Va.)
   Scale little (sometimes not at all) broader than long; basal margin more or less angulate in the middle; apical margin finely irregularly scalloped, with evident though slender radii; basal radii about 7 to 10, well developed; lateral circuli very widely spaced, but apical field with extremely fine transverse circuli, which are much broken, and in the nuclear area mostly reduced to dots..*Chirostoma crystallinum* Jordan & Snyder. (Lake Chapala, Mexico; J.N. Rose)
3. Basal radii distinct; lateral circuli very widely spaced; apical circuli transverse, very dense, more or less broken, toward the nucleus reduced to granules; apical radii very slender, irregular, not always evident.
   Menidia peninsulæ (Goode & Bean); *M. menidia* (Linnæus); *M. notata* (Mitchill)

Of this series, *Chirostoma* is possibly the most primitive, but *Atherinops* stands apart and has the primitive character of continuous, uniform circuli in the lateral and apical regions. *Kirtlandia* seems much modified, but hardly from a *Menidia*-like basis. Probably *Atherinops* and its allies should form a distinct subfamily.

The scales of *Menidia notata* described in my paper cited above were not adult; other scales from the Bureau of Fisheries collection are about 3.5 mm. broad, with the apical margin subangulate or roof-like in profile.

MUGILIDÆ. Mullets.

The white mullet, *Mugil curæma* Cuvier & Valenciennes, from the collection at Woods Hole, has large rounded scales, with a straight, medially emarginate base; length about 9.5–10 mm; breadth 11–11.5; basal radii few, crowded about the middle of the scale; nucleus apicad of middle; lateral circuli coarser than basal; apical margin minutely ctenoid, the apical region with the minutely imbricated structure of typical ctenoid scales.

Here, then, we first meet with the typically ctenoid type of scale, as developed among the Acanthopterygians. The ctenoid scales of certain Characinidæ are of an entirely different character.

There is no evident connection between the scales of *Mugil* and those of the Atherinidæ.

SPHYRÆNIDÆ. Barracudas.

The scales of *Sphyræna* are very peculiar, and wholly unlike those of the Atherinidæ or Mullidæ. *S. picuda* Bloch & Schneider, from Tampa, Florida, has relatively large reddish scales, about 7 mm. long and a little over 6 broad, the lateral and basal margins gently convex, laterobasal corners obtuse, the apical region thin and without sculpture. The sculptured part of the scale has throughout extremely dense circuli, which, except in the upper lateral region, are interrupted by very numerous radii. The radii are very uniform, about 5 to 9 to a millimeter of the margin. The midmost circuli are not only divided into short sections by the radii, but the sections themselves are cut at intervals by very fine

lines, so as to seem segmented. In *S. borealis* DeKay, from Woods Hole, the colorless scales have a diameter of hardly 1½ mm., and the fine radii, instead of continuously interrupting the circuli, are represented by series of minute round holes, which, however, coalesce in some places, producing a condition like that of the great barracuda, *S. picuda*. In the northern barracuda, *S. borealis*, the apical sculptureless area is very small or wanting. The sphyrænid scale is very suggestive of that of *Gadus* and allied genera.

FIG. 9.—*Mugil* (Mugilidæ). Ctenoid area. Bureau of Fisheries.

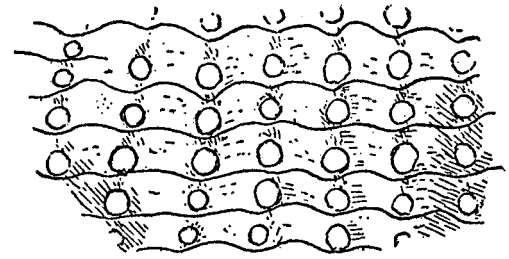


FIG. 10.—*Sphyræna borealis* (Sphyrænidæ). Sculpture. Bureau of Fisheries. The transverse strands are circuli.

Jordan & Evermann state that the families Atherinidæ, Mugilidæ, and Sphyrænidæ are closely related (Bulletin 47, U. S. National Museum, pt. 1, p. 788). They were associated together in the order Percesoces by Cope. Boulenger includes in Percesoces several other families, as Anabantidæ, Stromateidæ, Polynemidæ, Scombresocidæ, etc., stating that the group is perhaps only an artificial one, but "a gradual passage may be traced connecting the most aberrant types."

The scales would certainly suggest that the three families described above are not very closely related.

Suborder RHEGNOPTERI.

POLYNEMIDÆ. Threadfins.

Jordan states that the Polynemidæ are allied to the Mugilidæ, but differ from them and from all other fishes in the structure of the pectoral fin and its basal bones. In Boulenger's arrangement they go in the Percesoces, following the Mugilidæ. In *Polydactylus octonemus* Girard the scale is quite

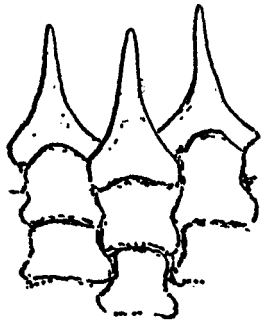


FIG. 11.—*Polydactylus* (Polynemidæ). Apical teeth. Bureau of Fisheries.

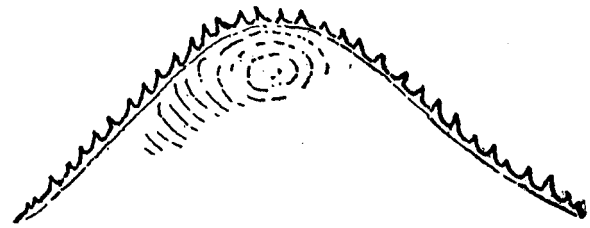


FIG. 12.—*Percopsis guttatus* (Percopsidæ). Marginal teeth. Bureau of Fisheries.

typically Acanthopterygian, with ctenoid apical area, nucleus apicad of middle, and well-developed basal radii. The scale is nearly as in *Mugil*, having the same basal emargination, but differing in the spreading basal radii. The minute elements of the apical area are not as in *Mugil*, the submarginal ones being truncate instead of pointed.

Although there are differences, the scales would suggest that the Polynemidæ are actually nearer to the Mugilidæ than the latter to the Atherinidæ or especially the Sphyrænidæ.

Suborder SALMOPERCÆ. Trout perch.

PERCOPSIDÆ. Sand rollers.

The trout perch, *Percopsis guttatus* Agassiz, from East Okoboji Lake, Iowa (Evermann), has broad subtriangulate scales, with the apical margin forming two sides of the triangle, each side with about 17 sharp teeth. Nucleus very close to apex; circuli widely spaced; a slight tendency to basal plication, but no distinct radii. In the form of the apical region, with the nucleus very far apicad and the single row of sharp teeth, this reminds one of *Gobius* and its allies. In the Gobiidæ, however, the basal radii are very well formed and numerous.

Suborder BERYCOIDEA. Berycoid fishes.

BERYCIDÆ. Alfonsinos.

Jordan & Fowler say of this family: "Covered with ctenoid, or cycloid, foliate, or granular scales." I have from the United States National Museum scales of *Beryx splendens* Lowe (fish 21 inches long) from Japan. They are about 8 mm. long and 9.5–10.5 mm. broad, with the exposed part colorless and the covered pale yellowish red. The apical margin is thin and rather irregular, wholly without teeth; lateral margins concave; laterobasal corners very prominent; lower margin convex, irregularly subcrenulate; nucleus a short distance apicad of middle; basal circuli dense; weak basal folds in place of radii; broad apical region with growth lines but no circuli, and with scattered small round perforations. These perforations in the apical region sometimes have elevated margins, and in the region of the nucleus their place is taken by small sharp spines. Probably they arise as spines in every case, and the spines breaking off leave perforations. Jordan & Fowler state that the scales of *Beryx splendens* "are furnished with fine prickles, giving a somewhat rough touch." In *Beryx lineatus*, as figured by Sauvage, the prickles or spines of the apical region are large and dense. In either case, the arrangement parallels that found in species of *Macrurus*, and it is interesting in this connection to note that Regan some years ago suggested that the Gadoids might have come from the same stock which also gave rise to the Berycidæ. In *Caulolepis subulidens* Garman, as figured by Garman (Memoirs Museum Comparative Zoology, XXIV, 1899), the scales are extremely modified, but still have some of the spines or teeth.

TRACHICHYIDÆ. Deep-sea berycoids.

Garman, in the work just cited, figures the scale of *Trachichthys mento* Garman. It is transversely oval, without the laterobasal corners of *Beryx*, but it has a number of true berycoid spines in the subapical region. Boulenger refers the genus to Berycidæ.

HOLOCENTRIDÆ. Squirrel-fishes. (Pl. XXXVI, fig. 26.)

The scales of the Holocentridæ resemble in shape those of the Berycidæ, being broad, with prominent laterobasal angles. In every case, so far as known to me, the apical margin is armed with strong, straight, comb-like teeth. In some (especially *Myripristis murdjan*) the subapical region has spiniferous pits, of the same character as the spine-bearing holes of *Beryx*. The basal margin is straight or nearly so, except that in the middle it is thrown into one or more folds or lobes, indicative of the rudiments of a basal radial system. The scales are all broader than long, but those of *Flammeo* are not so conspicuously so as those of *Holocentrus*, and especially *Myripristis murdjan;* the last are larger than any of the others, about 8½ mm. long and 14½ broad, strongly reddish. The basal circuli in all are excessively fine, more so than in *Beryx splendens*. The species examined are as follows:

Myripristis murdjan (Forskål). Strongs I., Carolines (M. C. Z.).
Flammeo scythrops. Hawaii.
Flammeo sammara (Forskål). Hawaii.
Holocentrus diadema Lacépède. Hawaii.
Holocentrus laticeps Cuvier & Valenciennes. Kaui, Hawaii (M. C. Z.).

Holocentrus xantherythrus Jordan & Evermann. Hawaii.
Holocentrus microstoma Günther. Samoa.

The species of *Holocentrus* are so uniform in their characters that I can not construct a satisfactory key. There are, however, minor differences; e. g., the apical teeth of *H. xantherythrus* are much coarser than those of *H. laticeps*, and the basal radial folds are more prominent in *H. diadema* and *laticeps* than in the others.

Finding that *H. laticeps* was not recorded from the Hawaiian Islands, I asked Dr. Garman to look at the specimens (M. C. Z., 3440). This he kindly did, and reports that the identification is correct.

Sauvage, in his work on the fishes of Madagascar, has figured scales of *Myripristis seychellensis*, *M. pralinus*, *M. borbonicus*, *Holocentrus* (or *Holocentrum*) *spiniferus*, *H. diadema*, *H. leo* and *Holotrachys lima*. These show various peculiarities, but all confirm the essential uniformity of the holocentrid type, and indicate its general affinity with that of the Berycidæ.

There is an evident resemblance between the holocentrid scale and that of *Aphredoderus*.

POLYMIXIIDÆ. Barbudos.

From the United States National Museum I have scales of *Polymixia japonica* Steindachner, from Japan (fish 7¼ inches long). They are very broad, with the same general shape and apical spines as *Holocentrus*, but the basal circuli are very much less dense, and the basal radial folds are very well marked, throwing the basal margin into numerous strong undulations. The laterobasal corners are less prominent than in the holocentrids, and the subapical region is without spines. Thus the Berycoidea, as regards their scales, form a sufficiently compact group, quite isolated from the groups standing on either side of it in the system.

Suborder PERCOMORPHI. Perciform fishes.

Superfamily SCOMBROIDEA. Mackerel-like fishes.

Broadly speaking, the families Scombridæ, Carangidæ, Cheilodipteridæ, Stromateidæ, Hemirhamphidæ, Scombresocidæ, Belonidæ, and Exocœtidæ may be ranged together (and apart from the percoid series) on their scales. Atherinidæ show some resemblances also. The fishes are of course variously diverse in other characters.

SCOMBRIDÆ. Mackerels.

I have figured the scales of *Scomber* in Smithsonian Miscellaneous Collections, volume 56, no. 1. They are small and thin, broader than long, with the circuli transverse. In the common mackerel, *Scomber scombrus* (Linnæus), from Woods Hole, the apical margin is more or less, but very irregularly, dentate, without the formation of definite structures like those on genuinely ctenoid scales. At these teeth the circuli are bent upward and angled, and this irregular waviness and angulation is seen here and there in the subapical field, indicating no doubt the teeth of an earlier stage. The fusiform area representing the nucleus is below the middle of the scale, and on each side of it the circuli are acutely angled. The circuli above the nucleus are somewhat denser than those below. The angulation of the lateral circuli in *S. scombrus* is like that of the basal ones in *Macrurus*.

In the bonito, *Sarda sarda* (Bloch), and the frigate mackerel, *Auxis thazard* (Lacépède), the scales are of the same general type, but still smaller and more degenerate, often practically without sculpture. Those of *Auxis* are often pointed laterally.

CARANGIDÆ. Cavallas, etc. (Pl. XXXVI, fig. 27.)

The jack, *Caranx hippos* (Linnæus), has circular scales about 2½ mm. diameter, with central nucleus and fine concentric circuli, not unlike some salmonid. There are no radii or marginal teeth. The inner circuli are variously angled laterally, and in the young the scales are transversely oval, and look just like those of *Scomber*. The carangid and scombrid scales are therefore very closely allied, although when adult appearing different.

CHEILODIPTERIDÆ. Bluefishes.

The bluefish, *Cheilodipterus saltatrix* (Linnæus), from Onset, Mass., has scales slightly over 2 mm. long and about 3 broad; apex broadly rounded, base flattened, slightly and obtusely angled in the middle; laterobasal corners rounded but evident; no radii; circuli transverse apically and basally, more or less angulate laterally; nucleus below the middle. The lateral circuli are often angulate only on one side. The apical margin is thin, and when not worn off is irregularly dentate; the coarse circuli are not deflected or angled below these teeth, as they are in *Scomber*. This scale is entirely of the scombrid type.

STROMATEIDAE. Butterfishes.

Gobiomorus gronovii (Gmelin), the Portuguese man-of-war fish, has feeble cycloid scales with widely spaced circuli which are more or less wavy. There are no radii. My material is perhaps immature. In the butterfish, *Poronotus triacanthus* (Peck), from Woods Hole, the scales are as in *Cheilodipterus* except that there are no signs of apical teeth, while the base often has one or two broad radial folds. The lateral circuli are angulate in most scales.

The pilot-fish, *Palinurichthys perciformis* (Mitchill), has quadrate scales about 4½ mm. long and broad; laterobasal corners distinct; nucleus below the middle; circuli very distinct, the basal denser than the apical, the lateral vertical, parallel with the margin; four or five indistinct basal circuli. This scale is like that of the lake herrings, *Leucichthys*, and does not at all suggest that of the Scombridæ and allies. Jordan & Evermann separated the Centrolophidæ (*Centrolophus* and *Palinurichthys*) from Stromateidæ, but Jordan has more recently made Stromateidæ include both Centrolophidæ and Nomeidæ (*Gobiomorus*). The scales would strongly suggest that Centrolophidæ, at least, are a valid family. There is a striking general resemblance between the scale of *Palinurichthys* and that of *Chirostoma crystallinum* Jordan & Snyder (Atherinidæ), but the apical region of the *Chirostoma* scale is quite different.

PEMPHERIDÆ. Deep-water Catalufas.

Pempheris otaitensis (species perhaps wrongly determined) from the Red Sea (M. C. Z.), has scales which differ greatly in size on the same fish. The larger ones are about 4 mm. long and 6 broad; strictly cycloid, with circuli all around, transverse in the apical region; no apical radii; nucleus basad of middle; laterobasal corners rounded; about 15 strong basal radii, arranged fan-like, the basal margin strongly crenate. This scale, while very different from that of *Palinurichthys*, shows enough resemblance to suggest affinity.

Superfamily PERCOIDEA.

CENTRARCHIDÆ. Sunfishes and basses.

Mr. B. A. Bean very kindly sent me from the United States National Museum a very full set of centrarchid scales, with numbers only, so that I might classify them without any bias derived from a knowledge of their generic and specific identity. This I did, and afterwards the names and localities were supplied. The result was that I found the group to be on the whole a very compact one, the principal differences being found in the development of the apical teeth (the ctenoid feature), the density of the apical circuli, and the number of basal radii. The scales are quadrate or subquadrate in form, sometimes (*Micropterus dolomieu*) longer than broad, others (as *Lepomis gibbosus*) broader than long. No doubt the forms with well developed apical teeth are the most primitive (at least as regards their scales), the centrarchid type being originally ctenoid. It is interesting to note that *Archoplites interruptus* from San Francisco, the only fresh-water percoid west of the Rocky Mountains, has very strongly ctenoid scales, and the basal radii with an extremely minute beading. It is remarkable that in other forms the ctenoid margin is lost as the scale matures, thus:

(1) *Ambloplites rupestris*, rock bass; young from Sodus Bay, N. Y., show a ctenoid V-shaped apical area, the apical margin with many sharp teeth; adults from Manchester, Va., show a perfectly entire apical margin, though (except in latinucleate scales) the V-shaped ctenoid patch is still visible as a sort of latticework pattern, failing below the margin. This is very different from the broad ctenoid area of *Archoplites*, the lower margin of which, in well-developed scales, is nearly straight.

(2) *Micropterus salmoides*, large-mouth black bass; young from Sodus Bay, N. Y., show in most (but not all) scales a V-shaped ctenoid area, with teeth projecting slightly beyond the margin; scales of about the same age, from Falmouth, Mass., show the same, but are considerably narrower; adults from Bemus Point, N. Y., show a very broad ctenoid area, but the margin is toothless, or with extremely short and feeble projections. *M. dolomieu* is without ctenoid features at any age, though the apical circuli sometimes become sharply zigzag.

Scales of *Enneacanthus gloriosus*, from Washington, D. C., are strongly ctenoid, the ctenoid area very broad and the marginal teeth distinct; they differ conspicuously from those of *Archoplites* by their broader form, more minute apical teeth, and more numerous (usually 12 or 13) basal radii.

Chænobrytus gulosus, warmouth, from Washington, D. C., has variably ctenoid scales, the ctenoid area sometimes reduced to a very small patch. A hybrid between *C. gulosus* and *Lepomis gibbosus*, from the District of Columbia, has the ctenoid feature well developed, the area broad.

I could find nothing in the scales to justify the division of *Lepomis* into *Apomotis*, *Lepomis*, and *Eupomotis*. In the classification made without knowledge of the names, nearly all the species with intermediate characters—poorly developed but visible ctenoid features—fall in *Lepomis*, which is thus fairly compact on scale characters; but the so-called genera segregated from *Lepomis* are inextricably mixed. In the blue-gills *Lepomis pallidus* and *holbrookii* the apical margin is entire in some specimens, herein agreeing with the normal condition of *Pomoxis*. A disturbing feature is the great variability of some of the species, not only individual but racial. I give some examples:

(1) *Micropterus salmoides* (Lacepédè), large-mouth black bass. Scales from Falmouth, Mass., narrower than those from Sodus Bay, N. Y.

(2) *Lepomis gibbosus* (Linnæus), pumpkin-seed, from Washington, D. C., with the ctenoid area large, though the teeth are rudimentary; from Upper St. Croix River, Douglas County, Wisconsin (Grænicher), with widely spaced transverse apical circuli, and the ctenoid patch either wholly absent or reduced to a few marginal teeth of small size.

(3) *Lepomis holbrookii* (Cuvier & Valenciennes), from the Carolinas, has the scale very broad (about 6⅓ mm. long and 8½ broad), with the ctenoid features distinct; other scales, also from the Carolinas, are much narrower and less ctenoid.

(4) *Lepomis cyanellus* (Rafinesque), green sunfish, from Washington, D. C., and New Orleans, La., is conspicuously ctenoid when not latinucleate; from Woods Lake, near Greeley, Colorado (Warren), it is completely cycloid, with widely-spaced apical circuli.

It will be observed that these variations follow rather narrow lines, and the racial differences are of the same sort as the individual ones. It remains to be seen whether the apparent racial differences in scale characters, as in color and other features, are the direct result of environmental conditions, or indicate incipient species. It would seem likely enough that there are, in fact, a number of unrecognized subspecific types among the centrarchids, and the individual variability noted may be due in large part to the crossing of such types, which have remained distinct only as long as isolated.

The following systematic treatment mainly follows the lines of Jordan & Evermann's work:

Subfamily CENTRARCHINÆ.

Scales strongly ctenoid, the ctenoid patch very broad, though the teeth are very small; basal radii about 8 to 12; apical circuli quite dense ..... *Centrarchus macropterus* (Lacépède) Dismal Swamp
Scales cycloid or with a small ctenoid patch; apical circuli dense, not differing from the lateral ones... 1
1. Scales yellowish, about as long as broad; basal radii 6 to 12..... *Pomoxis annularis* Rafinesque, Neosho River, Mo., and *P. sparoides* (Lacépède) New Orleans, La.
Scales white, broader than long; basal radii 12 to 14..... *P. sparoides* Sodus Bay, N. Y., and St. Croix River, Douglas Co., Wis., the latter from Dr. Grænicher.

Are there northern and southern races of *P. sparoides*?

Subfamily LEPOMINÆ.

Tribe AMBLOPLITINI. (Pl. XXXVII, fig. 29, 30.)

Strictly cycloid, but the apical circuli widely spaced, and more or less strongly undulate or zigzag, as in Gerridæ.....*Acantharchus pomotis* (Baird), Tarboro, N. C.
Sharply ctenoid when young, but margin cycloid in adults.....*Ambloplites rupestris* (Rafinesque)
With a small variously developed ctenoid area.....*Chænobryttus gulosus* (Cuvier & Valenciennes)
Very strongly and coarsely ctenoid.....*Archoplites interruptus* (Girard)

Thus *Centrarchus* stands at the base of the Centrarchinæ, and *Archoplites* at the base of the Ambloplitini.

Tribe LEPOMINI. (Pl. XXXVII, fig. 28.)

For the pharyngeal characters, see Bean & Weed, Proceedings United States National Museum, volume 40, pages 369–376. On the scale characters, *Enneacanthus* stands at the base of this series.

Scales strongly ctenoid.....*Enneacanthus gloriosus* (Holbrook)
Scales moderately ctenoid, not so broad as those of *Enneacanthus*.
Mesogonistius chætodon (Baird) Trenton, N. J.
Scales feebly ctenoid, rarely practically cycloid, with no generic difference from the last, except that they are usually less ctenoid and have fewer basal radii.....*Lepomis*

It seems impossible to make any key for the scales of the species of *Lepomis; L. gibbosus, cyanellus, punctatus, auritus* and some *euryorus* have the apical circuli more widely spaced than in the others. The species examined are *L. cyanellus, punctatus, symmetricus, auritus, megalotis, pallidus, albus, heros, holbrooki, euryorus, gibbosus.* The scale of *L. megalotis* (Lake Maxinkuckee, Ind.) is quite broad, with up to 12 basal radii, a larger number than is usual in the genus.

Subfamily MICROPTERINÆ. Black basses.

The genus *Micropterus* has been discussed above. The scales are the largest found in the Centrarchidæ, but *Ambloplites* runs them close. *Ambloplites* differs from *Micropterus* in having the adult scales conspicuously broader than long, with denser apical circuli. It is a question whether *M. salmoides* should not be called *Aplites salmoides*, or *Aplites* Rafinesque at least used in a subgeneric sense.

The following arrangement of the centrarchid genera is suggested: *Centrarchus, Pomoxis; Aplites, Micropterus; Archoplites, Chænobryttus, Ambloplites, Acantharchus; Enneacanthus, Mesogonistius Lepomis.*

APHREDODERIDÆ. Pirate perches.

Subfamily APHREDODERINÆ.

Aphredoderus sayanus Gilliams. Houston, Tex. (Evermann). Scales about 2⅓ mm. long and 1⅔ broad, parallel-sided, with four very deep basal plications, the basal margin strongly scalloped; apical margin with a row of about 25 to 30 very long teeth, free only at apex; nucleus subapical; nuclear area with fine labyrinthiform markings; lateral circuli widely spaced, but with rudiments of others between them. This is very different from *Percopsis*, though agreeing in having a single row of apical teeth. Except for the ctenoid feature, there is a rather strong resemblance to *Lucius*. In the character of the ctenoid fringe, there is much resemblance to the ctenoid Characinidæ of Africa. The ctenoid structures in *Percopsis* and *Aphredoderus* are quite different from those in *Perca*, but a fairly intermediate type occurs in *Pomacanthus arcuatus* (Linnæus).

Subfamily TRICHOPHANINÆ.

Trichophanes foliarum Cope, from the Miocene shales of Florissant, Colo., has been discussed and figured in the American Naturalist, volume XLII, pages 570–574. It is there regarded as the type of a distinct family, but I now believe that it deserves only subfamily rank. The scales have a subapical

nucleus, very coarse concentric circuli, and about 15 or more very long and strong sharp spines along the apical margin. Thus the scales agree in all essential features with those of *Aphredoderus*, and in their marginal teeth closely resemble *Xenochares* and *Distichodus* in the African characinid fauna.

The Aphredoderidæ seem quite out of place next to the Centrarchidæ. Jordan says of them: "Probably the most primitive of all living Percoid fishes, showing affinities with the Salmopercæ." *Aphredoderus* "agrees with the Berycoid fishes in scales and structure of the fins, and Boulenger places it with the Berycidæ." However, the resemblance to the berycoid scales is remote. In the Aphredoderidæ the apical teeth are articulated, as it were, on the margin, and in both the living and fossil fishes are movable. In the berycids they are instead rigid projections on the marginal area, into which they are basally prolonged.

Regan has recently referred the Aphredoderidæ to the Salmopercæ.

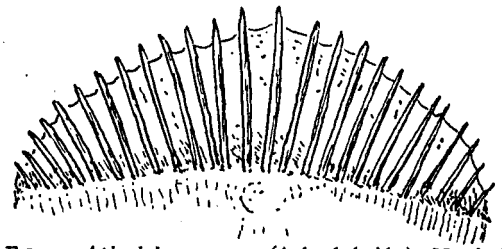


FIG. 13.—*Aphredoderus sayanus* (Aphredoderidæ). Marginal teeth. Bureau of Fisheries.

KUHLIIDÆ.

Kuhlia rupestris (Cuvier & Valenciennes) from Mauritius (M. C. Z. 5710) has rather large subquadrate scales, about 10 mm. long and broad, the laterobasal corners rectangular, and the lower margin nearly straight. The nucleus is about 6 mm. from the base; apical region typically ctenoid, of the usual Percoid type, the apical teeth numerous and sharp, the submarginal elements truncate (style of *Lagodon* in Sparidæ); basal radii delicate, about eleven. This agrees very well in general type with *Lucioperca*.

PERCIDÆ. Perches.

The typical percid scale is subquadrate, ctenoid, with nucleus apicad of the middle, and strong basal radii. The American subfamilies are separated on the scales as follows:

Basal radii many or few (e.g., 20 in some *Hypohomus*, 6 in some *Boleosoma*); basal margin not very deeply crenate; submarginal apical elements short and broad.....Etheostominæ
Basal radii few; submarginal apical elements quadrate; scales larger 1
1. Basal margin very deeply crenate.....Percinæ
Basal margin not very deeply crenate.....Lucipercinæ

In the Old World we find the following subfamilies:

Basal margin very deeply crenate or lobed; dorsal fins distinct; no canine teeth (*Perca*)...Percinæ
Basal margin moderately crenate or lobed..... 1
1. Submarginal apical elements short and broad; marginal teeth long (*Zingel*).....Etheostominæ
Submarginal apical elements longer, more quadrate; marginal teeth usually shorter..... 2
2. Dorsal fins distinct (and other characters).....Lucipercinæ
Dorsal fins united (etc.).....Acerininæ (*Acerina*)

I have not examined the genus *Percarina*.

In spite of the great development of Percidæ in North America, the group must surely have originated in the Old World, because (1) it is more varied in type there, and (2) it is more difficult to separate the European subfamilies than the American on their scales. However, the palæontological evidence indicates considerable antiquity for the percids both in Europe and America, and even if it is true that the living American subfamilies are of Old World origin, this does not prove anything regarding the history of the much older forms known as fossils.

The *Lucioperca-Acerina* type of scale is doubtless the primitive one in the family. It is difficult to find much difference between the scales of these genera, so different in other respects; but in *Acerina* the submarginal apical elements are more conspicuously broadened basally, approaching the condition

of the Etheostominæ very noticeably, whereas in *Lucioperca* they are more nearly as in *Perca*. This character varies, however, in *Lucioperca*, and in *L. sandra* Cuvier & Valenciennes, from the Danube, the submarginal elements are quite short. *L. volgensis* Pallas, from Astrachan, has the submarginal elements conspicuously elongated. Boulenger unites the American *Stizostedion* with *Lucioperca*, and it is impossible to find any substantial difference in the scales. Curiously, the pike perch, *Stizostedion vitreum* (Mitchell) from Cedar Point, Toledo, Ohio, has the submarginal elements elongated as in *L. volgensis;* while *S. canadense* (C. H. Smith) from Big Sycamore Creek, Tenn., has them short as in *L. sandra.*

The species of *Acerina* examined are *A. cernua* Linnæus (Danube River and Switzerland) and *A. schrœtser* Linnæus. I can not separate them on the scales. *Acerina acerina* (*Perca acerina* Gmelin) I have not seen. The genus *Zingel* Cloquet includes *Z. zingel* Linnæus, *Z. asper* (Linnæus) and *Z. streber* (Siebold), unless we follow Jordan, and recognize a second genus (*Aspro* Cuvier & Valenciennes) for the second and third of these. I have *Z. zingel* and *Z. streber.* The scales of *Z. streber,* at least in my material, are smaller and shorter, otherwise there is no appreciable difference. Scales of *Z. zingel* (fish 10¼ inches long) are about 4 mm. long and 3½ broad, therefore much larger than any of the American Etheostominæ, the largest of which are less than 2 mm. long. In the larger American scales (*Percini* and *Diplesion*) the basal radii are much stronger than in *Zingel,* and more parallel. Jordan remarks that *Zingel* is perhaps the ancestor of the entire group of Etheostominæ.

Of *Perca* I have the three known species, European perch, *P. fluviatilis* Linnæus, from Sweden; American perch *P. flavescens* (Mitchell), from Lyndonville, Vt., and Falmouth, Mass.; *P. schrenkii* Kessl from Khuldscha. *P. fluviatilis* (fish 17 inches long) has large reddish scales, fully 10 mm. long, with six basal radii; basal margin deeply cut into long lobes; apical teeth short; subapical elements quadrate, but not elongated. *P. flavescens* (fish 6 inches long) has colorless scales about 4 mm. long; six basal radii; lobes of basal margin not so long; apical teeth short; subapical elements distinctly elongated. In *P. schrenkii* the scale is about the same size as that of *P. flavescens,* but longer, and broader above the middle than at the base, the reverse being conspicuously true of *P. flavescens.* The basal radii are three to six, and the lobes of the basal margin are shorter than in either of the other species. The apical marginal elements are distinctly elongated. Scales of *P. schrenkii* are readily known from those of *Lucioperca volgensis* by their peculiar form, narrowing below (basad), the shorter apical teeth, and the much more strongly crenate base.

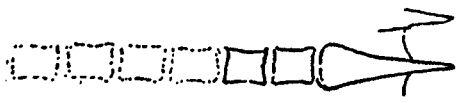


FIG. 14.—*Perca flavescens* (Percidæ). Ctenoid structures. Bureau of Fisheries.

It seems quite impossible to make a key to the genera or species of American darters, Etheostominæ. I give a list of the species studied, with some notes.

Percina caprodes (Rafinesque), log perch. Chili, Ind. Scales about 1½ (some 1¾) mm. long, and about as broad; about 6 to 10 basal radii; apical teeth long.

Hadropterus phoxocephalus (Nelson). Durkey's Ferry, Wabash River, Ind.

H. macrocephalus (Cope). Obeys River, Olympus, Tenn.

H. aspro (Cope & Jordan), black-sided darter. Upper Eel River, Allen Co., Ind.

H. guntheri (Eigenmann & Eigenmann). Cheyenne River, Valley City, N. Dak.

H. peltatus (Stauffer). Neuse River, Raleigh, N. C.

H. ouachitæ (Jordan & Gilbert). Marked Tree, Ark.

H. scierus Swain. Tippecanoe River, Marshland, Ind.

H. roanoka (Jordan & Jenkins). Neuse River, Raleigh, N. C. "Cotype."

H. maxinkuckiensis Evermann. Lake Maxinkuckee, Ind.

All have small scales with quite long apical teeth. They differ in size; thus *H. macrocephalus* has scales hardly over 1 mm. long, while *H. peltatus* has them fully 1.5 mm., the fishes in each case being 3 inches long. *H. peltatus* and *scierus* have scales of about the same size, but the apical teeth are distinctly longer in *scierus.*

Hypohomus spilotus (Gilbert). Hector Creek, Ky. (Woolman). Scales known from those of *Hadropterus* by the very large number of basal radii.

Cottogaster uranidea (Jordan & Gilbert). Vincennes, Ind.

C. copelandi (Jordan). Iowandi, Ky.

C. shumardi (Girard). Durkey's Ferry, Wabash River, Ind.; also Wabash River, Ind. (Evermann).

C. cheneyi Evermann & Kendall. Rackett River, N. Y. "Cotype." This genus has small scales like those of *Hadropterus*, with the basal radii only moderately numerous (e. g., 9 or 10), but the scales are conspicuously broader than long, averaging considerably shorter than those of *Hadropterus*.

Ulocentra stigmæa (Jordan). Obeys River, Olympus, Tenn.

U. gilberti Evermann & Thoburn. Walker's Ford, Clinch River, Tenn. "Cotype."

U. meadiæ Jordan & Evermann. Indian Creek, Tenn. "Cotype."

U. histrio (Jordan & Gilbert). Black Rock, Rock River, Ark.

U. simotera (Cope). Mount Verde, Tenn.

U. "probably new." Arnwine Creek, Athens, Tenn. 2¾ inches long.

Ulocentra has broad scales like those of *Cottogaster*, but the basal radii are more numerous (generally about 12), and the apical teeth are shorter, usually very short. *U. stigmæa* has very broad scales, some almost twice as broad as long, whereas in *U. gilberti* they are mostly not greatly broader than long.

Diplesion blennioides (Rafinesque), green-sided darter. Murfreesboro, Tenn., 5 inches long. Scales 1½ mm. long and broad, with long apical teeth and about a dozen basal radii. The scales are larger than those of *Ulocentra*, *Cottogaster*, etc., but so is the fish. I can not satisfactorily distinguish *Diplesion* scales from those of *Percina*.

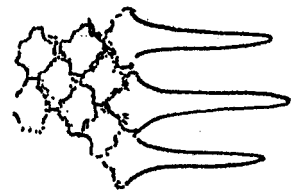


FIG. 15.—*Cottogaster shumardi* (Percidæ). Ctenoid structures. Bureau of Fisheries.

Boleosoma longimanus (Jordan). Lexington, Va.

B. podostemone (Jordan & Jenkins). Roanoke River, Va. "Cotype."

B. nigrum (Rafinesque). Osterville, Mass., and Columbia City, Ind.

In this genus the scales are broader than long, with about a dozen basal radii.

Crystallaria asprella (Jordan). Wabash River, Ind. 3 inches long; extremely small, rather broad scales, with long apical teeth.

Ammocrypta pellucida (Baird), sand darter. Adamsboro, Ind. 3 inches long.

A. beanii Jordan. Greenville, Ala. 2¾ inches long. The scales of this genus are also extremely minute, almost rudimentary.

Ioa vitrea (Cope). Raleigh, N. C. Scales minute, with long apical teeth; the principal character is found in the very widely spaced lateral circuli. The last three genera are the weakest scaled in the family.

Etheostoma. In this large genus the scales are of the same type as those of related genera, with pigment spots along the bases of the apical teeth, such as are found in other American Etheostominæ, in *Zingel*, and even in *Acerina cernua*. The basal radii vary from 9 (*zonale*, *flabellare*) to 16 (some *pottsii*, *juliæ*, and *iowæ*). In some species the scales average about as broad as long (*punctulatum*), in others they are conspicuously broader than long (*juliæ*, *pottsii*), but in no case are they longer than broad, if we take scales from the middle of the side and measure only to the bases of the apical teeth. In some the scales are comparatively large (*variatum*), in others very small (*flabellare*). After measuring what seemed to be fair average scales of each species, I have thrown my results into the following key, but it must be clearly understood that while it is indicative of general tendencies or types, it is not at all reliable for the determination of the species.

The following abbreviations are used: long., lat., length and breadth; ap., length of longer apical teeth; b. r., number of basal radii; measurements all in microns, except the length of the fish.

A. Length of scale less than 800.

a. Breadth of scale same as length.

E. flabellare Rafinesque, fan-tailed darter (1 inch). Cumberland Gap, Tenn.; long. and lat. 590; lateral radii very widely spaced; 9 b. r.

E. punctulatum (Agassiz) (1 inch). Marshfield, Ind.; long. and lat. 655; ap. 95; 10 b. r.

b. Breadth of scale much greater than length.

i. Scale very broad; pigment spots along margin light brown.

E. lepidum (Baird & Girard) (1½ inch). New Braunfels, Tex.; long. 770, lat. 1150; 12–14 b. r.

ii. Scale moderately broad.

E. australe Jordan. (1½ inch). Chihuahua, Mexico; very widely spaced circuli around nucleus; long. 775, lat. 935; ap. 95; 12 b. r.

E. camurum (Cope) blue-breasted darter (2¾ inches). Marshland, Ind.; long. 705, lat. 880; ap. 95; 10 b. r.

E. tippecanoe Jordan & Evermann (2 inches). Marshland, Ind.; long. 750, lat. 865; 9–12 b. r.

B. Length of scale 800 to 1,040.

a. Scale about as broad as long.

E. cragini Gilbert (1 inch). Garden City, Kansas; "cotype"; long. 815, lat. 830; ap. 95; 12 b. r.

E. jessiæ (Jordan & Brayton). Long. 1040, lat. 1055; ap. 145; 11–14 b. r.

E. whipplii (Girard). (1½ inch). Kaimishi, I. T.; long. and lat. 800; 10–11 b. r.

b. scale evidently broader than long.

i. Basal radii 9.

E. zonale (Cope) (1¾ inch). Cumberland Gap, Tenn.; long. 990, lat. 1090.

ii. Basal radii more than 10.

E. iowæ Jordan & Meek. Creighton, Nebr.; long. 800, lat. 1040; ap. 80; 14–16 b. r.

E. obeyense Kirsch (1¼ inch). Cumberland River, Wayne County, Ky.; long. 865, lat. 945; ap. 95; 11–13 b. r.

E. pottsii (Girard). (1¾ inch). Chihuahua, Mexico; long. 960, lat. 1250; 15–16 b. r.

E. juliæ Meek. Springfield, Mo.; long. 1040, lat. 1295; 13–16 b. r.

E. boreale (Jordan) (2¼ inch). Michigamme, Mich.; long. 925, lat. 1010 (another, long. 880, lat. 925); 12–14 b. r.

C. length of scale over 1040.

a. Length of scale 1490, breadth the same.

E. variatum Kirtland (2 inches). Blue River, Wyandotte Cave, Ind.; 11 b. r.

b. Length of scale not over 1330.

E. swannanoa Jordan & Evermann (1½ inch). Black Mountain, N. C.; long. 1055, lat. 1280; 10–13 b. r.

E. squamiceps Jordan (1¼ inch). Murfreesboro, Tenn.; circuli around nucleus not very widely spaced; long. 1310, lat. 1375; ap. 72; 14 b. r.

E. jordani Gilbert (2 inches). Oxford, Ala.; "cotype;" circuli around nucleus very widely spaced; long. 1170, lat. 1360; ap. 110; 9–12 b. r.

E. cinereum Storer (3½ inches). Olympus, Tenn.; long. 1330, lat. 1345; ap. 128; 12 b. r.

E. coeruleum Storer, blue darter. (1½ inch). Neosho, Mo.; long. 1120, lat. 1440; ap. 145; 11–15 b. r.

E. rufilineatus (Cope) (2¾ inches). Knoxville, Tenn.; long. 1150, lat. 1200; ap. 145; 13 b. r.

It will be observed that there is very little correspondence between this arrangement and the subgenera recognized by authors. It is certain that the scales are of very minor value in the taxonomy of this group, and no doubt individual variation oversteps most of the limits suggested by my data. At the same time there are good average differences between several of the species; thus, when we compare the species, *E. pottsii* and *E. australe*, both from Chihuahua, it is evident that *pottsii* has larger and broader scales, and the difference is greater than can be accounted for by the somewhat larger size of the fish. It is probable that if statistical studies are made of numerous scales, some help will be obtained for the separation of closely allied species.

Psychromaster tuscumbia (Gilbert & Swain). Tuscumbia, Ala. Scales broader than long, not differing from those of *Etheostoma*.

Boleichthys fusiformis (Girard). St. Francisco River, Ark. Scales broader than long, like those of *Etheostoma*, with prominent rectangular laterobasal corners; basal radii about 12 to 14.

Microperca punctulata Putnam. Lake Maxinkuckee, Ind. Scales very small, conspicuously broader than long (length about 765 μ, breadth 1040); about 11 to 14 basal radii. Easily known from *Boleichthys* scales by the smaller size and obtuse laterobasal corners.

M. fonticola (Jordan & Gilbert). San Marcos, Tex. Scales like those of *M. punctulata*.

For the North American percid scales described above I am indebted to the Bureau of Fisheries, and for the European species to the National Museum, in each case through Dr. H. M. Smith.

In general, the scales of the Percidæ are quite distinct from those of the Centrarchidæ, though of the same essential character. The scales of the two families approach in such genera as *Archoplites* and *Lucioperca* (*L. sandra*), but in the *Archoplites* the nucleus is not so far apicad as in the other.

THE VALIDITY OF BOLEOSOMA OLMSTEDI (STORER), AS INDICATED BY ITS SCALES.

BY T. D. A. COCKERELL AND MARY ESTHER ELDER.

We recently received from the Bureau of Fisheries some scales of *Boleosoma olmstedi* (Storer), a form which has been treated as a subspecies of *B. nigrum*, but which Dr. W. C. Kendall believes to be a valid species. It was suggested that perhaps the scales might

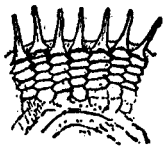


FIG. 16.—*Boleosoma nigrum*. Apical margin.

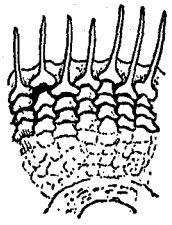


FIG. 17.—*Boleosoma podostemone*. Apical margin.

FIG. 18.—*Boleosoma olmstedi*. Apical margin. From specimen $3\frac{1}{8}$ inches long.

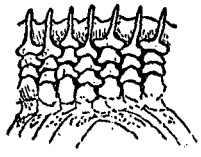


FIG. 19.—*Boleosoma olmstedi*. Apical margin. From specimen $1\frac{5}{8}$ inches long.

afford characters which would throw light on the question of the distinctness of *B. olmstedi*. We hardly expected positive results, on account of the undoubted affinity of the fishes, but a study of the material shows that, at least so far as our material goes, the scales of *B. nigrum* and *olmstedi* are readily separable. The observed difference can not well be a matter of age, as *olmstedi* scales were examined from fishes $1\frac{5}{8}$ inch and $3\frac{1}{16}$ inches, respectively, while the *B. nigrum* scales came from a fish $2\frac{1}{4}$ inches long. We also took occasion to compare scales of *B. podostemone* (cotype fish, $1\frac{3}{4}$ inches long), and found good characters to distinguish them from those of the others. The scales of the three may be diagnosed as follows:

(1) *Boleosoma nigrum* (Rafinesque). Columbus City, Ind. Apical teeth rather long, the greater part free from the marginal membrane; subapical elements below the teeth transversely elongated, and usually in four rows.

(2) *Boleosoma podostemone* (Jordan & Jenkins). Roanoke River, Va. Apical teeth very long, the greater part free from the marginal membrane; subapical elements below the teeth in two or three distinct rows, subtriangular in form.

(3) *Boleosoma olmstedi* (Storer). Falmouth, Mass. Apical teeth moderate, less than half free from the marginal membrane; subapical elements below the teeth in two or three distinct rows, subtriangular.

APOGONIDÆ. Cardinal fishes.

In *Apogonichthys pomaræ* Steindachner from the Society Islands (M. C. Z. 9698), the reddish scales are much broader than long, length about 4½, breadth about 5¼ mm.; general character percoid; 12 to 16 basal radii; laterobasal corners obtuse; lateral circuli numerous, oblique, running to the margin; apical teeth moderate; submarginal elements longer than broad, emarginate basally. Differs at once from *Lucioperca, Centropristes*, etc., by the oblique lateral circuli. The beginning of this obliquity is seen in *Percichthys*.

SERRANIDÆ. Sea basses. (Pl. XXXVII, fig. 32.)

The North American genera examined can be divided into subfamilies as follows:

Serraninæ (*Paralabrax, Centropristes*). Apical marginal spines truncate.

Epinephelinæ (*Epinephelus*). Apical marginal spines obtusely pointed, margined. Scales much longer than broad.

Moroninæ (*Morone, Roccus*). Apical marginal spines pointed or (adult *Morone*) minutely bifid at tip. *Roccus* is easily separated from *Morone* by the very numerous basal radii.

Another subfamily (Percichthyinæ) must be recognized for the freshwater genus *Percichthys* Girard, in which the adult scales are longer than broad, parallel-sided, with the broadly rounded apical margin entire, although there is a submarginal ctenoid patch, beset with spines.

Still another subfamily (Plesiopinæ) must contain *Plesiops* Cuvier, of which I have *P. corallicola* from the Ebon Islands (M. C. Z., 2473). The scale is 7 mm. long and 6½ broad, the exposed part covered with dark purplish skin. Laterobasal angles obtuse; nucleus in the submarginal apical region, and from it radiate about 15 long basal radii; lateral circuli dense, slightly oblique; apical marginal teeth slender, more or less obtuse or truncate at end; subapical elements narrow and elongate. This is nearer to *Centropristes* than to any of the other scales cited above. A lateral line scale of *P. corallicola* is curiously different, with the nucleus much further down, and having strong apical as well as basal radii Boulenger makes *P. corallicola* a synonym of *P. nigricans* (Ruppell).

Scales of *Aulacocephalus schlegelii* Günther (*A. temminckii* Bleeker) are figured by Sauvage in his work on the fishes of Madagascar. They somewhat approach those of *Epinephelus*.

Subfamily PERCICHTHYINÆ. The truchas.

My material of this group is from the United States National Museum.

Percosoma melanops (Girard). Santiago, Chile; 4⅞ inches long. Scales reddish, about 3 mm. long and 2 broad; parallel-sided, with the laterobasal corners more or less projecting downwards; nucleus about 2 mm. from base; 6 to 9 basal radii; lateral circuli coarse, somewhat oblique; ctenoid patch very variable in size, with long narrow elements, some of which occasionally project as spines over the margin.

Percichthys trucha (Cuvier & Valenciennes). South America; 12¼ inches long. Scales reddish, the larger ones about 5¼ mm. long and 4¾ broad; nucleus about 3 mm. from base; basal margin slightly convex, delicately crenate; apical field as in *Percosoma*. In latinucleate scales there is no ctenoid patch, and the widely spaced apical circuli run right across, parallel with the broadly rounded margin.

A young fish, 5¼ inches long, from Argentina, has scales less than 2 mm. long, but still without projecting apical spines.

Although this fish is closely allied to *Percosoma*, the latter is readily separated by the long and narrow scales.

Percichthys chilensis (Girard). Santiago, Chile; 7¾ inches long. Boulenger makes this a synonym of *P. trucha*, and the scales seem the same, though the basal radii may average somewhat less.

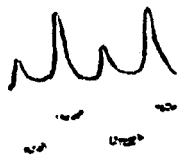
Subfamily SERRANINÆ. Sea basses. (Pl. xxxvii,fig. 31.)

The following have been examined:

Centropristes striatus (Linnæus), black sea bass. Woods Hole, Mass. Scales subquadrate, about 8 mm. long and broad; ctenoid area very beautifully developed; apical teeth truncate and often broadened at base; nucleus subapical; basal radii 9 or 10; lateral circuli running parallel with margin.

Paralabrax maculofasciatus (Steindachner), spotted cabrilla. Guaymas, Mexico (Albatross). Scales about 4 mm. long and 2¾ broad, the long, parallel-sided form very different from that of *Centropristes;* basal radii 8 to 11.

FIG. 20.—*Epinephelus niveatus* (Serranidæ). Ctenoid structures. Bureau of Fisheries.



Young.

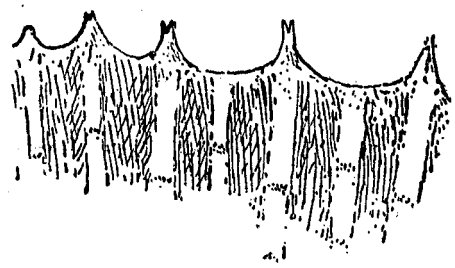


FIG. 21.—*Morone americana* (Serranidæ). Ctenoid structures. Bureau of Fisheries.

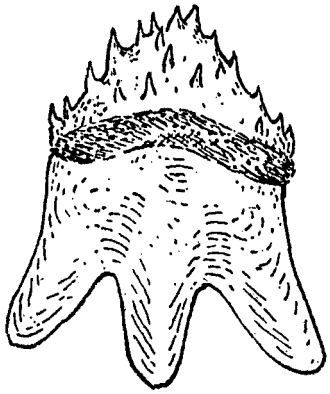


FIG. 22.—*Priacanthus* (Priacanthidæ). Bureau of Fisheries.

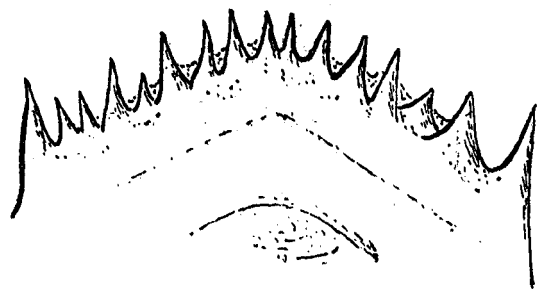


FIG. 23.—*Pscudopriacanthus altus* (Priacanthidæ). Bureau of Fisheries.

Paralabrax clathratus (Girard), cabrilla. San Diego Bay (Albatross). Scales similar, but smaller, and somewhat broader in proportion to their length. In both species of *Paralabrax* the scales are white; the finely mottled skin has the pigment light ferruginous in *P. maculatofasciatus*, purplish-brown in *P. clathratus*.

Subfamily EPHINEPHELINÆ. Groupers.

Epinephelus niveatus (Cuvier & Valenciennes), snowy grouper, from Katama Bay, has scales which remind one of *Paralabrax*, but the basal radii are only 4 to 6, and the apical area is quite different, with the spines much reduced in number, but larger.

Subfamily MORONINÆ. White perches.

The characters of *Roccus* and *Morone* are given in the table of Acanthopterygian scales on an earlier page.

LOBOTIDÆ. Flashers.

The flasher, *Lobotes surinamensis* (Bloch) has large subquadrate reddish scales, which resemble those of *Roccus* in the very numerous basal radii. Other characters are given in the table just cited.

PRIACANTHIDÆ. Catalufas.

Two subfamilies may be distinguished as follows:

Priacanthinæ (*Priacanthus*). Scales very strongly trilobed at base; apex produced, with irregularly placed teeth.

Pseudopriacanthinæ (*Pseudopriacanthus*). Scales quadrate (the apical margin produced to an obtuse angle), the base not at all trilobed, but its middle third crenate from the 5 or 6 basal radii; marginal teeth sharp and irregular, but not so irregular as in *Priacanthus*.

All the specimens examined are from Woods Hole, Mass. The *Pseudopriacanthus* is *P. altus* (Gill). The *Priacanthus* is presumably *P. arenatus* Cuvier & Valenciennes, with which it agrees in fin rays, color of fins, etc., but it has a large serrate preopercular spine, as in *P. cruentatus* (Lacépède).

LUTIANIDÆ. Snappers.

The scale of the gray snapper, *Neomænis griseus* (Linnæus), from Tampa, Fla., has been figured in Proceedings of the Biological Society of Washington, volume XXIII, page 91. The mutton fish, *N. analis* (Cuvier & Valenciennes) is included in the table of Acanthopterygian scales above. The scale of *N. griseus* figured was much worn, and had lost the apical teeth, but the figure shows well the numerous basal radii, the lateral circuli running parallel with the margin, etc.

HÆMULIDÆ. Grunts. (Pl. XXXVII, fig. 33.)

In the pigfishes, *Orthopristis*, the marginal teeth are truncate; in the grunts, *Hæmulon*, and the burritos, *Brachydeuterus*, they are pointed. From these and other characters perhaps two subfamilies (Orthopristinæ and Hæmulinæ) may be indicated. Jordan & Evermann say of the Hæmulidæ: "The group is very close to the Lutianidæ on the one hand and to the Sparidæ on the other, while some of its members show affinities with some Sciænidæ and Serranidæ." In its scales *Orthopristis* resembles some Sciænidæ, as the croakers *Micropogon*.

The scale of *Anisotremus virginicus* (Linnæus) is figured in Proceedings of the Biological Society of Washington, volume XXIII, page 92.

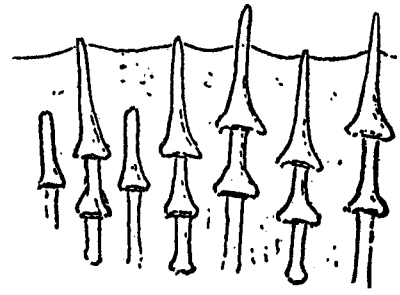


FIG. 24.—*Neomænis analis* (Lutianidæ). Bureau of Fisheries.

SPARIDÆ. Porgies.

I have examined scup, *Stenotomus chrysops* (Linnæus) from Woods Hole, Mass., and pinfish, *Lagodon rhomboides* (Linnæus). Both have large scales, those of *Lagodon* quadrate, about as broad as long, those of *Stenotomus* much broader than long. The broad apical field has the usual Acanthopterygian sculpture feebly indicated, but only the margin is distinctly sculptured, with the well-formed elements in two (*Stenotomus*) or three (*Lagodon*) rows. This condition leads in the direction of that found in the Gerridæ. The basal radii are 12 in *Lagodon*, 13 or fewer in *Stenotomus*. The apical structure is nearly as in the coral fishes, Pomacentridæ, while both resemble the surmullets, Mullidæ. The scale of *Lethrinus*, as figured by Günther, has very well-developed sculpture in the apical field, with 13 or 14 rows of minute teeth.

In *Box vulgaris* (Vienna Museum; M. C. Z.) the scales are about 3¼ mm. long and 5¼ broad, with the nucleus central and about 10 widely spreading basal radial folds. This is much like *Stenotomus*, differing in the less apical nucleus; the sloping sides, making the lower margin the broadest part; the broad apical region with the small quadrate elements distinct over the greater part, with no marked difference between the marginal and submarginal ones; and the much more oblique lateral circuli. (Pl. XXXVIII, fig. 34.)

Dr. G. A. Boulenger kindly collected for me scales of *Dentex vulgaris* Cuvier, from a fish 2 feet 10 inches long, in the Grimsby Market. The scales vary very much in size and form; a large one is about 21 mm. long and 27 broad; an unusually broad one is about 13 mm. long and 21 broad; another is 15½ long and 18 broad. These all come from the side of the fish. The circuli are excessively fine, and the lateral ones are little oblique, whereas in *Box* they are extremely oblique, reaching the margin at a large angle. The basal radial system is variably and often poorly developed, and the radii are not very numerous. The apical margin appears cycloid, but the apical field has a fine half obliterated honey-comb-like

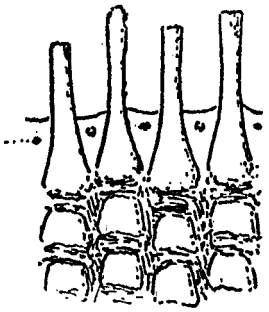


FIG. 25.—*Orthopristis chalceus* (Hæmulidæ). Ctenoid structures. The spots between the teeth are ferruginous pigment spots. Bureau of Fisheries.

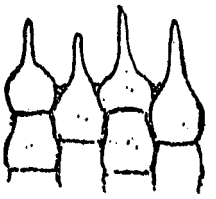


FIG. 26.—*Stenotomus chrysops* (Sparidæ). Ctenoid structures. Bureau of Fisheries.

structure representing the ctenoid patch. Curiously, the skin over the apical field is marked with a very distinct network of polygonal cells, corresponding to the structure beneath. The nucleus is apical of the middle.

In Dr. A. S. Woodward's Catalogue of Fossil Fishes (1901), and in earlier works, *Dentex* appears among the Percidæ (sens. lat.). Dr. Woodward states that *Dentex*, *Gerres*, etc., are intermediate between the Percidæ and Sparidæ.

MÆNIDÆ. Picarels. (Pl. XXXVIII, fig. 35.)

I have the scales of an undetermined species of *Smaris* (*Spicara*) from Trieste (M. C. Z., 10436). They are about 2½ mm. long and 3⅔ broad; nucleus a little above the middle; about 10 strong widely spreading basal radii; sides sloping, so that the base is much the widest part; lateral circuli extremely oblique, but wanting in upper lateral region; apical margin strongly angled in the middle; apical marginal teeth sharp, and below them about two rows of broad subquadrate elements, below which the apical field is almost without sculpture.

This may be regarded as an extreme development of the type of *Box*. The oblique lateral circuli also suggest *Apogonichthys*, which is, however, very different in the apical region.

GERRIDÆ. Mojarras.

The "broad shad," *Xystæma cinereum* (Walbaum), from La Paz Harbor (Albatross) has transversely oval or oblong scales about 6 mm. long and 7 broad, the laterobasal corners rounded, and the basal radii few (about 5) and more or less irregularly placed. The lower margin is only feebly crenate. The thin apical field shows rudiments of the usual ctenoid structures of Acanthopterygians, reduced to

irreguiar transverse lines and small marginal denticulations. The lateral circuli are transverse, entirely in the manner of a clupeid. This last character is remarkable; a certain approach to it is found in *Stenotomus* (Sparidæ), in which the upper lateral circuli are obliquely directed outward, pointing to the anterolateral angles.

The scales of the silver jenny, *Eucinostomus gula* (Cuvier & Valenciennes), from Rio Grande do Sul, Brazil (M. C. Z., 16452) are so exactly like those of *X. cinereum* that I am at a loss to describe any difference. Scales of *E. gula* from Tampa, Fla., received from Dr. Grænicher, differ by having the apical field almost entirely covered with transverse circuli (not so dense as those elsewhere), and the ctenoid patch hardly indicated by even a rudiment. It is possible that northern and southern races of *E. gula* exist? (Pl. XXXVIII, fig. 36.)

KYPHOSIDÆ. Chopas.

The "chopa blanca" or Bermuda chub, *Kyphosus sectatrix* (Linnæus) from Menemsha Bight, Mass., shows a modified type of acanthopterygian scale, with a thickened band with hyaline dots across the middle, and the apical area having a grooved appearance. There are two rows of distinct elements on

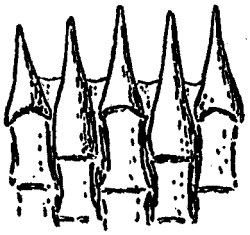


FIG. 27.—*Lagodon rhomboides* (Sparidæ). Ctenoid structures. Bureau of Fisheries.

FIG. 28.—*Kyphosus sectatrix* (Kyphosidæ). Apical teeth. Bureau of Fisheries.

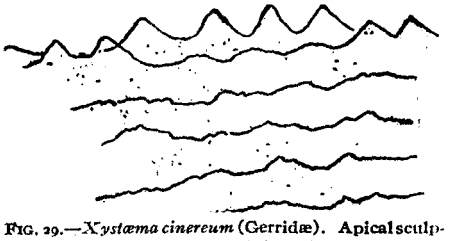


FIG. 29.—*Xystæma cinereum* (Gerridæ). Apical sculpture. Bureau of Fisheries.

the apical margin, the outermost ending in sharp teeth, and all triangular at base, approaching the condition found in *Neomænis* (Lutianidæ) and *Chætodon* (Chætodontidæ). The scales are broad-quadrate, rounded apically, with rectangular lower corners; length of scale about 5 mm., breadth about 5½. The basal radii are very few, 4 to 6. A constant peculiarity is the concavity of the sides of the apical margin. The lateral circuli are parallel with the margin.

This family is evidently not allied to the Gerridæ.

MULLIDÆ. Surmullets or goatfishes.

The characters of *Mullus*, *Upeneus*, and *Mulloides* have been given in the table of acanthopterygian scales above. In all these genera the lateral circuli are more or less oblique, and the basal radii are few.

SCIÆNIDÆ. Drums.

Two subfamilies can be separated as follows:

Otolithinæ (*Cynoscion*), the weakfishes. Elements of apical marginal and submarginal area with a median keel or ridge.

Sciæninæ (*Leiostomus, Micropogon, Menticirrhus*), the drums. Elements of apical marginal and submarginal area without any definite median keel or ridge; apical teeth pointed (*Menticirrhus*) or truncate.

The specific characters are given in the table of acanthopterygian scales above. In all the lateral circuli run parallel with the margin. The squeteague *Cynoscion regalis* is quite different from the

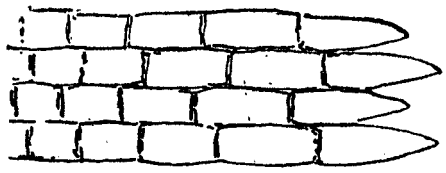


FIG. 30.—*Upeneus* (Mullidæ). Ctenoid area. Bureau of Fisheries.

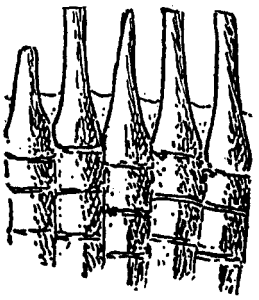


FIG. 31.—*Micropogon undulatus* (Sciænidæ). Apical teeth. Bureau of Fisheries.

others by the very numerous and densely placed basal radii, which, however, occupy only about the middle third of the scale. In all the apical elements run conspicuously in straight lines, producing a sort of fluted effect.

LATILIDÆ. Blanquellos.

In the tilefish *Lopholatilus chamæleonticeps* Goode & Bean, from the Gulf Stream, the scales are subquadrate, the larger ones about 9 mm. long and 8 broad, the laterobasal corners rectangular. Nucleus subapical; about five basal radii coming from the nucleus, but several of these are branched, and there are a few incomplete radii, so that about 13 reach the margin; lower margin crenate; lateral circuli coarse, not dense, parallel with the margin; apical ctenoid field very well developed, the marginal teeth

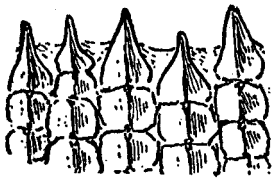
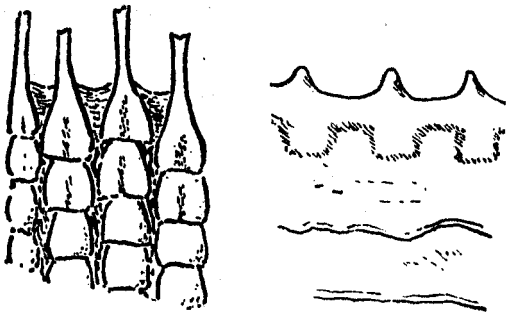


FIG. 32.—*Cynoscion regalis* (Sciænidæ). Apical teeth. Bureau of Fisheries.



A. B.

FIG. 33.—*Lopholatilus chamæleonticeps* (Latilidæ). Apical structures. A, normal scale; B, latinucleate scale. Bureau of Fisheries.

truncate. Latinucleate scales are greatly modified, and would not be recognized as coming from the same fish.

CIRRHITIDÆ. Cirrhitoids.

Cirrhitichthys maculatus Günther from the Red Sea (M. C. Z., 3686) has large broadly rounded scales, about 9 mm. long and 10½ broad, with the lower margin crenate, but otherwise straight, and the laterobasal corners rectangular. The strong basal radii are about 12 to 14. The excessively fine lateral

circuli are strictly parallel with the margin, and the apical field has coarse, widely spaced longitudinal circuli. The apical margin carries a broad band of dusky skin, and is not distinctly dentate. This is certainly a peculiar scale, but my specimens are more or less latinucleate.

Suborder KURTOIDEA.

KURTIDÆ.

The scales, according to Boulenger, are minute and rudimentary.

Suborder LABYRINTHICI.

ANABANTIDÆ. Climbing perches.

I have scales of *Anabas scandens*, from Lake Buhi, Philippine Islands, and *A. munii* from Sharb-el-Aish, Egypt; the latter from the British Museum. The characters of the Climbing perch, *A. scandens*,

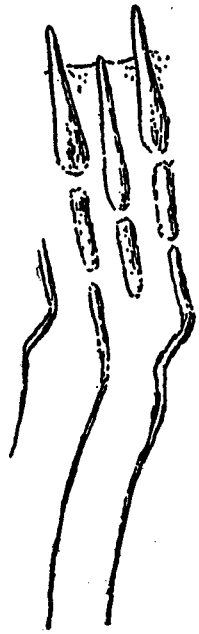


FIG. 34.—*Anabas*. The lines running downward are circuli.

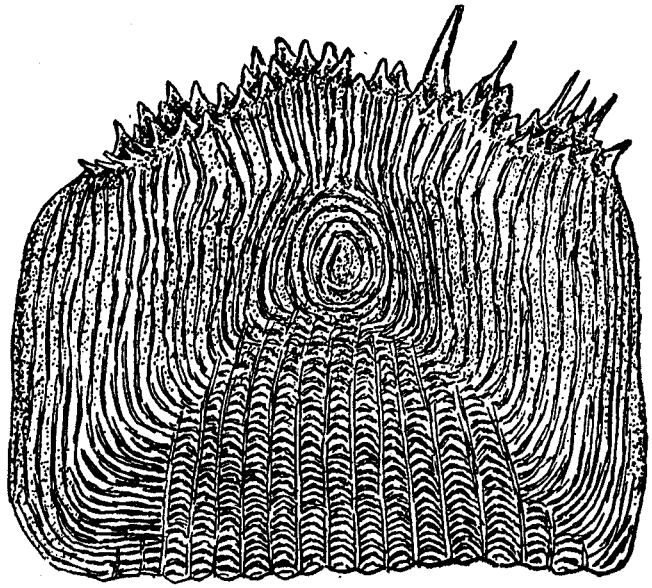


FIG. 35.—*Anabas munii* (Anabantidæ). Egypt. British Museum.

are given in the table of acanthopterygian scales above; *A. munii* scarcely differs. It is characteristic of *Anabas* that the basal circuli are dense, the lateral ones rather widely spaced, and those at the sides of the apical field strong and very far apart. The ctenoid patch is decidedly different from that of the percoids, and apparently less specialized. In *A. munii* the apical spines are broadened at base, and are singularly like those of *Aphoristia pigra*. Boulenger says the Anabantidæ are closely related to the Ophiocephalidæ, in which the scales are cycloid. Goodrich places them in a "subtribe" with the Osphromenidæ. The Anabantidæ apparently can not be derived from the percoids; they represent an early branch from the acanthopterygian stem.

Suborder HOLCONOTI. Surf-fishes.

EMBIOTOCIDÆ. Surf-fishes. (Pl. XXXVIII, fig. 37, 38.)

The material studied was all collected by the Albatross, as follows: *Zalembius rosaceus* (Jordan & Gilbert), above Santa Barbara Channel; *Amphisticus argenteus* Agassiz, St. Nicholas Island; *Phanerodon furcatus* (Girard), San Diego, Cal.; *Damalichthys argyrosomus* (Girard), Seattle, Wash. The scales are

similar, all purely cycloid, with the acanthopterygian type of basal radii. They probably represent a cycloid derivative from the ctenoid series, but they certainly can not be derived from the gerrid type I have examined. The nucleus is central or slightly above, and the basal radii are spread out fan-wise. The basal radii are about 15–19 in *Phanerodon*, 11–13 in *Damalichthys*, 9–10 in *Zalembius*, 7–10 in *Amphisticus*. The lateral circuli are angulate in *Amphisticus* and obtusely bent in *Zalembius;* in the large (8 mm. diam.) scales of *Phanerodon* the bending of the lateral circuli is evident near the middle, but becomes evanescent toward the periphery. The apical and basal circuli in *Phanerodon* are very fine and dense.

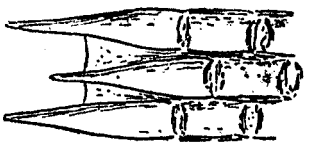


FIG. 36.—*Eupomacentrus leucostictus* (Pomacentridæ). Ctenoid structures. Bureau of Fisheries.

On comparing these scales with those of the Pœciliidæ, which appear to be primitively cycloid, it is not at first evident that there is any characteristic difference. The Pœciliids do not show the bending or angulation of the lateral circuli, and their system of basal radii is less regular and fan-like. The general facies is distinctly different, yet it is difficult to point out good diagnostic characters capable of being expressed in words. The atherinid scale, as one would expect, ranks rather with the pœciliid than the embiotocid.

Labrid and scarid scales, although cycloid, are entirely different from all these. Jordan places the Embiotocidæ in a separate suborder, Holconoti, remarking that "it contains fishes percoid in appearance, with much in common with the Gerridæ and Sparidæ, but with certain striking characteristics not possessed by any perch or bass. * * * The lower pharyngeals are solidly united, as in the Labridæ, a group which these fishes resemble in scarcely any other respects."

It seems just possible that the Embiotocidæ, although not close to the Labridæ, may agree with them in having had (as I certainly must suppose of Labridæ) no ctenoid ancestors. In this case they would apparently be distant relatives of the scombroid and atherinoid series. We have, however, in the Cichlidæ a scale development similar to that of the Embiotocidæ, and certainly from ctenoid ancestors. (Compare the scale of *Tilapia*, figured in Smithsonian Miscellaneous Collections, volume 56, no. 1.)

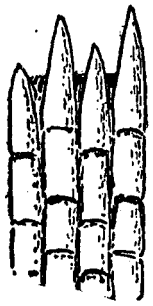


FIG. 37.—*Abudefduf saxatilis* (Pomacentridæ). Ctenoid structures. Bureau of Fisheries.

Suborder CHROMIDES

Here we return to the normal percoid type of scale.

POMACENTRIDÆ. Coral-fishes.

I have examined the cockeye pilot, *Eupomacentrus leucostictus* (Muller & Trochel), from Key West, Fla. (W. C. Kendall), and *Abudefduf saxatilis* (Linnæus), from Socorro Island (Albatross). The scales look like those of the Sparidæ. They are broader than long, those of *Eupomacentrus* being extremely broad (long. 3, lat. nearly 5 mm.). The basal radii are about 9 to 11. In both genera the lateral circuli are slightly oblique. This is a case in which the fishes have developed very marked structural characters, without any material evolution in the scales.

CICHLIDÆ. Cichlids. (Pl. XXXIX, fig. 39, 40, 41.)

The cichlid scales much resemble those of the pomacentrids, but the lateral circuli are not oblique, and the submarginal apical elements, instead of being truncate, are obtusely pointed and spinelike, herein approaching the condition of the Anabantidæ. It thus becomes possible to get an idea of the evolution of the complicated and specialized ctenoid patch of the percoids, the stages being represented more or less accurately by the Macruridæ, Anabantidæ, Cichlidæ, and Pomacentridæ, although, of course, this arrangement does not correctly represent the evolution of these particular families. It is also worthy of note that *Tilapia nilotica* (figured in Smith. Misc. Coll., 56, pl. 1, fig. 3) has exactly the anabantid type of circuli, with widely spaced coarse ones at the sides of the apical area. The middle of the apical area in *T. nilotica* is covered

with coarse granules or tubercles, and the scale appears to be strictly cycloid, but with a microscope it is possible to see minute short teeth all along the apical margin.

I give a key for the separation of the cichlid scales now before me:

Apical margin apparently cycloid, the rudimentary teeth microscopical.....*Tilapia nilotica*
Apical margin evidently ctenoid, the ctenoid patch highly developed, the elements imbricated... 1
1. Scales not greatly broader than long; elements of ctenoid area very distinct, relatively large, the submarginal ones broadened basally; basal radii 8 to 10 (Lake Hyanuary, Brazil, M. C. Z., 5285; *Cichla monoculus* Agassiz, det. Steindachner).
Chætobranchopsis ocellaris Bloch & Schneider
Scales much broader than long; elements of ctenoid area smaller..... 2
2. Nucleus much less than a third of total length from apex; scales large, about 8 mm. long and 10½ broad; basal radii about 11; basal margin very deeply crenate (Coary, Brazil, M. C. Z., 15516).....*Geophagus jurupari* Heckel
Nucleus a third of total length from apex..... 3
3. Basal radii about 11 or 12 (Rio Novo, Brazil, M. C. Z., 15739).
Geophagus brasiliensis Quoy & Gaimard
Basal radii about 16 (Lake Hyanuary, Brazil, M. C. Z., 15706)..*Chætobranchus flavescens* Heckel

On the label of the *G. brasiliensis* is a manuscript generic name proposed by Steindachner for this fish, but not published. As the fish was named by Steindachner, it is perhaps really *G. steindachneri* Eigenmann & Hildebrandt, which Steindachner confused with *brasiliensis*.

The present distribution of the Cichlidæ is much like that of the Characinidæ, except that they occur in India and Madagascar, where the characinids are absent. Their northern origin is strongly suggested by the occurrence of a genus (*Priscacara*) in the Eocene of Wyoming. This genus has ctenoid scales of the normal cichlid type, and numerous basal radii, closely placed in the central part of the scale. The character of the ctenoid area confirms the view that the genus is cichlid, not pomacentrid.

Suborder PHARYNGOGNATHI. Labroid fishes.

The Pharyngognathi are variously limited by different authors. Thus Günther (1880) includes the Pomacentridæ, Labridæ, Embiotocidæ, and Chromides. Goodrich (1909) has the same series: Pomacentridæ, Cichlidæ, Embiotocidæ, Labridæ, and Scaridæ. Jordan (1905) includes Labridæ, Odacidæ, Siphonognathidæ, Scaridæ (Scarichthyidæ). Jordan's arrangement is strongly supported by scale characters (I do not know the siphonognathid scale, however); the Günther-Goodrich series includes forms with extremely diverse scales, and is surely unnatural. The scales of the true Pharyngognathi (sens. Jordan) are characterized by the very thin apical margin, wholly without teeth, and especially the presence of apical as well as basal radii. They are thus quite unlike any other acanthopterygian scales known to me, unless they may be associated with the Atherinidæ, in which the shape and general appearance of the scale is quite different. Such atherinids as *Chirostoma crystallinum* Jordan & Snyder (Lake Chapala, Mexico; J. N. Rose) and *Menidia notata* Mitchill show weak but evident apical radii, in the *Chirostoma* leading to a strong lobulation of the apical margin. Outside of the acanthopterygian series the pharyngognath scale is strikingly similar to that of the cyprinoids.

LABRIDÆ. Wrasses.

Scales more or less elongate, parallel-sided, having the form seen in the cyprinid genus *Labeo* (see Biological Bulletin, vol. XX, pl. 1, fig. 8). The lateral line canals of *Labrichthys* are branched anteriorly, as shown by Günther. The regular basal radii in *Pimelometopon*, *Emmeekia*, and *Coris* are in the manner of the acanthopterygians. The species examined are *Coris venusta* Sauvage, Honolulu, H. I. (Jordan & Evermann); *Emmeekia venusta* (Jenkins & Evermann), Gulf of California (Albatross); slippery dick, *Iridio bivittatus* Bloch, Key West, Fla.; fathead, *Pimelometopon pulcher* (Ayres), Santa Barbara Island (Albatross); tautog, *Tautoga onitis* (Linnæus), Woods Hole, Mass.; and cunner, *Tautogolabrus adspersus* (Walbaum).

These may be separated by the following key:

Inner apical circuli usually strengthened, forming wavy longitudinal ridges; apical circuli longitudinal; apical margin broadly thin, with only shadowy indications of radii; basal radii about 8, and laterobasal (ending above the basal corners) one to four on each side; scales about 3¾ mm. long and 2 broad ..... *Pimelometopon pulcher* (subfamily Harpinæ)

Inner apical circuli not thus modified 1

1. Scale is very large and broad, yellowish; about 13-14 mm. long and 11-12 broad; basal radii numerous, usually over 20 2

   Smaller, 7 mm. or less broad 3

2. Apical radii very well developed, extending from nuclear region to apex. *Iridio bivattatus* [a] (subfamily Julidinæ)

   Apical radii very poorly developed, skin of apical region very thick. *Tautogolabrus adspersus* [a] (subfamily Labrinæ)

3. Basal radii more than 20, laterobasal (ending above basal corners) 7 to 10; apical radii numerous and close together, though imperfect; lateral circuli very dense; scale very long, about 7 mm. long and 3½ wide ..... *Coris venusta* (subfamily Julidinæ)

   Basal radii less than 20 (perhaps sometimes over 20, counting rudiments), laterobasal 1 to 7; scale not twice as long as wide [b] 4

4. Apical radii distinct; scale about 9 mm. long and 6 broad. *Emmeekia venusta* (subfamily Julidinæ)

   Apical radii indistinct or imperfect; scale about 10 mm. long and 6 broad. *Tautoga onitis* (subfamily Labrinæ)

ODACIDÆ.

The scale of *Odax lineatus*, as figured by Günther, is entirely of the labrid type, and is very like that of *Coris*.

SCARIDÆ. Parrot-fishes. (Pl. XXXIX, fig. 44.)

Scarus croicensis (Bloch) has scales differing from those of the Labridæ in being short and broad, shield-shaped, about 6 mm. long and a little less in width. Lateral and basal circuli excessively fine; basal margin broadly truncate, lobed in middle, but not in the least crenulate; basal and apical radii very well marked, but only the inner ones reaching the nucleus; there are about 16 apical and the same number basal and laterobasal; apical region papillose, but the apical margin very broadly thin and subhyaline. A very cyprinid-looking scale.

Suborder SQUAMIPINNES. Scaly-fins.

EPHIPPIDÆ. Spadefishes.

Günther has figured the scale of *Ephippus* or *Scatophagus multifasciatus*. It is represented as strongly ctenoid, with several rows of teeth; the basal radii are feebly indicated by a few broad depressions.

CHÆTODONTIDÆ. Butterfly-fishes.

I have *Chætodon ulietensis* Cuvier & Valenciennes from Apia, Samoa; *C. bricei* Smith, from Katama Bay; and *Pomacanthus arcuatus* (Linnæus). The characteristic ctenoid sculpture of these genera is shown in figures 38 and 39. The marginal teeth in *Chætodon* are very sharp, and both the teeth and the truncate submarginal elements have a specialized triangular area, shaped like a thorn, superimposed, as it were, upon their surface. All this is exactly the same in the Atlantic *C. bricei* as in the Pacific *C. ulietensis*, notwithstanding the great geographical separation.

In *C. ulietensis* the ctenoid area is very large and well-formed in all its details; the basal radii are about 17; laterobasal angles obtuse; lateral circuli very slightly oblique. (Pl. XXXIX, fig. 45.)

In the *Pomacanthus* the ctenoid region is much modified, the broad though sharp apical teeth each having a very strong rib which extends more than a millimeter basad, the successive ctenoid elements

[a] Superficially these scales look exactly alike.

[b] In young *Tautoga* scales, 5 mm. long, the length is twice the width.

having perhaps coalesced. The basal radii are weak, about 3 to 7, and the excessively dense lateral circuli are not at all oblique.

The fishes represent two subfamilies, Chætodontinæ and Pomacanthinæ.

Suborder SCLERODERMI. Hardskin fishes.

BALISTIDÆ. Trigger-fishes.

The leather jacket, *Balistes carolinensis* Gmelin, has peculiar thickened, extremely broad scales, about 3¼ mm. long and 7 broad, the apical half covered with large tubercles, which appear to be homologous with the spines of the Macruridæ. These tubercles or spines are curiously suggestive of those on

FIG. 38.—*Chætodon ulietensis* (Chætodontidæ). Ctenoid structures. Bureau of Fisheries.

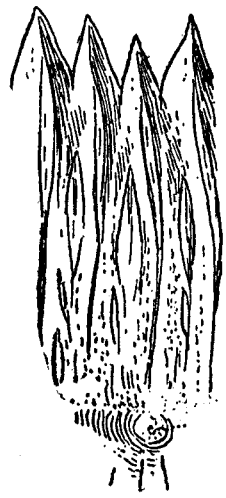


FIG. 39.—*Pomacanthus arcuatus* (Chætodontidæ). Ctenoid structures. Bureau of Fisheries.

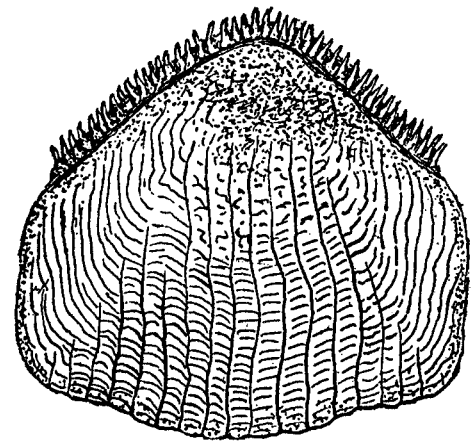


FIG. 40.—*Ctenogobius* (or *Rhinogobius*) *hadropterus*. Japan. Stanford University.

the scutes of *Acipenser*. Those along the basad margin of the tuberculate area are arranged in a regular row, which is angled in the middle, the very broad angle looking apicad. A quite different looking *Balistes* scale, with six large spines, is figured in the Cambridge Natural History, Fishes, page 191.

MONACANTHIDÆ. Filefishes.

A scale of *Monacanthus*, of the same general type as that of *Balistes*, is figured in the Cambridge Natural History, on the page just cited. The large spines are arranged much as in the macrurids (e. g., *Macrurus carminifer* Garman).

I have material of the orange filefish, *Ceratacanthus schæpfii* (Walbaum), from near Woods Hole, Mass., kindly given to me by Dr. E. Linton. The skin contains many minute spots of black pigment, and in places a fine dark blue pigment, which does not turn red in acids. The scales are shaped nearly as in *Monacanthus* and the exposed area of each has numerous large spine-like structures, one of which is much larger than the others. The concealed part of the scale is striate, with the appearance under the microscope of tree trunks closely packed, branching more or less distally.

Suborder GOBIOIDEA.

GOBIIDÆ. Gobies.

Jordan remarks that the Gobiidæ have no near relations among the spiny-rayed fishes. Günther has figured the scale of *Gobius*, and I am indebted to Dr. Jordan for material of the Japanese *Mapo fuscus* (from Tanegashima), *Ctenogobius virgatulus* (from Shiogama) and *C. hadropterus* (from Tanegashima). These fishes have basal radii as in the acanthopterygians, but the nucleus is at the very apex of the scale, and the marginal teeth form a single apical row as in the Aphredoderidæ; exactly, also, as in the ctenoid African Characinidæ. In the ctenoid African characinids the basal radii are not developed, or rather are represented by mere folds; in *Aphredoderus* they are very distinct, but not numerous; in the Gobiidæ they are very numerous and close together. In the gobiids the relatively short (though very strongly developed) apical teeth are more like those of the ctenoid characinids than those of *Aphredoderus*, and the characinid *Distichodus*, with its more or less pointed or angled apical margin, suggests the very strong angulation of that margin seen in the Gobiidæ. *Percopsis* has the apical nucleus and angled margin of the gobiids, but the marginal teeth are less developed, and the basal radii are absent.

FIG. 41.—*Leptecheneis naucrates* (Echeneidæ). Apical end to the right. Bureau of Fisheries.

The gobiid scales before me may be separated as follows:

Lateral margin (from apicolateral to basolateral angles) somewhat larger than apical margin of one side; some radii lateral (entering margin above basolateral corner); radii about 22. . *Mapo fuscus*
Lateral margin shorter or not longer than apical margin of one side; no radii lateral..... 1
1. Lateral circuli quite dense; radii about 30, some imperfect.
Ctenogobius virgatulus Jordan & Snyder
Lateral circuli not dense; radii about 14, some imperfect.
Ctenogobius hadropterus Jordan & Snyder

Latinucleate scales are common and are of course much modified, though they retain the characteristic margin.

Suborder DISCOCEPHALI.

ECHENEIDÆ. Remoras.

I had examined the shark sucker, *Leptecheneis naucrates* (Linnæus), collected at Woods Hole, Mass., and concluded that there were no scales. Dr. E. Linton, who was working on the parasites of this fish, suggested that scales might be found in the skin, and so it proved. The completely embedded scales have an elongate-lanceolate form, pointed or obtuse at the ends, length about 2½ mm. The sculpture consists only of rather widely spaced concentric circuli. No other similar scale is known to me, though in the matter of sculpture (though not at all in form) the scales substantially agree with those of *Lota*.

Suborder SCLEROPAREI.

SCORPÆNIDÆ. Scorpion fishes.

In this family the scales may be fully ctenoid, or may entirely lose the teeth.

Subfamily SEBASTINÆ.

Sebastes Cuvier, rosefish. *S. marinus* (Linnæus) from Woods Hole (V. N. Edwards), has small oblong scales with five basal radii, very widely spaced circuli, and three or four very large and stout apical spines (fig. 74). The apical circuli are angled in the middle.

Sebastodes Gill. Mr. A. R. Moore very kindly sent a number of species of *Sebastodes* from California, showing that the genus has rather large scales, very strongly ctenoid, with very numerous, strong and crowded apical teeth, and the ctenoid patch with several rows of distinct elements (fig. 76). The basal radii are fairly numerous.

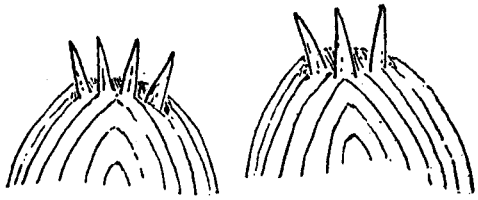


FIG. 42.—*Sebastes marinus* (Scorpænidæ). Apical structures. Bureau of Fisheries.

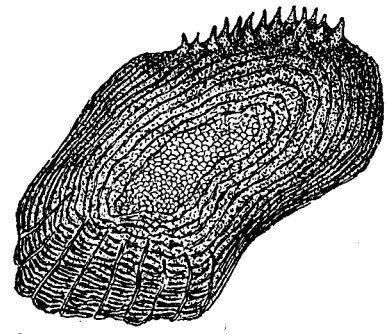


FIG. 43.—*Sebastodes paucispinis* (Scorpænidæ). California.

Mr. Moore sent *S. paucispinis* (Ayres), *S. flavidus* (Ayres), *S. mystinus* Jordan & Gilbert, *S. ruberrimus* Cramer, *S. constellatus* (Jordan & Gilbert), *S. rosaceus* (Girard), *S. carnatus* (Jordan & Gilbert), and *S. nebulosus* (Ayres), and although the scales of all these were carefully examined by Miss Evelyn Moore and myself, we could find no satisfactory specific characters.

Subfamily SCORPÆNINÆ.

Scorpæna Linnæus. *S. plumieri* Bloch, from Katama Bay, has small scales a little over 1 mm. long, and about 1 mm. broad, with coarse but dense circuli, and about seven basal radii. The circuli fail in the apical field, and the margin is cycloid, with, however, occasional rudiments of minute teeth.

Helicolenus Goode & Bean. *H. dactylopterus* (De la Roche), from off Woods Hole, in gulf weed, has comparatively large scales, oval in form, about 4 mm. long and 3 wide. They are cycloid, and formed much as in *Scorpæna*, but with about 13 basal radii. The apical field is covered with little tubercles, resulting from the breaking up of the apical circuli. The basal circuli are very minutely beaded. Jordan & Evermann state that this genus has ctenoid scales on the top and sides of the head, which is not true of *Scorpæna*.

So far as the scales go *Sebastodes* should be in the most primitive of the above genera.

COTTIDÆ. Sculpins.

In the fossil *Lepidocottus brevis* (Agassiz), from the Upper Miocene at Wangen, Baden (E. Penard), the scales are as in the Gobiidæ, with angled apical margin, a single row of marginal teeth, apical nucleus,

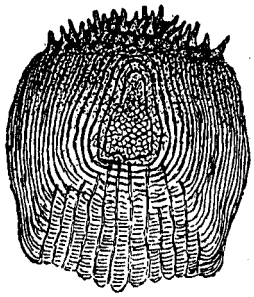


FIG. 44.—*Sebastodes paucispinis* (Scorpænidæ). California.

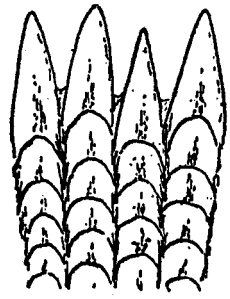


FIG. 45.—*Prionotus strigatus* (Triglidæ). Apical structures. Bureau of Fisheries.

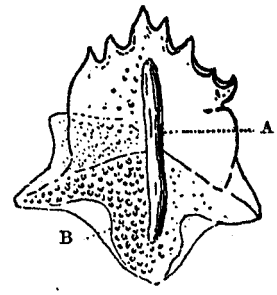


FIG. 46.—*Cephalacanthus volitans* (Cephalacanthidæ). A, high crest; B, pigment spots. Bureau of Fisheries.

etc. Is it quite certain that this fish really is a cottid? Species of *Lepidocottus* have actually been described under *Gobius*.

PLATYCEPHALIDÆ. Flatheads.

Günther has figured the scale of *Platycephalus cirrhonasus*. It is of typically ctenoid character with about four basal radii, but long and parallel sides, the shape suggesting the labrids.

Suborder CRANIOMI.

TRIGLIDÆ. Sea robins.

Prionotus strigatus (Cuvier & Valenciennes), the striped sea robin, from Woods Hole, has the scales subquadrate, about 4½ mm. long and 5 broad, typically ctenoid, with the ctenoid patch large; basal radii about seven or eight; lateral circuli parallel with margin. The submarginal apical elements are very short, broader than long.

CEPHALACANTHIDÆ. Flying gurnards.

Cephalacanthus volitans (Linnaeus), the flying gurnard, from Woods Hole, has greatly modified, strongly keeled scales, with the margin toothed. The form is sufficiently shown in the accompanying figure. There is nothing in the scales to suggest affinity between the triglids and cephalacanthids.

Suborder HETEROSOMATA. Flatfishes.

I have given an account of the scales of these fishes in Proceedings of the Biological Society of Washington, volume XXIV, pages 209–211; it remains now only to present some figures, and a few additional details.

PLEURONECTIDÆ. Flounders.

I am indebted to Dr. F. B. Sumner for scales of *Platophrys* (or *Rhomboidichthys*) *podas*, from the Bay of Naples. In my table, in the paper just cited, they run to *Platophrys constellatus*, from which they scarcely differ. Both have traces of radial lines crossing the lateral circuli, producing a sort of delicate cancellation. The apical teeth in *P. podas* are about 7 or 8, very stout and strong.

SOLEIDÆ. Soles.

Scales of a species of *Cynoglossus* from Hongkong (M. C. Z., 11329) are large, about 9 mm. long and nearly 6 broad; strongly ctenoid on the upper (pigmented) side of the fish, strictly cycloid below.

The basal radii are excessively numerous and close together (pl. XL, fig. 52). The ctenoid elements are formed essentially as in the tongue sole, *Aphoristia pigra*, which belongs to the subfamily Cynoglossinæ. A truly remarkable feature, equally developed in the cycloid and ctenoid scales, is found in the basal (interradial) circuli, which as they leave the radii are directed obliquely apicad, and in the middle third of the interradial field are broken up into minute more or less pyriform bodies. In *Symphurus* (or *Aphoristia*) *piger* the beginning of this is seen in the fact that some of the interradial sections of the circuli are bent and V-like. The extreme and unique modification of the basal circuli in *Cynoglossus* is important, as I think it amounts to a demonstration that *Cynoglossus* (with cycloid scales on the lower side) is not a primitive member of the Soleidæ and is not connected in any way with the pleuronectids. The general characters of the fish also support this idea.

Suborder JUGULARES.[a]

BLENNIIDÆ. Blennies.

The rock eel, *Pholis gunnellus* (Linnæus), from Menemsha Bight, Mass., has extremely minute more or less oval cycloid scales, with the nucleus a little above the middle, very widely spaced circuli,

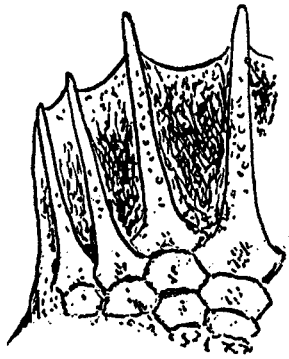


FIG. 47.—*Achirus lineatus* (Soleidæ). Apical structures. Bureau of Fisheries.

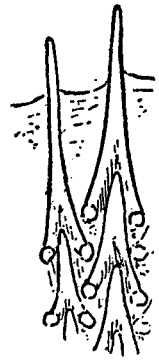


FIG. 48.—*Aphoristia pigra* (Soleidæ). Apical structures. Bureau of Fisheries.

FIG. 49.—*Solea solea* (Soleidæ). Apical structures. Bureau of Fisheries.

and rather widely separated radii basally and laterally. *Ulvaria subbifurcata* Storer, taken by Mr. V. N. Edwards from the stomach of a red-breasted merganser (*Merganser serrator* Linnæus), has similar but longer scales, with the nucleus more apicad, and the 3 to 6 radii all basal. The circuli fail in the apical region.

These are very degenerate scales, which do not suggest any acanthopterygian affinities.

ANARHICHADIDÆ. Wolf-fishes.

The wolf-fish, *Anarhichas lupus* (Linnæus), from Woods Hole, has small nearly circular scales, with central nucleus and radii almost all around, in every way very like those of *Pholis*.

GADOPSIDÆ. New Zealand "trouts."

Gadopsis, a fresh-water genus of New Zealand and Australia, has been figured by Günther. The scale is long oval, cycloid, with regular circuli, which are not dense; nucleus a little apicad of middle; six strong radii. All this is very close to the blenniid *Ulvaria*. The fact that the three families of

[a] See also Proceedings Biological Society of Washington, vol. XXVI, p. 89-92.

Jugulares, of which the scales are known to me, agree so closely in scale characters must indicate that, degenerate as they are, these scales really represent an ancient type, less modified than other characters of the fishes on which they occur.

Suborder ANACANTHINI. Gadoid fishes.

I have discussed this series at some length in Proceedings of the Biological Society of Washington, volume XXIV, pages 211–212. I now offer some figures.

GADIDÆ. Cods.

Since the account cited above was printed I have examined scales of the European burbot, *Lota lota* (Linnæus), from the Danube (M. C. Z. 12366), and the American burbot, *L. maculosa* (Le Sueur), from

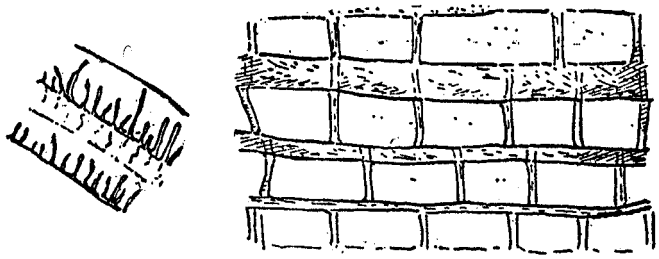


FIG. 50.—*Brosmius brosme* (Gadidæ). Sculptural details, submarginal region. Bureau of Fisheries. Smaller figure shows sculpture of a latinucleate scale near middle.

Erie, Pa. (Bureau of Fisheries). This genus, typical of the subfamily Lotinæ, has extremely minute circular to suboval scales, with nucleus central or almost; coarse, widely separated circuli, and no radii. It is, however, to be noted that the circuli are crenate or denticulate on the inner margin, a relic of the

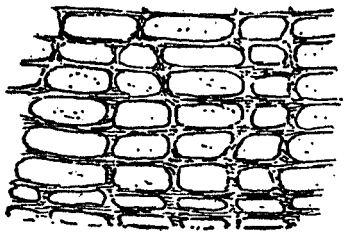


FIG. 51.—*Melanogrammus æglefinus* (Gadidæ). Details of sculpture, submarginal region. Bureau of Fisheries.

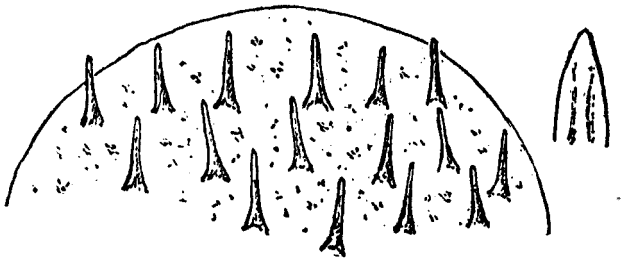


FIG. 52.—*Cælorhynchus caribbæus*, and spine of *Macrurus bairdii* (Macruridæ). U. S. National Museum.

condition so well marked in *Brosmius*. I am quite unable to find any difference between the scales of the European and American species.

A scale of *Urophysis regius* is figured on plate XL (fig. 51.)

MACRURIDÆ. Grenadiers. (Pl. XL, fig. 48.)

Dr. S. Garman (Mem. Mus. Comp. Zool., vol. XXIV) has figured the scales of a number of species of *Macrurus*, namely *M. barbiger* Garman, *M. bulbiceps* Garman, *M. bucephalus* Garman, *M. liraticeps*

Garman, *M. fragilis* Garman, M. *tenuicauda* Garman, and *M. carminifer* Garman. *M. barbiger* has no teeth whatever; *M. fragilis* is represented with a single little tooth. *M. bulbiceps* has very many little spines in the apical field; *M. carminifer* has very large spines. The figure of *M. tenuicauda* looks like a latinucleate scale.

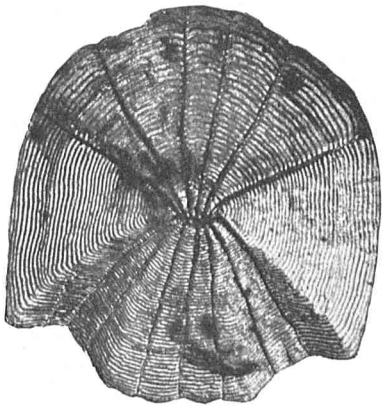
Order PEDICULATI.

ANTENNARIIDÆ. Fishing-frogs.

Dr. Garman, in the work just cited, figures the spiniferous scales of *Chaunax coloratus* Garman. In the Cambridge Natural History, Fishes, page 191, is a figure of the scale of *Antennarius hispidus*.

OGCOCEPHALIDÆ. Batfishes.

In the Cambridge Natural History, on the page just cited, is a figure of the spine-bearing scale of *Ogcocephalus* or *Malthe vespertilo* (Linnæus).



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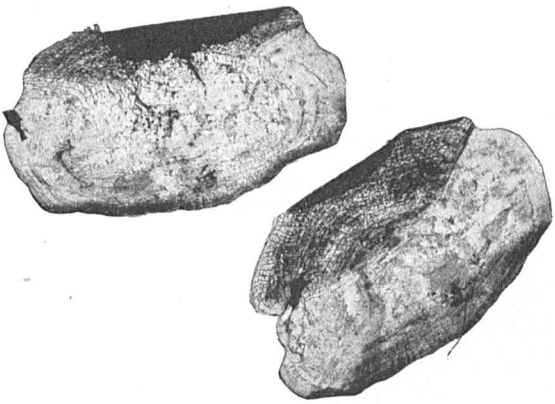

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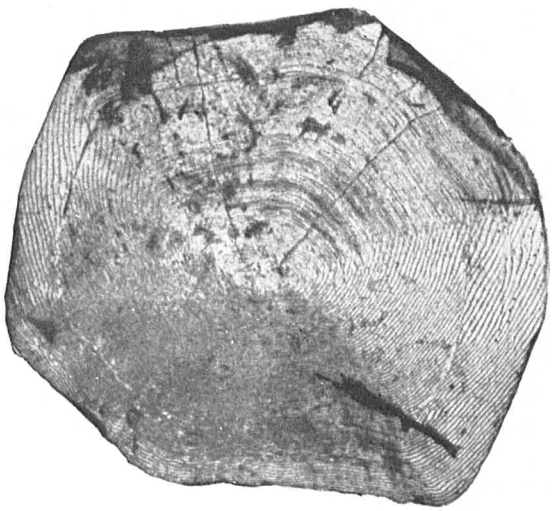

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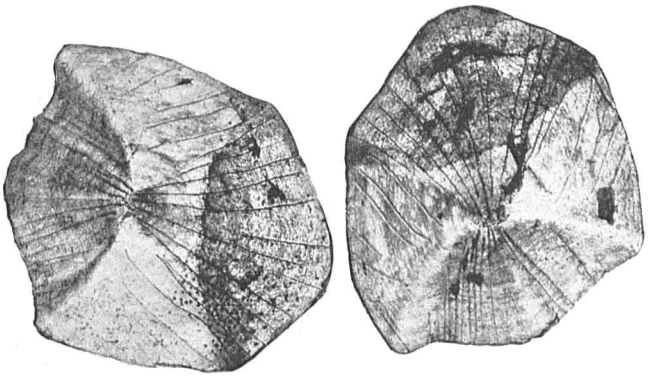
FIG. 1.—Placopharynx duquesnii. Cherokee, Iowa (S. E. Meek).
FIG. 2.—Acanthorhodeus tænianalis. Shanghai (Swinhoe). The wavy apical radii are not well shown.
FIG. 3.—Algansea sallæi. Guanajuato, Mexico (A. Dugès).
FIG. 4.—Chela paralaubuca. British Museum.
FIG. 5.—Chondrostoma meigii. San Domingo de Silos, Burgos, Spain (Gonzales).
FIG. 6.—Nocomis kentuckiensis. Stone River, Tennessee.



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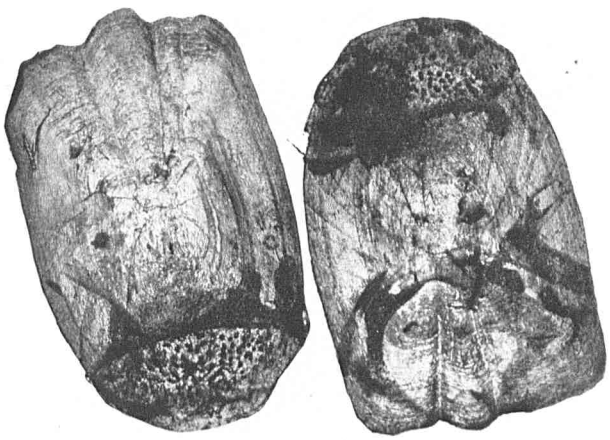

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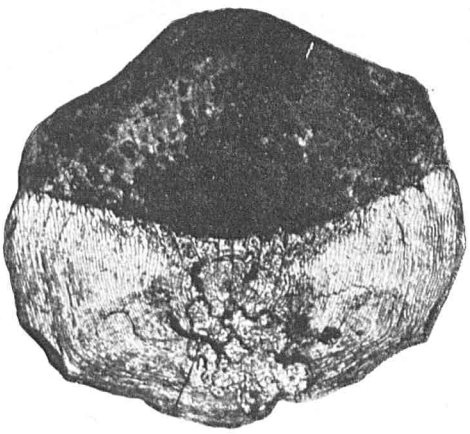

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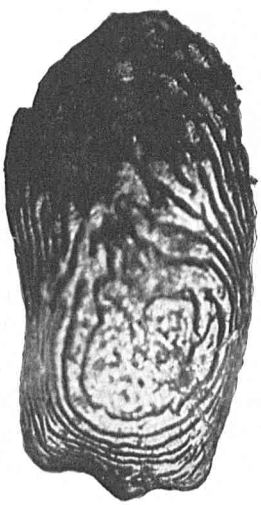

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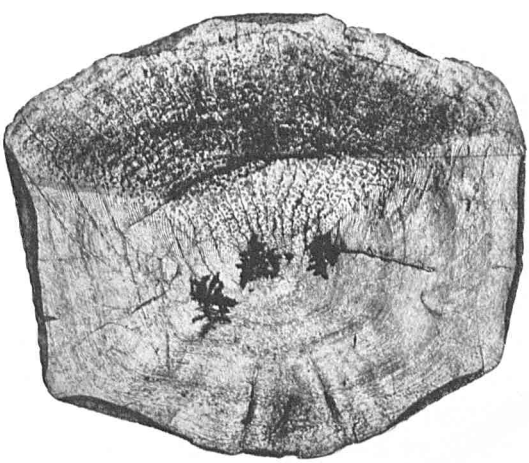

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FIG. 7.—Luciosoma trinema. Upper Baram River (C. Hose).
FIG. 8.—Notemigonus chrysoleucus. Falmouth, Mass.
FIG. 9.—Rohiita lineata. Sittang River (E. W. Oates). British Museum.
FIG. 10.—Scaphiodon muscatensis. Muscat, Arabia. British Museum.
FIG. 11.—Schizothorax intermedius. Kashgar. British Museum.
FIG. 12.—Semiplotus macclellandi. Assam (F. Day). British Museum.

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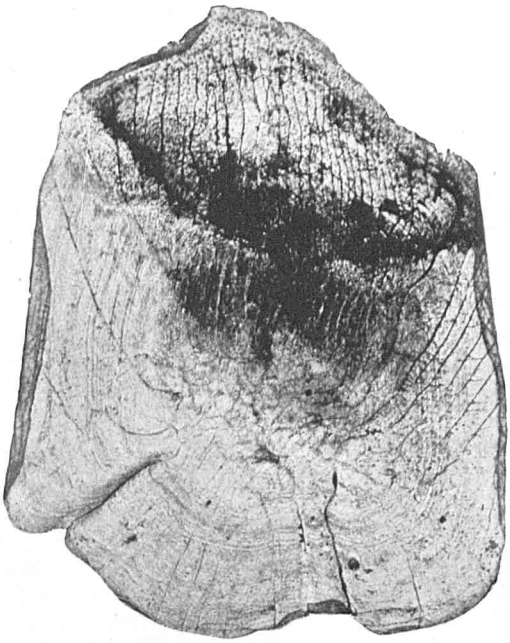

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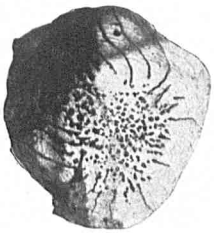

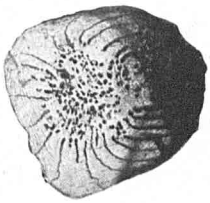

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FIG. 13.—Capoeta fratercula. Persia. British Museum.
FIG. 14.—Culter erythropterus. R. Keroulen, Mongolia (Chaffanjon). British Museum.
FIG. 15.—Leptobarbus hoevenii. Tinjar River (C. Hose). British Museum.
FIG. 16.—Oreinus grahami. British Museum.
FIG. 17.—Homaloptera maculata. Khassya (Dr. Jerdon). British Museum.

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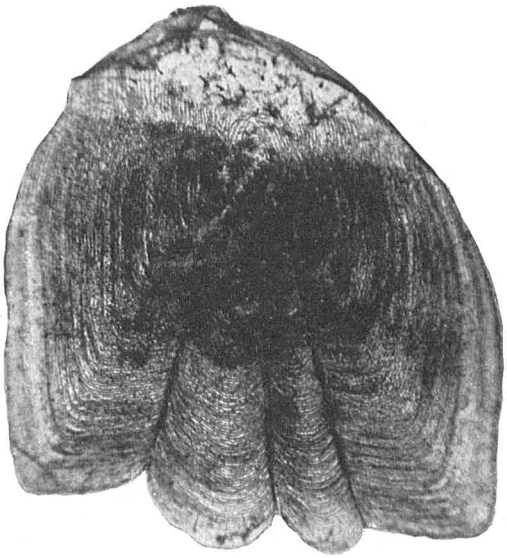

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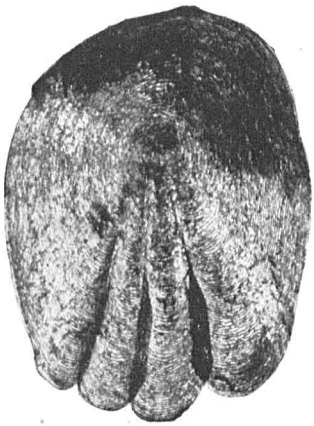

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FIG. 18.—Clupanodon pseudohispanicus. Woods Hole, Mass.
FIG. 19.—Synodus foetens. Galveston, Texas (Evermann).
FIG. 20.—Lucius lucius. Toledo, Ohio (Rutter).
FIG. 21.—Fundulus majalis. Latinucleate scale.
FIG. 22.—Fundulus heteroclitus. Woods Hole, Mass.

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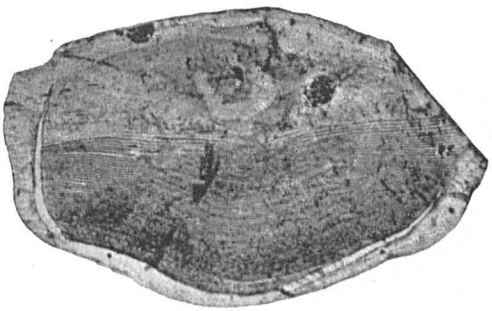

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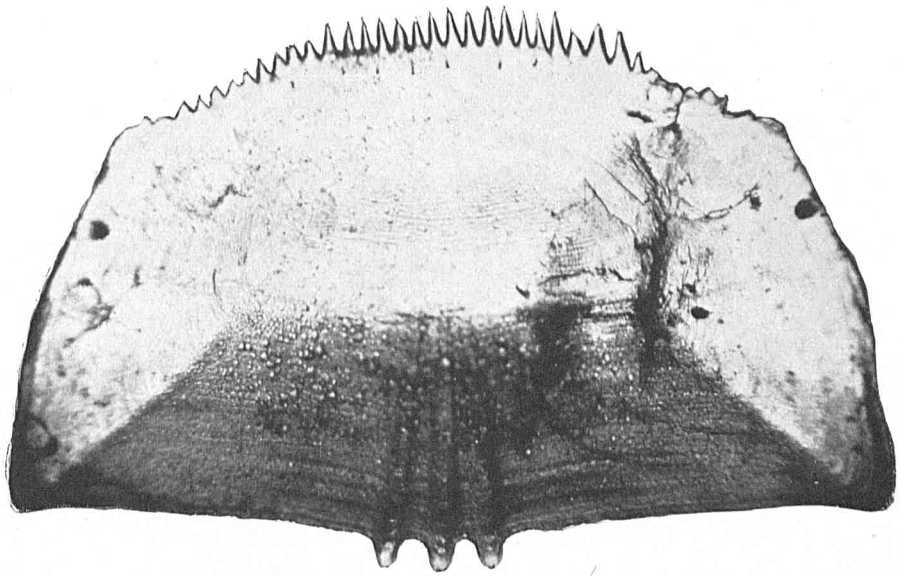

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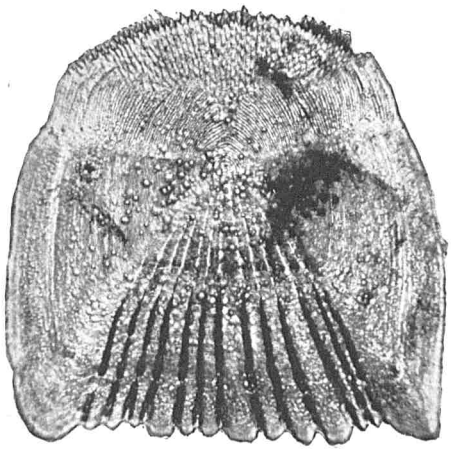
FIG. 23.—Mollienisia latipinna. Gordons Pass, Florida (Henshall).
FIG. 24.—Scombresox saurus. Woods Hole Collection.
FIG. 25.—Chirostoma crystallinum. Lake Chapala, Mexico (J. N. Rose).
FIG. 26.—Holocentrum laticeps. Kaui, H. I. Museum of Comparative Zoology.
FIG. 27.—Caranx hippos. Woods Hole Collection.



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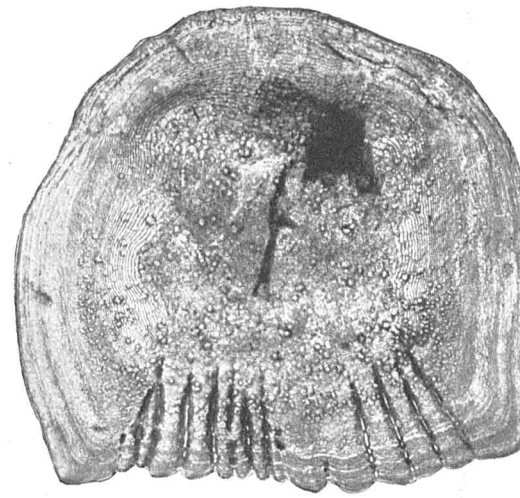

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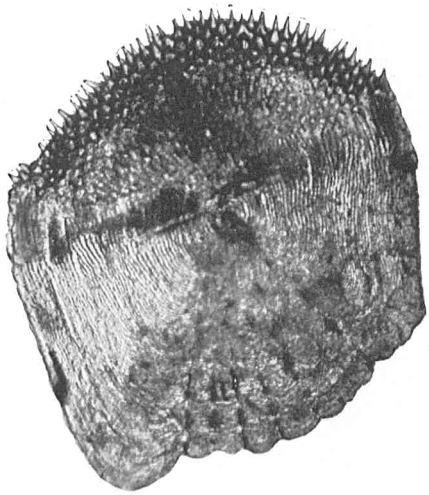

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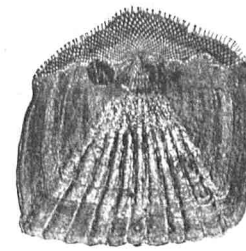

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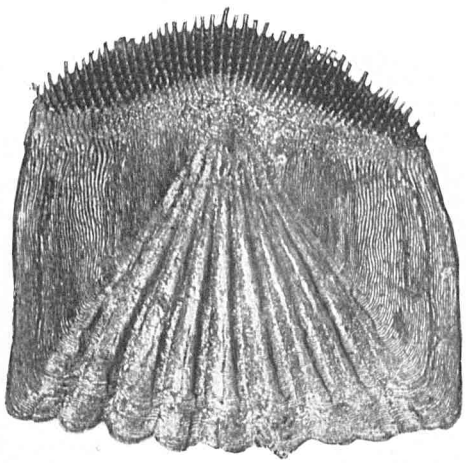

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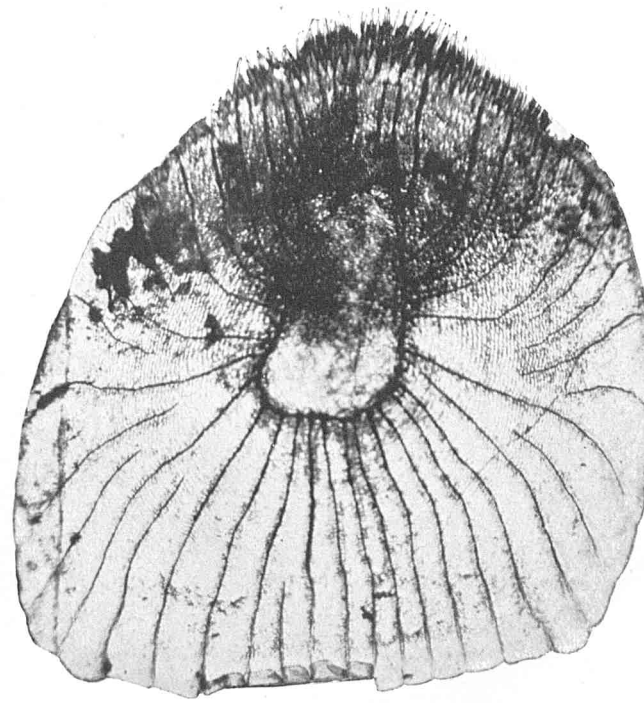

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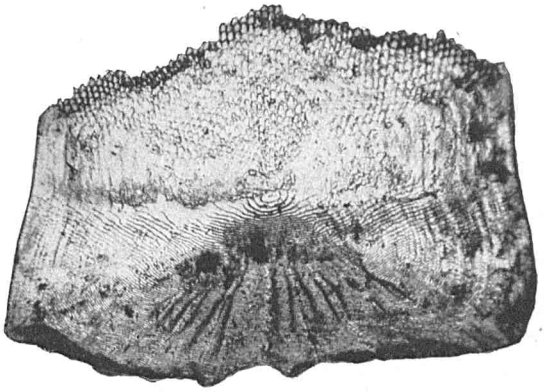
FIG. 28.—Mesogonistius chætodon. Trenton, N. J.
FIG. 29.—Ambloplites rupestris. Huntington, Tenn.
FIG. 30.—Archoplites interruptus. San Francisco, Cal.
FIG. 31.—Centropristes striatus. Woods Hole, Mass.
FIG. 32.—Plesiops corallicola. Ebon Islands. Museum of Comparative Zoology.
FIG. 33.—Orthopristis chalceus. Guaymas or Clarion Island. (Albatross).



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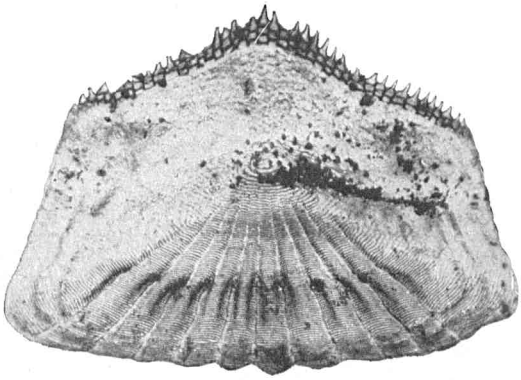

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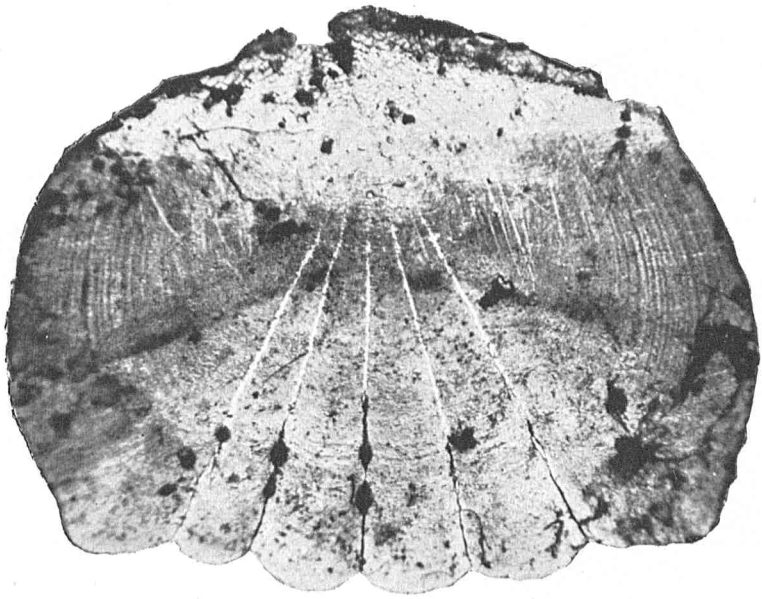

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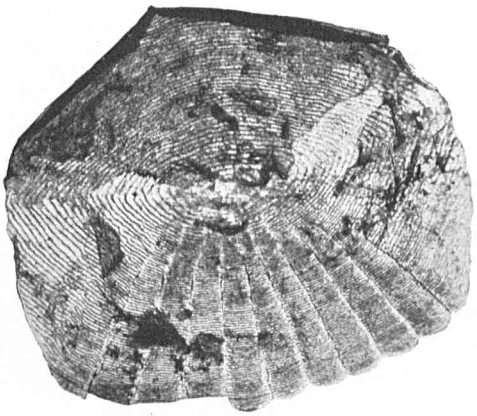

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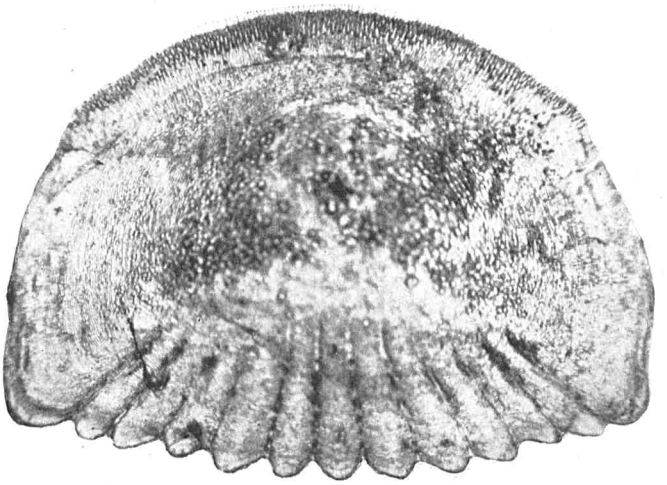
FIG. 34.—Box vulgaris. Vienna Museum.
FIG. 35.—Smaris sp. Trieste.
FIG. 36.—Gerres gula. Brazil. Museum of Comparative Zoology.
FIG. 37.—Amphisticus argenteus. St. Nicholas Island. (Albatross.)
FIG. 38.—Zalembius rosaceus. Above Santa Barbara Channel. (Albatross.)



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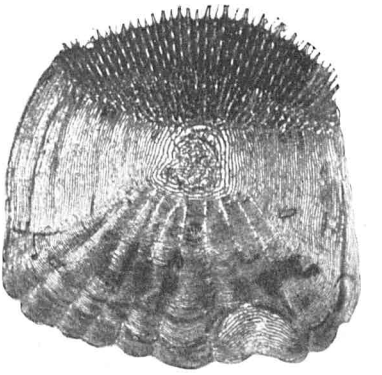

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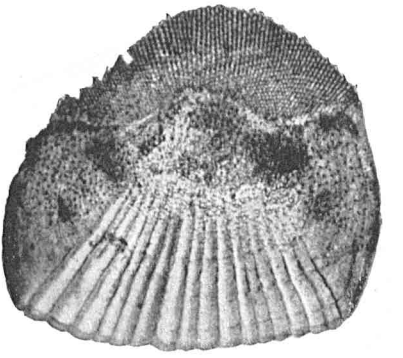

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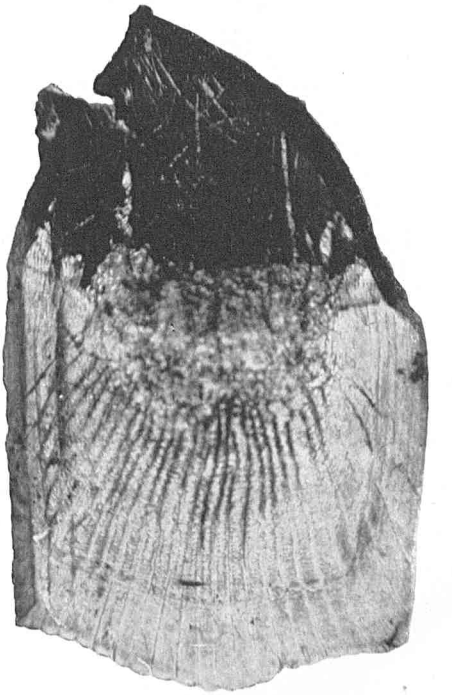

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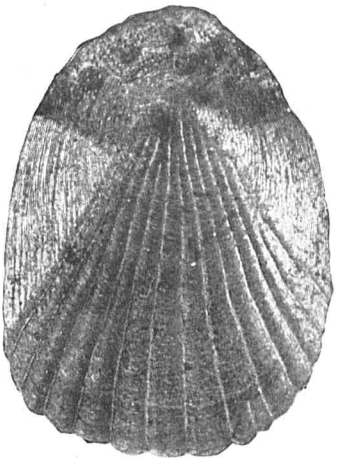
FIG. 39.—Geophagus brasiliensis. Rio Novo, Brazil.
FIG. 40.—Cichla monoculus. Lake Hyanuary, Brazil. Museum of Comparative Zoology.
FIG. 41.—Chætobranchus flavescens. Lake Hyanuary, Brazil.
FIG. 42.—Pimelometopon pulcher. Santa Barbara Islands. (Albatross.)
FIG. 43.—Emmekia venusta. Gulf of California. (Albatross.)
FIG. 44.—Scarus croicensis. Woods Hole Collection.
FIG. 45.—Chætodon ulietensis. Apia, Samoa. (Jordan.)



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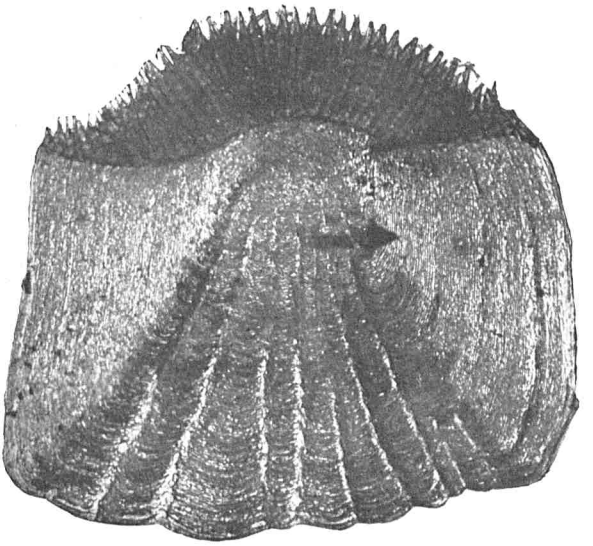

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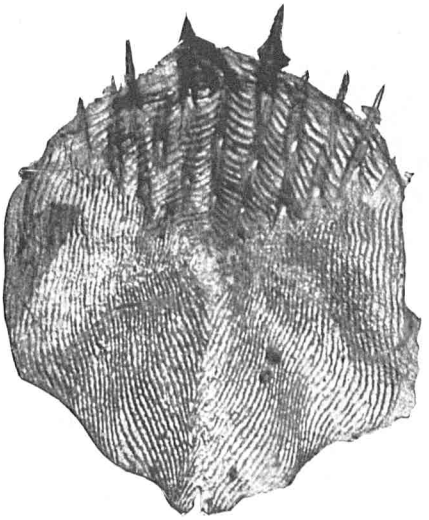

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FIG. 46.—Helicolenus dactylopterus. Off Woods Hole.
FIG. 47.—Prionotus strigatus. Woods Hole, Mass.
FIG. 48.—Macrurus sp. Albatross station 2426.
FIG. 49.—Lota vulgaris. Danube. Museum of Comparative Zoology.
FIG. 50.—Gadus callarias. Woods Hole Collection.
FIG. 51.—Urophycis regius. Woods Hole, Mass.
FIG. 52.—Cynoglossus sp., upper side. Hongkong. Museum of Comparative Zoology.

A NEW METHOD FOR THE DETERMINATION OF THE FOOD VALUE OF PROTEINS, WITH APPLICATION TO CYNOSCION REGALIS

By George F. White and Adrian Thomas

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A NEW METHOD FOR THE DETERMINATION OF THE FOOD VALUE OF PROTEINS, WITH APPLICATION TO CYNOSCION REGALIS.

By GEORGE F. WHITE and ADRIAN THOMAS.

It is frequently desired to compare the rate and course of digestion of various proteins by enzymes according to methods which, while not complicated, will give distinctive and reliable results. Van Slyke's[a] method for the determination of amino acids has been applied by White and Crozier[b] with evidently great success to a comparison of the tryptic proteolysis of beef and several fish meats. The ease of manipulation of the apparatus, the brief time required for a determination, and the regularity of the experimental data, make the process generally useful. The conclusions drawn also conform with those from metabolism experiments, making the results of still greater value.

The method which Sörensen[c] has proposed for the estimation of amino acids and polypeptides, by titration with caustic soda after the addition of formaldehyde, by its simplicity suggests itself for artificial digestion processes. It is the object of this article to show its application to the hydrolysis of *Cynoscion regalis* (squeteague, weakfish) by trypsin, and to compare the results with those obtained by Van Slyke's method.

The squeteague was boiled in water for a quarter of an hour, allowed to drain from excess of liquid, and preserved ice-cold. An analysis of two samples gave an average of 4.52 per cent nitrogen.

The digestion was carried on in 250 c. c. volumetric flasks placed in a thermostat kept at temperature of 37.5° C. Enough meat to furnish 1.5 g. of nitrogen was weighed out, ground up with water together with 1 g. of trypsin, and this mixture poured into the flask; 25 c. c. of N/10 sodium hydroxide solution was added, and the whole made up to 250 c. c. with water. Trypsin is presumably most active in a medium made alkaline with sodium carbonate, but the presence of this salt would interfere with the titration for the amino acids where phenolphthalein must be used as an indicator, so that the alkalinity was insured by the presence of the hydrate. Separate mixtures were made

[a] Van Slyke, D. D.: A method for quantitative determination of aliphatic amino groups. Journal of Biological Chemistry, vol. IX, p. 185–204, 1911. Baltimore.

[b] White, G. F. & Crozier, W.: Comparative proteolysis experiments with trypsin. Journal of the American Chemical Society, vol. 33, p. 2042–2048, 1911. Easton, Pa.

[c] Sörensen, S. P. L.: Fermentstudien. Biochemische Zeitschrift, bd. 7, p. 45–101, 1907. Berlin.

and analyses run in duplicate for the time periods of 1, ½, 2, 5, and 8 hours, respectively. A sample similar to the above but containing no trypsin was also prepared and analyzed with the others according to the following method: At the end of the desired time of digestion, the mixtures were filtered and aliquot portions of the filtrate taken for the various tests; 10 c. c. were used for the determination of total soluble nitrogen by the Kjeldahl method; 10 c. c. for the amino nitrogen by Van Slyke's method; 20 c. c. were treated with 10 c. c. of 40 per cent formaldehyde solution and titrated to a distinct pink color with N/10 sodium hydroxide solution. We found that in every case a distinct end point was obtained, duplicate analyses agreeing within 0.2 per cent. Finally, 10 c. c. of the filtrate from the digested fish were completely hydrolyzed by prolonged digestion on the water bath with 40 c. c. of concentrated hydrochloric acid. This solution was evaporated to dryness, made up to 50 c. c. with water, 10 c. c. tested for amino nitrogen by Van Slyke's method, and 20 c. c. analyzed for amino acids by Sörensen's method.

All the results as obtained above were corrected for amino nitrogen before and after complete hydrolysis, for total soluble nitrogen, and for amino acids as determined by titration with caustic soda, by carrying through the same experiments with trypsin and alkali, but with no protein. Correction was also made for the alkali required to neutralize the formaldehyde solution.

In table 1 are presented the results obtained by applying Van Slyke's method to the tryptic proteolysis of squeteague. The average size of the peptides was calculated by dividing the amount of amino nitrogen present after complete hydrolysis with hydrochloric acid by that in the solution before such hydrolysis. The last two columns of data show the increase with time of proportion of soluble to insoluble nitrogen and of amino to total soluble nitrogen, respectively. The average results of duplicate analyses are given.

TABLE I.—TOTAL AND AMINO NITROGEN IN SOLUTIONS OF CYNOSCION REGALIS HYDROLYZED BY TRYPSIN.

Time in hours.	Soluble nitrogen.	Insoluble nitrogen.	Amino nitrogen.	Amino nitrogen after hydrolysis.	Average size of peptids.	Soluble $\frac{100X}{\text{total nitrogen.}}$	Amino $\frac{100X}{\text{soluble nitrogen.}}$
0	0.170	1.330	0.017	0.056	3.29	11.32	10.00
½	1.115	.385	.230	.464	2.02	74.32	20.63
1	1.175	.340	.250	.464	1.86	78.34	21.27
2	1.173	.327	.289	.464	1.61	78.20	24.63
5	1.361	.139	.357	.....	.....	90.72	26.23
8	1.432	.068	.406	.646	1.59	95.45	28.35

In table II are given the average results of the analysis of the proteolyzed solutions according to Sörensen's method. In column 2 the figures represent cubic centimeters of N/10 sodium hydroxide solution required for neutralization after addition of formaldehyde solution. Column 3 is the same for the solutions after complete hydrolysis with hydrochloric acid. The next column gives the ratio of the latter to the former. In

column 5 are given figures for amino nitrogen calculated from the data in column 2, while the values in the last column were obtained by calculating the per cent calculated amino nitrogen of the total soluble nitrogen.

TABLE II.—ANALYSIS BY SÖRENSEN'S METHOD OF SOLUTIONS OF CYNOSCION REGALIS HYDROLYZED BY TRYPSIN.

Time in hours.	Quantity N/10 NaOH required.	Quantity N/10 NaOH required after hydrolysis.	Average size of peptids.	Amino nitrogen calculated.	Amino nitrogen $\frac{100\times}{\text{soluble nitrogen.}}$
	c. c.	*c. c.*			
0	24.85	125.0	5.02	0.035	20.52
¼	182.8	536.8	2.94	.257	23.02
1	213.8	598.0	2.80	.300	25.87
2	232.9	.....	.....	.327	27.87
5	293.5	776.0	2.64	.412	30.28
8	314.8	787.1	2.50	.442	30.87

From table 1 it is seen from the ratio of the soluble to the total nitrogen that the fish meat goes very rapidly into solution, 74.32 per cent of the nitrogen being in solution at the end of a half hour's digestion. Solution, however, is not complete in eight hours' time, a fact which is apparently not in harmony with the results of White and Crozier,[a] who found with the proteins they studied that all the nitrogen was in the soluble form in four to eight hours. The trypsin used, a commercial sample, was of the same activity in both series of experiments. These latter experiments were carried on in a medium made alkaline with sodium carbonate, while the experiments described in this article required sodium hydroxide for reasons already stated. Schierbeck[b] has proved that the action of trypsin in digesting proteins is accelerated by the presence of carbon dioxide in solutions which are slightly alkaline, and it is very probably at least partly due to this fact that the above differences are found. The variation of the proportion of soluble to total nitrogen with increase of time is shown graphically in figure 1. Extrapolation of the curve would indicate that the squeteague would be completely dissolved in about 14 hours.

White and Crozier have shown that their artificial digestion experiments gave results agreeing closely with those obtained by metabolism work with dogs, rates of digestion of different proteins being in the same ratio to each other. Van Slyke and White,[c] in a study of the relation between the digestion and the retention of ingested proteins, found that squeteague is digested more slowly than either beef or cod. From the above facts it is fair to conclude that the tardy solution of the squeteague by trypsin shown by our data is not alone due to the absence of carbon dioxide, but is a consequence of the inherent nature of the protein itself.

---

[a] White & Crozier, op. cit.

[b] Schierbeck, N. P.: Ueber den einfluss der kohlensaure auf die diastatischen und peptonbildenden fermente im thierischen organismus. Skandinavisches Archiv fur Physiologie, bd. 3, s. 344–375, 1892. Leipzig.

[c] Van Slyke, D. D. & White, G. F.: The relation between the digestibility and the retention of ingested proteins. Journal of Biological Chemistry, vol. IX, p. 219–229, 1911. Baltimore.

The amino nitrogen in solution increases of course with length of time. The average size of the peptids split off from the protein should be especially noted. From these data and the experiments of White and Crozier it is evident that the proteins studied break down into simple cleavage products practically as soon as they go into solution. At the end of a half hour's digestion the average size of the peptids is only 2.02; the cleavage products on the whole are indicated to be amino acids. The cleavage of certain proteins by trypsin has been intimately studied, and it is known that some amino acids are readily formed, while others are produced slowly or not at all. The above results, however, show that the greater portion of the nitrogen in solution exists in bodies of exceedingly simple character. The significance of this physiologically can not be pointed out here, but will be reserved for future discussion.

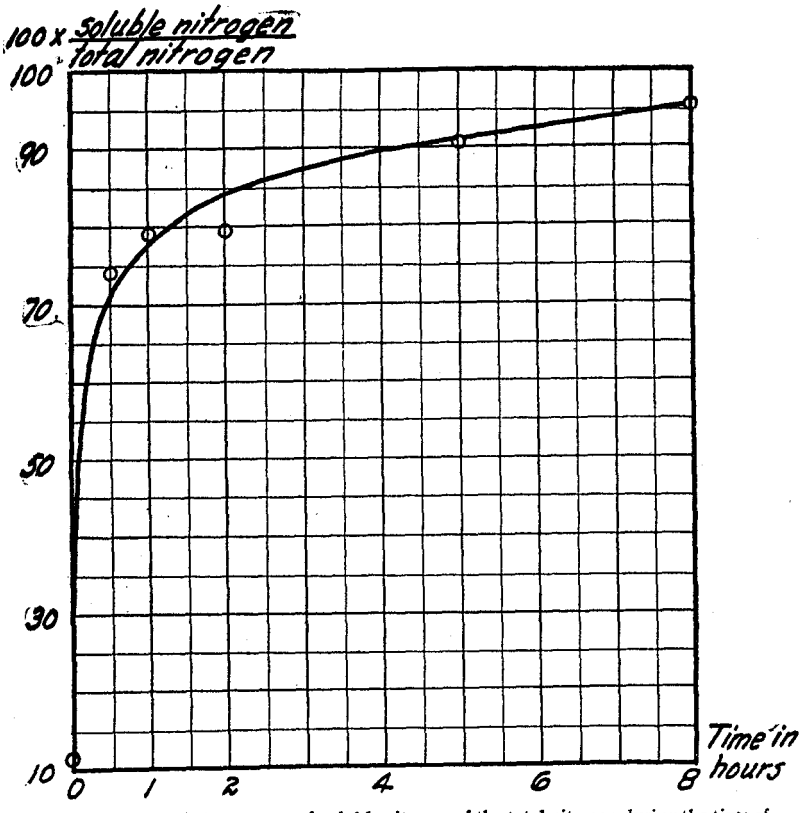

FIG. 1.—Change of the per cent of soluble nitrogen of the total nitrogen during the time of proteolysis.

The relation of the amino to the total soluble nitrogen is shown in figure 2. After eight hours' digestion only 28.35 per cent of the nitrogen is in the amino form. This is a confirmation of earlier work which, as just mentioned, has shown that there are certain substances which resist the hydrolytic action of trypsin altogether. The increase in the proportion of amino nitrogen during the eight hours' digestion is very slight, and we must conclude, therefore, that the cleavage of the meat, while yielding amino bodies of a simple nature, leaves the greater part of the soluble nitrogen combined in substances which are extremely stable.

The same conclusions may be drawn from the results of our experiments involving Sörensen's method. In figure 2 the curves are of the same slope, although, of course,

only approximate figures are expected on assuming the presence of one amino group for every carboxyl group indicated by the sodium hydroxide required. The amino nitrogen thus estimated is regularly greater than that determined by the nitrous acid method, and the peptids as computed are about 1.5 times as large. It is possible that in such calculations this effect is produced by the presence of such monaminodicarboxylic compounds as glutamic acid. The discrepancy in the results is not of such a magnitude as to prevent deducing rigid conclusions concerning the rate and course of digestion of such proteins as the one under investigation.

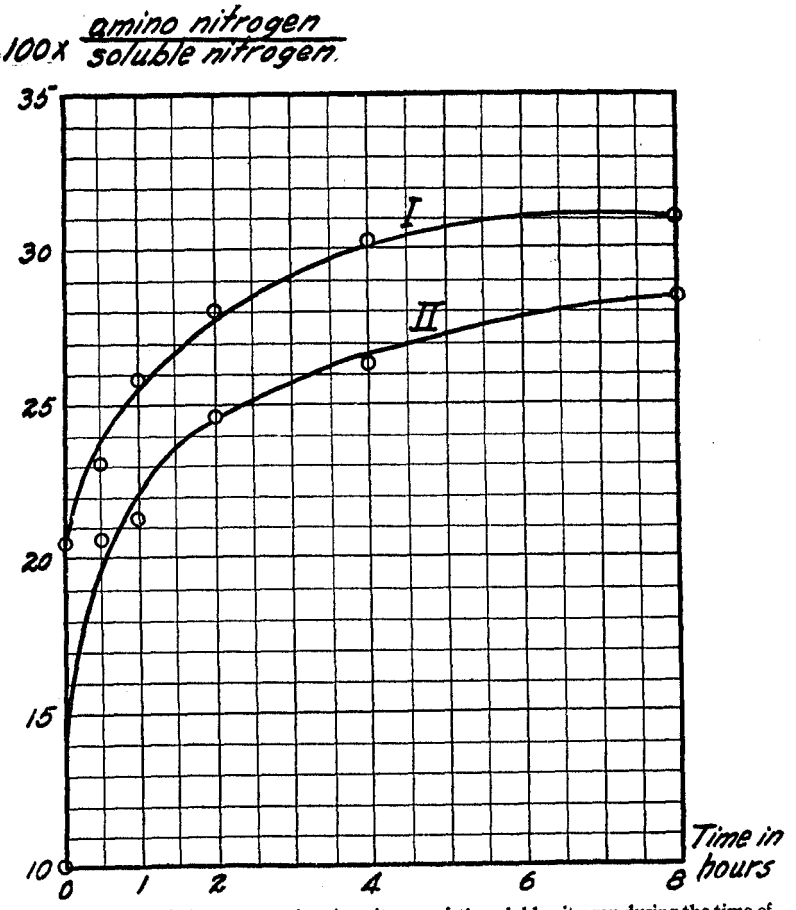

FIG. 2.—Change of the per cent of amino nitrogen of the soluble nitrogen during the time of proteolysis.

SUMMARY.

1. Sörensen's method for the determination of amino acids was applied to a study of the tryptic proteolysis of *Cynoscion regalis*. The results were regular and in accord with those obtained by the nitrous acid method for the analysis for amino nitrogen. A practical method for the determination of the food value of proteins has therefore been developed.

2. The relatively low rate at which the protein is made soluble agrees with the results of metabolism experiments.

3. Very low cleavage products are formed as soon as the protein goes into solution, the average size of the peptids being 2.02 after a half hour's digestion.

4. There is a very stable nitrogen complex which is not attacked by trypsin.

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PROPERTIES OF FISH AND VEGETABLE OIL MIXTURES

By George F. White and Adrian Thomas

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PROPERTIES OF FISH AND VEGETABLE OIL MIXTURES.

BY GEORGE F. WHITE AND ADRIAN THOMAS.

In consequence of the increasing interest in the utilization of various fish oils for the most diverse commercial operations, their substitution where possible for the more valuable vegetable oils, and the lack of intimate and complete knowledge of their physical and chemical properties, it has seemed desirable to continue and extend the work which was carried out recently by one of us,[a] on fish oils of known origin. The uncertainty of the various tests which have been applied to any oil to detect possible adulteration by another of inferior value has been due rather to the want of a full conception of the behavior of fish oils under all circumstances than any inherent difficulty connected with the problem. A careful study of mixtures of fish oils with each other and with vegetable oils should yield results of value to both analyst and manufacturer.

In this article there are presented the results of the analysis of dogfish liver (*Mustelus canis*), soya-bean, linseed, China-wood oils, and mixtures of these with each other. The fish oil was extracted from livers by steam pressure by the method previously described by one of us. Mixtures were made up by weight. The viscosity, density, index of refraction, saponification number, acid number, and iodine number were then measured according to the following description.

VISCOSITY AND FLUIDITY.

It has been shown that the fluidites of fish-oil mixtures are additive, and it should be expected that the same condition would obtain with all oils except in those cases where there is association, decomposition, or some other exceptionally disturbing factor. As the viscosity of an oil is of particular interest to the paint manufacturer, and fish oils are used largely for outside paints or to adulterate oils for other purposes, this property has therefore been especially considered in our study of these oils.

[a] White, G. F.: A study of the viscosity of fish oils. The fluidity of fish oil mixtures as an additive property. Journal of Industrial and Engineering Chemistry, vol. 4, p. 106–110, and p. 267–270, 1912. Easton, Pa.

A viscosimeter capable of very accurate measurement gave satisfactory service in our previous work[a] and a new one was made and calibrated according to the method already given. Following are the constants obtained for this instrument:

Length of capillary (approximate)	1. 6 cm.
Volume of left limb	2. 1310 c. c.
Volume of right limb	2. 0748 c. c.
Pressure correction (30°), left limb	−0. 30 cm.
Pressure correction (30°), right limb	− . 30 cm.
Ratio of r^4 to l	. 00005835
	. 00005822
	. 00005837

The formula used for the calculation of the viscosity was

$$n = \frac{\pi r^4 p t}{8 v l} - \frac{v d}{8 \pi t l}$$

where n is the viscosity, r the radius, and l the length of the capillary, v the volume of liquid passing through the capillary, d the density of the liquid, p the pressure, and t the time of flow. As has been stated, the method of calibration and manipulation has been fully described in previous papers.

In the following tables are presented the results of the viscosity measurements, which were taken at 30°, 50°, 70°, and 90°, for the right and left limbs, the average of the two, and the reciprocal of the latter value, which is the fluidity. The China-wood oil was measured at 35° and the value at 30° extrapolated from the curve, as the oil was so viscous at the lower temperature that the time necessary for a determination was very long. The pure oils were cooled after measurement at 90° and the viscosity redetermined at 30° to note any possible change due to chemical decomposition.

TABLE I.—DOGFISH-LIVER OIL.

Temperature.	Viscosity.			Fluidity.
	Right limb.	Left limb.	Average.	
Degrees.				
30	0. 4143	0. 4140	0. 4142	2. 414
50	. 2113	. 2110	. 2112	4. 735
70	. 1247	. 1247	. 1247	8. 020
90	. 08046	. 08063	. 08055	12. 41
30	. 4142	. 4142	. 4142	2. 414

TABLE II.—LINSEED OIL.

Temperature.	Viscosity.			Fluidity.
	Right limb.	Left limb.	Average.	
Degrees.				
30	0. 3312	0. 3311	0. 3312	3. 019
50	. 1757	. 1757	. 1757	5. 692
70	. 1071	. 1069	. 1070	9. 346
90	. 07103	. 07119	. 07111	14. 06
30	. 3312	. 3316	. 3314	3. 016

[a] White, G. F., op. cit.

TABLE III.—SOYA-BEAN OIL.

Temperature.	Viscosity.			Fluidity.
	Right limb.	Left limb.	Average.	
Degrees.				
30	0.4067	0.4058	0.4063	2.461
50	.2060	.2065	.2063	4.847
70	.1207	.1209	.1208	8.278
90	.07807	.07836	.07822	12.79
30	.4069	.4067	.4068	2.458

TABLE IV.—CHINA-WOOD OIL.

Temperature.	Viscosity.			Fluidity.
	Right limb.	Left limb.	Average.	
Degrees.				
30	.....	.....	1.859	0.5379
35	1.591	1.587	1.589	.6293
50	.7796	.7805	.7801	1.282
70	.3699	.3717	.3708	2.697
90	.2126	.2128	.2127	4.702
35	1.933	1.957	1.946	.5139

TABLE V.—DOGFISH-LIVER AND LINSEED OIL MIXTURES.

25 PER CENT LINSEED.

Temperature.	Viscosity.			Fluidity.
	Right limb.	Left limb.	Average.	
Degrees.				
30	0.3954	0.3943	0.3949	2.533
50	.2027	.2018	.2023	4.943
70	.1204	.1201	.1203	8.313
90	.07784	.07798	.07791	12.84

50 PER CENT LINSEED.

30	0.3712	0.3712	0.3712	2.694
50	.1930	.1925	.1928	4.694
70	.1150	.1152	.1151	8.688
90	.07554	.07561	.07558	13.23

75 PER CENT LINSEED.

30	0.3555	0.3556	0.3556	2.812
50	.1866	.1866	.1866	5.354
70	.1123	.1124	.1124	8.897
90	.07425	.07427	.07426	13.47

TABLE VI.—DOGFISH-LIVER AND SOYA-BEAN OIL MIXTURES.

25 PER CENT SOYA BEAN.

Temperature.	Viscosity.			Fluidity.
	Right limb.	Left limb.	Average.	
Degrees.				
30	0.4121	0.4125	0.4123	2.425
50	.2121	.2094	.2108	4.744
70	.1234	.1227	.1231	8.123
90	.07952	.07934	.07941	12.59

50 PER CENT SOYA BEAN.

30	0.4099	0.4130	0.4115	2.430
50	.2074	.2082	.2078	4.813
70	.1215	.1227	.1221	8.190
90	.07930	.07954	.07942	12.59

75 PER CENT SOYA BEAN.

30	0.4074	0.4071	0.4073	2.455
50	.2072	.2075	.2074	4.822
70	.1210	.1214	.1212	8.251
90	.07852	.07865	.07859	12.72

TABLE VII.—DOGFISH-LIVER AND CHINA-WOOD OIL MIXTURES.

50 PER CENT CHINA WOOD.

Temperature.	Viscosity.			Fluidity.
	Right limb.	Left limb.	Average.	
Degrees.				
30	.....	.....	0.7950	1.258
35	0.6926	0.6942	.6934	1.442
50	.3895	.3875	.3885	2.574
70	.2085	.2080	.2083	4.801
90	.1258	.1259	.1259	7.943

The viscosity and fluidity are pictured graphically in figures 1 to 3. According to Bingham's fluidity hypothesis,[a] the fluidities of liquid mixtures should be additive when there is no association or action between the components. This is true when the fluidity-temperature curve is linear. It may be seen from figure 2 that the fluidities of dogfish, linseed, and soya-bean oils are nearly linear functions of the temperature and their curves have the same slope.

Figure 3 shows that mixtures of these oils have fluidities which are linear functions of the composition. On the other hand, China-wood oil behaves differently. Its

[a] Bingham, E. C. and Harrison, J. P.: Viskosität und fluidität. Zeitschrift für physikalische Chemie, bd. 66, p. 1–32, 1909. Leipzig.

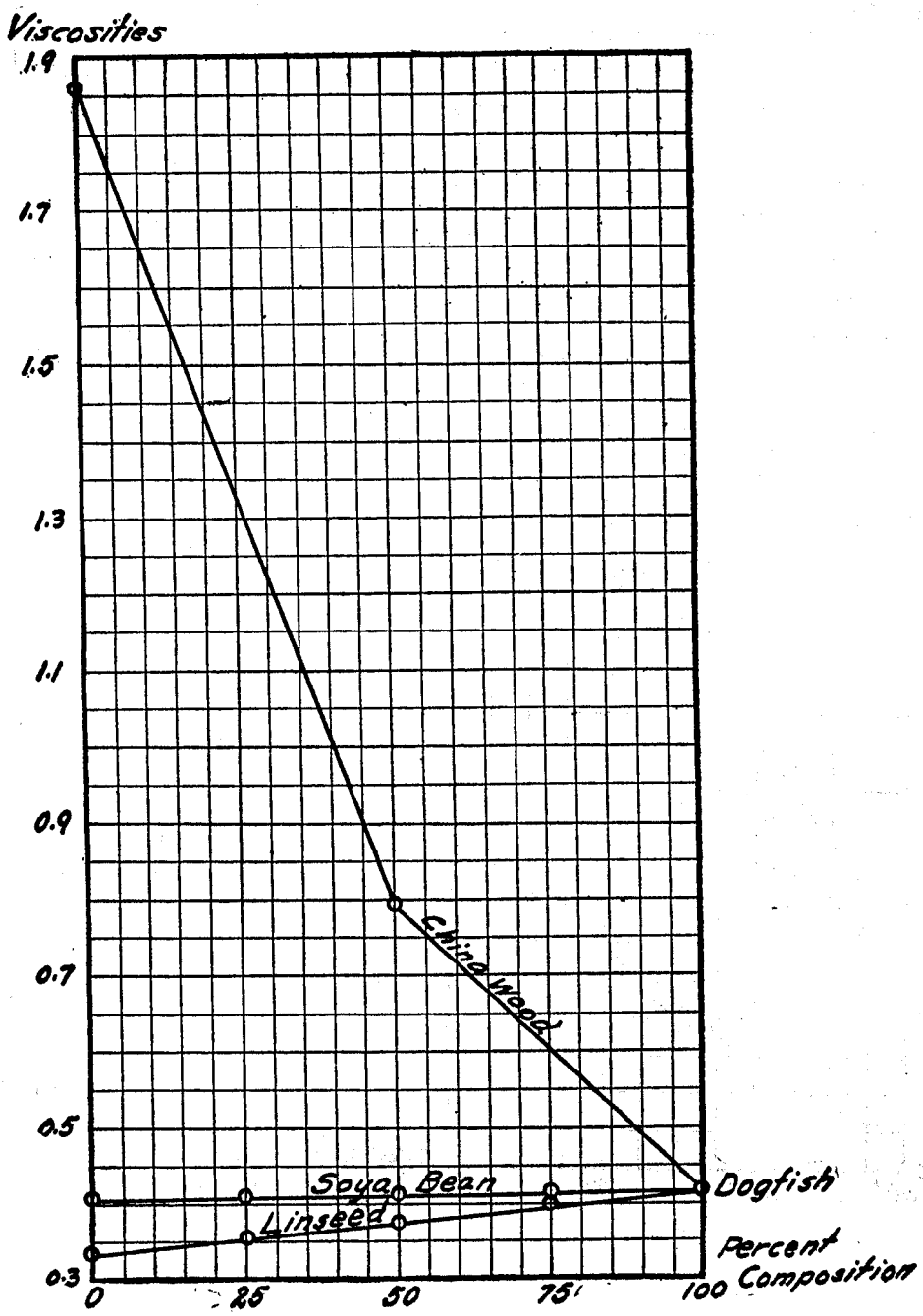

FIG. 1.—Viscosity Curves, 30°.

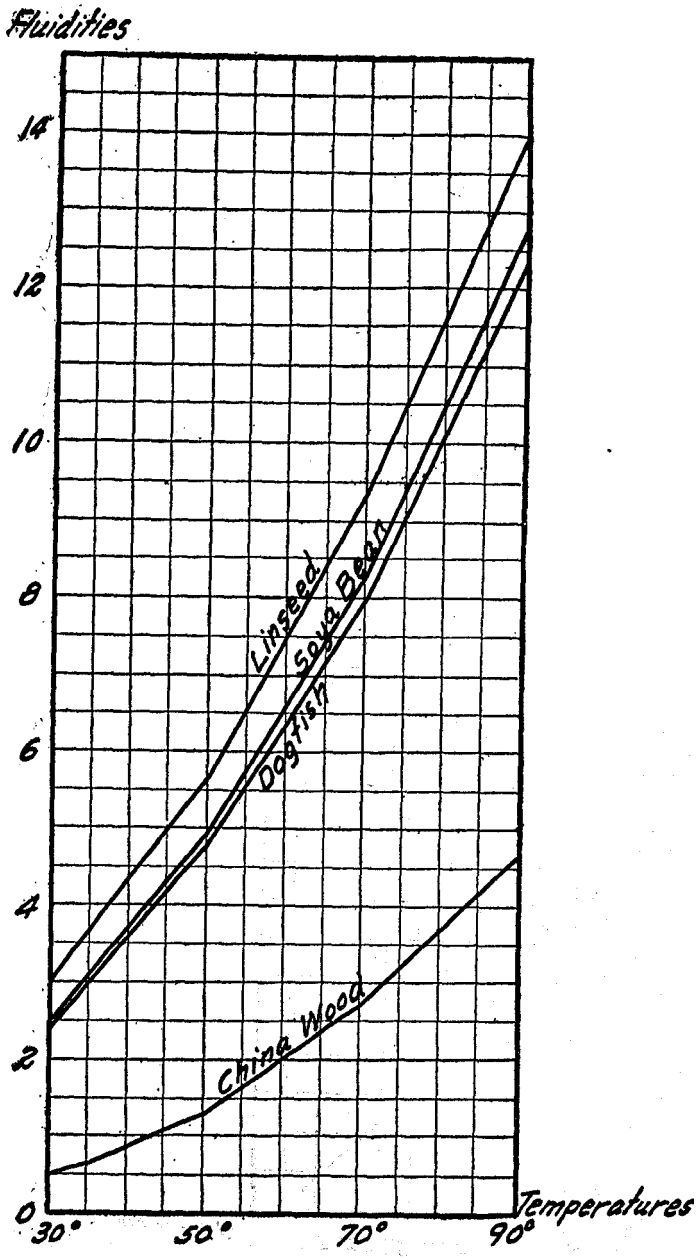

FIG. 2.—Fluidity curves, 30°–90°.

fluidity curve does not have the same slope as those of the other oils, and also its fish-oil mixtures do not give additive fluidities. The data in table IV show that it changes in composition on being heated to 90° since its viscosity at 35° changes from 1.589 to 1.946. The values for the other oils remain constant.

It is interesting to note how much more viscous is the China-wood oil than the other three oils, this property being a good test of its purity, since a little adulteration by other oils of viscosity approximating the others would lower the viscosity of the China-wood oil markedly.

The viscosity curves of the mixtures are given for 30° in figure 1. As has been shown before, the linear curves obtained for soya-bean oil and linseed oil mixtures were to be expected, since the viscosities of the components are nearly identical. Neither the viscosity nor the fluidity curves for the China-wood oil mixtures are linear.

DENSITY.

There is little to be said in regard to the data furnished by specific gravity determinations. These were made by use of the Ostwald pycnometer. The results are given in table VIII and shown by graphs in figures 4 and 5. Figure 4 shows that the densities

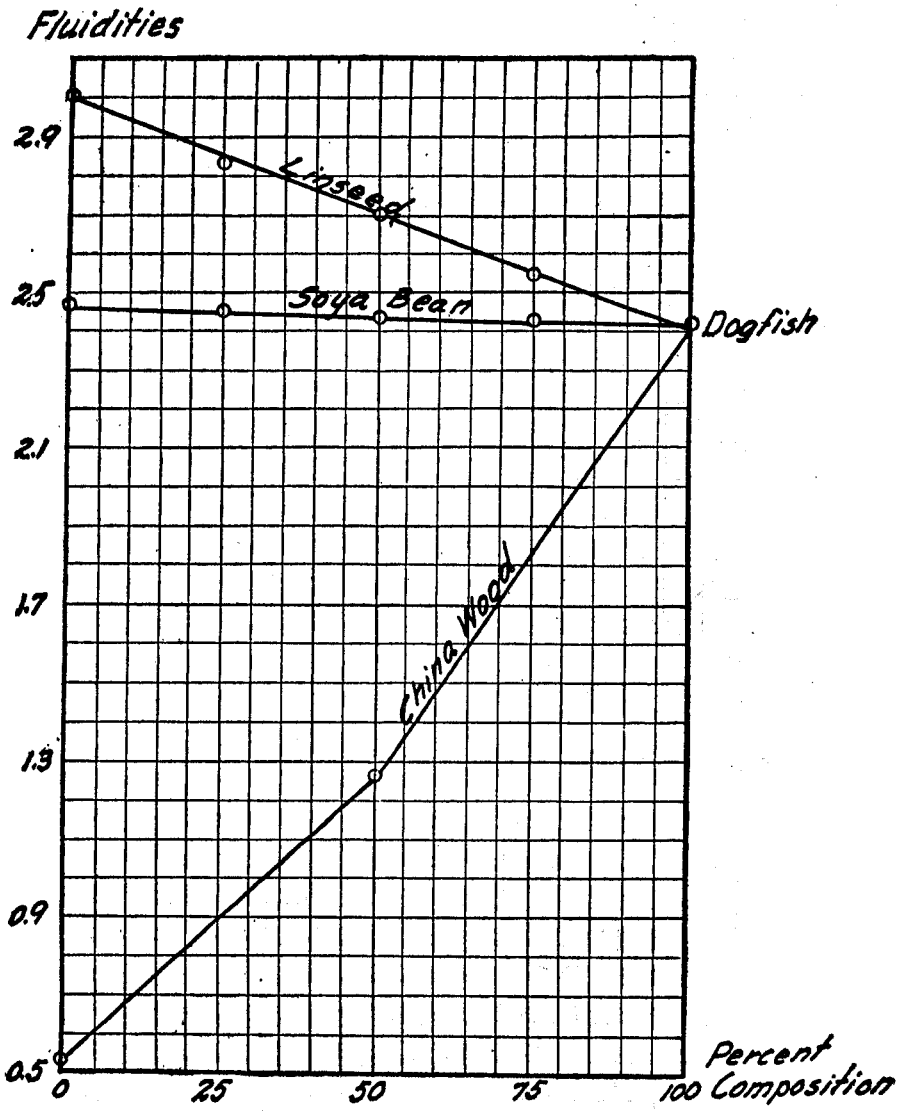

FIG. 3.—Fluidity curves, 30°.

are linear functions of the temperature over the range at which we worked, except with the China-wood oil, the composition of which changes on heating. Linseed and dogfish-liver oil mixtures have additive densities at 30° while the other mixtures do not. This data was of value to us principally in our calculation of the viscosities.

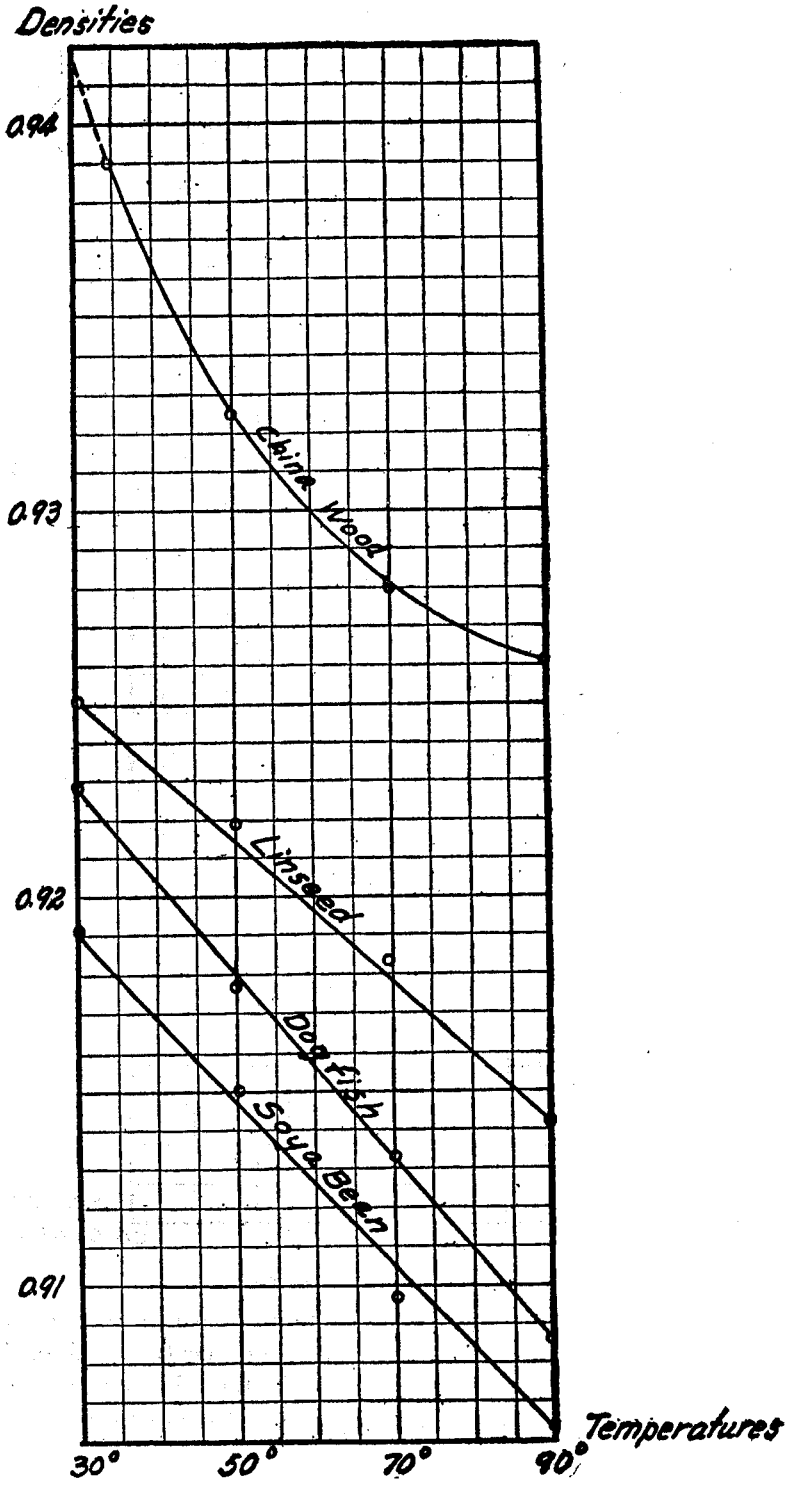

FIG. 4.—Density curves, 30°–90°.

TABLE VIII.—DENSITIES OF OILS AT GIVEN TEMPERATURES.

Oils.	30°	35°	50°	70°	90°
Dogfish-liver	0.9228	.....	0.9175	0.9131	0.9082
Linseed	.9251	.....	.9219	.9183	.9141
Soya-bean	.9191	.....	.9149	.9095	.9063
China-wood	.9411	0.9389	.9324	.9279	.9260
Dogfish-liver:					
25 per cent linseed	.9237	.....	.9158	.9120	.9090
50 per cent linseed	.9235	.....	.9124	.9051	.8986
75 per cent linseed	.9245	.....	.9169	.9100	.9051
25 per cent soya-bean	.9200	.....	.9158	.9111	.9082
50 per cent soya-bean	.9200	.....	.9149	.9076	.9055
75 per cent soya-bean	.9191	.....	.9141	.9103	.9046
25 per cent China-wood	.9268	.9237	.9149	.9209	.9074
50 per cent China-wood	.9300	.9289	.9255	.9230	.9188
75 per cent China-wood	.9348	.9322	.9245	.9230	.9204

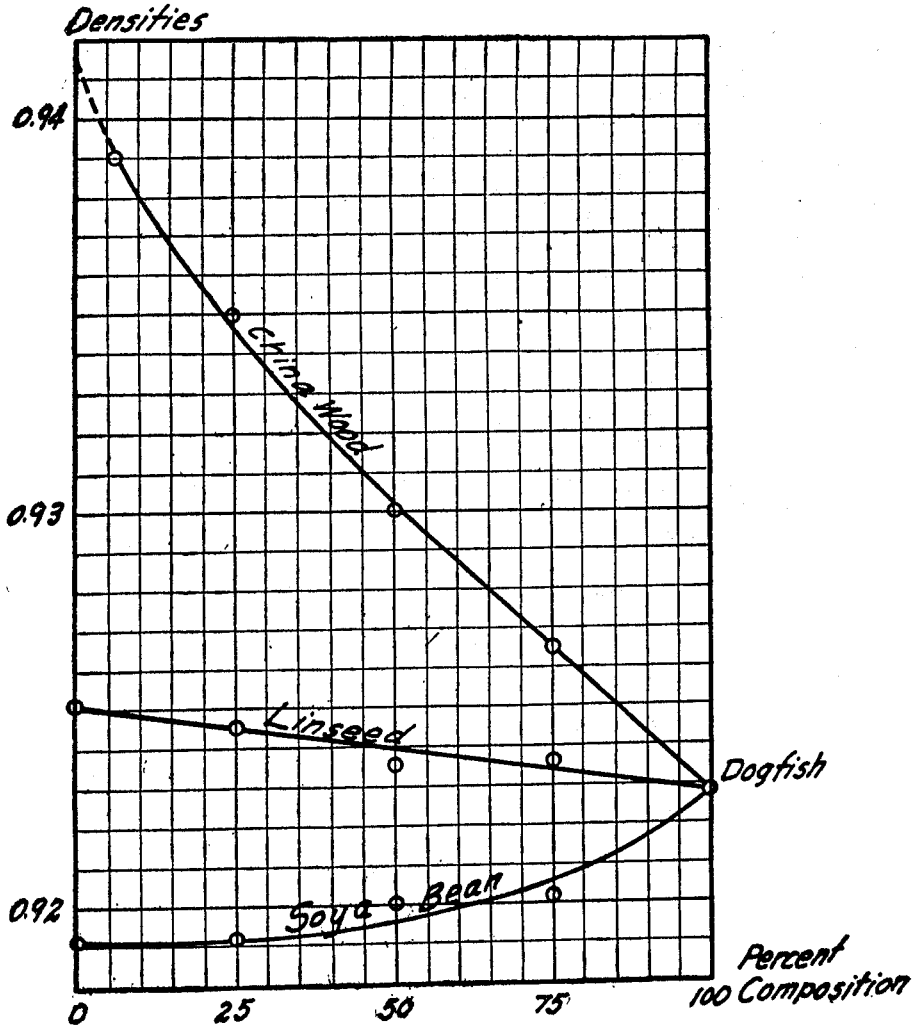

FIG. 5.—Density curves, 30°.

INDEX OF REFRACTION.

The refractive indices were measured by the use of a microscope, the apparent and true depths of a column of liquid being compared. Figure 6 shows that the index of refraction is not a good criterion of the purity of linseed and soya-bean oils when being tested for the presence of fish oil, but it should be valuable in the case of China-wood oil,

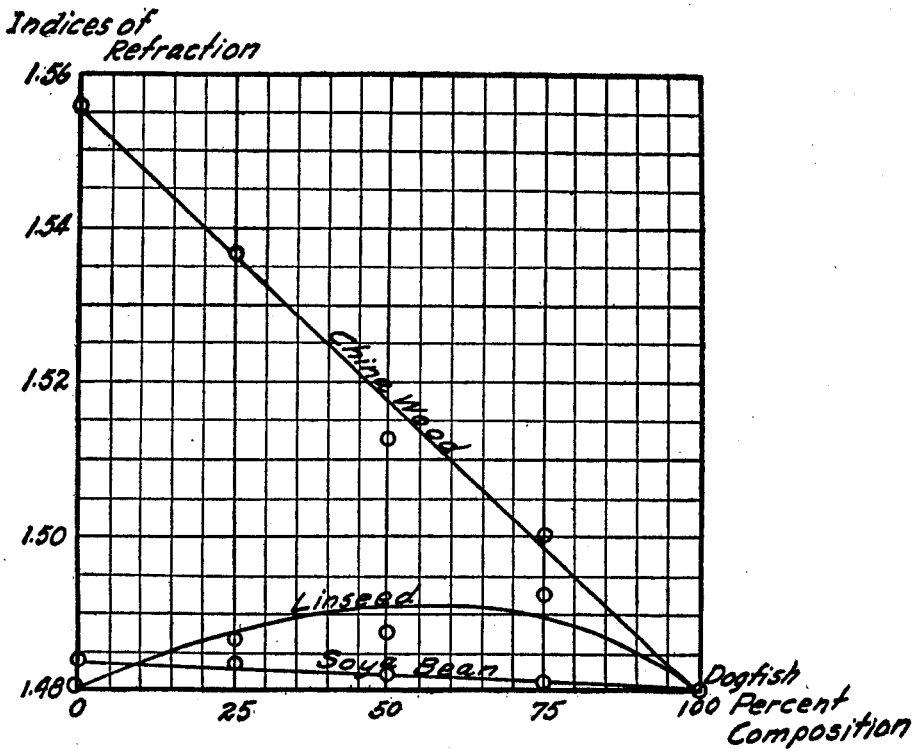

FIG. 6.—Index of refraction curves, 25°.

the refractive index of which is considerably greater than that of the other oils. This has been brought out by the work of Wise[a] in a recent study of this oil.

ACID, SAPONIFICATION, AND IODINE NUMBERS.

The results of the acid, saponification, and iodine number measurements are presented in table IX and figures 7 to 9. The first two numbers represent the milligrams of potassium hydroxide necessary for 1 gram of oil, while the iodine numbers were obtained by Hübl's method, being per cent iodine required by the oil.

[a] Wise, L. E.: On the indices of refraction of China-wood oil. Journal of Industrial and Engineering Chemistry, vol. 4, 1912, p. 497–498. Easton, Pa.

The acid numbers are seen to be additive generally for the mixtures, while the saponification numbers offer no general behavior. The iodine numbers are additive for

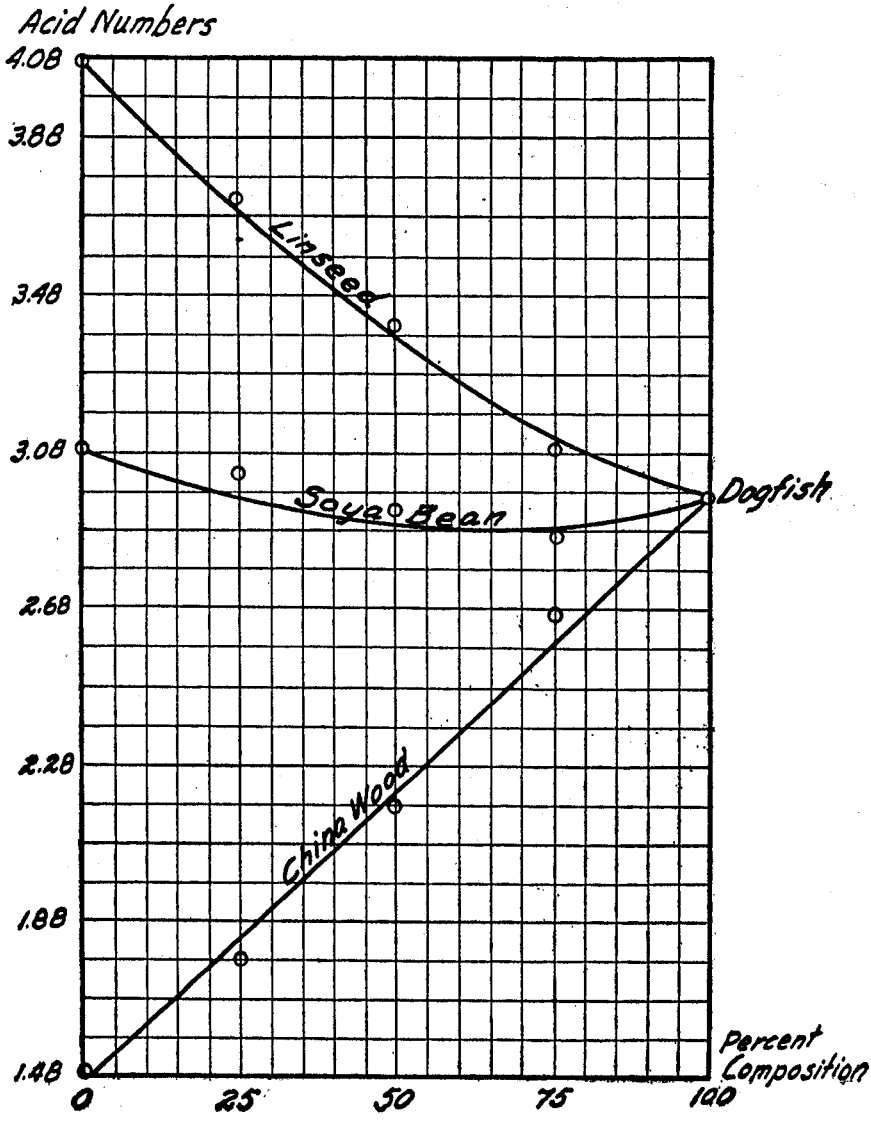

FIG. 7.—Acid number curves.

the linseed and soya-bean mixtures, the China-wood mixtures, however, giving a hyperbolic curve. As the iodine number of the linseed is so much higher than that of the dogfish-liver oil, this, as is well known, furnishes good evidence of the purity of the former.

The values for the other vegetable oils are so near those of the fish oil that great value can not be placed in this test. Reference may be made to the work of McIlhiney [a] for a method of examining China-wood oil.

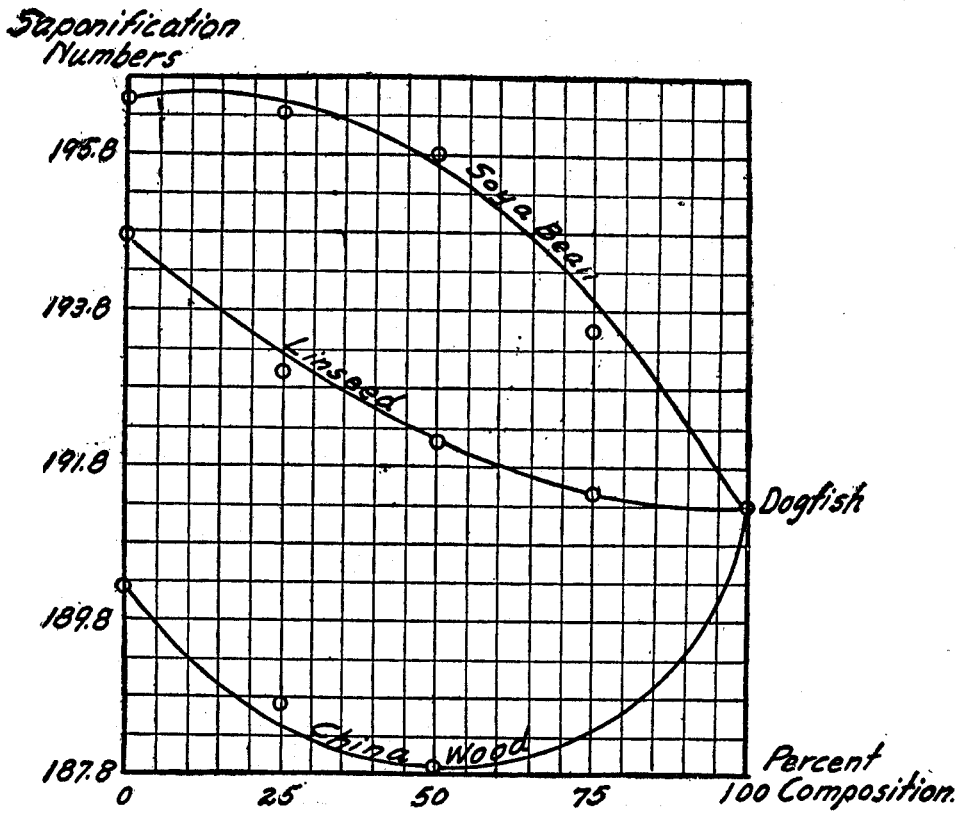

FIG. 8.—Saponification number curves.

TABLE IX.—INDEX OF REFRACTION, ACID, SAPONIFICATION, AND IODINE NUMBERS.

Oils.	Index of refraction at 25°.	Acid number.			Saponification number.			Iodine number.		
		1	2	Average.	1	2	Average.	1	2	Average.
Dogfish-liver	1.4801	2.91	2.94	2.93	191.3	191.2	191.3	122.7	120.3	121.5
Linseed	1.4805	3.98	4.01	4.00	194.0	195.3	194.7	152.1	152.7	152.4
Soya-bean	1.4837	3.08	3.08	3.08	196.7	196.4	196.5	130.5	125.1	127.8
China-wood	1.5560	1.47	1.49	1.48	190.1	190.2	190.2	(124.47)	137.1	137.1
25 per cent linseed	1.4948	3.06	3.06	3.06	191.4	191.6	191.5	129.2	.....	129.2
50 per cent linseed	1.4872	3.41	3.43	3.42	192.0	192.4	192.1	137.9	139.1	138.5
75 per cent linseed	1.4870	3.75	3.68	3.72	191.0	194.9	193.0	144.3	145.1	144.7
25 per cent soya-bean	1.4790	2.85	2.85	2.85	193.5	193.5	193.5	123.3	123.1	123.2
50 per cent soya-bean	1.4819	2.94	2.92	2.93	195.6	195.9	195.8	123.1	122.1	122.6
75 per cent soya-bean	1.4834	3.00	3.03	3.02	196.4	196.1	196.3	126.9	127.7	127.3
25 per cent China-wood	1.4997	2.60	2.72	2.66	193.2	193.0	193.1	128.0	126.4	127.2
50 per cent China-wood	1.5120	2.14	2.19	2.17	187.6	187.9	187.8	133.2	131.4	132.3
75 per cent China-wood	1.5363	1.78	1.76	1.77	188.5	188.9	188.7	135.6	136.5	136.1

[a] McIlhiney: A method of examining China-wood oil. Journal of Industrial and Engineering Chemistry, vol. 4, 1912, p. 496–497. Easton, Pa.

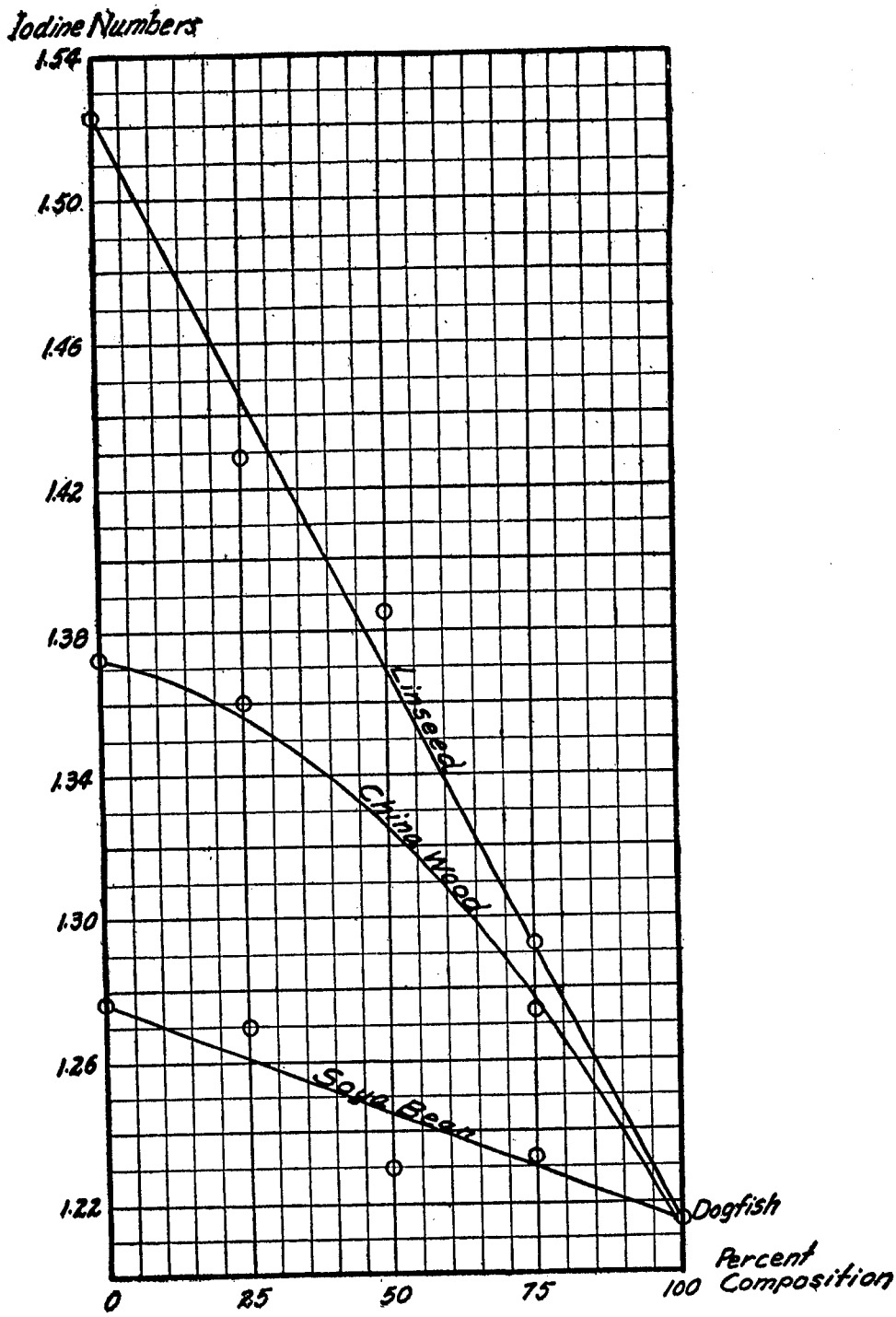

FIG. 9.—Iodine number curves.

SUMMARY.

1. The fluidities of fish and vegetable oil mixtures are additive, except where there is decomposition of either component on heating.

2. The viscosities of these mixtures are also additive when the values for the components approximate each other closely.

3. The fluidities of vegetable oils are nearly linear functions of the temperature. It has been previously shown that this holds true for various fish oils.

4. The fluidity of China-wood oil is a good test of its purity, as it is unusually low.

5. The specific gravities of the mixtures are approximately additive and vary linearly with the temperature. The density of China-wood oil is very high.

6. The index of refraction, acid number, and saponification number of the mixtures do not allow any general conclusions. The acid number of linseed oil is high and that of dogfish-liver oil is low compared with that of China-wood oil. The refractive index of China-wood oil is lowered by the introduction of small amounts of fish oil.

7. The low iodine number of the dogfish-liver oil makes the presence of this oil in vegetable oils known by marked lowering of their iodine values.

THE EFFECT OF WATER-GAS TAR ON OYSTERS

By Philip H. Mitchell

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THE EFFECT OF WATER-GAS TAR ON OYSTERS.

By PHILIP H. MITCHELL.

For a number of reasons it has become desirable to know the effects of oily and tar-like wastes on marine life of economic importance. Damages have been claimed for pollution of oyster beds by wastes from the manufacture of gas. A report to the Rhode Island shellfish commission has attributed to water-gas tar harmful effects to oysters in Narragansett Bay.[a] Tar of various sorts is used for coating piles or stakes, which might be in proximity to shellfish. Oily wastes are constantly escaping from passing craft in inland waters.

The present investigation does not cover the entire subject, but is confined to one important phase—the effect of water-gas tar on oysters. The experiments made during the summer of 1912 at the laboratory of the Bureau of Fisheries at Woods Hole could not then be carried further.

The tar was obtained from the separator at the works of the Providence Gas Co. on October 25, 1910, and was a mixture of the heavier and lighter tars as obtained in the manufacture of water gas, using an average temperature of 1,450° F. An analysis of tar taken under comparable conditions from the same separator at another time showed, according to the records of the Providence Gas Co., the following analysis:

Specific gravity at 65.5° F., 1.050.	Per cent by volume.
Water	7.65
Light oil at 200° F	13.95
Dark oil at 400° F	42.20
Medium pitch	36.20
Free carbon	2.70

Three series of experiments were made. In the first, oysters were exposed to water-gas tar in stagnant sea water; in the second series they were exposed to the tar in running sea water; while in the third small amounts of water-gas tar were introduced inside the shells of oysters.

SERIES I.

Experiment 1.—An oyster, marked with a file for identification, as were all the oysters used in these experiments, and weighing 83.2 grams, was put into a battery jar with 40 c. c. of water-gas tar and 2,500 c. c. of sea water. On the following day the water was changed by the method used in all the experiments of this series. A siphon delivered sea water from an aquarium to a point about 2 inches from the bottom of the jar, while another siphon at the same time drew off water from the middle of the jar. Water was allowed to run thus 10 to 15 minutes. As the tar stuck to the sides

[a] Field, G. W. In Annual Report of the Commissioners of Shell Fisheries, Rhode Island, 1906, appendix D, p. 46–64.

and bottom of the jar, or, in the case of the lighter more oily portions, floated on the surface of the water, none, or very little of it, was removed while the water flowed through the siphons. The water, therefore, was almost completely changed without removing the tar. Shortly after the water had been changed the oyster was seen to be slightly open, but could close at the slightest jar. The water was changed in this manner once or twice daily for 10 days, The oyster was often seen partly open during this time, but would always respond to a mechanical stimulus by closing. After 10 days the water was no longer changed, but was left entirely stagnant. At the end of two weeks under these conditions the oyster seemed to be affected. It now remained continuously open, and appeared unable to close when stimulated. A few days later it showed signs of putrefactive disintegration.

Experiment 2.—An oyster weighing 63.7 grams was treated exactly as in experiment 1. The results were quite the same, except that when the water was left entirely stagnant disintegration set in after five days.

Experiment 3.—An oyster weighing 71.6 grams was treated as in the preceding experiments, except that the tar was smeared all over the inside of the jar and on the oysters. After 24 hours the oyster was found wide open and unable to close when stimulated. It was removed from the jar, and was seen to have its mantle greatly retracted. It would spring open when closed by hand. It was washed and put into an aquarium in running sea water. Two days later it appeared to be entirely recovered, as it would close normally when stimulated. It was then put back into the jar of sea water and tar in which it had been at first. It was now kept in this jar during six days, with the water changed once or twice daily. At the end of this time it had again lost the ability to close normally, but when put in the aquarium once more it again apparently recovered. About three weeks later, however, it became disintegrated.

Experiment 4.—An oyster weighing 95 grams was arranged exactly as in experiment 3. The results were quite the same, that is, after 24 hours it refused to close, but recovered when put in the aquarium of running sea water. Some weeks later, however, it died. That its death was due to the tar is not certain, because at that time other oysters in the same aquarium died without any previous exposure to tar.

Experiment 5.—An oyster weighing 78.7 grams was treated exactly as in the preceding experiment. It, too, became unable to close after 24 hours, and when put in running sea water entirely recovered. At the end of the summer, nine weeks later, it seemed entirely normal and had a normal appearance when opened.

Experiment 6.—An oyster weighing 62 grams was treated exactly as in the preceding experiment. The result was slightly different in that the oyster did not begin to show a tendency to remain open until after three days, and became entirely unable to close after five days in the tarry water with daily changing of the water. It was then put in running sea water and began to disintegrate a few days later.

Experiment 7.—An oyster weighing 70.8 grams was put into a battery jar with 20 c. c. of the tar not in contact with it and 2,500 c. c. of sea water. The water was changed daily during the next 10 days. It was then left stagnant during 8 weeks. The oyster was sometimes observed to be open, but would then close if jarred. At the end of that

time it was cleaned and dried and found to weigh 71.6 grams. It had formed new shell all around the edge. Opened it gave no smell of tar, the heart was beating and the mantle was normally sensitive to mechanical stimuli. Part of the heart and portions of the gills were discolored.

Control experiment.—An oyster weighing 72.4 grams was put in a battery jar with 2,500 c. c. of sea water. The water was changed during the next 10 days as in the preceding experiment and was then left stagnant during 8 weeks. Examination then showed no noticeable new shell, but the heart, gills, and mantle were quite normal.

The experiments of this series indicate that when considerable quantities of water-gas tar are in intimate contact with oysters in stagnant water serious or fatal effects are produced. Under these circumstances the oyster can not use its natural defense against a relatively or entirely insoluble substance. When the water is stagnant, there is little opportunity to eject such substances and free the organism from them. As will be shown later, the oyster can rid itself of water-gas tar when in running sea water. When the tar can not be ejected it seems to produce an effect similar to paralysis, so that the initial symptom is a failure of the adductor muscle to respond to stimulation of the sensory nerves. No conclusions as to the structures specifically affected can be drawn from these experiments. Whether the fatal effects produced in five of the above experiments were due to a direct toxic effect of water-gas tar, or to some indirect effect also, does not appear from these experiments.

SERIES II.

Method.—Two oysters were put in each of four battery jars. Each jar was arranged with two siphons, one bringing sea water from an aquarium to the jar with the lower end of the siphon about 2 inches below the level of water maintained by the other siphon, which carried water from the jar to a sink. The running water therefore tended to carry off the light floating oils but left the heavier tar sticking to the bottom and sides of the jar. The siphons were so arranged that each jar contained constantly about 2,500 c. c. of sea water. Into each jar there were put 30 c. c. of water-gas tar mixed with sand and thoroughly smeared over the bottom and sides of the jar and on the shells of the two oysters. From time to time during the following weeks small amounts of tar were added to replace that carried away by the siphons. After remaining in the jars as described during nine weeks the oysters were cleaned, weighed, and examined. Comparison of their weights at the beginning and at the end of the experiments is given in tabular form:

Jar.	Initial weight.	Final weight.
	Grams.	*Grams.*
1	98.0	99.0
	47.8	47.8
2	92.0	92.0
	52.4	52.3
3	96.8	94.0
	61.8	62.5
4	101.1	100.7
	45.2	44.3

That these variations in weight have no special significance is indicated by comparison with the variations in the weights of oysters kept in the aquarium during the summer but not exposed to tar.

Initial weight.	Weight after five weeks.
Grams.	*Grams.*
66.5	66.0
76.0	76.5
244.0	243.0
147.0	151.0

When opened all were found to be normal in appearance and function. No odor of tar was detectable in the shell contents of the oysters, although an abundance of tar was left in the jars at the end of the experiment. Smears of tar were also still present on the outside of the oyster shells.

These experiments indicate that even intimate contact with water-gas tar does not injure oysters in the course of nine weeks, provided facilities for defense in the form of moving water frequently renewed are available.

SERIES III.

Experiment 1.—A small oyster was first pried open and injected with 0.5 c. c. of water-gas tar. It was then put in a jar of running sea water. It remained tightly closed during the next two hours. On the next day it was found to be quite normal. It was open and apparently feeding, but closed when stimulated. Drops of tar near it indicated that the foreign material had been ejected. One week later it still appeared entirely normal. It was then again injected with 0.5 c. c. of tar, and was now put in stagnant sea water. Four days later it did not, when stimulated, close as readily and tightly as a normal oyster. It was then opened and found normal in its heartbeat and in contractility of the bivalve muscle, but the mantle was not normally responsive to mechanical stimulus.

This experiment indicates that when an oyster ingests tar and can not get rid of it because the surrounding water is stagnant, some impairment of the sensory apparatus in the mantle results. This interferes with certain activities of the oyster, prevents normal closure, and eventually causes degeneration of muscular and other tissues.

Experiment 2.—Three medium-sized oysters were each injected with about 1.5 c. c. of water-gas tar and then put in separate jars of running sea water. Some time after they were seen in each case to open slightly and in a few minutes close violently so as to eject masses of tar. This process was repeated a number of times in the course of one to three hours after injection. They then remained constantly closed for some time, but were found normally open on the following day. They were left in the running sea water for a period of eight weeks and behaved throughout that time like control oysters in the aquarium. As it was then necessary to terminate the experiments, the oysters were

opened and carefully examined. They were found to be normal in color, odor, heartbeat, responsiveness of the mantle, ciliary movement, and in short in every respect.

This experiment distinctly indicates that water-gas tar in considerable doses is harmless to an oyster in running sea water. The conditions of this experiment more closely resemble those of the native habitat of the oyster than do those of the preceding experiment, because tides and other currents over oyster beds maintain a constant movement and a continuous changing of the surrounding medium.

Experiment 3.—A medium-sized oyster was injected with 1 c. c. of water-gas tar, which was distributed all around the mantle. It was then put into about 1,500 c. c. of sea water and carefully observed. During the next five hours it did not visibly open and no tar escaped from it. On the following day, however, a few drops of tar were floating on the surface of the water. During the next two days the oyster was only infrequently observed and was not seen open, but on the third day it was found normally opened and able to close when stimulated. It was left in the same sea water during the next two weeks. It had then developed the usual symptoms of imperfect closure and when opened did not show a normally beating heart or a responsive mantle. This experiment confirms the first one of this series.

EFFECT OF WATER-GAS TAR ON THE DISSOLVED OXYGEN OF SEA WATER.

It seemed possible that tar and similar substances might in a measure reduce the oxygen content of water so as to affect shellfish. Mixtures of tar and sea water were, therefore, allowed to stand for varying periods of time and then tested by Winkler's titration method to measure the quantity of dissolved oxygen in the water. The experiments are summarized in the following table. Three liters of sea water were used in each case.

Amount of water-gas tar used.	Time mixture was allowed to stand at room temperature.	Oxygen remaining in water at end of the time.
Cubic centimeters.	*Hours.*	*Parts per million.*
200	20	6.61
200	24	6.10
200	45	.00
200	130	.08
50	40	2.71
50	45	1.10
50	130	.08
None.	40	[a] 7.10
None.	45	[a] 8.09
None.	130	[a] 8.26

[a] Control, sea water alone.

These experiments show that the tar can cause the disappearance of dissolved oxygen in sea water. How potent a factor this may be in causing the effects of the tar on oysters in stagnant water it is not, however, safe to say. Oysters, as the author has shown, are remarkably resistant to lack of oxygen and do not when deprived of it

show inability to close except in the advanced stages of oxygen starvation. That oxygen consumption by tar may help to account for the fact that oysters are injured by stagnant tarry water, while they are uninjured by the tar in running sea water, is quite probable. In the natural habitat of the oyster, however, it seems quite impossible that the slight reduction of dissolved oxygen which small amounts of tar could effect would alter the results of oyster culture.

CONCLUSION.

These experiments show no noticeable effects of water-gas tar on oysters in constantly renewed sea water. This is true in spite of the fact that large amounts of tar mixed with stagnant sea water, or small amounts injected into oysters which are kept in stagnant water, do cause serious or fatal effects. Considerable quantities (1.5 c. c.) may be put inside the shell of an oyster kept under conditions resembling those of its natural habitat without causing any effect. The harmlessness of the tar under these circumstances is due apparently to the ability of the oyster to rid itself of such foreign matter. In stagnant water the organism can not be effectively washed out, and effects involving a loss of sensitiveness in the mantle result. That consumption of the dissolved oxygen in the stagnant water by tar may have some effect on oysters is a possibility.

THE OXYGEN REQUIREMENTS OF SHELLFISH

By Philip H. Mitchell

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THE OXYGEN REQUIREMENTS OF SHELLFISH.

By PHILIP H. MITCHELL.

The respiratory exchanges in lamellibranchs seem not to have been investigated. Probably the most notable work related to it is that of Vernon.[a] He measured the oxygen utilization and carbon dioxide emission in a large number of marine forms, including certain Mollusca but no lamellibranchs. He showed that in the lower marine forms investigated, including Coelenterata, Tunicata, and Mollusca, the respiratory exchange was very small compared to the higher ones, for example, teleosts. There were, however, certain exceptions to this rule, notably the protozoan *Collozoum inerme*, which showed nearly as high a respiratory exchange as the fishes. He found also that, in general, the respiratory activity was more readily responsive to temperature in the lower than in the higher forms. He further showed that the gaseous exchange was relatively greater in the small than in the large individuals of the same species and found that, in general, the same distinction held between small and large species. The transparent pelagic animals were shown to have a very small proportion of solid organic matter in their tissues, so that calculated on that basis their respiratory activity was very large, greater indeed than fishes, amphibians, or even mammals.

In the present work some of those findings have been confirmed for the lamellibranchs. They show a ready responsiveness to temperature changes, a smaller utilization of oxygen in proportion to the body weight with increase in size, and those forms which showed a low oxygen requirement in relation to their entire weight showed a higher utilization in proportion to their dried weight.

The resistance to lack of oxygen in forms which have no power of locomotion is an important factor in adverse conditions. This is especially true of the edible shellfish, which, because of enforced closure during cold weather, or in the presence of polluted or roily water, or in water whose oxygen has been lowered by the presence of certain wastes or an abundance of life, must at times be deprived of their normal supply of oxygen. The subject therefore possesses an economic significance, and it was, in fact, the possibility that certain manufacturing wastes, removing oxygen from sea water, might therefore cause the death of oysters and clams which first directed the writer's attention to the subject. The particular wastes involved were those of gas works con-

[a] Vernon, H. M.: Respiration in marine forms, Journal of Physiology, vol. XIX, 1895, p. 18.

taining at least traces and sometimes significant quantities of water-gas tar and other oily matter. The results of this investigation indicate, in a word, that the tar or oily wastes could have no effect on shellfish in this way. The details of this part of the work, however, are reserved for a report dealing specifically with the effect of water-gas tar on oysters. This paper is confined to oxygen requirements of shellfish and their resistance to lack of oxygen.

METHOD OF EXPERIMENT.

The method of manipulation was, in brief, to place the shellfish in a desiccator completely filled with sea water of known content of dissolved oxygen, leave the apparatus at some constant temperature during a definite period, and then to sample the water in the desiccator so as to compute its decrease in dissolved oxygen. Winkler's well-known titration method was used to measure the oxygen both at the beginning and end of each experiment. A vacuum desiccator was used for the containing vessel because it could easily be closed water-tight, could accommodate almost any size of shellfish, and enabled one to take through the side opening with glass stopcock a fair sample of the contents.

In practice a number of precautions were found necessary. The hollow dome of the desiccator cover was entirely filled with paraffin to exclude air from entrapment in it. A glass tube within the desiccator was connected to its side stopcock and reached nearly to the bottom. When, therefore, the filled desiccator was opened at the top water could be sucked off through the opened side cock into the sampling bottle so that the sample would come from a point well below the surface of the water, where the oxygen content would be fairly constant. The sea water [a] used in each experiment was brought to the required temperature and placed in a large reservoir jar on a shelf, from which it could be siphoned without bubbling into the desiccator. When it was thus nearly filled, an oyster was gently placed on a glass tripod, where it would rest near the center of the desiccator. With clams it was found necessary to leave them in the desiccator submerged in water for a few hours before the experiment, because, unlike oysters, they would not open quickly after they had been handled. In either case, though, water from the shelf reservoir was siphoned into the overflowing desiccator for sufficient time to bring the oxygen content to approximate constancy and then the cover was put on, leaving just opening enough to admit the siphon tube.

The side cock of the desiccator was then connected by rubber tubing to the sampling bottle, and after starting by suction the water was allowed to siphon through the bottle two to three minutes. This period was found quite sufficient to give reliable duplicate results for water containing any percentage of oxygen measured in these experiments. The water running into the desiccator meantime was in excess of that running into the bottle, so that an overflow was maintained from the top of the desiccator and the sample rendered as fair as possible. At the exact second recorded as the beginning of the experiment the side stopcock was closed, the siphon quickly withdrawn from the desiccator,

[a] From aquarium of running sea water, a part of the aquarium system of the laboratory.

and its lid put completely on, excluding bubbles. The entire apparatus was then kept in a bath of sea water whose temperature was maintained approximately the same as the water within the desiccator. The oxygen in the sample was meantime measured by titration.

After a period, usually about an hour in length, the desiccator was two or three times inverted to render its contents uniform and to stimulate the shellfish to close and thus stop using oxygen. The exact time of the first rough movement of the apparatus was recorded as the closing time of the experiment. The outside of the desiccator was then dried with a towel and the entire apparatus weighed. When currents in the water had come practically to rest, the side stopcock was again connected to the same sampling bottle used at the beginning of the experiment and a sample taken as before. Since the capacity of the desiccators was sufficient for 1,200 grams of water, even with the large shellfish, and as the sampling bottles held approximately 300 grams, it is plain that water could run through the sampling bottle some time without emptying the desiccator. The stream indeed was allowed to run at least two minutes. The capacity of the desiccators was not enough to permit of taking a duplicate sample that would be reliable, but this was not necessary because there is little chance of error in the Winkler's titration.

The last step in the process was to empty the desiccator completely, dry it and the shellfish, and weigh them together. This gave a means of determining by difference the weight of the water. It was probably accurate to within 2 grams. As the dissolved oxygen of the water both at the beginning and the end of the experiment was calculated in parts per million, it was only necessary to multiply the weight of water used by the decrease in its oxygen content expressed in parts per million and divide the result by 100 to find the decimilligrams of oxygen used by the shellfish. Experiment showed that no correction for change in the oxygen content of the water due to microorganisms or physical factors was, under the circumstances of constant temperature, etc., necessary. Results were expressed in decimilligrams of oxygen per hour and in most cases also computed in decimilligrams per hour per 100 grams of shellfish and in some cases in decimilligrams per hour per 1 gram of the dried weight of the total shell contents of the organism.

A formula for the first of these three computations might be expressed, therefore, as follows:

$$A = W\frac{a' - a''}{100} \cdot \frac{60}{t}$$

where A is the decimilligrams of O used per hour, W the weight, in grams, of water in the desiccator, a' the parts per million of oxygen in the first sample and a'' in the second sample, and t is the time of the experiment in minutes.

Throughout the experiments it was found necessary to observe the animal at frequent intervals, and if the shells closed up to discard the experiment, or if the shells closed only after a considerable number of minutes had elapsed to terminate the experiment immediately. This precaution was necessary because, as is well known, certain of the shellfish used in this work can close water tight and in that condition take from the

water, as will be shown below, no oxygen except the very small amount absorbed by their shells.

It appeared early in the work that constancy of results was exceedingly difficult to obtain. This was due to a variety of causes, chief of which was the great variability in the openness of the shells, for not only could the oyster or clam entirely or at least obviously close so that the experiment had to be terminated, but it could partially and unnoticeably close or indeed fail to open wide even from the beginning of the experiment. For the oyster, at least, the author succeeded in demonstrating this by graphic records. One shell of an oyster was connected by tying a string to the projections with a lightly balanced lever recording on a slow kymograph. As soon as the oyster in a water bath at a temperature between 18° and 20° C. had opened somewhat, the kymograph was started and the temperature of the bath raised at the rate of 1° C. in about eight minutes. The oysters remained fairly well open with brief periods of partial closure as the temperature increased to about 22° C. At that point there invariably appeared in the three individuals observed periods of maximum openness lasting as long as no disturbing factor intervened. Sufficient stimulus for partial closure, however, was likely to occur frequently. A light tap on the table or water bath, a heavy step in the room, the slamming of a door in a neighboring part of the building, or, indeed, any slight jar was surely registered by some movement of the shell. As the temperature increased up to about 26° or 27° C., the effect of these stimuli was much less marked. The oysters then maintained their maximum openness very persistently. Between 27° and 30° a tendency to very slow and incomplete opening after closure was noticeable, indeed no maximum openness was seen. At about 30° or 31° C., the oysters closed tightly, even if no mechanical stimulus was given.

As the kymograph method served to detect movements of the shell not noticeable to unaided observation and also slight openings of the shell not otherwise visible, these experiments were an aid to planning and interpreting measurements of oxygen utilization. They showed that below 19° C. and above 26° C. observations on the opened oyster were impossible, that temperature must be maintained constant throughout the experiment, and mechanical disturbances must be avoided as far as possible. A further source of difficulty had also to be overcome. When the oyster excreted it closed violently, to drive the fecal matter out of the shell. If the position of the animal rendered complete excretion difficult, closures were frequently repeated, and sometimes the oyster shut up tightly. It was necessary, therefore, to lay the oyster in the desiccator tipped so that the more concave side of the shell, where excretion occurs, would be lower than the other.

In spite of all precautions, however, perfectly consistent results could not always be obtained. Under the same or comparable conditions of temperature, oxygen content of the water, and physical conditions, the same individual would sometimes in different experiments give results disagreeing beyond the limits of the calculated, probable, experimental error. Various observations make it seem likely that the nutritive condition of the individual could account for some, at least, of these discrepancies. Thus, after

remaining at a high temperature (e. g., 24°–26° C.) for some time, the oxygen requirement at a slightly lower temperature would tend to be greater than if the shellfish had been at a lower temperature before the experiment. If an oyster had been out of water for some time before the measurement, more oxygen would be used, generally, than if the specimen were left in the aquarium until the time of the experiment. After the shellfish had been kept in the aquarium some weeks they tended to use less oxygen than when taken recently from their native environment. Exceptionally an individual would show a high utilization of oxygen out of proportion to previous measurements and lasting for several days. As many of the interfering conditions as possible were, of course, eliminated, but still it seemed necessary to make a considerable number of experiments and draw conclusions only from averages. More than 350 measurements were made under various conditions on three types of lamellibranchs—the oyster (*Ostrea virginica*), the soft-shell or long clam (*Mya arenaria*), and the quahog or round clam (*Venus mercenaria*).

RESULTS.

OXYGEN REQUIREMENTS OF THE OYSTER.

Three series of experiments, each made on a limited number of individuals, are submitted. Although the results can scarcely be taken to show any seasonal variation, they are grouped, for convenience, according to the time they were carried out. In table I are the results of measurements taken during July, 1911; in table II, those of July and August, 1912; and in table III are results obtained during the latter part of August, 1912.

In the experiments of table I definite temperatures were not previously chosen and carefully adhered to as in the later work. The results, therefore, are here grouped for comparison as follows: All measurements taken at temperatures between 20° and 21.3° C. appear in one column, those at 21.5° to 23.5° C. in another, and those between 26° and 28° C. in a third. Where two or more experiments were made with one oyster at temperatures within a given range the average of the results is placed in parentheses. In the last three columns are the averages of comparable experiments computed as the decimilligrams of oxygen used per hour per 100 grams of oyster. By weight of oyster is meant in this and other tables not otherwise specified the weight in grams taken after it was closed under water, wiped as dry as possible with a towel, and left to dry in the air not more than half an hour. Such weighings were shown by duplication to be accurate to within two-tenths of a gram.

In table II are the results of experiments performed at definite chosen temperatures so controlled that the variation was not more than half a degree centigrade in any single experiment. The first five columns of results show the decimilligrams of oxygen used per hour at five temperatures by nine oysters. The averages of all comparable experiments are put in parentheses. The last five columns contain the averages, expressed in decimilligrams, of the oxygen used per hour per 100 grams of oysters.

TABLE I.—OXYGEN USED BY OYSTERS.

NOTE.—Figures in parentheses are averages of experiments under approximately uniform conditions.

Weight of whole oyster.	Decimilligrams of oxygen used per hour.			Average decimilligrams of oxygen per hour per 100 grams of oyster.		
	At 20° to 21.3° C.	At 21.5° to 23.5° C.	At 26° to 28° C.	At 20° to 21.3° C.	At 21.5° to 23.5° C.	At 26° to 28° C.
Grams.						
42.0	.....	5.6 9.0 7.8 6.8 (7.3)	.....	.....	17.4	.....
56.6	.....	11.8 7.6 (9.7)	.....	.....	17.2	.....
85.0	9.4 14.7 14.0 (12.7)	.....	19.3 18.8 (19.1)	14.9	.....	22.4
106.0	10.1 15.6 (12.8)	19.4	22.9 22.9 26.2 (24.0)	12.1	18.3	22.6
113.0	14.6	18.2 16.1 (17.1)	.....	12.9	15.1	.....
127.0	12.7 13.6 15.7 (14.0)	21.8 21.5 19.0 21.2 (20.9)	.....	11.1	16.5	.....
141.0	.....	19.0 18.0 (18.5)	.....	.....	13.1	.....

TABLE II.—OXYGEN USED BY OYSTERS.

NOTE.—Figures in parentheses are averages of measurements under approximately uniform conditions.

Weight of whole oyster.	Decimilligrams of oxygen used per hour.					Decimilligrams of oxygen used per hour per 100 grams.				
	At 19.5° to 20° C.	At 21° to 21.5° C.	At 22° to 22.5° C.	At 24° to 24.5° C.	At 26° to 26.5° C.	At 19.5° to 20° C.	At 21° to 21.5° C.	At 22° to 22.5° C.	At 24° to 24.5° C.	At 26° to 26.5° C.
Grams.										
42.0	7.6 9.8 (8.7)	12.3 13.8 (13.1)	10.3 13.9 (12.2)	14.6	13.4 14.9 11.2 (13.1)	20.7	31.0	29.1	34.8	31.3
51.0	11.6 10.7 11.8 (11.3)	9.3 11.4 9.6 6.2 (9.6)	11.7 11.5 (11.6)	12.6 12.7 (12.65)	13.6	22.2	17.9	22.8	24.8	26.7
66.5	15.1 9.4 10.5 9.1 (11.2)	16.0 9.9 16.1 14.0 (14.0)	15.5 11.8 (13.7)	16.0	18.6 17.2 (17.9)	16.9	21.0	20.6	24.1	26.9
76.0	11.5 14.0 (12.7)	13.9 15.3 14.2 (14.5)	15.3 12.8 (14.05)	15.8 20.5 16.2 (17.5)	23.5 20.9 24.5 20.7 (22.4)	16.7	19.0	18.5	23.0	29.5
97.4	13.4	14.6	.....	18.0	22.1	13.8	15.0	.....	18.5	22.7
128.0	13.7 17.8 (15.75)	.....	17.9 25.9 18.6 18.4 (20.2)	25.9 19.8 (22.8)	24.8	12.3	.....	15.7	17.8	19.4
147.0	16.0 19.4 (17.7)	18.4 18.2 (18.3)	20.4 19.3 (19.8)	20.8 21.9 (21.3)	26.6 26.0 (26.3)	12.1	12.5	13.5	14.5	17.9
244.0	18.1 22.3 (20.2)	23.5 25.7 (24.6)	34.6 25.7 (30.1)	30.0 26.1 24.0 (26.7)	35.1	8.3	10.1	12.3	11.0	14.4
262.0	19.0	29.1 29.5 21.4 20.8 (25.2)	27.4 24.8 (26.1)	28.7 30.7 (29.7)	37.0	7.3	9.6	10.0	11.3	14.1
Average..	.....	.....	.....	.....	.....	14.5	17.0	17.8	20.0	22.5

In table III are the results of measurements at four chosen temperatures on four oysters. These experiments were all done within a few days after the oysters were taken from the beds and therefore serve to some extent as a control on the condition of the oysters used in the other series. The first columns of results show the decimilligrams of oxygen used per hour at the designated temperatures. The averages of comparable experiments are put in parentheses. The figures in the next four columns are obtained by computing the averages of the oxygen utilization per 100 grams of oyster. In the next column is the weight, in grams, of the shell contents of each oyster when dried to constant weight. The last four columns show average decimilligrams of oxygen used per gram of dried substance. The figures in these columns were corrected for the

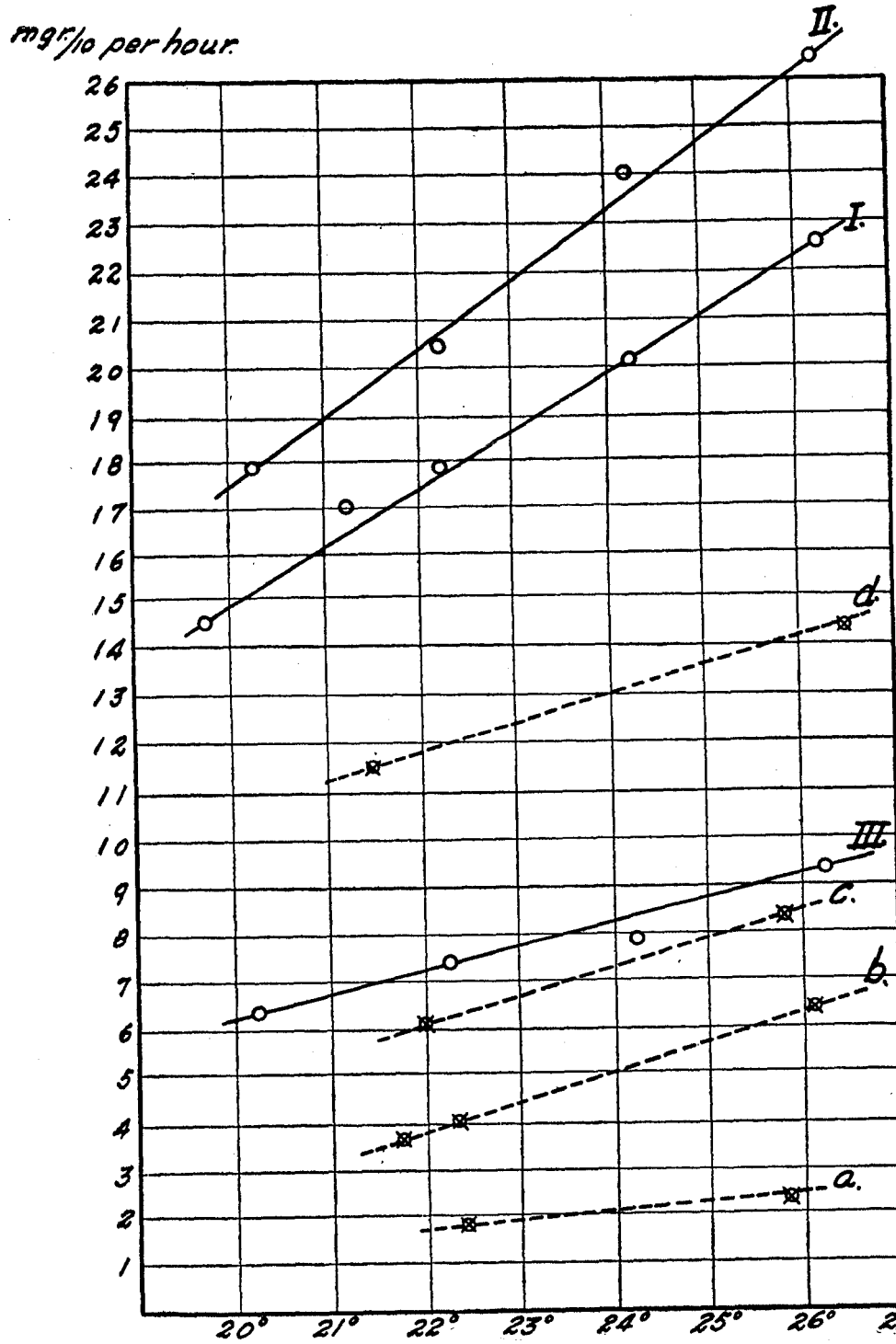
oxygen used by the shells. The shells of each oyster were at the end of the observations carefully cleaned in sea water and then used for two or three measurements of their oxygen-absorbing power at different temperatures. As these results were obtained under the same conditions as those expressed in table III, they represent a fair estimate of the oxygen absorbed by the shells during measurements with the intact oyster. There is reason, as will be shown below, to believe that oxygen removed from the water in this way is not utilized by the active tissues of the oyster. It seems reasonable, therefore, to subtract the amount (measured or computed) of oxygen utilized by the shells from that used by the whole oyster before computing the oxygen requirements per gram of dried tissue.

TABLE III.—OXYGEN USED BY OYSTERS.

NOTE.—Figures in parentheses are averages of measurements under approximately uniform conditions.

Weight, whole oyster.	Decimilligrams of oxygen used per hour.				Averages of same per hour per 100 grams.				Weight, dried oyster.	Average decimilligrams used per hour per gram of dried weight.			
	At 20° to 20.5° C.	At 22° to 22.5° C.	At 24° to 24.5° C.	At 26° to 26.5° C.	At 20° to 20.5° C.	At 22° to 22.5° C.	At 24° to 24.5° C.	At 26° to 26.5° C.		At 20° to 20.5° C.	At 22° to 22.5° C.	At 24° to 24.5° C.	At 26° to 26.5° C.
Grams.									*Grams.*				
47.8	10.6	12.2 14.1 (13.1)	14.2	17.1	22.2	27.4	29.7	35.7	1.15	7.92	9.74	10.40	12.90
73.5	16.6	20.0 17.5 (18.3)	23.1 18.3 (20.7)	22.0	22.6	25.0	28.2	30.0	1.66	8.20	8.61	9.43	9.56
153.0	19.4	22.4	21.4 21.7 24.5 (22.5)	25.2 25.9 (25.5)	12.7	14.6	14.7	16.6	2.36	5.98	6.78	6.56	7.15
173.0	23.5	24.5 24.7 (24.6)	29.2 30.8 (30.0)	39.0 34.3 (36.6)	13.6	14.2	17.3	21.2	3.64	3.49	4.00	4.53	6.10
Average.	17.5	19.7	21.9	25.3	17.8	20.3	23.5	25.9	.....	6.41	7.28	7.73	8.94

A graphic representation of the oxygen utilization of oysters at different temperatures is given on page 217. The ordinates represent decimilligrams of oxygen used per hour and the abscissæ are degrees Centigrade. The full lines represent measurements on intact oysters. Curve I is constructed from the averages of the oxygen utilization per hour per 100 grams in experiments on nine oysters as summarized in table II. Curve II is constructed from similar averages of experimental results on four oysters as shown in table III. Curve III is based on the same results used for curve II, but represents the averages of oxygen used per hour per gram of dried shell contents. The relationship between oxygen and temperature is apparently a simple one. The interrupted lines represent measurements on empty oyster shells showing the decimilligrams of oxygen used per hour by shells as recorded in table IV. Curves *a*, *b*, *c*, and *d* refer, respectively, to shells weighing 47.8, 73.4, 153, and 161 grams. The effect of temperature on the three larger shells seems to be fairly constant; their curves are parallel. The discrepancy in the smallest shell may be due to experimental error as so few determinations were made.



Relation of oxygen utilization in the oyster to temperature. Explanations in the text on page 216.

NONUTILIZATION OF OXYGEN BY CLOSED OYSTERS.

Since oysters can close absolutely water tight, it seemed possible that under such conditions they would take in no oxygen. The very small oxygen requirements of voluntarily closed individuals could not, however, be interpreted as proof of this because when the oyster appears to be closed it may be slightly and invisibly open. This was proved by graphic records. To insure closure throughout an observation it was necessary, therefore, to use some artificial closing device. Several clamps were tried. An ordinary surgeon's artery clamp was found to be most satisfactory. If clamps without imperfections, carefully vaselined, were used, they did not appreciably rust during the experiment and withdrew from the water only a small and constant quantity of oxygen. As control experiments the oxygen absorption of empty shells of oysters about the same size as the one observed was measured. The control shells were fastened together by a clamp duplicating the one used on the oyster. Water had some access to the interior of the empty shells through nicks in their edges. On their immersion in water all air was driven from them. In many experiments controls were deferred until the same oyster could be emptied and its shells used for control measurements.

The results of a number of determinations are given in table V. It is seen that in every case the experiment and its control are in close agreement, as the difference is within the limit of experimental error except in the case of the largest oyster used. Even these differences, however, show a larger oxygen absorption by the empty shells than by the closed intact oysters. That the slight oxygen disappearance does not represent a respiratory intake by diffusion through the shells is indicated not only by the controls but by the observation that a two hours' exposure of the clamped oyster does not cause twice the oxygen absorption observed during one hour. Thus in one experiment a clamped oyster used 1.83 decimilligrams of oxygen in one hour, but 3.01 in two hours, while another, which used 1.70 decimilligrams in one hour, required 2.80 for two hours.

The explanation of the constant slight absorption of oxygen by clamped oysters and empty shells was not positively determined, but would seem to lie in several causes. Bacteria and various marine vegetative growths on the shells were first considered as possible oxygen users. Oyster shells that had been soaked 16 hours in 80 per cent alcohol and then carefully scrubbed and dried, did, indeed, show a diminished oxygen absorbing capacity, in one case lowered from 5.25 decimilligrams per hour before the alcohol treatment to 4.68 after it, and in another, from 3.08 to 2.34. This indicates that foreign growths do not account for all the oxygen absorption, and, indeed, it was found that the cleanest and most carefully sterilized shells took oxygen from the water.

An adsorption effect of porous substances on dissolved oxygen suggested itself as another possibility. It was found that porcelain evaporating dishes about the size of oysters showed equivalent oxygen absorbing powers. Corks had the same capacity. Water containing medium sized corks lost 2.34 decimilligrams of oxygen per hour, while in a control experiment water alone lost only 0.26 decimilligram, which is within the limit of experimental error.

TABLE IV.—OXYGEN ABSORBED BY EMPTY OYSTER SHELLS.

Weight of whole oyster in grams	47.8	47.8	73.4	73.4	73.4	153	153	161	161
Temperature of experiment in degrees centigrade	22.4	25.8	21.7	22.3	26.1	22.0	25.8	21.5	26.5
Oxygen absorbed per hour in mgr/10	1.9	2.4	3.6	4.1	6.3	6.1	8.3	11.5	14.4

TABLE V.—OXYGEN ABSORBED BY CLOSED OYSTERS.

Weight of oyster.	Temperature of experiment.	Oxygen used per hour.	Description of control experiment.
	°C.	Mgr/10.	
45 grams...	22.0	1.70	
Control....	22.0	1.70	Empty shells of same oyster with artery clamp.
50 grams...	22.0	1.83	
Control.....	22.0	1.83	Do.
66.5 grams..	23.2	2.04	
Control.....	21.0	1.92	Do.
Control.....	23.2	2.58	Empty shells of oyster weighing 45 grams with clamp.
66.5 grams..	20.5	1.41	
Control.....	20.5	1.48	Empty shells of oyster weighing 51 grams with clamp.
128 grams..	20.5	1.79	
Control.....	20.5	1.92	Empty shells of same oyster with artery clamp.
147 grams..	20.5	1.74	
Control.....	20.5	1.62	Do.
244 grams..	20.5	1.70	
Control.....	21.0	2.34	Do.
262 grams..	20.5	3.39	
Control.....	21.0	4.68	Do.
244 grams..	27.5	3.47	
128 grams..	27.5	2.36	Control experiments not made.
66.5 grams..	27.5	2.49	
76 grams...	27.5	2.80	

RESISTANCE OF OYSTERS TO LACK OF OXYGEN.

A series of experiments was undertaken to find out the minimum oxygen supply that would maintain an oyster alive. The sea water surrounding an oyster in a vacuum desiccator was as far as possible rendered oxygen free by boiling at room temperature under diminished pressure for half an hour. It was found in two trials that sea water alone when so treated and kept twelve hours in the closed desiccator still had an oxygen content less than 0.5 of a part per million. An oyster kept under these circumstances four days showed no ill effects. Another was kept thus three days, transferred to a second desiccator of exhausted sea water, which was quickly again pumped out, and was then kept four days further in the oxygen poor medium. The shells then had some black deposits on them indicative of incipient anaerobic putrefaction. The sea water on opening the desiccator was found absolutely oxygen free. The oyster, however, seemed unimpaired, and after remaining in the aquarium some time was opened and found apparently entirely normal. As each desiccator held about 1,200 c. c. and the oxygen content of the water in each case was at the most 0.5 of a part per million, the oxygen available to the oyster might be estimated as 1.2 milligrams plus the small amount obtained during the transfer from one desiccator to the other. If we disregard the latter source because the oyster was tight closed at the time, only 1.2 milligrams of oxygen were used during seven days.

In another experiment an oyster was kept three days in the first desiccator full of pumped-out water, three days in the second, two days in the third, two days in the fourth, and two days in the fifth. By that time it was black and unable to close properly. After a few hours in the aquarium it showed disintegration, so that twelve days of life in oxygen-poor water proved fatal. Time and facilities for carrying out many of these experiments were missing, although the seven-day experiment was practically duplicated by one in which an oyster was kept in the same desiccator full of water six days with no ill effects. That the fatal effect of a twelve days' exposure was not due to insufficient renewal of the water was shown by control experiments in which several oysters were kept in the same water during fourteen days while air was bubbled through it. The oysters survived this treatment uninjured.

OXYGEN REQUIREMENTS OF CLAMS.

Measurements on clams were made by the same method used for oysters. The results of successful experiments are embodied in table VI. They show a general agreement with measurements on oysters. The amount of oxygen used by clams weighing about 60 grams is somewhat higher per 100 grams than that used by an oyster of about the same weight and observed at the same temperature. Computed per gram of dried shell contents, however, the oxygen requirements of the clam seem somewhat smaller than those of the oyster. Here, as with oysters, the amount of oxygen used is more or less proportional to increase in the temperature, though sufficient data to show a simple relationship were not obtained. In this case, also, the oxygen requirement per gram is less in the larger individual than in the smaller, again like the oyster.

TABLE VI.—OXYGEN USED BY CLAMS.

NOTE.—Figures in parentheses are averages of measurements under approximately uniform conditions.

Weight whole clam.	Decimilligrams of oxygen used per hour.			Averages of same per hour per 100 grams.			Weight dried clam.	Average mgr/10 used per hour per gram, dried weight.		
	At 20° to 21° C.	At 22° to 22.5° C.	At 24° to 24.5° C.	At 20° to 21° C.	At 22° to 22.5° C.	At 24° to 24.5° C.		At 20° to 21° C.	At 22° to 22.5° C.	At 24° to 24.5° C.
Grams.							*Grams.*			
7.0	1.2	.....	.....	29.6	.....	.....	.....	.....	.....	.....
	3.0									
	(2.1)									
19.5	5.19	9.7	15.1	26.7	49.7	77.4	1.32	3.93	7.35	11.4
21.0	9.2	.....	.....	26.9	.....	.....	.....	.....	.....	.....
	6.7									
	(7.9)									
28.0	8.2	.....	.....	29.3	.....	.....	.....	.....	.....	.....
57.0	11.0	.....	.....	20.7	.....	.....	.....	.....	.....	.....
	12.4									
	(11.7)									
57.5	.....	17.2	30.0	.....	30.0	52.2	3.97	.....	4.34	7.55
60.0	.....	19.1	.....	.....	31.9	.....	.....	.....	.....	.....
63.0	17.7	.....	.....	25.8	.....	.....	.....	.....	.....	.....
	15.2									
	(16.4)									

TABLE VII.—OXYGEN ABSORBED BY CLOSED QUAHOGS.

Weight of quahog in grams	150	150	91	91	246	246 [a]	150 [a]	150 [b]	91 [b]
Temperature in degrees centigrade	24.0	24.0	24.0	23.0	24.3	23.0	23.0	23.6	23.5
Oxygen per hour in mgr/10	.37	.25	.38	.25	.23	4.60	4.30	2.43	2.95

[a] Voluntarily closed but not clamped. [b] Measurements on empty shells alone.

OXYGEN ABSORPTION OF CLOSED CLAMS.

Only one experiment was made in this connection. A medium-sized clam was closed by an artery clamp over the siphon end of the shells. As a control, empty shells of an oyster of the same size similarly clamped were used. The live clam absorbed 2.68 decimilligrams of oxygen per hour at a temperature of 23.5° C., while the shell took 2.58. This indicates that the clam, like the oyster, has little or no opportunity to obtain oxygen when the shell is not open. Further observations incidentally made confirm this conclusion. A medium-sized clam which visibly failed to open throughout an experiment to determine its oxygen requirements took only 2.44 decimilligrams of oxygen from the water in an hour. Other similar results were obtained.

OXYGEN REQUIREMENTS OF QUAHOGS.

Great difficulty was experienced in measuring the oxygen utilization of quahogs, because they seldom opened for any length of time under the conditions of experimentation. As a result of this, only a few measurements that could be considered reliable were obtained. It was found necessary to place the specimen in sea water in the desiccator a long time before the experiment, usually the night before, in order to have it open at the time of observation. Handling or moving caused it to close and stay closed for some hours.

The few successful observations showed a rather low oxygen utilization. One specimen weighing 91 grams used, at 24° C., 10.1 decimilligrams of oxygen in one hour, 10.8 in another measurement, and 6.4 in a third. Another quahog, weighing 150 grams, used, at 24° C., 7.8 decimilligrams per hour, and a large one (470 grams) used 22.4 decimilligrams per hour. Many other measurements were attempted, but owing to closure soon after the beginning of observation were unreliable. The oxygen requirements in proportion to the dried weight showed a still greater discrepancy in comparison with similar computations for the oyster. The dried weights of the shell contents of the first two quahogs observed were, respectively, 2.22 grams and 3.86 grams. The oxygen used per hour and per gram of dried weight, then, was 4.10 decimilligrams for the first and 2.21 for the second. This is less than half the amount of oxygen used by oysters of comparable weight observed at the same temperature. To prop the shells open seemed hardly worth while, because the oxygen utilization under such circumstances would be abnormal on account of the resulting violent contractions of adductor muscles. It seemed best, therefore, to be content with the conclusion that under the circumstances of these experiments quahogs used only a small quantity of oxygen.

UTILIZATION OF OXYGEN BY CLOSED QUAHOGS.

Clamping these shells as in the experiments described for oysters showed that closed quahogs used no oxygen. Their very smooth shells apparently took almost no oxygen from the water. With various sizes of quahogs clamped and observed at 24° C., results were obtained as follows: 0.37, 0.25, 0.38, 0.23, and 0.25 decimilligram of oxygen per hour. The empty shells, considerably broken in the process of opening, used a distinctly larger amount of oxygen than did the closed intact animal. The small amounts of oxygen taken up under these conditions are no more than would disappear from the sea water with a clamp in it.

It was clearly shown, however, that voluntarily closed quahogs did take up appreciable quantities of oxygen. In observations where the shells were apparently quite closed, various medium and large sized specimens took up, at 24° C., 2.9, 6.1, 4.6, and 4.3 decimilligrams of oxygen per hour. It would seem, then, that when voluntarily closed they do not remain shut absolutely tight, but take in small amounts of water through an aperture too narrow to be visible to the naked eye. The results are summarized in table VII.

CONCLUSIONS.

1. Oysters of medium sizes, at temperatures between 19° and 28° C., used from 7 to 35 decimilligrams of oxygen per hour per 100 grams of entire weight. The amount varies with the temperature, so far as experiments show, according to simple relationship, so that the curve approximates a straight line. It is proportionally less for larger specimens. The oxygen utilization is, however, exceedingly variable, depending on a variety of conditions, most of which probably affect the openness of the shell.

2. Oysters when tightly closed take no oxygen from the surrounding water; at least, no more than is taken by empty shells.

3. Oysters show considerable resistance to lack of oxygen. Only exposure for more than a week to water containing very small quantities of oxygen proved fatal. This indicates that any conditions causing temporary decrease in the available oxygen are not a significant factor in oyster culture.

4. The common clam (*Mya arenaria*) shows a higher oxygen requirement than the oyster. This seems surprising, in view of the fact that clams so often exist in muds where oxygen-consuming putrefactions are going on. The oxygen requirements of clams and oysters in proportion to their dried weights are about equal.

5. Both clams and quahogs (*Venus mercenaria*) use no oxygen from the water when tightly closed, but the quahog takes up oxygen while slightly and invisibly open.

6. The oxygen requirements of the quahog are, under the conditions of these experiments, conspicuously low.

THE ANTHOZOA OF THE WOODS HOLE REGION

By Charles W. Hargitt

Professor of Zoology, Syracuse University

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INTRODUCTORY.

The present report aims to present in convenient form a synoptic account of the Anthozoa (Actinozoa) of the region, adapted alike to the needs of the general worker in systematic zoology and those desiring in brief compass a modern survey of the habits, characteristics, and local distribution of the group.

The material forming the basis of the report has been collected for the most part by the writer at various times during the past five years, though some of the specimens of deep-water habitat were collected by the *Fish Hawk* during dredging expeditions at various times within the past 10 years. A record of these latter collections will be noted in connection with the several species concerned.

It is again my pleasure to acknowledge the assistance of Mr. Vinal N. Edwards in many ways. My thanks are also due to Commissioner George M. Bowers and to Dr. F. B. Sumner, director of the laboratory, for many courtesies.

GENERAL ACCOUNT.

Anthozoa are marine animals of various range of distribution, habit, size, etc., and variously known as actinians, sea anemones, polyps, etc. In general they are more or less sedentary, i. e., attached to some permanent support, such as rocks, piles, etc., or in some cases (Alcyonaria) rooted in the sandy bottoms where they thrive, or in still other cases (corals) forming a calcareous skeleton, which in the subtropical species gives rise to complex reef masses. Not a few of the actinians have a measure of locomotor power and creep, snail-like, over the supporting base to which they are attached. And again still others are given to a commensal mode of life, forming the well-known partnerships with hermit crabs or other creatures of similar habit. Further notice of these peculiarities will be given in connection with the species which exhibit the trait.

Anthozoa, in common with other classes of cœlenterates, may live a wholly solitary and independent life, as in most actinians, or may form highly complex colonies, as in most corals and Alcyonaria. In the case of colonial species the polyps are usually

united in more or less compact masses, the whole colony being brought into communal relations by means of a common body substance, the cœnenchyme, through which a system of gastric canals ramifies in various degrees, and thus directly or indirectly brings the various individuals into communication, both for nutritive and for protective purposes. It is most interesting to observe the sensory continuity which prevails in one of these colonies. Any irritation which disturbs one polyp is promptly conveyed to every individual of the colony, a sensory wave passing over the community not unlike that produced by the wind upon a field of grain or tall grass.

MORPHOLOGY.

In form and structure Anthozoa have many features of very considerable interest, not only to the critical student of morphology but to the casual observer or student of natural history. In form there is exhibited a wide range, from the simple polyp, of minute size and of structure hardly more complex than that of a hydrozoan, to the complexity and mass of immense communal aggregates of reef corals and sea plumes and gigantic anemones more than a foot in diameter.

In fundamentals of structure there is of course a more or less intimate homology running throughout the entire class, though with considerable ordinal peculiarities, and even generic and specific features more or less unique. The general form of the individual polyp, whether actinian or alcyonarian, is cylindrical or barrel-shaped, with a hollow gastric interior. Usually the height is considerably greater than the diameter, but owing to the highly contractile powers of the organisms these proportions vary greatly under various conditions of contraction. The body is terminated by a basal portion usually known as the foot, or pedal disk, and by an upper terminal portion, the oral disk, or peristome. The body proper is usually designated as the column. In sedentary species the pedal disk forms an organ of attachment, or in those having motile power constitutes the chief organ of locomotion. This feature is rather peculiar to the free-living species, though it may be absent in such tube-dwelling forms as *Cerianthus*.

The oral disk is characterized by the presence of a distinct mouth, which is usually of oval shape, especially in actinians, and with its edges, or lips, more or less folded or corrugated. The mouth communicates with the gastric cavity or enteron through an œsophagus, the inner end of which opens abruptly into the gastric cavity.

A series of radially arranged septa, the mesenteries, connect the inner walls of the œsophagus with those of the body, thereby forming a regular series of alternating septa and pockets, the latter ending blindly at the oral disk above, except as they may communicate with the bases of hollow tentacles, but opening freely below into the enteron. The margins of the mesenteries below their œsophageal connections are often more or less thickened, and bear filaments which are characteristic of Anthozoa. They are composed of entoderm, and are richly supplied with gland and nettling organs. In many actinians these latter organs are threadlike, highly contractile structures known as acontia, which are loaded with specialized nettling cells, and may be

thrust out of special pores, cinclides, or through improvised openings in the tissues of the body wall.

The marginal portion of the oral disk bears the tentacles, which are usually hollow outgrowths from this part of the body. They vary greatly in size and number in different species and genera. In Cerianthidæ they form two distinct sets, the circumoral, surrounding the mouth, and the marginal, corresponding to those of other orders. The latter are often designated as primary or principal tentacles; the former as accessory or circumoral.

As indicated above, the general form of the body as a whole is more or less cylindrical. Peculiarities of distinction will be considered in connection with those species exhibiting them. This will also be the case in reference to particular features of oral or pedal disks. In many of the orders some form of skeleton, calcareous or horny, is present. This is particularly the case with most corals and alcyonarians. On the other hand, most or all actinians are entirely devoid of anything of the sort.

Another feature of some significance is the habit of certain actinians to expand and inflate the pedal disk and thus convert it into a float by means of which they are able to migrate under the influence of currents, much as do certain other pelagic coelenterates (*Vesalia*). This has been observed in several local species, and it seems not unlikely that it may be of more general occurrence than might be supposed. Among those which exhibit the phenomenon may be mentioned *Sagartia luciæ*, *S. leucolena*, and *Anemonia sargassensis*. It should be stated, however, that this has been noted only in specimens in the aquarium; but its occurrence under these conditions with more or less frequency would strongly suggest its occurrence in nature under certain circumstances.

COLORATION.

In comparatively few classes of animals are there richer or more varied exhibitions of color than among Anthozoa. This is particularly striking in the tropical or subtropical species. To those who may have had the exquisite pleasure of looking upon the splendid display of colors associated with coral reefs no emphasis will be needed on this point; and to others an adequate verbal description would seem highly exaggerated. The profusion of coloration and the plantlike features of many of these cœlenterates are doubtless the occasion of such names as anemones, anthozoa, zoophytes, etc., by which many of them are known even to this day.

Into the problem of the origin or significance of colors in these lower classes no attempt will be made to enter seriously. Something of this has been done by the writer in an earlier paper (1904) and to a less extent in a report on the Medusæ of Woods Hole (1905). However, there are some points of particular phases of color involved in Anthozoa which call for notice. In the first place, it is interesting and significant that among these creatures color is due to distinctly different factors. For example, Duerden (1905) has shown that among many corals the dominant color is due to the presence of commensal algæ, *Zooxanthellæ*, which thrive in the entodermal tissues of the polyps.

In such cases the problem of color is transferred from the animal to the plant, which relieves the present discussion of any particular consideration of the matter. It may suffice, therefore, to say that in such cases color is only of secondary or incidental biological significance, and is meaningless in relation to any problem of adaptation or protection. In the words of Duerden, "The rich profusion and beauty of color in coral polyps certainly seems to have no protective or warning significance" (op. cit., p. 16).

But even in organisms in which color is constitutional there is little or no relation to environmental influences. For example, many actinians and alcyonarians living under identical conditions have very different color features; and, on the other hand, species of widely differing habitats and diverse environments exhibit closely similar aspects of coloration. Furthermore, a species which shows remarkable color variations in a given habitat will often show the same variations through its entire range of distribution. As an example of this may be cited the well-known case of the common *Metridium marginatum*. The world-wide distribution of this species (assuming with McMurrich its identity with *M. dianthus*), and the very similar aspects of coloration, illustrates the point under consideration, showing that conditions of environment or habitat have little to do with the character or variation of colors, at least so far as this species may have any significance.

The influence of conditions of nutrition, as already shown by me in former papers (op. cit.), act in similar manner on Anthozoa. Actinians kept in the aquarium very soon show color changes indicative of lowered states of vitality, unless pains be taken to obtain approximately natural conditions. In the celebrated Naples aquarium this has been more successfully done than I have seen elsewhere. Here certain species of actinians have thrived for years with little loss of vitality or change of coloration.

PHOSPHORESCENCE.

Among the many various and complex phenomena of life few are more unique or obscure than that of phosphorescence, or vital luminosity, the former name being more or less a misnomer, since except in appearance there is little or nothing in common between the phenomena to which it was originally applied, and those associated with living things. However, the term has become so generally associated with all sorts of luminous phenomena of similar appearance, and devoid of appreciable heat, that its use is likely to continue; and if care be taken to discriminate no serious confusion is likely to arise.

The occurrence of phosphorescence in many species, and in a wide range throughout the entire class, makes some reference to the subject more or less incumbent. While probably much more general in tropical and subtropical waters it is yet fairly common elsewhere, being well known throughout the region concerned in this report.

Much speculation has been aroused concerning its use or significance, and various and conflicting theories projected. No attempt will be made here to review the subject historically, nor to cite the various differences of opinion which have grown up.

Among the older students of cœlenterates Johnson and Forbes made observations and experiments in connection with the subject, and in turn cite similar observations made by Ehrenberg, Spallanzani, and others, showing no less interest than has been common in later times.

Macartney proved by experiments that the phenomenon might be aroused by a wide variety of stimuli, such as temperature, mechanical disturbance, chemical agents (as alcohol), electricity, etc. Forbes was able to confirm certain of these results, and also proved that in the phenomenon there was no evidence of electrical discharge, and further that no heat was evolved in connection with the emission of light.

Allman also studied the subject in connection with hydroids. He found the phenomenon exhibited by various calyptoblastic hydroids, but not in any known gymnoblastea. Like other observers, he found that various physical and chemical stimuli were needed to evoke displays of light. He was not able to find any phosphorescent secretion in the hydroids, such as had been found in connection with insects and other phosphorescent organisms.

Among Anthozoa its occurrence has been best known in groups of alcyonaria, especially in species of *Pennatula*, *Gorgonia*, etc., but not unknown in such solitary forms as the actinians. In the latter it has been observed chiefly in the slimy secretion of the ectoderm.

Reference has already been made to the conflicting theories as to the significance of phosphorescence. A few words must suffice on this point. It was suggested by both Carpenter and Thomson that it might have some importance as a source of abyssal light, thus affording some means by which the inhabitants of the darkness of great depths might be aided in finding food, evading enemies, etc. But, on the other hand, Mosely has pointed out the inadequacy of such a view. Many facts seem utterly in conflict with the theory. For example, the light of organisms from these depths has been found to be more or less monochromatic, or of only two or three colors. This would suggest that other colors would be invisible under such light, hence incompatible with the theory. He concludes that colors of deep-sea forms are probably only incidental, or features persisting from earlier conditions when the creatures were inhabitants of shallow waters. And on this and similar grounds he adduces a strong argument as to the comparatively recent migration of many of the abyssal forms into their present habitat.

Verrill has suggested that phosphorescence might serve as a warning to predaceous fishes that luminous organisms were provided with weapons of defense which it were well to evade. A. Agassiz has pertinently suggested that the well-known cases of *Physalia*, *Cyanea*, etc., and their commensals, and the habits of many fishes of feeding constantly in the coral and alcyonarian forests, all went to prove that "they are not in dread of lasso-cells." Among the most brilliantly phosphorescent of our local fauna are ctenophores. But it is well known that these are fed upon by a number of fishes. It may be safely assumed, therefore, that Verrill's suggestion is utterly without significance as an explanation.

More recently Nutting has suggested the ingenious view that phosphorescence may serve as a lure, attracting copepods and various larvæ within reach of the luminous organism. "The process would be analogous, perhaps, to what is known as the effect of alluring coloration among insects and birds. The phosphorescence would thus be of direct utility to the fixed cœlenterates in securing food." Unfortunately, there is no more evidence in support of this than in that of Prof. Verrill. And on the other hand, there is much which goes to show that such a view is directly in conflict with too large a mass of facts to render it at all probable. Such are the facts of phosphorescence in littoral forms, and in free-swimming and surface forms, whose modes of taking prey render it highly improbable that they have any need of such an aid. Phosphorescence is not solely a property of deep-sea life nor of nocturnal feeders. The writer regards it as associated with processes of metabolism; and while not beyond the realm of utility to the organism it is not directly so. Theories dealing with the subject have been propounded on the assumption that every vital feature and phenomenon must be brought into alignment with natural selection. It is to be hoped that we are emerging from the shadow of that assumption.

REPRODUCTION.

Generation in this class, as in others of the phylum, is both sexual and asexual, though without the more or less rhythmic alternation of generations so characteristic of the Hydrozoa. The sexual products are borne on certain of the mesenteries, and when ripe are usually extruded through the mouth. In some species, however, development may take place within the mesenterial chambers, and the young later discharged in a fully formed condition. The sexes are usually distinct, as in most Hydrozoa, but may be united in a single individual in certain species. That is, Anthozoa may be either dicœcious or moncœcious—unisexual or bisexual. Duerden has shown (1904), in the case of certain corals, that the bisexual or hermaphrodite condition may prevail, a given individual producing both ova and sperms, though not at the same time. That is, the genital products mature at somewhat different intervals, the organism being protogynous, maturing the ova first; or it may be protandrous, maturing the sperms first.

Asexual propagation is of general occurrence and of great importance. It is chiefly by the process of budding; though fission is not unknown among actinians, a given specimen dividing longitudinally, much as in *Vorticella*. Parker (1897, Bulletin of Museum of Comparative Zoology, p. 43) has described this process in *Metridium marginatum*, and Torrey has shown the same in the case of *M. fimbriatum* (Proceedings California Academy of Sciences, vol. 1, p. 345, 1898). The writer has observed the entire process take place in *Sagartia luciæ*, a small but extremely interesting anemone of our coast. In this species fission is apparently a common feature of reproduction. In text figure 1 is shown a sketch of a *Metridium* in process of fission. Such specimens are not particularly rare. Still another mode of asexual reproduction is more or less familiar, namely, that known as fragmentation. It consists of the formation of numerous minute individuals by a sort of indefinite budding from the margins of the pedal disk. This process seems

to be rather common in *Metridium marginatum*, as I have found many cases occurring, both in the aquarium and in a state of nature. Torrey (op. cit.), has suggested that it may be due to the unfavorable conditions of the aquarium, but its occurrence in natural conditions as just cited would preclude this as a cause.

DISTRIBUTION.

Anthozoa are of wide distribution, both in time (geological) and in space (geographical), and also in bathymetrical range. Of the first, or geological, it is not within the scope of the present paper to take notice. Of geographical range it may suffice to say that, like the former, a general consideration of the problem is not designed in the present review. Many conditions are involved in the matter of distribution, among which temperature plays an important part. This is particularly the case with alcyonaria, which are predominantly tropical or subtropical organisms. The same may also be said of the coral group, or Zoanthariæ.

In bathymetrical range there is great variation among the several groups. Many of each have been dredged from great depths, but by far the larger number have their habitat in shallower seas and along shore lines. In certain cases a given species may find itself equally at home in depths of from 50 to 1,500 fathoms. *Bathyactis* is recorded as being found in depths of from 50 to 3,000 fathoms.

ECONOMIC RELATIONS.

In common with cœlenterates in general, the economic relations of Anthozoa are chiefly incidental and indirect. A few fishes are known to feed on corals, a few on hydroids, perhaps still fewer on alcyonarians or others. So far as I am aware, actinians are usually immune from predatory attacks. Furthermore, certain actinians may serve as hiding places for small fishes, which have established commensal relations with them. On the other hand, not a few actinians feed upon fishes more or less freely. The commensal relations of actinians and hermit crabs are well known.

Indirectly corals have played a very important part in the contour of islands and continents from Paleozoic to recent times. And at present in subtropical regions these organisms are constantly concerned in the extension of certain coast lines by the formations of reefs along its margins. Thus, may be reclaimed something of the areas constantly being lost through erosion and transportation of continental débris into the seas; but, on the other hand, growth of these organisms in harbors and roadways of steamships often involve obstructions and dangers hard to overcome.

SYSTEMATIC ACCOUNT.

In common with that of other classes of cœlenterates, existing conditions of taxonomy of Anthozoa are not highly satisfactory. Several attempts at revision have been made within comparatively recent times, but much yet remains to be done before an orderly and adequate system of classification will be established. Among those who

have contributed materially to this end may be mentioned the following: Hertwig, R. and O. (1879); Hertwig, R. (1882); Andre, A. (1884); McMurrich, J. P. (1894); Van Beneden (1897); Carlgren (1900). These works are devoted almost exclusively to the Actinozoa. Similar work upon the Alcyonaria has been done by May (1899), Kukenthal (1905), and Studer.

While it is no part of the purpose of this report to enter into the matter of taxonomy in any detail, it may not be amiss to include brief synoptic tables indicative of opinion as to this phase of our subject, at least, as relates to Actiniaria. A valuable review of the history of taxonomic development along this line may be found in the report of McMurrich on the Actiniæ of the *Albatross* Expedition (Proceedings, U. S. National Museum, vol. XVI, 1893, p. 119–135). Brief historical references are also made by Hertwig (*Challenger* Report, vol. VI, p. 16–18) to this phase of the general subject, though with no attempt to trace the development of taxonomic systems.

Concerning the systems proposed by Van Beneden (1897) and Carlgren (1900), it is hardly within the scope of this paper to undertake an adequate review. Both are noteworthy contributions and will command the attention of specialists everywhere. They involve, however, considerable of embryological and histological details and methods, and are hence somewhat too technical for use in the present instance.

Under almost all modern systems of classification the musculature of the body has constituted one of the most important taxonomic characters. It becomes necessary, therefore, to devote some further attention to this feature. As to their relations, the muscles may be said to be ectodermal, entodermal, or mesodermal, as they are associated with these several tissues. The musculature is disposed chiefly in two positions, namely, (1) as longitudinal fibers distributed to the walls of the column; (2) as circular bands distributed variously over the body. Of the latter there is usually a special development in the oral region known as the sphincter. This acts as an organ for closing the mouth, much as one might close the opening of a bag by a draw string.

R. Hertwig has emphasized the importance of various aspects of the musculature as taxonomic features and says:

> The nature of the sphincter varies greatly. We talk of a diffuse sphincter when it arises from repeated pleatings of the muscular lamella; in that case because it is not sharply defined at the upper and lower margins, it does not strike the eye in looking at the surface, and is shown in transverse sections only by the local thickening of the wall in whose substance it is completely embedded. A circumscribed sphincter is formed when the pleated muscular mass projects above the inner surface of the wall, with which it is connected only by a narrow band, so that an annular swelling arises which is easily observed both in looking at the surface and in transverse section.
>
> Finally, in the mesodermal sphincter, the muscles have left their original position in the epithelium and are completely hidden in the supporting substance, which consequently increases doubly or trebly in thickness. The complete absence of the sphincter is comparatively rare. I have only observed it in a few species, almost invariably animals which are not capable of contracting the upper margin of the wall over the oral disk. This is, however, also the case in animals with a weak sphincter, such as the Antheadæ. On the other hand, the existence of a strong circular muscle can often be inferred with tolerable certainly from a high degree of contraction. The capacity for concealing the oral disk plays an important part in the systematic division of the Actiniaria; this is generally most inappropriately expressed by the term "retractile tentacles." It would be decidedly more rational to make the ana-

tomical reason, and not the physiological appearance, of systematic value. We shall therefore talk of Actiniaria without sphincter, and Actiniaria with weak and with strong sphincter, and further distinguish in the latter case whether the muscle is entodermal or mesodermal.

The systematic value of the circular muscle does not end here, as it furnishes a character not to be undervalued for determining the species. * * * I lay stress upon this point, as the circular muscle can be examined in the preserved animals even when their state of preservation is not very favorable, and because, moreover, a small piece of the wall, which can be cut away without essential damage to the whole animal, is sufficient for such an investigation. (Challenger Report, vol. VI, p. 6–8.)

Class ANTHOZOA.

The class Anthozoa, as limited in this synopsis, comprises some two well-marked subclasses, namely, the Alcyonaria and the Zoantharia. A third subclass, the Rugosa, includes only fossil forms, which makes it undesirable to cumber the present report with any account of it.

Each of the two subclasses above named comprises in turn three rather well differentiated orders, all, with a single exception to be named later, having representatives among the local species. The following synopsis of orders may serve as a formal introduction to the taxonomy of the Anthozoa.

ALCYONARIA.

The order Alcyonaria includes those members of the class Anthozoa which are characterized by the presence of eight pinnate tentacles and a corresponding number of mesenteries. All are of marine habit, and most are colonial, forming more or less complex clusters of polyps united to a common stock, and with or without definite skeletal structures. In most cases, however, there is a skeleton composed of calcareous spicules of various form and color giving to the colonies the characteristic spiny surface of many gorgonians and similar forms.

The distribution of these spicules may be somewhat general throughout the tissues of the body, or they may be aggregated into a dense axis as in the so-called black and red corals and in the familiar sea fans, etc.

ORDERS OF ALCYONARIA.

I. ALCYONACEA.—Colonial, with a well developed anastomosing canal system. Stem usually devoid of axial skeleton, but the cœnenchyma bearing numerous separate spicules.

II. PENNATULACEA.—Colonial, with a stem loosely attached in mud or sand, and capable of some degree of locomotion; an axial skeleton extends through the stem in most cases, though lacking in not a few. A specialized portion of the stem, the rachis, bears the polyps either as sessile individuals, or on numerous pinnæ which branch from the rachis, as in the familiar sea pens.

III. GORGONACEA.—Colonial, firmly attached by root-like bases or holdfasts. Stem and branches with definite axial skeleton of calcareous or horny character, overlaid by a cortical cœnenchyma from which the polyps arise.

ZOANTHARIA (Hexactinia).

Polyps and polyp colonies chacterized by simple or unbranched tentacles in one or more cycles about the mouth. Paired mesenteries usually in some multiple of six, though exceptions to this are more numerous than formerly supposed.

ORDERS OF ZOANTHARIA.

I. ACTINIARIA.—Polyps solitary, or rarely colonial, devoid of any skeletal structures, and usually adherent by a suctorial or adhesive base, the pedal disk, though capable of more or less locomotion. Mesenteries in most cases paired and in multiples of six.

II. MADREPORARIA.—Polyps colonial, or rarely solitary, and with a dense calcareous skeleton, forming, in most cases, a complex corallum.

III. ANTIPATHARIA.—Colonial zoantharia, usually with a hollow, branching skeleton of horny nature. So far as known, no representatives of this order occur in the region, which obviates the necessity for further account of it in this report.

SYNOPSIS OF TRIBES OF ACTINIARIA.

EDWARDSIAE R. Hertwig, 1882.

Noncolonial Actiniaria with eight mesenteries, two pairs of which are directives; others unpaired, and their longitudinal muscles face the same direction; all mesenteries gonad bearing. Tentacles simple, few in number, usually more numerous than the mesenteries, varying from 12 to 36. Column more or less linear and cylindrical, often fluted along the lines of attached mesenteries.

ZOANTHEAE R. Hertwig, 1882.

Colonial Actiniaria, with numerous mesenteries of two sorts, namely, small, incomplete, and devoid of gonads; large, complete, and gonad bearing. A single œsophageal groove. Outer surface of body usually incrusted with a coating of sand or other foreign particles. Tentacles simple.

CERIANTHEAE R. Hertwig, 1882.

Actiniaria with numerous, unpaired mesenteries, except a single pair of directives, which are very short and attached to the deep œsophageal groove. On either side of these will be found the much longer perfect mesenteries, which increase in size in regular order to the opposite (dorsal) side. Tentacles numerous and in two series—an outer principal and an inner accessory series—the circumoral tentacles. Body elongate, usually inclosed in a slimy flexible tube. Aboral end of body rounded and provided with a terminal pore.

HEXACTINIAE R. Hertwig, 1882.

Actiniaria with six or more pairs of primary mesenteries. Other cycles arise in pairs, some of which may become perfect, others incomplete. The primary mesenteries are provided with retractor muscle fibers on their inner faces i.e., the muscles of each pair facing the intramesenterial space. There are usually two œsophageal grooves, with directive mesenteries, whose muscles face outward, or opposite the aspect of the other pairs. Body more or less smooth, often with longitudinal furrows, and in certain cases with wartlike nodular processes, verucæ. Tentacles usually numerous and of various characters.

The above tribal characteristics have been variously compiled from those given by Hertwig, McMurrich, Haddon, Duerden, and Gosse, and to a less extent from Andres, Verrill, and others.

FAMILIES OF HEXACTINIÆ.

ILYANTHIDÆ Gosse (in part), 1858.

Body usually elongate, cylindrical, aboral end rounded and with somewhat constricted, bulblike physa, but devoid of definite pedal disk. Tentacles simple and relatively few in number, or in some cases numerous; sphincter weak.

There is considerable uncertainty as to the constitution of this family, some authorities even excluding it altogether. Gosse, who established it, included under it the Edwardsiæ as well as the Cerianthea. Hertwig considers the family as intermediate between the Edwardsiæ and true Hexactiniæ, and so ranks them in his system. (Op. cit., p. 92.)

ANTHEIDÆ Gosse (in part), 1858.

Hexactiniæ with well-developed pedal disk, often capable of expansion and inflation as a pneumatophore. (Cf. Gosse, Actinologea Britannica, p. 149.) Column generally smooth, sometimes with verucæ; tentacles long, very flexible, and disposed chiefly about the margin of the disk; mesenteries numerous; sphincter muscle very weak, rendering difficult any considerable contraction of disk or tentacles.

SAGARTIIDÆ Gosse, 1858.

Body with strong oral sphincter and numerous highly contractile tentacles. Mesenteries of two sorts; principal series in six pairs attached to œsophagus, and devoid of gonads; second series incomplete, and bearing gonads in breeding season. Acontia present and protrusible through cinclides or directly through the tissues.

BOLOCERIDÆ McMurrich, 1893.

Sphincter more or less diffuse and weak; mesenteries devoid of acontia; pedal disk well developed; tentacles stout, nonretractile, strongly constricted at base, hence often deciduous.

BUNODIDÆ Gosse, 1858.

Sphincter entodermal, "body usually studded with numerous tubercles, which are disposed in longitudinal rows, and may serve as suckers by means of which they have the faculty of adhering with force to foreign bodies." (Gosse.) Mesenteries often numerous and perfect but devoid of acontia.

PARACTIDÆ Hertwig, 1882.

Sphincter mesogleal, strong; body usually devoid of tuberculation, but with numerous longitudinal flutings; mesenteries numerous and perfect; no acontia.

TEALIIDÆ Hertwig, 1882.

"Hexactinia with numerous perfect mesenteries; sphincter strong, entodermal, projecting as a thick swelling into gastric cavity."

"The most important feature of the family is, I consider, the extremely characteristic circular muscle, which can be recognized with the naked eye, as a thick swelling on the inner side of the wall. In transverse section it shows a circular or oval figure, fastened on one side to the wall; it is formed by the extremely strong pleating of the entodermal circular muscle layer. The large number of perfect septa is also important; on the other hand, I have entirely disregarded the nature of the surface of the body, so that forms both with smooth and warty wall may find their place in the family." (Hertwig, op. cit., p. 35.)

Diagnostic Synopsis of Families of Hexactiniæ (modified from Hertwig).[a]

A. Tentacles forming simple wreath.
- *a*. Digitate.
  - *b*. Pedal disk absent.
    - *c*. Siphonoglyphs and sphincter obscure
      - Without conchula ..... Ilyanthidæ.
      - With conchula ..... Siphonactinidæ.
  - *bb*. Pedal disk present.
    - *d*. Acontia present, sphincter mesodermal, cuticular covering
      - Absent .. Sagartiidæ.
      - Present .. Phellidæ.
    - *dd*. Acontia absent, sphincter
      - Absent ..... Antheomorphidæ.
      - Present
        - Weak ..... Actiniidæ.
        - Strong entodermal ..... Bunodidæ.
        - Strong mesodermal ..... Paractidæ.
        - Mesodermal, transverse axis elongated ..... Amphianthidæ.
- *aa*. Tentacles abnormal in shape.
  - *e*. Clavate, knobbed ..... Heteractidæ.
  - *ee*. Replaced by stomidia ..... Liponemidæ.
  - *eee*. Branching or bushy .....
    - Sarcophianthidæ.
    - Thalassianthidæ.

B. Tentacles form double or multiple wreaths ..... Corallimorphidæ.

[a] Cf. Challenger Report, vol. xxvi, pt. 73, p. 7.

DIAGNOSTIC SYNOPSIS OF FAMILIES OF HEXACTINIÆ (adapted from McMurrich).[a]

A. Tentacles in cyles—Actininæ.
  a. Column simple.
    b. Tentacles cylindrical, smooth.
      c. Sphincter absent or weak { Mesenteries not numerous ..... HALCAMPIDÆ.
                                  { Mesenteries numerous ..... ANTHEIDÆ.
      cc. Sphincter entodermal, tentacles deciduous ..... BOLOCERIDÆ.
      ccc. Sphincter mesodermal { Acontia absent ..... PARACTIDÆ.
                                { Acontia present ..... SAGARTIDÆ.
      cccc. Sphincter entodermal, circumscribed { Acrorhagi wartlike ..... BUNODIDÆ.
                                                { Acrorhagi foliate ..... PHYLLACTIDÆ.
    bb. Tentacles warty or branched { Simple ..... HETERACTIDÆ.
                                    { Compound ..... THALASSIANTHIDÆ.
    bbb. Tentacles reduced to stomidia { ..... POLYOPIDÆ.
                                       { ..... SICYONIDÆ.
  aa. Column in upper part with branched or globular processes ..... DENDROMELIDÆ.
B. Tentacles radially arranged—Stychodacylinidæ.
  a. Tentacles of one form { Few, capitate ..... CORALLIMORPHIDÆ.
                           { Numerous, cylindrical ..... DISCOSOMIDÆ.
                           { Nodulated ..... AURELIANIDÆ.
  aa. Tentacles of two forms { Marginal cylindrical, disk tentacles wartlike, branched or foliate ..... RHODACTIDÆ.
                             { Marginal pinnate, disk tentacles wartlike ..... PHYMANTHIDÆ.
  aaa. Tentacles of various forms, not cylindrical ..... CRIPTODENDRIDÆ.

METRIDIUM Oken, 1815.

Metridium dianthus (Ellis), Oken. [Text fig. 1.]

Actinia dianthus Ellis, Phil. Trans., vol. 57, 1767.
Metridium dianthus Oken, Lehrb. der Naturgesch., 1815.
Actinia marginata Lesueur, Jour. Nat. Sci., Phil., vol. 1, p. 172, 1817.
Metridium marginatum Milne-Edwards, Hist. Nat. des Cor., vol. 1, p. 254, 1857.
Actinia marginata L. Agassiz, Cont. Nat. Hist. U. S., vol. III, 1860.
Actinoloba dianthus Gosse, Brit. Sea Anem., p. 12, 1860.
Metridium fimbriatum Verrill, Mem. Boston Soc. Nat. His., vol. 1, 1864.
marginatum Verrill, Inv. An. Vineyard Sound, p. 444, 1874.
dianthus McMurrich, Ann. N. Y. Acad. Sci., vol. XIV, 1901, p. 3. Torrey, Proc. Wash. Acad. Sci., vol. IV, 1902.

(For full details of synonymy, see Andres, 1883.)

This beautiful actinian, often designated as the "fringed sea anemone," is altogether the most common and at the same time the most conspicuous of our actinian fauna. It abounds almost everywhere from New York to Nova Scotia, from tide pools to a depth of 75 fathoms and beyond, and is one of the largest anemones of the region.

It is a remarkably variable species. This pertains to almost every aspect of the creature—size, color, habitat, structure, mode of propagation, etc. In distribution it seems to be almost cosmopolitan, being found upon both the eastern and western coasts of America, and variously over the European coasts.[b] It may be doubted whether another of its relatives has a range of distribution at all comparable.

[a] Cf. Proceedings U. S. National Museum, vol. XVI, p. 134.

[b] In identifying the local species with *M. dianthus* of Oken, I am but following several well-known authorities, especially McMurrich, vide supra.

It may not be out of place to briefly glance at certain features of variation more or less common. In color it varies from yellowish brown, which is the more common, to orange, pink, white, or various combinations of these, in stripes, mottlings, etc. McMurrich has pointed out an apparent tendency in the coloration to assume some three types, brown, orange or salmon, and white, and has suggested a correlation as to age, modes of reproduction, etc.

Parker (1897) has also proposed similar suggestions as to this and other aspects of variation.

Duerden, whose work on Anthozoa is well known, has in a recent paper suggested the influence of light as a factor affecting color varieties.

In a still more recent paper Torrey (1902) has undertaken to ascertain more certainly the factors concerned in this and other aspects of variation, especially as it relates to this species along the Pacific coast. He concludes that as yet it is impossible to ascribe it to any definite known cause.

Body cylindrical, smooth, capable of a high degree of contractility; disk well defined, with distinct marginal lobes which are abundantly supplied with short, pointed tentacles.[a] In full expansion this actinian is a most exquisite creature, beautiful and plant like, and meriting the title "the fringed anemone," often applied to it. The disk is smooth and more or less concave. Mouth rather prominent, with corrugated, or tuberculate lips, and with well-marked œsophageal grooves, often with but one, and more rarely with three or several. Parker has directed particular attention to this feature of variation, as has also Torrey. (Cf. op. cit., supra.)

As an explanation of this feature the suggestion has been made that it may have its origin in the process of fission, often involved in asexual reproduction. Torrey doubts the validity of this view. In text figure 1 is shown a careful drawing of one of these twin anemones in process of fission. A brief reference has been made in an earlier connection to this aspect of reproduction. In this connection may also be noted the process known as fragmentation, the origination of small individuals by a sort of budding process of portions of the margin of the pedal disk. This is frequently observed in specimens in the aquarium, but I have found it occurring also in specimens taken from piles about the docks, making it quite certain that it is not due to any unusual or abnormal conditions.

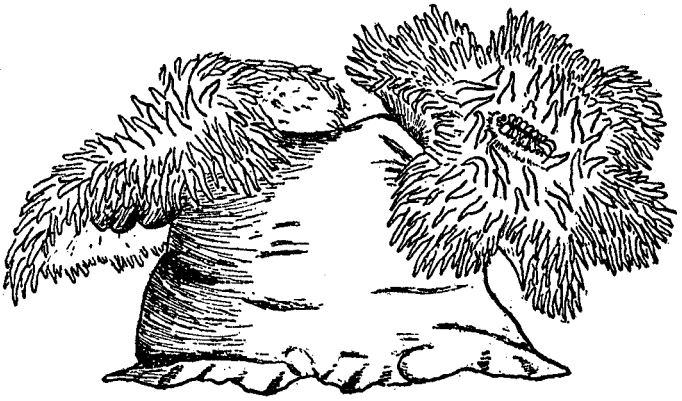

FIG. 1.—*Metridium dianthus*. Specimen in process of fission.

The pedal disk is strongly adhesive and capable of being used as an organ of locomotion, the creature creeping with a slow, snail-like movement from place to place. The mesenteries are abundantly supplied with acontia, which are protruded in profusion from both the mouth and through cinclides when a specimen is irritated. The sphincter is mesogleal and strongly developed, enabling the creature to contract in a most remarkable degree. Mesenteries very numerous in adult specimens and more or less variable as to number and arrangement.

Distribution and habitat: As has already been pointed out, the range of this species is very wide. It may be doubted whether any other known species has quite so remarkable a distribution. It is found abundantly throughout the region of Woods Hole and along the entire New England coast. Its habitat is in keeping with the range of distribution. It abounds in tide pools, upon rocks, piles, shells, algæ, etc.

[a] Tentacles of inner or oral series larger, attentuate in form, and often marked by transverse bars or rings of opaque whitish color.

HALCAMPA Gosse, 1858.

Halcampa farinacea (Verrill), Andres.

Edwardsia farinacea Verrill, Am. Jour. Sci., vol. 42, 1866, p. 118; Inv. An. Vineyard Sound, 1873, p. 510, 739.
Halcampa farinacea Andres, Fauna u. Flora Golfes Neapel, bd. IX. Parker, Am. Nat., vol. XXXIV, 1900, p. 750.

This species has been reported by Verrill as occurring off Gay Head in 19 fathoms. Its chief range, however, seems to be north of Cape Cod. The present writer has not taken it in the Woods Hole region. The following brief description is chiefly compiled from that of Verrill (vide supra): "It is a cylindrical species, about an inch long, and from 0.10 to 0.12 inch in diameter, remarkable for having only 12 tentacles, which are equal, unusually short, thick, and blunt." Tentacles rather translucent, with transverse bars on inner side of brownish bands or spots. Alternating with these are bars or spots yellowish or white. Disk pale yellow, varied with small brown spots, mostly forming radial rows from mouth to tentacles.

Habitat: Found only on muddy bottoms.

EPIZOANTHUS Gray, 1867.

Epizoanthus americanus Verrill.

Zoanthus parasiticus Verrill, Mem. Boston Soc. Nat. Hist., vol. I, 1864, p. 34.
Epizoanthus papillosus Gray, Proc. Zool. Soc. Lond., 1867, p. 237.
americanus Verrill, Am. Jour. Sci., 2d ser., 1871, p. 361; Inv. An. Vineyard Sd., 1873, p. 446, 510; Bull. Mus. Comp. Zool., vol XI, 1883, p. 60.
paguriphilus Verrill, Am. Jour. Sci., 1882, p. 137; Bull. Mus. Comp. Zool., vol. XI, p. 61.
parasiticus Hertwig, Rept. Chal. Exp., vol. VI, 1882, p. 116.

This interesting actinian is one of very few among our fauna having a definitely colonial habit. The species has a rather extended range of distribution, as may be inferred from the above list of references, and the recorded localities from Maine to Maryland. It is also more or less abundant, Verrill reporting "many thousands of specimens taken off Nantucket, Marthas Vineyard," etc. Its range of depth seems to be from 25 to 400 or more fathoms. The species, while most familiar in association with the hermit crab, has apparently considerable variability as to habitat. Verrill has reported them as in some cases investing the tubes of Hyalinœcia, in others forming a similar investment of stems or branches of *Paramuricia grandis*. Those taken in the Woods Hole region have all been associated with hermit crabs. Several species have been described, among them *E. parasiticus*, *E. papillosus*, *E. americanus*, *E. paguriphilus*, etc.; but it is safe to say that among these several are identical. And it may be doubted if of the entire list herein referred to there is hardly more than varietal distinction, the variation expressing for the most part the influence of the varying habitats of the examples concerned.

The many excellent figures of the species easily available in the reports of Verrill, Hertwig, and others, obviate any special necessity for a duplication in this report.

PARACTIS Milne-Edwards, 1857.

The genus was established by Milne-Edwards and has been distinguished by the following characters, given in merest outline: Body smooth, devoid of papillæ or marginal spherules, numerous longitudinal furrows on the column; tentacles of about the same size and character.

Paractis rapiformis (Lesueur).

Actinia rapiformis Lesueur, Jour. Acad. Nat. Sci., Phil., 1817, vol. I.
Paractis rapiformis Milne-Edwards, Hist. Nat. des Corallaires, 1857, p. 249.
Actinia rapiformis Verrill, Mem. Boston Soc. Nat. Hist., vol. I, 1864, p. 35.
Paractis rapiformis Verrill, Inv. An. Vineyard Sound, 1873, p. 363, 738; Am. Jour. Sci., vol. III, p. 436. Andres, Le Attinie, Fauna u. Flora Golfes Neapel, bd. IX 1883, p. 262. McMurrich, Stud, Biol. Lab. Johns Hopkins Univ., vol. IV, p. 62.
Ammophilactis rapiformis Verrill, Am. Jour. Sci., 1899, vol. VII, p. 213. Parker, Am. Nat., 1900, vol. XXXIV, p. 753.

This species has not been taken by the present writer but is known to occur within the region. According to Verrill, its distribution ranges from North Carolina to Long Island Sound. The following brief description is taken from that of Verrill and may serve as a summary of the chief characters of the

species: "Surface nearly smooth, slightly sulcated lengthwise, color pale flesh color, or pink, translucent. Tentacles numerous, short, tapering, pale greenish olive, with dark band around the base, connecting with a dark line radiating from mouth." To this the author adds that its size when extended is 3 or 4 inches long, by about 1 inch in diameter.

BICIDIUM L. Agassiz, 1859.

Bicidium parasitica Agassiz [text fig. 2].

Bicidium parasitica L. Agassiz, Proc. Boston Soc. Nat. Hist., vol. VII, 1859, p. 24; Verrill, Mem. Boston Soc. Nat. Hist., vol. I, 1864, p. 31; E. C. and A. Agassiz, Sea-side Nat. Hist., 1865, p. 15.
Peachia parasitica Verrill, Proc. Boston Soc. Nat. Hist., vol. X, 1866, p. 338; Inv. An. Vineyard Sd., 1874, p. 739.
Philomedusa parasitica Andres, Le Attinie, 1884, p. 112.

Though reported by Agassiz and Verrill as more or less common in its relation as a parasite or commensal on *Cyanea arctica*, the writer has not found it on any specimens taken at Woods Hole. Verrill also reports it as having been found buried in gravel at low water at Eastport, Me. So far as I am aware, it has not been reported south of Cape Cod. Not having seen living specimens of the species the following description is compiled in part from the accounts of Agassiz and Verrill, and in part from specimens loaned by Mr. George M. Gray, who collected them at Eastport, Me. The figure was drawn from these specimens.

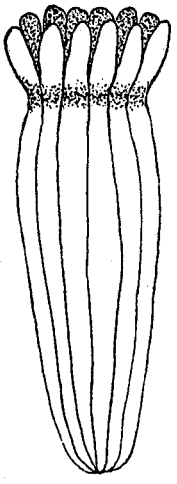

FIG. 2.—*Bicidium parasiticum.*

Figures of the shape as given differ somewhat, that of A. Agassiz showing a rather large oral end, and tapering to a rather small rounded point at the aboral. According to Verrill, it is more nearly barrel shaped. The size is about 35 mm. in length by about 10 mm. in largest diameter. Body with longitudinal furrows and "transverse wrinkles, by means of which it fastens itself securely among the fluted membranes around the mouth of the jellyfish." It is said to live for some time in confinement, where it attaches itself "for its whole length to the vessel in which it is kept, and clinging quite firmly if any attempt is made to remove it." This mode of adherence may be taken to imply the presence of such suckers as are more or less common in several other species of actinians. According to Verrill, it resembles very closely species of *Peachia* as described by Gosse.

ANEMONIA Risso, 1826.

Anemonia sargassensis Hargitt. [Pl. XLI, fig. 3.]

Anemonia sargassensis Hargitt, Biological Bulletin, vol. XIV, p. 117, 1908.

This anemone was briefly described in a recent note (vide supra), and some reference made to its habitat. Several other points call for further elucidation. Figure 3 of plate XLI shows well the general aspects of the creature and its mode of attachment to the gulf weed which forms apparently its chief or only habitat. The figure was made from life and gives approximately the color and aspects of average specimens. The base is adapted to clasping the stems of the weed to which it adheres with great tenacity. It is also able to creep along from place to place by means of the disk, though it does this only occasionally. A specimen in the aquarium was observed to remain in one identical spot for more than 30 hours. Another feature, more or less rare, is that of inflating the pedal disk, and thus making of it a float by means of which the creature may drift oral end downward, indefinitely. Duerden (1902) reports a similar habit in *Bunodosoma spherulata*, *Bunodeopsis antilliensis*, and cites observations of Duchassaing and Michelotti of a similar trait in *Cystiactis eugenia*. I have occasionally observed the same thing in several other actinians, but only in the artificial conditions of the aquarium; and it may not yet be improbable that this has something to do with the performance, yet its occurrence in nature may not be unusual. (Cf. also Gosse on this feature, p. 144.)

In 1833 Quoy et Gaimard, Voyage de l'Astrolabe (Zoologie, t. IV, p. 146), described a species, *Anemonia pelagica*, having several points in common with that here under discussion; for example, its pelagic habitat, "Trouvée sur des *fucus* au milieu de l'Ocean Atlantique;" also the prehensile nature of the tentacles. Their description is, however, very vague and Andres regards the species as doubtful. Moreover, as compared with *A. sargassensis* it has many points of difference, such as color, number of tentacles, etc. (Cf. Milne-Edwards et Haime, Histoire Naturelle des Corallaires, t. I, p. 235).

The following may be regarded as diagnostic characters: Column short and rather broad, in about the relation of 1 to 2, more or less fluted; pedal disk well developed and adapted to clasping stems of the weed; oral disk marked by radiating lines of flake white, or cream-colored lines varying in size and extending upon bases of tentacles; tentacles cylindrical, long and tapering, but slightly contractile, of various sizes and disposition about the margin of the disk; tentacles highly prehensile, and more or less adhesive, both of which characters seem of great importance as a means of catching prey, and in locomotion; tentacles variable in number, from 25 to 30 in smaller specimens to 50 in larger, and from 5 to 15 mm. in length, inner series nearly twice diameter of disk; in several cases bifurcated tentacles were observed. Tactile sense highly developed in larger tentacles.

Dimensions of body: An average of about 5 to 6 mm. high by 9 mm. in diameter. Color is various, though light brownish to chestnut or olivaceous tints are predominant. These with the whitish lines of disk and tentacles give a simulation to the color of the Sargassum in a most remarkable degree, so much so that unless careful scrutiny is made the specimens are certain to be overlooked. This feature they seem to share in common with many of the Sargassum fauna.

Acontia seem to be entirely lacking, no amount of irritation being able to secure their discharge; subsequent sections likewise failed to reveal their presence.

Primary mesenteries, six pairs (see pl. XLI, fig. 3). The figure was drawn from a small specimen, and the secondary mesenteries are only slightly developed. Directives quite well marked as shown.

Sphincter very weak or lacking, rendering contraction slight, in no case sufficient to withdraw the tentacles or wholly cover the oral disk. Body quite smooth, except for the slight vertical fluting referred to above; no tubercles or marginal spherules.

SAGARTIA Gosse, 1858.

According to Hertwig (Challenger Rept., vol. VI, pt. XV, p. 72), the genus *Sagartia* should be limited to those "*Sagartidæ* with smooth wall and numerous powerful tentacles arranged in several rows; without anatomically perceptible sinclides." This definition excludes several forms which have been hitherto usually referred to this genus, among them at least one of our local species, namely, *S. leucolena*, which has been referred by Andres to the genus *Cylista*.

Sagartia modesta Verrill. [Pl. XLII, fig. 5, 6; XLIII, fig. 7.]

Sagartia modesta Verrill, Proc. Boston Soc. Nat. Hist., vol. X, 1866, p. 337; Inv. An. Vineyard Sound, 1874, pp. 330, 738. Andres, Fauna u. Flora Golfes Neapel, bd. IX. Parker, Am. Nat., vol. XXXIV, 1900.

Body elongate, cylindrical, in expansion about five times longer than in diameter. Pedal disk more or less evident, effective as an organ of adhesion, by means of which it attached itself to a rock or other substratum. This may be best observed in a small aquarium, or by careful examination of specimens when first taken from the normal habitat, adherent to some supporting base. Tentacles are numerous, from 60 to 100, more or less marginal in several rows; they are slender and tapering, about twice the length of the diameter of oral disk, or perhaps slightly more. Color of tentacles pale grayish or greenish, with dark lateral spots near the base, and with lighter bars or bands toward the distal portion, interspersed with whitish bands or spots (pl. XLII, fig. 6). Oral disk yellowish or white, with darker radial lines; mouth with 15 to 20 rather prominent liplike folds. General color more or less variable; column pale flesh color. When first taken from the water or sand the body is often covered with a sheath of mucous and adherent sand grains. Acontia extruded over various portions of body, but without evident cinclides.

Habitat: The species has been found by me only in burrows on sandy and pebbly beaches usually just about or slightly below low-tide line, and always attached to a smooth cobblestone. In the aquarium it will adhere to almost any smooth support, or even the sides or bottom of the dish or aquarium.

Distribution: The species is accounted rather rare. This may be due in part to the burrowing habit and to the close simulation in color of the tentacles and oral disk as they appear at the mouth of the burrow, rendering difficult its detection unless one looks for it with some care. But I have not found it in any such numbers as to suggest it as a common or abundant species. Verrill reports its distribution from Long Island Sound to Vineyard Sound. I have also taken it in Buzzards Bay adjacent to Woods Hole.

Sagartia luciæ Verrill. [Pl. XLI, fig. 1 and 2.]

Sagartia luciæ Verrill, Am. Jour. Sci., 4th, vol. VI, 1898, p. 493. Parker, Am. Nat., vol. XXXIV, 1900; ibid., vol. XXXVI, 1902, p. 491. Davenport, Mark Mem. Vol.

This beautiful little actinian, formerly a stranger to the fauna of Woods Hole, is now one of the most abundant of the littoral species, occurring almost everywhere—on rocks, eelgrass, fucus, shells, piles, etc. It is a small species, varying from 10 to 18 mm. in height, by about 4 to 6 mm. in diameter. The body is smooth and highly contractile, dull olive greenish in color, with a variable number of vertical yellowish or orange stripes. Tentacles rather numerous, from 25 to 50, in several illy defined whorls, long and delicate, and very contractile, pale greenish, sometimes tinged with whitish. Oral disk variable as to shape and color; usually flat or concave, greenish, or sometimes with darker radial lines, and often with conspicuous bars at base of directive tentacles. It will more often be observed that only a single bar is present. This is due to the fact that a common mode of fission, to be mentioned later, often leaves but one of these bars apparent. Acontia freely extruded through body or mouth.

Reproduction: At certain times sexual propagation is active, and in his original description Verrill states that young embryos might be seen swimming in the cavity of the translucent tentacles. One may also find at certain times in sections of the animal the inclusion in the mesenteries of genital cells. So far as my own observation has gone, however, another mode seems to be of more general occurrence—an asexual one, namely, fission. I have repeatedly observed this process in all stages at almost any time during midsummer. It is not difficult, indeed, to observe the process from its inception to completion, for it goes forward with surprising rapidity, the entire operation occupying from two to three hours, probably often less time. This is most easily studied in small aquaria, or even finger bowls or other glass dishes capable of holding a pint or a liter of water.

Unlike the process which has been described for *Metridium* and a few other species, in which fission begins at the mouth or oral disk and proceeds vertically downward, in *S. luciæ* the very opposite direction is the one invariably followed, at least so far as I have observed. The first evidence of such fission may be noted in an extension of the pedal disk in a plane parallel with the oral axis. If this extension is to initiate the process of fission there will soon be distinguishable the appearance of a constriction of this elongated disk and the organization of a sort of double foot, in which may be seen the radial arrangements of the proximal ends of the mesenteries. The stretching of the disk is followed by a corresponding condition of the walls of the column, a condition which will soon be seen to involve the entire body and oral disk. Careful observation will show a gradual thinning of the basal disk as the stretching goes on more and more, and sooner or later the actual rupture of the bottom of the disk, a rent appearing and passing in a direction at right angles to the oral axis. When this is clearly underway the pulling of the opposite halves of the body continues with increased vigor, and the rent may be followed in an upward and vertical direction, which enables the observer to actually see the inner organs, mesenteries, acontia, etc. A most curious phenomenon may be seen occasionally as the process continues, namely, as the pulling and consequent tearing proceeds there will occasionally be witnessed the explosion and shooting out of acontia, apparently in response to the physical stimulus involved in the rending of the tissues. It is as if at certain times the pulling was too vigorous and the consequent "hurt" more than the creature could stand with equanimity, and the extrusion of the acontia the expression of protest on the part of the

injured tissues. The process goes on usually without interruption till the fission has separated the basal portion completely, the last rupture of the lateral threads occurring with a more or less sudden break and the prompt contraction of the free ends.

The upward fission is fairly rapid, and soon the oral disk and mouth become involved in the operation. The fission is almost invariably finished upon one side at a time; that is, one half seems to yield more readily than the other, and the rending of the tissues of that side may be complete as much as a half hour before that of the other. Indeed, it would seem as if there was something of arrest in the vigor of the pulling when the fission had completed itself throughout one half. As the process of either side approaches completion the last vestige of the oral disk becomes spun out into a delicate thread 5 or 6 mm. or more long, in a tremendous state of tension, the final rupture of which takes place with a more or less sudden rebound of the ends and sides of the body. The final rupture of the other side seems to take place more slowly, but is soon accomplished, when the two halves of the divided actinian assume a more or less erect aspect, fold the edges inward until the opposite edges approximate and finally unite and gradually heal over, each becoming an independent individual. The healing and internal adjustments would seem to be much slower than the fission, appearing to require for completion a day or two, perhaps more in some cases.

That this process of propagation is a normal one and of general occurrence during the summer can hardly be doubted. The immense colonies which may often be found on a given stone, or on a shell of *Mytilus*, could hardly have happened thus by other mode. Furthermore, when one seeks for perfectly symmetrical specimens in a state of nature they are difficult to find. The figure shown in plate XLI, made from a living specimen, illustrates the asymmetry in the single white line connecting the directive tentacle of only one side. But this is not all. Sections of the body show the asymmetry to involve the whole internal organization—mesenteries, siphonoglyphes, etc.

In most cases the species is normally diglyphic; but during the season of asexual propagation this feature is more or less obscured or disguised. Further reference to figure 1 will make this point more evident. I have occasionally found triglyphic individuals, but they are rather unusual. One such was observed undergoing fission, and in this case the process involved very nearly an exact third of the parent body, leaving an unsymmetrical diglyphic specimen. I was somewhat curious to see whether a fission into three individuals at once might not occur, but this did not happen; and though the specimen was followed during two or three succeeding days there was no indication of further fission.

Carlgren (1904) in a recent paper has described experiments and observations on several species of actinians which have interesting features in common with those herein described. On page 77 he gives some account of fission found occurring in nature, and certain of his figures might be duplicated by this phenomenon in *S. luciæ* (e. g., fig. 6, 24, 25, 26, 27, taf. I and II.)

The mesenteries of this species vary greatly in number and arrangement. I had the privilege of looking over a large number of sections made by Mr. D. W. Davis, who has been engaged in experiments upon it, and sought in vain for a single case of what might be regarded as typical hexamerous symmetry.

Distribution: The species was first described by Verrill in 1898. It was first observed at New Haven about 1892, and was then quite rare. Within the past 10 years, to the personal knowledge of the writer, the occurrence of the species at Woods Hole has passed from a condition of comparative rarity to one of extreme abundance. A brief paper by Parker (1902) gives a succinct account of its dispersal along the coast since its first occurrence about New Haven. Apparently the same species has been recently found at Plymouth, England (1908), and a few brief comments made to the effect that instead of having got its introduction into our region and spread from that as a center, the fact would seem to be that it had found distribution from some unknown source and had been simultaneously scattered and established in several remote localities. Mr. Davis has recorded the species at San Francisco, and states that its identity with *S. luciæ* seems beyond question. I looked in vain for it at South Harpswell, Me., in 1909.[a]

[a] The writer identified this species at Naples in 1911, having the same distinctive features of structure, color, mode of fission, etc. This would seem to show that it is probably very widely distributed over the shallower seas.

Habitat: Very general. It seems to find itself at home almost anywhere—on rocks in tide guts, brackish ponds, upon eelgrass, on living shells of *Mytilus*, among colonies of *Molgula* and *Cynthia*, and others too numerous to mention.

Sagartia abyssicola Verrill.

Sagartia abyssicola Verrill, Am. Jour. Sci., vol. XXIII, 1882, p. 314; Bull. Mus. Com. Zool., vol. XI, 1883, p. 45. Parker, Am. Nat., vol. XXXIV, 1900.

Assuming a valid significance in the name of this species, its habitat might seem to carry it easily beyond the scope of this report. It has, however, become so familiar from recent collections, and from depths in no sense abyssal, that it seems very proper to make at least a brief record of its occurrence.

In view of the excellent descriptions and figures given by Verrill (vide supra), there is no occasion for attempting anything of the sort here. Its more usual habitat is the tubes of the annelid, *Hyalinœcia artifax*, but it is occasionally found attached to stones, shells, etc. When brought up in the dredge it is almost invariably contracted into a low conical lump, resembling more or less a small *Metridium* in a state of close contraction. The tentacles are numerous, longer than the diameter of the body, slender, and tapering. Acontia are numerous and protruded freely. The color is usually a dull brown in preserved specimens.

Distribution: Various records show it to be more or less common along much of the coast line, at depths of 50 to 60 fathoms and beyond.

CYLISTA Gosse, 1860.

Cylista leucolena Verrill. [Pl. XLIII, fig. 8.]

Sagartia leucolena Verrill, Proc. Boston Soc. Nat. Hist., vol. X, 1866, p. 336; Inv. An. Vineyard Sound, 1874, pp. 329, 738; Am. Jour. Sci., 4th, vol. VI, 1898, p. 495.
Cylista leucolena Andres, Fauna u. Flora Golfes Neapel, bd. IX, p. 151. Parker, Am. Nat., vol. XXXIV, 1900.

This species is common and abundant throughout the region, but its small size and retiring habits tend to render its presence more or less obscure or even unknown.

The following characteristics may be regarded as diagnostic. Body elongated, cylindrical even in contraction, smooth, or with minute papillæ disposed in scattered but more or less vertical rows. Pedal disk well developed, by means of which the creature may adhere tenaciously to almost any object, and also serving as a means of locomotion. Oral disk concave, mouth with about 10 pairs of corrugations, or lips, which are of a brownish color. Body translucent, enabling one to observe the mesenteries which appear as whitish longitudinal lines within the body. Tentacles rather numerous, 40 to 60 or more, in some three series, the inner longest, all delicate, attenuate at tips. Color usually delicate pinkish or flesh color to almost white, sometimes with a greenish tinge, especially near oral end and bases of tentacles when contracted;[a] tentacles whitish, often greenish at basal ends. Size variable according to age, the average being about 30 to 40 mm. in height by about 5 or 6 mm. in diameter.

In a few points this description does not wholly agree with that of Verrill. For example, the size ranges somewhat smaller, Verrill giving the height as from 50 to 65 mm. Again, his statement that "one of the primary tentacles in the longitudinal plane opposite one end of the mouth is much longer than the others, and often differently colored than the others," I was not able to confirm, except in a rare specimen now and then. Surely it can not be regarded as a diagnostic feature. It was not unusual to find at certain times that one or even several of the tentacles of the inner series might become more

[a] Occasionally an interesting variety of this species is found, distinguished by a marked color difference, specimens being bright or deeply orange colored. A few specimens were taken at Woods Hole and at first taken to be a new species; but a study of sections failed to show any structural distinction of consequence.

Later I received from Miss Anna Luther, of Jersey City, several living specimens which had been taken at Bay Shore, Long Island, and all of the same distinct orange coloration. At this locality the orange color predominates, only an occasional specimen of the white variety occurring. They are quite hardy and live in a balanced aquarium for months if occasionally fed. In this they are quite like the white variety of Woods Hole. So far as I am aware this marked color distinction has not hitherto been pointed out.

or less specialized at times, apparently serving as tactile organs, being greatly extended and vigorously vibrated in various directions. Figure 8, plate XLIII, will give a good general impression of the appearance of the animal.

Habitat: More or less common on rocky or gravelly beaches adhering to the under side of rocks, or in crevices; also found among masses of ascidians on piles of docks, and among colonies of sponges, worm tubes, etc. It is quite susceptible to light and invariably seeks shaded or protected localities. They are much more commonly found under stones along rocky beaches than elsewhere. They are readily adaptable to an aquarium habitat, living in apparently normal vigor for several weeks if some care be taken to provide fairly good water and occasionally some shreds of meat, as bits of shrimp or clam, etc. In this habitat it is quite easy to study the habits of the organism to one's content. Elsewhere I have given some account of their behavior in relation to light intensity, etc. Specimens occasionally adopt a burrowing habit and secrete themselves in sand.

Reproduction: This seems to be wholly of the sexual sort. During several years of fairly close observations I have never seen the slightest indications of budding or fission. Furthermore, the sexes seem to be quite distinct. I have repeatedly undertaken to study the development of the species, but have found it difficult to secure ripe males and females at the same time. Only once have I succeeded in getting early traces of cleavage. Whether the transfer of specimens to the aquarium tends to check the reproductive function I am uncertain. I have repeatedly had eggs deposited in the dishes, and in a few cases sperms were deposited at the same time, but in only one instance have normal fertilization and development followed. I have had a similar experience with other actinians, e. g., *Metridium*, and am disposed to regard the transfer to an artificial condition as tending to check or modify the sexual activity. An examination of sperms obtained under these circumstances showed them to be quite active and apparently normal; but attempts to fertilize eggs liberated at the same time seldom gave any response.

Distribution: This is given by Verrill as from North Carolina to Cape Cod. I have taken them in Long Island Sound and in Vineyard Sound, Buzzards Bay, etc.—a fairly abundant species throughout the entire region.

TEALIA Gosse, 1858.

Tealia crassicornis Muller. [Text fig. 3 and 4.]

Actinia crassicornis Muller, 1776; Gmelin, 1788, 1793, 1798; Johnston, Hist. Brit, Zooph., 1847, p. 226.
Rhodactinia davisii Agassiz, Compt. Rend., 1847, p. 677; Verrill, Mem. Boston Soc. Nat. Hist., vol. 1, 1864, p. 18.
Bunodes crassicornis Gosse, Ann. Nat. Hist., 1855, p. 294.
Tealia crassicornis Gosse, ibid., 1858, p. 417; Actinologia Britannica, 1860, p. 209.
Andres, Fauna u. Flora Golfes v. Neapel, bd. IX, p. 199.

The synonomy of this species is extremely intricate and confusing. It may be doubted whether in the entire literature of Actiniaria a more complicated case can be found. This may be due in part to the highly variable external features, which have been so largely taken by the early naturalists as diagnostic. No attempt has been made to present more than the briefest outline in the above list. To those who are concerned as to this feature fuller details may be found in the masterful work of Andres (vide supra).

In connection with the above reference to the variable aspects of the species it may be well to cite certain facts. For example, Verrill had long ago pointed out this feature, saying "in form it is very mutable, both ends being capable of great distension or contraction. It will often assume a variety of the most diversified forms within a very few minutes." As to color he makes similar reference: "Deep crimson, mottled with pink; littoral specimens most commonly of a clear bluish-green color, irregularly blotched with crimson or reddish brown." The specimens taken by me, though comparatively few, have shown similar variability, especially as to coloration. I have not observed the extreme variation of form mentioned by Verrill. It should be stated, however, that my specimens were mostly of small size, and being dredged from a depth of some 20 fathoms were more or less contracted, only a few of them living long after being taken and these apparently not extending fully in the aquarium.

In only a few instances have representatives of the species been taken in the region. On two occasions I have taken specimens at Crab Ledge, off Chatham, Mass.; another specimen was taken by Dr. Sumner, late in the summer of 1907, off Gay Head, which was presumably of this species, though unfortunately was not preserved.

The following may be taken as fairly diagnostic characters: Column generally smooth, or with slight papillose bodies variously disposed over the body, more particularly on the upper portion, and in the specimen there was a marginal series of spherular bodies. Pedal disk well developed and larger than diameter of column. Oral disk well defined and with darker radial lines extending toward the margin. Tentacles rather stout, fingerlike, about 50 in number in specimens taken by me, arranged in some three series.

Sphincter strongly developed, and almost diagrammatically comparable with Hertwig's figure of this organ for the genus. (Cf. fig. 4.) I regret that my material was found badly preserved for histological details, so that it has been found impracticable to submit figures of other internal organs. It was not difficult to determine the presence of numerous mesenteries, two siphonoglyphes, and the appropriate directives, as shown in text figure 3.

Reproduction: So far as known this is exclusively sexual. In the cases under observation it was found that earlier development takes place within the gastric cavity of the adult. Several young were brought forth during life in the aquarium in a stage of perfect development, and continued to thrive for some time.

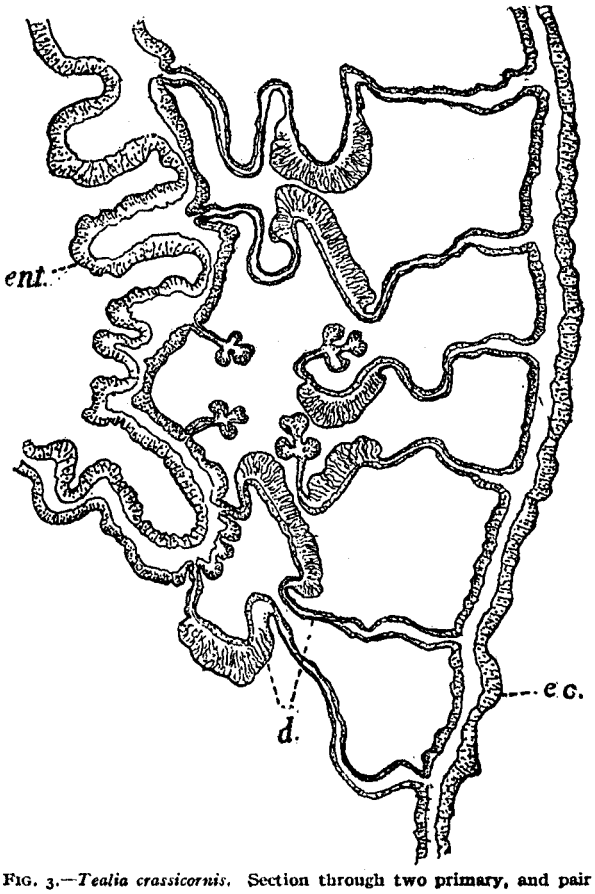

FIG. 3.—*Tealia crassicornis*. Section through two primary, and pair of directive mesenteries; *ent*, entoderm; *ec*, ectoderm; *d*, directive mesenteries.

Distribution: While rather rare within the region the cases given make certain its presence as an integral feature of the fauna. According to Verrill, from Nantucket Shoals to Grand Manan.

ELOACTIS Andres, 1883.

Eloactis producta (Stimpson). [Pl. XLII, fig. 4.]

Actinia producta Stimpson, Proc. Soc. Nat. Hist., Boston, vol. V, p. 110, 1856.
Halcampa producta Verrill, Mem. Boston Soc. Nat. Hist., vol. I, 1862, p. 30.
albida Verrill, ibid., p. 29.
producta Verrill, Inv. An. Vineyard Sound, 1874, pp. 330, 738. Andres, Fauna u. Flora Golfes v. Neapel, bd. IX, p. 106.
Eloactis producta McMurrich, Proc. U. S. Nat. Mus., vol. XVI, 1894, pp. 141–142.
Eloactis producta Parker, Am. Nat., vol. XXXIV, 1900.

Andres (op. cit., p. 106) was the first to express doubt as to the exact generic relations of this actinian and to suggest the probable necessity of establishing a new genus. This suggestion was later

acted upon by McMurrich (vide supra), who proposed its reference to the genus *Eloactis* of Andres. This was later followed by Parker, and following these proposals I have formally accepted this reference. At the same time it should be said that the grounds of the proposed reference to another genus are not altogether conclusive. Whether a given species be hexamerous or decamerous, in view of the range of variation now known to prevail to considerable extent, can hardly be of great significance as a taxonomic feature. While the species under consideration is apparently predominently decamerous, I have found considerable variation in this respect. In younger specimens the hexamerous condition is not at all uncommon. In several different specimens some 50 to 70 mm. in length which I took occasion to section and examine the hexamerous state was prevalent. In very large specimens the decamerous arrangement was quite as prevalent.

The general features of the species will be fairly well shown in figure 4, plate XLII. As will be seen, the body is elongated, more or less cylindrical, and comprises some three distinguishable regions: An oral, retractile portion, or capitulum; a basal, bulbous portion, or pedal-like disk, or physa; and an intermediate portion, the column. This is marked by a series of about 20 longitudinal grooves, whose intermediate ridges are provided with numerous papilliform suckers, by means of which the creature is able to retain itself in the burrow. The length of the body varies greatly, averaging perhaps 100 to 150 mm. in ordinary life. In some cases at full extension it may become twice this length (Verrill). The diameter also varies greatly. It probably averages about 8 to 10 mm. The tentacles are normally 20 in number, with occasional variations, rather stout, with brownish knob-like tips. The color varies from whitish to pale salmon on the column, the base translucent, with bluish tint. A white variety has been described under the name *Halcampa albida;* but this is doubtless a merely varietal character, and in nowise entitled to specific distinction.

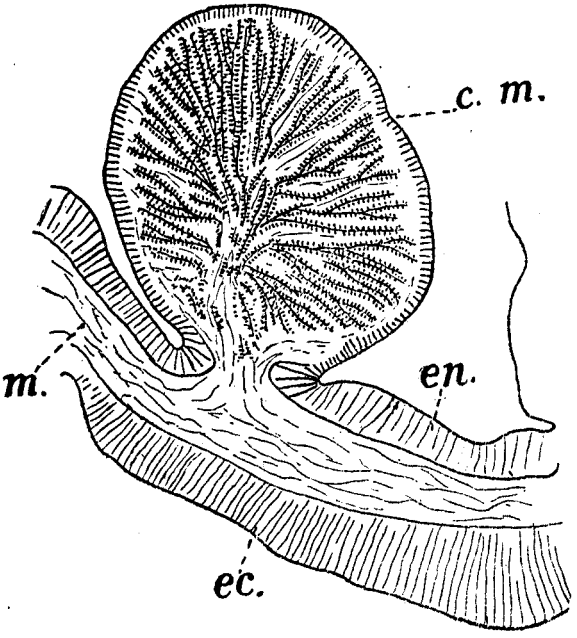

FIG. 4.—*Tealia crassicornis.* Section of circular muscle (*c. m.*); *en* entoderm; *m*, mesoderm; *ec*, ectoderm.

Habitat: The species is characterized in a remarkable degree by the burrowing habit. In many years of observation I have never found it except in burrows on sand flats between tide lines. In this habitat it forms burrows wherein it lives, perhaps more or less permanently. However, it should be said that specimens in the aquarium, in which, by the way, it will thrive for weeks in apparent vigor, yet show a tendency to emerge from the burrows at night and to migrate variously about the aquarium. A further fact may not be without some significance to the same effect, namely, that its burrows do not become lined by a tubular product, such as is provided by *Cerianthus*. I have elsewhere (Biological Bulletin, vol. XII, p. 274) pointed out certain peculiarities of behavior of some significance in this connection, and also as indicating something as to modes of life. That it is markedly sensitive to varying degrees of light, even to the extent of distinguishing between light and darkness, which has rendered the species predominantly nocturnal, seems to be beyond doubt.

These two features, namely, the burrowing and nocturnal habits, conspire to render its presence unknown by most people, except those who especially direct attention to its discovery. While more abundant locally than either *Sagartia modesta* or *Edwardsia elegans* it is yet far from common.

It may be suggested in this connection that the act of burrowing is effected exclusively by the aboral end, or physa. This is bent downward upon the sand, and then by a process of pushing, and at the same time a twisting motion, and by alternate contractions and expansions of the disk, the foot is forced downward. It is by no means a rapid process, and very differently effective by different individuals, as I have elsewhere shown (op. cit.).

Distribution: Verrill reports it from South Carolina to Cape Cod. I have taken it at certain points in Buzzards Bay, and at Catama Bay, and elsewhere about Marthas Vineyard. Its distribution would seem to be more or less local, and dependent upon favorable conditions as to food and for burrowing, etc.

EDWARDSIA Quatrefages, 1842.

Edwardsia elegans Verrill. [Text fig. 5 and pl. XLIV, fig. 12.]

Edwardsia elegans Verrill, Am. Journ. Science, ser. 2, vol. 48, p. 118. Andres, Fauna u. Flora Golf. v. Neapel, vol. IX, p. 95. Parker, Am. Nat., vol. XXXIV, p. 749.

This elegant little actinian is seldom seen except by those who diligently search for it, its burrowing habit giving it effective seclusion.

Body elongate, comprising three more or less distinctive portions, namely, (1) an upper, smooth, necklike portion, of faint brownish color; (2) the body or column, rough from the presence of a sandy accretion over a tough cuticular covering; (3) a somewhat roundish basal portion, translucent or of slightly bluish tint. The entire body is marked by 8 longitudinal grooves or sulcations. Tentacles 16, rather short and fingerlike in moderate contraction, or long and delicately attenuate when fully expanded; apparently of two series, an outer, which is usually depressed close upon the sand at the mouth of the burrow; and a second, alternating series, which extend upward. In color the tentacles are pale brownish, with transverse bars or blotches whitish or pale greenish.

Length of body in expansion 20 to 35 mm., diameter 3 to 5 mm. The organization of the body is shown in the sections taken through the œsophageal region. (Pl. XLIV, fig. 12.)

Distribution and habitat: Found generally throughout the region in favorable sand flats between tide lines, where it burrows. Taken at West Falmouth, Woods Hole, Great Pond, Falmouth, etc.

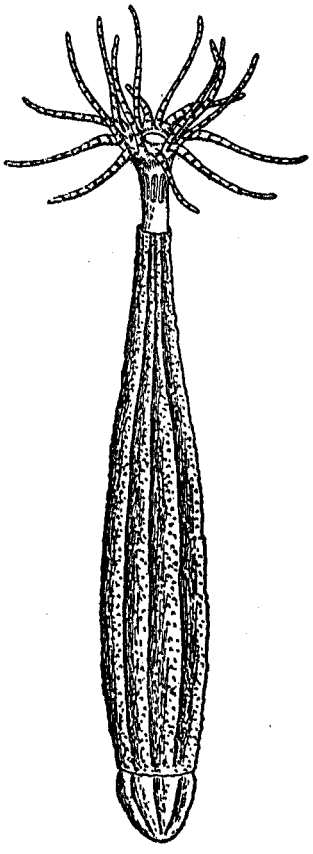

FIG. 5.—*Edwardsia elegans*.

In a paper on the "Behavior of sea anemones" (Biological Bulletin, vol. XII), I have given some account of phases of activity as exhibited by tube-dwelling anemones. At the time this paper was prepared I had not been able to include any account of this species. This was later included in a report upon the reactions of these organisms given at the International Zoological Congress, Boston, 1907. It may suffice in this connection to say that in almost every respect the reactions and behavior of *E. elegans* are comparable with those of *Sagartia* and *Eloactis*.

The species lives well in aquaria and affords a favorable object upon which to observe various aspects of behavior. This is particularly the case with food taking and reactions to varying degrees of light intensity.

Edwardsia sipunculoides (Stimpson) Verrill.

Actinia sipunculoides Stimpson, Marine Inv. of Grand Manan, 1853. *Edwardsia sipunculoides* Verrill, Mem. Soc. Nat. Hist., Boston, vol. I, p. 28, 1864; Andres, Fauna u. Flora Golfes Neapel, bd. IX; Parker, Am. Nat., vol. XXXIV, 1900.

This species has not hitherto been recorded south of Cape Cod. The writer several years ago found a single specimen of an Edwardsia at West Falmouth, Buzzards Bay, which was thought to be *E. sipun-*

culoides, but in some way it was lost before any decisive identification was made, and hence the matter must remain somewhat doubtful. During the present summer (1909) I took a single specimen at South Harpswell, Me., of exactly the same general characters, and conforming so far as distinguishable with the descriptions of Stimpson and Verrill. When first dug out of the sand the specimen was about 50 to 60 mm. in length, of whitish or pale flesh color. After it was placed in the collecting pail along with a few other objects it became greatly contracted and remained in that condition for more than a week in the laboratory, though every means available to induce it to expand was tried. Finally, before leaving it was killed and preserved, and later carefully sectioned in the hope of finding conclusive evidence as to its specific relations. Unfortunately the state of contraction had been so great that the killing proved to have been unsatisfactorily done, and while the main generic features were easily distinguishable it was not practicable to certainly determine the number of tentacles and other specific characters. So far as known only one other species could be possibly confused with it, namely, *E. farinacea*, and it seemed not to have been this. I am strongly convinced that the specimen was *E. sipunculoides*, and that, moreover, the one taken at Woods Hole previously was also this species. Hence it seems altogether proper to include the species as coming within the region.

I much regret that I am not able to present good anatomical descriptions of the species. However, the earlier description of Verrill (vide supra) renders this lack less serious.

Edwardsia lineata Verrill.

Edwardsia lineata Verrill, Inv. An. Vineyard Sound, p. 739, 1874; Andres, Fauna u. Flora v. Golf. Neapel, bd. IX; Parker, Am. Nat., vol. XXXIV, 1900, p. 750.

"Body cylindrical, elongate, covered with dirty brownish, slightly wrinkled epidermis, except just below tentacles, where it is smooth, translucent, and usually with eight longitudinal, flake-white lines showing through. Tentacles 24 to 30, or more in large specimens; slender, tapering, obtuse, white or pale flesh color, each with a flake-white longitudinal line along inner side. Disk with white circle around the mouth, and often with eight or more radiating white lines extending to the base of inner tentacles; border of mouth somewhat pale red; naked part of column pale flesh color, often with circle of white below bases of tentacles. Length 25 to 30 mm., diameter 2.5 to 3 mm. Species remarkable in lacking any naked basal portion, or any true disk for attachment. This may be due to the peculiar habit of nestling in crevices between rocks, worm tubes, etc. Off Gay Head, 6 to 12 fathoms, among ascidians and annelid tubes, etc. Abundant."

I have not seen this species, and the above description has been compiled from that of Verrill. Having been on constant lookout for the species for several years, it seems rather strange not to have obtained a single record of its occurrence.

Edwardsia leidyi Verrill.

Edwardsia leidyi Verrill, Am Jour. Sci., ser. 4, vol. VI, p. 493; Parker, Am. Nat., vol. XXXIV, 1900, p. 750.

This remarkable Edwardsian was first noted by A. Agassiz as a parasite in *Mnemiopsis leidyi* and taken to be a leechlike worm. (Cf. Catalogue of North American Acalephæ, p. 23.) It was later observed by Verrill. (Invertebrate animals of Vineyard Sound, p. 457.) Its true character seems first to have been recognized by Mark. (Memoirs of Museum Comparative Zoology, vol. IX, p. 43.) Mark also pointed out the fact that this stage was a larval one, and that during this period it was a true parasite within the ctenophore. Following the development so far as conditions made it possible, he suggested that the larva might not improbably be a stage in the life history of *Edwardsia lineata*. To the present writer it seems rather more probably related to *E. elegans*. As evidence of this may be noted the number of tentacles in Mark's oldest specimen, namely, 16, while in *E. lineata* the number is from 24 to 30, or more. Again the aspect of the tentacles is very much like that of *E. elegans*.

It is much to be regretted that as yet we are without a final account of the life history, no later observer having been able to carry the record beyond that at which it was left by Mark. The present writer has sought to discover some clue to the later stages, but without success. The occurrence of the larvæ is most erratic. During some seasons it abounds to such extent that hardly a specimen of Mnemiopsis can

be found without from one to a half dozen or more of the parasites within the canals, and during other summers scarcely a single specimen can be found at all. During the entire summer of 1907 the writer sought from June to September for larvæ, but without finding a trace. In November of the same year Mr. Vinal Edwards and Dr. Sumner found them in immense numbers, almost every ctenophore being infected.

Morphology of the larval stage: Polyp slender and wormlike, and variously coiled in the canals of the ctenophore. Length of larger specimens 20 to 30 mm., diameter 1 to 2 mm., varying under conditions of contraction. Tentacles 16 (?), color pinkish or flesh color.

CERIANTHUS Delle Chiaje, 1841.

Cerianthus americanus Verrill. [Pl. XLIV, fig. 10.]

Cerianthus americanus Verrill, Mem. Boston Soc. Nat. Hist., vol. 1, 1866, p. 32; McMurrich, Jour. Morph., vol. IV, 1890, p. 131; Parker, Am. Nat., vol. XXXIV, 1900, p. 756.

Originally described by Verrill from a southern habitat, this species has but rarely been found at Woods Hole. The writer found a single specimen several years ago, but failed to secure it. In a collection of *Edwardsia* taken at Ram Island, Woods Hole, in 1902, there was found a single specimen which was turned over to the writer for identification. It resembled at first a specimen of *Sagartia leucolena*, or a very small specimen of *S. modesta*. A careful examination of the specimen, however, proved it to be an immature specimen of *Cerianthus*. The size was only about 35 mm. in length by about 5 mm. in diameter, in contraction. Sections showed no signs of gonads, and there were but 45 to 50 tentacles; all of which go to show a condition of immaturity. The sectional figures were made from the specimen and leave no doubt as to its identity.

The specimens originally described by Verrill were of very large size—2 feet or more in expansion. McMurrich, who has studied specimens from the same general region, has not been able to confirm Verrill's account as to size. Specimens examined by the writer from the Woods Hole region agree very closely with McMurrich's account in this particular. His account gives the length as not more than 20 cm., with a diameter of 1.5 to 2 cm.

In the matter of color there seems to be considerable variation. The specimen from which this account is chiefly derived was in life translucent and pale flesh color. Another specimen examined by the writer was brownish, especially near the oral portion, the aboral region being paler. A purplish tint is not unusual along with the brown.

Habitat: This seems to be almost exclusively at or just below average tide line and in muddy flats. The species is of burrowing habit, these burrows extending at an angle for considerable depths. The creature secretes a tubular lining for its burrow, which is composed of mucus secreted by ectodermal glands, in which are also agglutinated extruded nematocysts, grains of sand, etc. In the aquarium the specimens also secrete a similar tube, but, according to McMurrich, of much lighter texture.

ACTINAUGE Verrill, 1883.

Actinauge verrilli McMurrich.

Actinauge nodosa, Verrill, Am. Jour. Sci., vol. VI, 1873, p. 440; Bull. Mus. Comp. Zool., vol. XI, 1883, p. 50.
Actinauge verrilli, McMurrich, Proc. U. S. Nat. Mus., vol. XVI, 1893, p. 184.

Among the collections at Woods Hole I found four specimens of this species, two of which were taken by the *Albatross* in 1885 at station 2506 from a depth of 27 fathoms. The other two were taken by the *Fish Hawk* in 1899 at station 7070. These specimens differ more or less in general external features. The *Albatross* specimens (contracted) measured 5 and 7 cm. in height by about 4 and 5 cm. in diameter. The warty nodules, or verrucæ, were very prominent and characteristic. They were disposed in about 24 longitudinal rows in the smaller specimen. The capitular ridges were somewhat less evident and definite but about 40 in number. The larger specimen was much more contracted, making it impracticable to determine exactly the number and disposition of these structures, but the longitudinal rows seemed to be about 28 in number.

In the *Fish Hawk* specimens the verrucæ were much less prominent, and the capitular ridges and longitudinal rows likewise indistinct and correspondingly indefinite. They appeared, therefore, of smoother and cleaner texture than the former, which were rough and the furrows and nodular interstices coated with a brownish deposit in marked contrast to the whitish points of the nodules themselves.

While this species is seldom seen among the fauna of the region as strictly interpreted, still it has seemed quite proper to make at least a brief reference to their presence among contiguous fauna.

MADREPORARIA.

Of the Madreporaria there are comparatively few species which come within the range of the present synopsis. Of these by far the most common is *Astrangia*, which abounds almost everywhere. The more characteristic features of the order have been given in an earlier section.

ASTRANGIA M. Edwards and Haime.

Corallum forming an encrusting mass over the substructure, the colony forming variously disposed aggregates of polyps, mostly of small dimensions, though occasionally branching in rather complex fashion, as shown in figure 9, plate XLIII. The polyps are very transparent, but appear white as viewed against a dark background.

Astrangia danæ Agassiz. [Pl. XLIII, fig. 9.]

Astrangia danæ Agassiz, Proc. Am. Assoc. Adv. Sci., vol. II, p. 68, 1847; Milne-Edwards and Haime, Ann. des Sci. Nat., 3d ser., T. XII, 1850.
Astrangia astreiformis Leidy, Jour. Acad. Nat. Sci., vol. III, 1855, p. 139.
danæ Verrill, Mem. Boston Soc. Nat. His., vol. I, 1864, p. 40; Inv. An. Vineyard Sound, 1874, p. 740.

This is the best-known coral, having a natural habitat within the region. Indeed, it is the only one at all familiar along the shore waters of the New England coast. It occurs almost everywhere, growing on rocks, piles of docks, shells, etc., at or just below low-water line to a depth of 15 to 20 fathoms. Its range is given as from Florida to Cape Cod. It has also been reported from the waters of Casco Bay, Me. The species forms irregular incrustations of rather small dimensions over shells, rocks, etc., though it occasionally becomes larger and branches in rather complex fashion. It lives well in the aquarium for an indefinite time. Polyps in expansion about 10 to 15 mm. in height and with about 24 delicate tentacles, which bristle with nematocysts, especially about the tips. Cells of the corallum rather shallow and with numerous septa, as shown in the figure. The breeding season seems to be chiefly in midsummer. I have occasionally obtained eggs in the aquarium but it has been found difficult to secure them under conditions favorable for development.

ORBICELLA Dana, 1846.

Orbicella acropora (Linnæus).

Madrepora acropora Linnæus, Syst. Nat., X ed., p. 708.
Madrepora annularis Ellis & Solander, Nat. Hist. Zooph., 1786, p. 169.
faveolata Ellis & Solander, op. cit., p. 166.
Heliastrea annularis M. Edwards & Haime, Hist. Nat. Corall., vol. II, p. 473, 1857.
acropora Milne-Edwards & Haime, op. cit., p. 477.
Astrea annularis Lamarck, An. sans Vert., 2d ed., vol. II, p. 405.
Orbicella annularis Pourtales, Mem. Mus. Comp. Zool., vol. VII, 1880; A. Agassiz, Bull. Mus. Comp. Zool., vol. XX, p. 61, 1890.
acropora Vaughan, Bull. U. S. Fish Comm., vol. II, p. 301, 1901.

A fragment of this coral was found by Dr. F. B. Sumner on the beach at Nobska (Woods Hole) in July, 1906, and still another some two years later. Both specimens were somewhat worn by water action, yet easily identified. So far as known, the species has not hitherto been recorded north of Bermuda, Porto Rico, or similar range. And while at first I was disposed to regard its occurrence here as accidental, possibly through tourist agency, still the facts seem to warrant recording, leaving to

subsequent events the determination of its relation to the region. The specimen measured about 50 by 85 mm., and while more or less eroded was in good state of preservation. The extended dredgings made in the waters of Vineyard Sound for many years would seem to have made more or less certain its discovery if native to these waters. Vaughan's description of the species from Porto Rico gives no account as to depth from which taken, but merely the locality (Mayaguez) and from reef. Its habitat is probably quite shallow, and the course of the Gulf Stream in the region of Woods Hole might warrant its northern range. However, speculation is uncalled for; the facts are given for what they are, as suggested above.

ALCYONARIA.

The alcyonarian fauna of the region is so limited in species as to call for only passing notice. At most but two or three species are represented—one under the genus *Alcyonium* and perhaps two under the genus *Penatula*. In the deeper waters adjacent to Nantucket and off Marthas Vineyard the group has numerous representatives, accounts of which may be found in the reports of the dredging operations of the *Albatross* and *Fish Hawk* from 1880 to 1898. But as recent collections have added no additional facts, either as to species or distribution, it will suffice to call attention to the above reports.

It seems well to briefly describe the two species more likely to be met with by the student, though without attempting details as to structure and habits.

ALCYONIUM Linnæus, 1758.

Linnæus, Syst. Nat., Ed. x, vol. 1, p. 803.
Dana, Zoophytes, 1846, p. 611.
Milne-Edwards, Corallines, 1857.

Corallum fleshy, with granular spicules which do not project beyond the surface; base more or less enlarged and adherent to rocks, shells, etc. Colony variously branched, the branches thick and fingerlike, stem more or less devoid of polyps, which are abundant on the branches and terminal portions, and retractile within the cœnosarc.

Alcyonium carneum Agassiz.

Halcyonium carneum Agassiz, Proc. Am. Assoc. Adv. Sci., 1850, p. 209.
Alcyonium digitatum Stimpson, Marine Inv. Grand Manan, 1853, p. 7; Smithsonian Contr., vol. VI.
Alcyonium carneum Verrill, Mem. Boston Nat. Hist., 1866, vol. I; Inv. An. Vineyard Sound, p. 497, 737.

This conspicuous alcyonarian is well known to almost every collector along the New England coast who has paid attention to the cœlenterate fauna to any extent. It is rather common from Vineyard Sound northward to Maine and beyond, occurring on rocks, shells, etc., and in depths of from 10 to 30 fathoms. It shows small adaptability to aquarium conditions, soon dying when placed therein. The color is variable, from pale flesh color to bright pink or reddish or orange. The colony is branched variously, the branches thick and fingerlike, from which probably arose the common name, "dead men's fingers," often used by fishermen. The stem is attached by an expanded base to any convenient support, such as shells, etc. Polyps variously distributed over upper portions of stem and branches, and in expansion rather conspicuous, having a length of from 7 to 10 mm.; they are highly contractile, and capable of entire retraction within the cœnenchyma. The tentacles are eight in number, beautifully fringed with delicate lobes so characteristic of the order.

PENNATULA.

Pennatula aculeata Danielson and Koren.

Pennatula aculeata Danielson and Koren, Forhandl. Vidansk. Selsk, 1858; same authors, Fauna Litt. Norv., III, 1877. Verrill, Am. Jour. Sci., 1873.

This species was taken by the *Fish Hawk* at several stations off Marthas Vineyard and Block Island in 1882 and 1899, several specimens being now in the collection at Woods Hole. This is a well-known and very beautiful pennatulid; stems usually bulbous at base, the bulb larger at the proximal end,

rachis rather larger in median portion; general shape featherlike, hence the name; polyps borne on upper portion of the pinnæ. The colony varies in size from 10 to 25 cm.; color beautiful purplish red, bulb whitish and opaque in preservation. Species widely distributed over both eastern and western Atlantic and along the entire New England coast and south to Chesapeake Bay.

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DESCRIPTION OF PLATES.

PLATE XLI.

FIG. 1. *Sagartia luciæ*, general view from side. × 2.

FIG. 2. *Sagartia luciæ*, oral view, showing whitish lines marking position of œsophageal grooves, and on the left the evidence of recent fission of specimen as shown in dim outlines of the disk markings.

FIG. 3. *Anemonia sargassensis*, drawn and colored from life, showing also the clasping aspect of pedal disk.

PLATE XLII.

FIG. 4. *Eloactis producta*, drawn and colored from life, showing the expanded disk, the smooth, pinkish lower and papillose upper portions of the column.

FIG. 5. *Sagartia modesta*, drawn and colored from life, showing expanded pedal disk, numerous tentacles, and the sinuous aspect of body as freely expanded in aquarium.

FIG. 6. Single tentacle of specimen, showing characteristic markings. × 3.

PLATE XLIII.

FIG. 7. *Sagartia modesta*, photograph from life as expanded in aquarium, the pedal disk attached to bottom under layer of sand.

FIG. 8. *Cylista leucolena*, photograph from life, in aquarium.

FIG. 9. *Astrangia danæ*, an unusually large coral mass of this species. × ½.

PLATE XLIV.

FIG. 10. *Cerianthus americanus*, section through œsophagus, showing groove and numerous mesenteries and their distribution; *oe*, œsophagus; *ec*, ectoderm.

FIG. 11. *Cylista leucolena*, section through œsophagus, showing paired grooves, mesenteries, and directives (*d*), and secondary mesenterial buds.

FIG. 12. *Edwardsia elegans*, section showing distinctive mesenteries and paired directives (*d*); *oe*, œsophagus; *ec*, ectoderm.

FIG. 13. *Anemonia sargassensis*, section through œsophagus, showing primary mesenteries and numerous secondary mesenterial buds; *d*, directive mesenteries; *ec*, ectoderm.

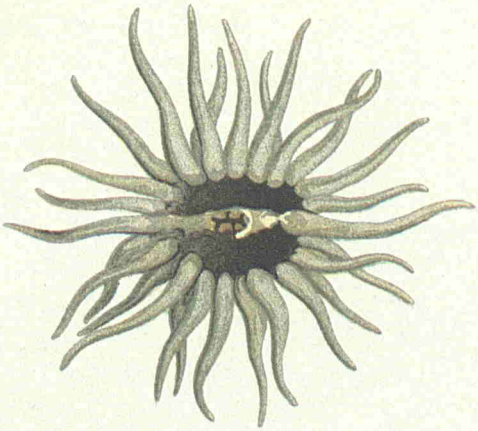


Fig. 2. Sagartia luciae
Oral view

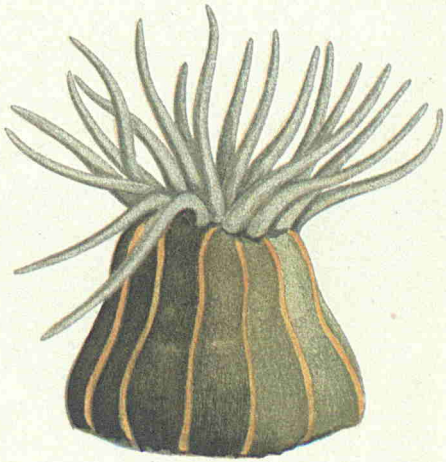


Fig. 1. Sagartia luciae
Side view

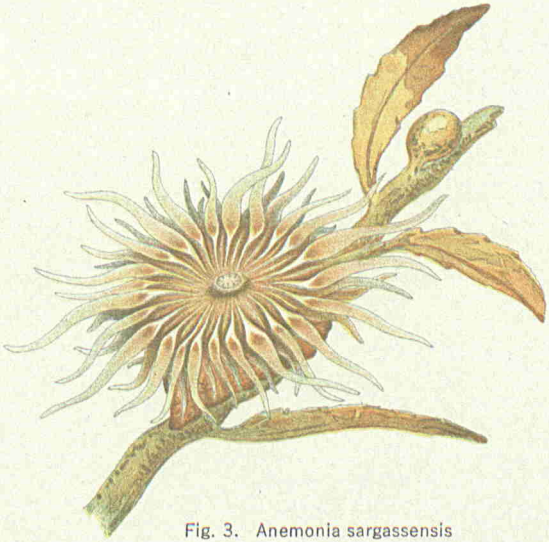


Fig. 3. Anemonia sargassensis

A. HOEN & CO. BALTIMORE.

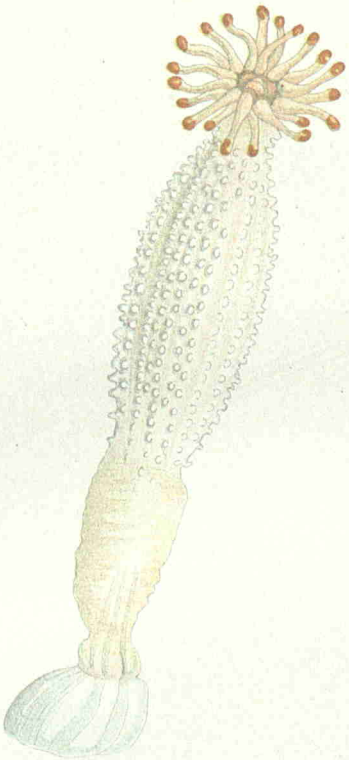
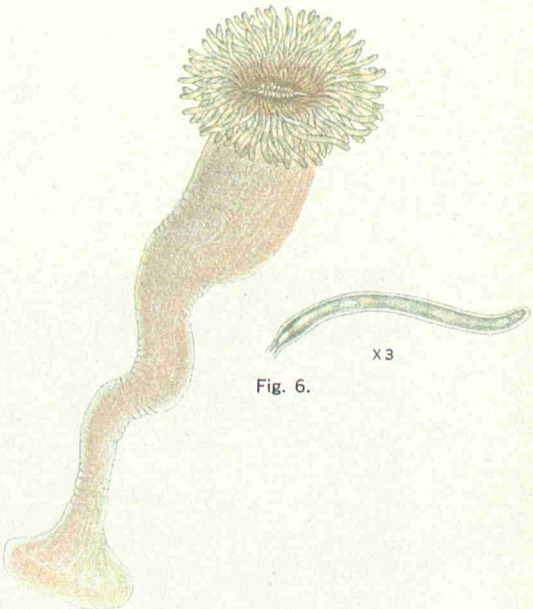


Fig. 4. Eloactis producta



X 3

Fig. 6.

Fig. 5. Sagartia modesta

A. HOEN & CO. BALTIMORE.

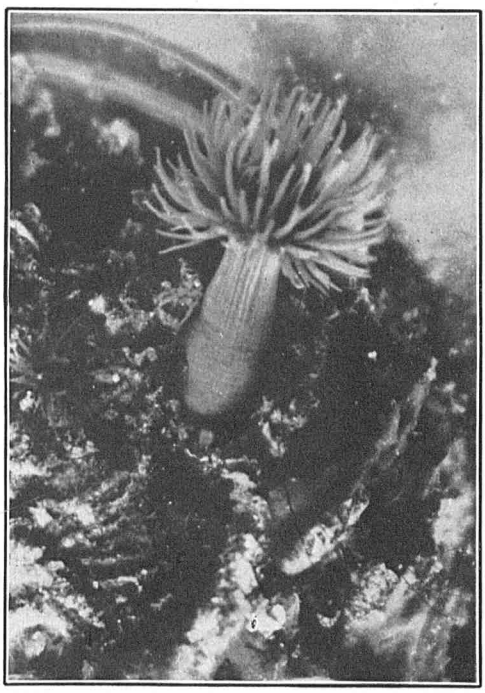


FIG. 8.—Cylista leucolena.

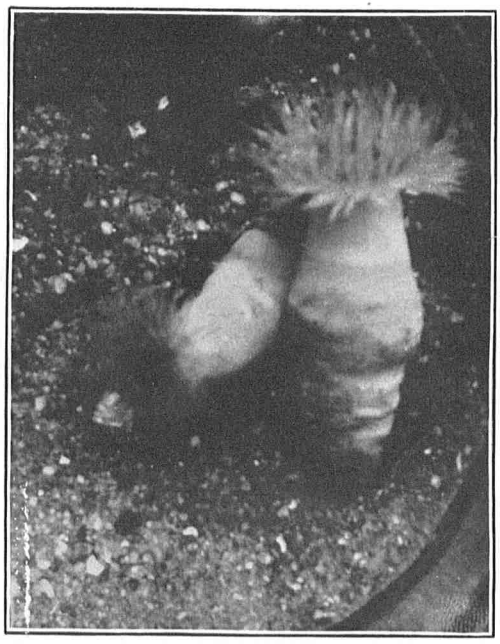


FIG. 7.—Sagartia modesta.

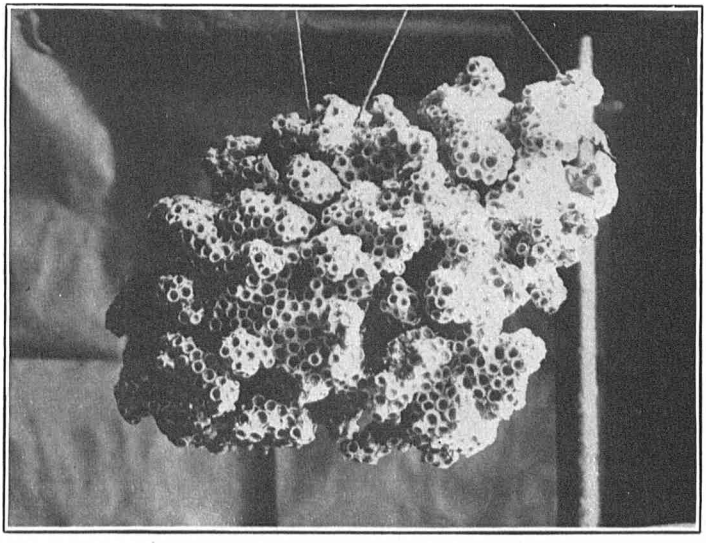


FIG. 9.—Astrangia danæ.

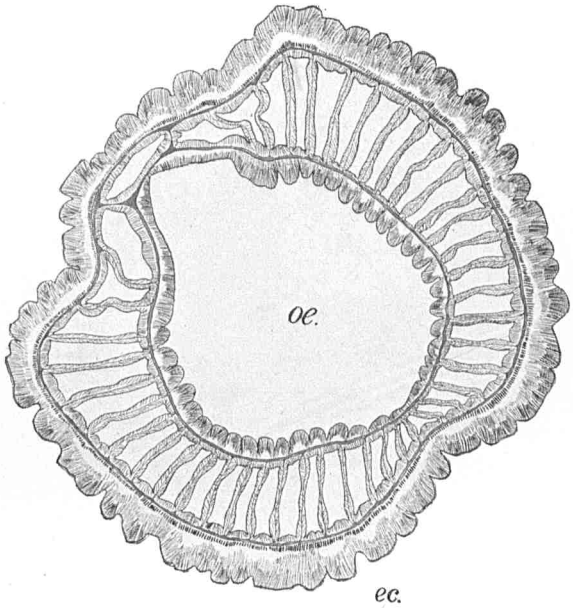


FIG. 10.—Cerianthus americanus.

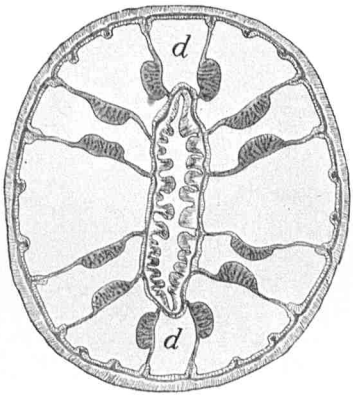


FIG. 11.—Cylista leucolena.

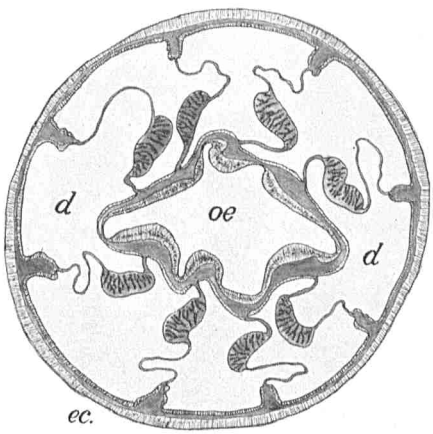


FIG. 12.—Edwardsia elegans.

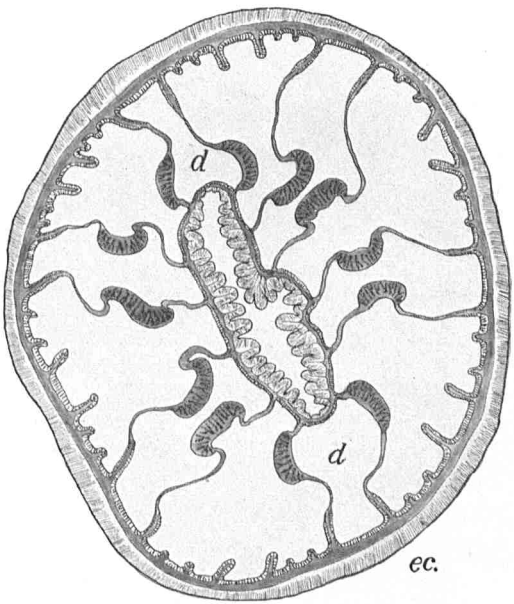


FIG. 13.—Anemonia sargassensis.

THE CEPHALOPODA OF THE HAWAIIAN ISLANDS

By S. Stillman Berry

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THE CEPHALOPODA OF THE HAWAIIAN ISLANDS.

By S. STILLMAN BERRY.

INTRODUCTION.

The ensuing monograph was originally projected as a report on the collection of cephalopod mollusks taken by the United States Bureau of Fisheries steamer *Albatross* during her Hawaiian cruise of 1902. It was found, however, that the pages required to be only slightly amplified to become practically a monographic survey of the entire Hawaiian region, and this has accordingly been done. Wherever possible a full description is given from Hawaiian material of each species under consideration. This is succeeded by a brief discussion of the further range of the species, tables of dimensions, a short critical comparison with other nearly allied forms, and such other items as seemed relevant. In some cases, especially where a species has been known to the writer only through the descriptions of other authors, it has been thought well to reprint the diagnosis of the original author in full. The work was commenced at Stanford University in the autumn of 1908, and, with the exception of the season of 1909–10, was prosecuted more or less continuously in the zoological laboratories there from that time to November, 1912.[a]

SOURCES OF MATERIAL.

The great bulk of the material upon which this report is based is the property of the United States Bureau of Fisheries and was obtained during the explorations of the United States Fisheries steamer *Albatross* on her extensive investigation in 1902 of the waters adjacent to the Hawaiian Islands, which constitute, zoologically speaking, what is known as the Hawaiian region. The principal part of the specimens have been turned over to the United States National Museum, but a set of the duplicates is deposited in the Stanford University collections.

I have further had for study the small series of shore forms already in the collections of Stanford University, most of them obtained by Dr. O. P. Jenkins during his visit to the islands in 1889, or by Dr. D. S. Jordan and Dr. B. W. Evermann in 1901. These

[a] As on a former occasion, I must express my gratitude to Dr. Walter Kenrick Fisher, of Stanford University, for the kindly interest with which he has constantly followed the progress of this work in his laboratory. It is of interest to note, also, that Dr. Fisher was a member of the *Albatross* staff during the Hawaiian explorations, and the occasional color and habit notes which appear in his handwriting on the labels of some of the specimens are of more than ordinary interest, especially when we consider how few data of the sort are available for even the commoner species of this group of animals.

To Dr. Harold Heath I am once more under obligation for the opportunity to work up an important collection originally placed in his own hands for study. It is also due to him that the series of drawings prepared by Mr. R. L. Hudson came into my hands at the same time with the specimens, so that the major portion of them could be utilized in the present report. Other illustrations in these pages are the work of Miss Lora Woodhead, Mr. Henry Varnum Poor, and Mr. John Howard Paine, all of Stanford University.

collections include one species (*Onychoteuthis banksii*) which was not taken by the *Albatross*.

In addition to the above there have constantly been available the collections of cephalopods made by the *Albatross* during the Alaska salmon investigations of 1903 and the dredgings off the California coast in 1904, together with the considerable series of west American and Japanese specimens owned by Stanford University. Although all of these have already been made the subject of reports (Berry 1912a, 1912b), their value for comparative study in the present consideration has been inestimable.

The type specimens of new species together with certain others have already been assigned catalogue numbers by the authorities of the National Museum, and such numbers are carefully cited in the proper paragraphs of the following pages. In referring to the Stanford University material, I have for the sake of brevity adopted the University initials—L. S. J. U.—immediately succeeded by a catalogue number which has reference to the invertebrate series in the University collections.

As will be seen, the material thus utilized lacks only *Polypus hawaiiensis*, *Symplectoteuthis oualaniensis*, and the clearly erroneous *Loligo gahi* and *Polypus fontanianus*, to embrace all the species known or reported from the islands, the great bulk of the records being nevertheless entirely new. The total number of specimens which I have personally examined is 210. These are distributed among 24 genera and include somewhat more than 29 species, only 4 of which have been previously recorded from the region. Some 15 of these species it has been found advisable to describe as new, and it is quite probable that several of the 10 or more forms represented by specimens too immature or too poorly preserved for accurate determination belong to species not yet described.

The *Albatross* collection has already formed the basis of two brief preliminary papers (Berry 1909, 1913), in which the majority of the new species were tersely described and in the first of which a provisional check list of all the species was also given.

HISTORICAL SURVEY.

With the exception of the two papers which have been just referred to as preliminary to the present report, no work specially devoted to Hawaiian Cephalopoda has ever been published. Even the scattered references contained in volumes of wider scope are not numerous and only to be found by dint of the most exhaustive searching. Despite its brevity, therefore, the following cursory survey of the literature is thought to be practically complete.

I have been unable to determine to what author belongs the honor of first bringing a Hawaiian member of our group to the public notice, since Gould in America and Souleyet in France both published in the same year. The latter author, reporting in 1852 on the mollusks taken during the voyage of the *Bonite*, describes only a single species from the islands, the *Octopus hawaiiensis*, a form which would naturally be expected to be abundant, but which has not been recognized with any certainty since.

In the magnificent memoir by Gould (1852) on the Mollusca of the Wilkes exploring expedition, two Hawaiian species are described for the first time, both of them common littoral forms, namely, *Octopus ornatus* Gould, and *Sepioteuthis arctipinnis* Gould.

In 1879 Tryon published a monograph of the Cephalopoda as the first volume of his Manual of Conchology. In addition to the three species just noted, two other forms are accredited to our region, namely, *Loligo gahi* d'Orbigny and *Polypus fontanianus* d'Orbigny. Both of these, however, are characteristic South American types and the Hawaiian record in each case seems almost certainly to be an error.

The *Challenger* steamed through the very heart of the region and made a brief call at Honolulu, yet took but a single species of cephalopod. This was a common reef *Polypus*, three specimens of which reached England and were there described by Hoyle (1885) as *Octopus marmoratus*.

In 1899 Schauinsland reported the occurrence of the following species in the neighborhood of Laysan Island, his identifications being based on determinations by Dr. G. Pfeffer:[a]

Octopus sp.
Onychoteuthis Banksii.
Ommastrephes oualaniensis.
Ommastrephes Sloanei.

In 1909 the present writer published preliminary diagnoses of seven supposedly new forms from the Hawaiian Islands, and as an appendix to the same paper added a simple check list of all the species known to occur in the region (Berry, 1909, p. 418). In this list some 22 species are named and 11 other forms are recorded without precise determination. This list, which follows herewith, should now be regarded as entirely supplanted by the present paper:

Cirroteuthis (?) sp.
Argonauta böttgeri.
Argonauta (argo?).
Tremoctopus (near quoyanus).
Alloposus mollis.
Bolitæna sp.
Polypus hawaiiensis.
Polypus hoylei n. sp.
Polypus ornatus.
Polypus marmoratus.
Polypus α.
Polypus β.
Polypus γ.
Scæurgus sp.
Stephanoteuthis hawaiiensis n. gen. and sp.
Euprymna morsei.
Semirossia (?) sp.
Stoloteuthis iris n. sp.
Sepioteuthis arctipinnis.
Ommastrephes sagittata near sloanei.
Ommastrephid (young).
Onychoteuthis banski.
Symplectoteuthis oualaniensis.
Teleoteuthis appellöfi.
Abralia astrosticta n. sp.
Abralia sp.
Abraliopsis sp.
Pterygioteuthis giardi.
Tracheloteuthis riisei.
Chiroteuthis famelica n. sp.
Cranchia (Liocranchia) globula n. sp.
Cranchiid sp.
Helicocranchia fisheri n. sp.

Three years later Naef (1912, p. 247) proposed the new genus *Iridoteuthis*, basing it upon the Hawaiian *Stoloteuthis iris* Berry as its type and single known representative.

[a] Although fragmentary, Schauinsland's notes are of considerable interest, and in view of their inaccessibility to most students it may be worth while to repeat them here.

(P. 25) " . . . nicht selten hat man das Glück, hier auch einen der abenteuerlichen Tintenfische (Octopus) zu erbeuten, und zwar bisweilen in solcher Grösse, dass man sich vor seinen Saugarmen und scharfen Kiefern zu hüten hat."

(P. 92) "Neben den häufig bei Laysan sich findenden *Octopus*-Arten kommen dort an *Cephalopoden* (det. *Pfeffer*) noch vor: *Ommastrephes oualaniensis* Less. und *Omm. Sloanei* Gray, sowie *Onychoteuthis Banksii* Fér. Die drei letzten Arten bilden überwiegend die Nahrung der *Albatrosse*, wenigstens in der Zeit, in welcher sie ihre Jungen füttern. Die Exkremente derselben bestanden fast ausschliesslich aus Cephalopoden-Kiefern. Auch die *Sula*-Arten füttern anfangs ihren Nachwuchs mit verdauten Cephalopoden, später allerdings mit Fischen."

The same year a brief note was published by the writer (Berry, 1912b, p. 434) in which the Hawaiian *Ommastrephes* was awarded separate recognition as *O. hawaiiensis* n. sp. and a very brief definition given.

At about the same time (Berry, 1912c, p. 645) the identity of *Stephanoteuthis* with *Heteroteuthis* Gray 1849 having been recognized, the subsequent name was abandoned as a synonym (for this also see Naef, 1912, p. 246).

In 1913 the writer described the following new forms from the present material:

Lætmoteuthis lugubris n. gen. and sp.	Teleoteuthis compacta n. sp.
Scæurgus patagiatus n. sp.	Abralia trigonura n. sp.
Euprymna scolopes n. sp.	Pterygioteuthis microlampas n. sp.

In the present monograph all the species diagnosed in 1909 and 1913 are redescribed in better detail and figured throughout. Identifications corrected from the list of 1909, together with the few changes in nomenclature which have been found necessary since that time, will be made readily apparent by a glance at the following synopsis of the fauna. No additional new species are here described.

SYNOPSIS OF HAWAIIAN CEPHALOPODS.[a]

ORDER DIBRANCHIATA OWEN.

SUBORDER OCTOPODA LEACH.

Family Cirroteuthidæ Keferstein.

Genus Laetmoteuthis Berry.

Laetmoteuthis lugubris Berry (2).

Family Argonautidæ (Cantraine).

Genus Argonauta Linné.

Argonauta böttgeri Maltzan (1+).

Argonauta sp. (1).

Genus Tremoctopus delle Chiaje.

Tremoctopus violaceus delle Chiaje (31).

Family Alloposidæ Verrill.

Genus Alloposus Verrill.

Alloposus mollis Verrill (1).

Family Bolitænidæ Chun.

Genus Eledonella Verrill.

Eledonella sp. (1)

Family Polypodidæ Hoyle.

Genus Polypus Schneider.

Polypus hawaiiensis (Souleyet) (0).

Polypus marmoratus (Hoyle) (13).

Polypus ornatus (Gould) (3).

Polypus hoylei Berry (4).

Polypus α (4).

Polypus β (15).

Polypus γ (4).

Polypus δ (1).

Polypus ϵ (2).

Genus Scæurgus Troschel.

Scæurgus patagiatus Berry (7).

[a] The number of specimens of each species examined is given in parenthesis after the specific name.

ORDER DIBRANCHIATA OWEN—Continued.
SUBORDER DECAPODA LEACH.
Division Myopsida d'Orbigny.
Family Sepiolidæ Keferstein.
Genus Euprymna Steenstrup.
Euprymna scolopes Berry (64).
Genus Stoloteuthis Verrill.
Stoloteuthis iris Berry (1).
Genus Heteroteuthis Gray.
Heteroteuthis hawaiiensis (Berry) (4).
Family Loliginidæ (d'Orbigny).
Genus Sepioteuthis de Blainville.
Sepioteuthis arctipinnis Gould (4).
Division Œgopsida d'Orbigny.
Family Onychoteuthidæ Gray.
Genus Onychoteuthis Lichtenstein.
Onychoteuthis banksii (Leach) (1).
Genus Teleoteuthis Verrill.
Teleoteuthis compacta Berry (1).
Family Enoploteuthidæ Pfeffer.
Genus Abralia Gray.
Abralia astrosticta Berry (1).
Abralia trigonura Berry (1).
Genus Abraliopsis Joubin.
Abraliopsis sp. (1).
Genus Pterygioteuthis Fischer.
Pterygioteuthis microlampas Berry (2).
Family Histioteuthidæ Verrill.
Histioteuthid, young (3).
Family Brachioteuthidæ Pfeffer.
Genus Brachioteuthis Verrill.
Brachioteuthis riisei (Steenstrup) (8).
Family Ommastrephidæ Gill.
Genus Ommastrephes d'Orbigny.
Ommastrephes hawaiiensis Berry (7).
Genus Symplectoteuthis Pfeffer.
Symplectoteuthis oualaniensis (Lesson) (0).
Genus Rhyncoteuthion Pfeffer.
Rhyncoteuthion α (11).
Rhyncoteuthion β (1).
Family Chiroteuthidæ Gray.
Genus Mastigoteuthis Verrill.
Mastigoteuthis (?) famelica Berry (1).
Family Cranchiidæ (Prosch).
Genus Liocranchia Pfeffer.
Liocranchia globulus Berry (3).
Genus Megalocranchia Pfeffer.
Megalocranchia fisheri (Berry) (1).
Genus Helicocranchia Massy.
Helicocranchia sp. (1).

CHARACTER AND RELATIONSHIPS OF THE HAWAIIAN FAUNA.

From the foregoing it will be seen that so far as is known the Hawaiian fauna includes about 25 named species of cephalopods, together with half as many more uncertain forms, some of which are doubtless worthy of recognition but which are only familiar to us by specimens either too young or too poorly preserved for a positive determination of the species. The total number of genera represented is 24, or about two-thirds as great as the total number of species. This is due to the fact that the genus *Polypus* with 9 forms listed (at least 5 of them doubtful), *Argonauta* with 2 species, and *Abralia* with 2 species, are the only genera which appear more than once in the list. (Owing to various facts which are to be summarized on another page, *Rhyncoteuthion* should obviously be excluded from the present discussion.) The apportionment of the fauna among higher groups is conveniently shown in the following table:

TABLE I.

Divisions.	Number of genera represented.	Named species.	Unnamed or doubtful species.
Octopoda	7	9	7
Myopsida	4	4	0
Oegopsida	13	11	5
Total	24	24	12

One very striking feature which is brought out with particular emphasis in such a table is the surprising weakness of the myopsid element in the fauna. Of the four myopsid genera, one is *Sepioteuthis*, the remaining three are *Sepiolidæ*, and even of each of these but a single species has come to hand.[a] The total absence of any representatives whatsoever of the great genera *Loligo* and *Sepia* in any of the collections was entirely unexpected. Of course Hawaiian species of one or both of these groups not improbably may yet come to light, but in any case I feel that the series of specimens collected by the *Albatross* is so representative that we may assert with confidence that neither genus attains any very great development in these waters, or even the prominence which we might reasonably expect when we consider what a dominant element they compose in the fauna of the Malaysian Archipelago as well as of Japan. *Loligo* especially is so abundant a genus and so cosmopolitan that it would be hazardous with our present knowledge to deny its occurrence anywhere. In the case of *Sepia*, however, it should be remembered that with the exception of a solitary and ill-authenticated record from the West Indies, not a single species is known from the waters adjacent to the American Continent nor indeed from the entire Western Hemisphere. The group being mainly a littoral one, we thus have *a priori* grounds for suggesting that wide oceanic areas may in some way form a special barrier to its dispersion. If this be true we should perhaps expect other littoral forms, such as the *Polypi*, to be distributed in accordance with the same principle; but this, as we shall see later, does not appear to be the case. An explanation of this anomaly may be found in the hypothesis that the dissemination of these other forms took place at a more ancient period. That the rise and dissemination of

[a] It should be remembered, however, that to one of these species, *Euprymna scolopes*, belongs the distinction of being by far the most abundant Hawaiian cephalopod. Nearly one-third of the total number of specimens examined are referable here.

the *Sepiidæ* actually is of comparatively recent occurrence receives distinct support from the circumstance that the dominion occupied by them is almost perfectly continuous and very symmetrically populated, with an extraordinarily rich development of species in the Indo-Malayan and Japanese regions, the apparent center of dispersion.

TABLE II.—DISTRIBUTION OF HAWAIIAN CEPHALOPODS.

Hawaiian species.	Bathymetric range.	Further distribution.	Bathymetric range.	Nearest analogue.	Distribution.	Bathymetric range.	Apparent degree of relationship.
	Fathoms.		*Fathoms.*			*Fathoms.*	
Lætmoteuthis lugubris.	258–284	.....	.....	(?)	.....	.....	
Argonauta böttgeri.	Surface.	Mauritius; Philippines; Australia.	Surface.	(?)	.....	.....	
Argonauta sp.....	Surface.	(?)	.....	Argonauta argo.	Mediterranean to Japan.	Surface.	(?)
				Argonauta pacifica.	Southern California to Galapagos Islands.	Surface.	(?)
Tremoctopus violaceus.	Surface.	Eastern Mid-Pacific; Indo-Malayan; Japan; Mediterranean.	Surface.	.....	.....	.....	
Alloposus mollis....	286–290	North Atlantic..	197–715	Alloposus pacificus.	Japan.....	.....	Close.
Polypus hawaiiensis.	Shore.	.....	.....	(?)	.....	.....	
Polypus marmoratus.	Shore.	Ceylon, Rotuma, Amboina.	Shore.	Polypus bimaculatus.	Southern California to Panama.	Shore.	Fairly close.
Polypus ornatus....	Shore.	.....	.....	Polypus macropus.	Mediterranean; Indian Ocean; Japan.	Shore.	Fairly close.
Polypus hoylei.....	257–460	.....	.....	.....	.....	.....	
Scæurgus patagiatus.	127–178	.....	.....	Scæurgus unicirrus.	Mediterranean..	.....	Close.
Euprymna scolopes.	0–138	.....	.....	Euprymna stenodactyla.	Mauritius; South Pacific.	0–?	Very close.
Stoloteuthis iris.....	142–153	.....	.....	Stoloteuthis leucoptera?	New England...	94–388	Not very close.
Heteroteuthis hawaiiensis.	385–733	.....	.....	Heteroteuthis dispar.	Mediterranean..	500–700	Fairly close.
Sepioteuthis arctipinnis.	Shore.	.....	.....	Sepioteuthis lessoniana.	Red Sea to Japan and New Zealand.	.....	Close.
Onychoteuthis banksii.	Surface.	Cosmopolitan...	Surface.	.....	.....	.....	
Teleoteuthis compacta.	385–733	.....	.....	.....	.....	.....	
Abralia astrosticta..	192–352	.....	.....	Abralia steindachneri.	Red Sea.....	.....	Close.
Abralia trigonura...	306–308	.....	.....	Abralia andamanica.	Bay of Bengal...	188–320	Close.
Abraliopsis sp.....	Surface.	(?)	.....	Abraliopsishoylei	Mascarene Island; west coast Middle America.	1200–2200	Close.
Pterygioteuthis microlampas.	314–335	.....	.....	Pterygioteuthis giardi.	Morocco; Indian Ocean; west coast of middle America.	551–1250	Close.
Brachioteuthis riisei	Surface.	Nearly cosmopolitan.	Surface.	.....	.....	.....	
Ommastrephes hawaiiensis.	220–312	.....	.....	Ommastrephes pacificus.	Japan.....	.....	Fairly close.
Symplectoteuthis oualaniensis.	.....	Red Sea to Japan; Australia; Cocos Is.	.....	.....	.....	.....	
Mastigoteuthis (?) famelica.	385–733	.....	.....	Chiroteuthis pellucida?	Bay of Bengal..	922	Fairly close (?).
Liocranchia globulus	Surface.	.....	.....	Liocranchia reinhardtii.	Atlantic; Indo-Malayan.	Surface.	Close.
Megalocranchia fisheri.	277–284	.....	.....	Megalocranchia maxima.	Cape of Good Hope.	.....	Close.
Helicocranchia sp...	230–277	(?)		Helicocranchia pfefferi.	Ireland.....	350	Fairly close.

This brings us to a consideration of the relationships of the Hawaiian cephalopod fauna with that of other regions and an inquiry as to which of the great Pacific areas can be brought most closely into correlation with it. In Table II (p. 263) I have endeavored to present in compact form a summary of the more essential data to which we must look for an answer to the question. Although admittedly our knowledge is still little more than fragmentary, certain facts seem to be brought out with sufficient prominence to demand consideration. Of the 24 named species listed in the first column, it will be seen that 16, or about two-thirds and including all but one of the shore species, are unknown from any other region. Two others may be eliminated from the discussion as being practically cosmopolitan. Another (*Symplectoteuthis oualaniensis*) occurs very generally throughout the Indian and Pacific Oceans. Of the remainder four are inhabitants also of the Indo-Malayan region. One species is shared with the north Atlantic, but this one (*Alloposus mollis*) appears to be of oceanic habit, so that a wide distribution is in a way to be anticipated.

It is evident therefore that we must turn to the species which are peculiarly Hawaiian in order to gain any proper idea of the true elements which enter into the composition of the fauna. In one of the succeeding columns of the table I have accordingly listed the species which appear to be most closely allied to these, and in yet another column the regions where such analogues are known to occur. The parallel with the Indo-Malayan fauna here appears very striking and again, as in the latter region, a very respectable assemblage of species possesses decided Mediterranean affinities. Indeed one genus, *Scæurgus*, is now known for the first time outside the bounds of the Mediterranean, and, although the species from the two sources appear to be separately nameable, they are nevertheless surprisingly close. *Heteroteuthis hawaiiensis* is another species which finds its nearest ally no nearer than the Mediterranean and here again the relationship is close. The widespread stock of *Polypus macropus*, which ranges in great abundance from the Mediterranean through the Red Sea, around southern Asia to the Malaysian Archipelago, and even to Japan, with practically no change in any of its characters throughout this entire area, also manages to reach the Hawaiian Islands, for it seems obvious that *P. ornatus*, though very distinct in itself, must have had its primary origin as an isolated outpost of this group. Of distinctly Indo-Malayan affinities, but not Mediterranean, are *Euprymna scolopes*, *Polypus marmoratus*, *Abralia astrosticta* (apparently near to *A. steindachneri* of the Red Sea), and perhaps *Mastigoteuthis*(?) *famelica*. *Polypus marmoratus* appears to be allied to the common *P. bimaculatus* of southern and Lower California, but aside from this somewhat anomalous example the fauna has little in common with that of western America.[a]

With the Japanese fauna likewise, outside of the invading Indo-Malayan element shared by both, the Hawaiian cephalopods exhibit no particular relationship. *Ommastrephes hawaiiensis* is doubtless to be regarded as an offshoot of the same stock which gave

[a] So little is at present known regarding the teuthology of the south Pacific that the Australian region has not here been considered as separate from the Indo-Malayan, although the reported presence of *Dosidicus gigas* in those waters would tend to show a certain relationship with the South American fauna.

origin to *O. pacificus* (and *sloanii* ?), and *Sepioteuthis arctipinnis* is similar or identical with *S. lessoniana*, but without exception all the species most truly characteristic of the one area are conspicuous only by their absence in the other. We are able to correlate at least a portion of the Japanese fauna with that of western North America much more successfully.

In summing up, then, it may be said that, although the ensemble of Hawaiian cephalopods shows many features peculiar to itself, it appears reasonable to regard it as an offshoot, now largely isolated, of the great Indo-Malayan fauna, and therefore impossible of any definite or satisfactory correlation with that of other regions of the north Pacific. That this statement is in substantial accord with the conclusions reached by students of other groups of animals is readily seen by a glance at almost any of the monographs dealing particularly with the fauna of the archipelago.

Nutting (Bulletin U. S. Fish Commission, vol. xxiii, for 1903, p. 934, 1906) in discussing the hydroids says that they "have unmistakable relationship with the Australian region," although (p. 935) "as would be expected from the isolated position of the Hawaiian Islands, the preponderance of peculiar species is very exceptionally large."

Miss Rathbun reaches similar conclusions from a study of the decapod crustaceans. She says that "the Hawaiian fauna is almost entirely Indo-Pacific, the islands forming the northeastern, as the Indian Ocean is the southwestern, limit for the majority of the species" (t. cit., p. 830, 1905). She finds but few species peculiar to the islands, however.

Fisher (t. cit., p. 999, 1906) finds the distribution of the starfishes indicative of entirely similar phenomena. He writes that "we are at once struck by the fact that the Hawaiian fauna bears more resemblance to that of the distant Indian region than it does to the fauna of America, notwithstanding that all the ocean currents which pass the Hawaiian Islands are coming from America and not from the west."

In the case of the shore fishes Jordan and Evermann (t. cit., p. 32, 1905) have found the fauna to be "frankly and entirely tropical, all the species belonging to genera characteristic of the tropical Pacific," but most of the species themselves seem to be peculiar to the islands.

The conclusions of Gilbert (t. cit., p. 578, 1905), after his critical examination of the deep-sea fishes collected by the *Albatross*, are especially full of interest: "An analysis of the list of species recorded in the present paper shows conclusively that the bathybial fishes of Hawaii, like those of its reefs and shores, have been derived as a whole from the west and south, and not from the east or north. In its entire facies, the fauna is strikingly unlike that of the Pacific coast of Mexico and Central America, and resembles strongly the assemblage of forms discovered by the *Albatross* and the *Challenger* off the coasts of Japan and the East Indies. Some of its members find their nearest known affines in the Bay of Bengal."

On the other hand, Mayer (t. cit., p. 1133, 1906) in his report on the Medusæ writes that "it appears the majority of the Hawaiian forms are of wide distribution," a conclusion entirely harmonious with what we know regarding such cephalopods as are of similar habit.

BATHYMETRICAL DISTRIBUTION.

The data accompanying the lists of specimens taken by the *Albatross* as given in this paper are partial extracts from the records of the voyage as given in the Report of the United States Fish Commission for 1902 (p. 397–432, Washington, 1903). For more full and detailed stational observations reference may be had to the original paper.

It is worthy of note that no truly abyssal forms were captured unless we so consider the two specimens of *Lætmoteuthis*, the mangled condition of which may perhaps be partly due to their having gotten considerably "out of their depth" when taken, as well as to rocks in the dredge. A glance at the table of stations given in the appendix of this report shows that the greatest depths from which any specimens of cephalopods were obtained were those sounded at stations 3989 (385–733 fathoms, *Heteroteuthis hawaiiensis*, *Teleoteuthis compacta*, *Mastigoteuthis*(?) *famelica*), 4039 (670–697 fathoms, *Eledonella* sp.), and 4110 (449–460 fathoms, *Polypus hoylei*). In no other instances was a member of the class obtained at a greater depth than 400 fathoms, and even in the cases above cited it seems by no means improbable that some of the actively nectonic species may have become ensnared in the dredge during its transit to the surface. Altogether it must be admitted that even the archibenthal regions have been scarcely drawn upon, and it is only concerning the reef and pelagic fauna that we can presume even a fair degree of knowledge. The two latter habitats have each their characteristic group of species, although certain of the smaller free-swimming forms are not uncommon in the reef pools, and both attain the richness customary in tropical regions. As is well known in the case of the fishes and other groups, many of the reef species are truly regal in their brilliantly variegated coloring and other ornamentation. *Polypus* entirely fulfills expectations in being the group most conspicuous on the reefs both in species and in number of individuals, but *Euprymna* and *Sepioteuthis* are also to be captured there. In the plankton we find the usual run of more delicate, less actively swimming forms—*Argonauta*, *Tremoctopus*, *Tracheloteuthis*, larval ommastrephids, histioteuthids, and octopods of various species and genera, *Liocranchia*, and the omnipresent *Euprymna*—nearly all warm-water species of wide dispersion.

As is shown in the table following, five species, mainly of very active habit, are found between the surface and the 100-fathom mark, the richest and by far the most varied fauna of all occurring in the deeper water down to a depth of 400 fathoms. The most remarkable bathymetric range exhibited by any single species is that of *Euprymna scolopes*, which, though very abundant at or near the surface, is frequently met with in all depths down to 130 or 140 fathoms and therefore appears in no less than four columns of the table. *Polypus hoylei* is recorded from 257 to 460 fathoms.

TABLE III.—BATHYMETRIC DISTRIBUTION OF HAWAIIAN CEPHALOPODS.

Shore.	Surface.	Surface to 100 fathoms.	100 to 500 fathoms.	Over 500 fathoms.
OCTOPODA.	OCTOPODA.	OCTOPODA.	OCTOPODA.	OCTOPODA.
Polypus hawaiiensis. Polypus marmoratus. Polypus ornatus. Polypus γ. Polyphus δ.	Argonauta böttgeri. Tremoctopus violaceus. Polypus α. Polypus β. Polypus γ.	Polypus ε.	Laetmoteuthis lugubris. Alloposus mollis. Polypus hoylei. Polypus ε. Scæurgus patagiatus	Eledonella sp.
DECAPODA.	DECAPODA.	DECAPODA.	DECAPODA.	DECAPODA
Sepioteuthis arctipinnis. Euprymna scolopes.	Euprymna scolopes. Onychoteuthis banksii. Abraliopsis (young). Histioteuthid (young). Brachioteuthis riisei. Rhyncoteuthion α. Rhyncoteuthion β. Liocranchia globulus.	Euprymna scolopes Onychoteuthis banksii. Ommastrephes hawaiiensis. Symplectoteuthis oualaniensis.	Euprymna scolopes. Stoloteuthis iris. Heteroteuthis hawaiiensis. Teleoteuthis compacta. Abralia astrosticta. Abralia trigonura. Pterygioteuthis microlampas. Ommastrephes hawaiiensis. Mastigoteuthis (?) famelica. Megalocranchia fisheri. Helicocranchia sp.	Heteroteuthis hawaiiensis (?) Teleoteuthis compacta(?) Mastigoteuthis(?)famelica(?)

COMPARATIVE ABUNDANCE.

The comparative abundance of the different species in the collection is readily appreciated by a glance at the figures appended to the synopsis on page 260. It is remarkable that out of a total of 210 specimens examined, 64, or nearly one-third, are *Euprymna scolopes*. Of the remainder, 31, or nearly one-sixth of the total, are *Tremoctopus violaceus;* 15 are the immature *Polypus* designated as β; 13 are *Polypus marmoratus;* eleven are the larval ommastrephids known as *Rhyncoteuthion;* 8 are *Brachioteuthis riisei*, while *Scæurgus patagiatus* and *Ommastrephes hawaiiensis* are represented by 7 specimens each.

The most notable catch of cephalopods made by the *Albatross* in any single haul was in the surface nets at station 3926, between Oahu and Laysan Islands, where 11 specimens representing 1 species each of no less than 5 genera were obtained.

LOCAL DISTRIBUTION.

Regarding the distribution and relative frequency of the littoral and shallow-water species among the respective islands of the archipelago, little or nothing can be said at the present time. As would be expected, most of the collecting has been done on Oahu in the neighborhood of Honolulu; a few specimens have occasionally come to hand from Maui, but almost nothing from the other islands. The remote islands of the Midway Group ought to prove particularly interesting in this respect, since their oceanic extent is large and we are completely ignorant concerning the cephalopods of their littoral fauna.

CLASSIFICATION AND NOMENCLATURE.

In conformity with my "Review of the Cephalopods of Western North America" (Berry, 1912a) I have followed the general lines of cephalopod classification laid down in the various works of Hoyle, with certain modifications adapted from Pfeffer's "Synopsis" (1900) and the masterly monograph of the *Valdivia* Œgopsida by Chun (1910). The present material has afforded few bizarre forms and, although highly important from a distributional and local standpoint, accomplishes very little toward the elucidation of the wider evolutionary problems. Of decided importance, however, is the discovery of an otherwise typical member of the family *Cirroteuthidæ*, which is remarkable not only for being the second species in the entire group known to possess an odontophore, but also for its apparently total lack of the alternating rows of cirri along the arms, hitherto thought to be a characteristic as invariable as it is puzzling. The occurrence of a Pacific *Scæurgus* and a new sepiolid having affinity with the Atlantic *Stoloteuthis leucoptera* is also noteworthy. The presence in the collection of a large series of young ommastrephids comprising at least two *Rhyncoteuthion*-like forms specifically distinct from one another indicates that the occurrence of the curious *Rhyncoteuthion* stage is an exceedingly widespread ontogenetic character in this family and one by no means confined to the typical genus.

The primary division of the Dibranchiata of Owen into the Octopoda (devilfishes) and Decapoda (squids[a]), as proposed by Leach in 1817, is here adhered to, although the latter term is very confusing in view of the prior use of the name for a well-known group of Crustacea (Decapoda Latreille 1806). In many respects the restoration of Blainville's Octocera and Decacera would be much more satisfactory, an excuse for discarding the complementary term Octopoda being possibly available because of the existence of Octopodia Schneider 1784, which was proposed as a general term for the entire class over a decade before Cuvier called them Cephalopoda.

I have found myself quite unable to accept the various major divisions into which some authors have grouped the Octopoda, but on the other hand I have been unable to formulate any more natural arrangement of my own which could be utilized in their stead. In regard to the Decapoda, however, the anciently recognized bifurcation into Myopsid and Œgopsid forms seems very convenient and on the whole a natural separation. Chun's further division of the latter group into Œgopsida libera and Œgopsida consuta appears to me cumbersome and but little superior to the nearly or quite synonymous Teuthidea and Taonidea of Verrill. For the purposes of the present paper it is not, however, necessary to adopt either system.

In the arrangement of the families themselves scarcely any two authors are in entire agreement, so that the sequence herein followed can be regarded as in no way more than provisional.

A word should be said in regard to the sort of morphological characters chiefly depended upon by the author in distinguishing species; that is, beyond such conspicuous differences in bodily structure and general form as obviously require no explanation

[a] In the Hawaiian Islands the term "squid" is colloquially employed to include nearly all cephalopods, especially the edible forms such as *Polypus*, even though the usage is not scientific nor accurate English.

or apology even to the layman. This is particularly needful concerning the Octopoda, as in this group it is often very difficult to lay down on paper a hard and fast line respecting a given character which will invariably serve to separate a species from some other perhaps very closely allied. Here, in the absence of direct comparison between specimens, a sort of average of the entire physiognomy is largely depended upon, taking into consideration the relative length of the arms, the shape and extent of the umbrella, the presence or absence of ornamental processes of various sorts upon the integument, and the more evident conditions of preservation, which frequently affect the features already stated to a degree which can scarcely be too strongly emphasized. When the specimens are males, however, the structure of the hectocotylized arm is variously modified, usually constant in its peculiarities, and hence a criterion of the highest importance; perhaps no other single feature so well maintains its value in preserved material. I am also inclined to treat with respect any decided peculiarities of color, particularly when the various pigments appear to be disposed after the manner of a definite pattern. Frequently the so-called "funnel organ" exhibits tangible modifications in shape, though whether these latter are more valuable than confusing as a key to interrelationship is not yet apparent.

Among the Decapoda some of the above-mentioned features are of very minor specific significance. Here I have frequently given considerable weight to relatively minute differences in the form and arrangement of the suckers (or hooks) on the sessile arms and more particularly, on the terminal clubs of the tentacles, as these characters, even though small, are definitely to be apprehended and usually little affected by the action of the preserving medium. Nevertheless, there is certainly need for a greater quantity of comparative data showing the range of variation in these organs and until this is available there is constant danger that too much emphasis has been placed upon their details. Among the luminous forms, particularly the Œgopsida, the arrangement and structure of the photogenic organs is nearly always subject to important modification, both specific and generic or even of higher significance. The funnel organ appears to be of less practical systematic value in the Decapoda than in the Octopoda, for although it undergoes considerable modification among different genera (particularly the various Cranchiidæ), the differences between those of closely allied species are apt to be too slight to be appreciable.

On account of their easy preservation as "hard parts," the gladius and radula have occupied a dominant position in the schemes of classification of many of the older authors as well as a few of the more recent ones, but the undesirable mutilation of the specimen entailed by their examination, coupled with the writer's belief that their relative importance has been greatly overrated, has in the present work prevented their receiving the attention to which they are perhaps more justly entitled. Other "hard parts" which are ofttimes very useful to observe are the horny rings which arm the apertures of the suckers in most if not all Decapoda and which often show interesting modifications, chiefly depending upon the varying degrees of smoothness or denticulation of their outer margins.

Wherever a specimen appeared to possess definable characters of its own, however minute, the present writer has ranked himself frankly with the "splitters," especially in cases where the nearest known ally of such a form has been described from a far distant region. This procedure has not been resorted to from any desire to describe "new species," but because of a conviction that wherever a given animal from a definite locality can be referred to a previously named species only with considerable doubt, the exigencies of systematic zoology are much better to be subserved by the provisional use of a separate name. To many a student of geographical distribution the possible evil of one more synonym does not seem nearly so repugnant as the improper listing of a species, through imperfect or incorrect knowledge of its totality of characters, from a region where it does not (often even remotely) belong.

In matters of taxonomy the writer has unreservedly sought strict literal obedience to the published rules of the International Commission for Zoological Nomenclature. Thanks to the careful work of previous authors, notably Hoyle, this procedure has not resulted in the demolition of very many teuthologic landmarks. It is possible that additional changes ought in some instances to be made, but wherever any given case did not clearly appear to be governed by some definite rule in the code, the current prevailing usage was adhered to.

It might be well to call attention to the fact that in the verbal orientation of specimens for purposes of description, the terms anterior and posterior, dorsal and ventral have been used in their usual physiological sense (i. e., with relation to the normal activities of the adult animal) rather than in their strict morphological (and embryological) significance, which latter would necessarily result in a more complete reformation of the current anatomical nomenclature than could well be attempted at the present time. It must be admitted, however, that to the student of molluscan comparative anatomy recourse to a system of topographic names based on the latter system would have much to commend it.

ECONOMIC IMPORTANCE.

In the Hawaiian Islands, as in most other maritime countries, the common littoral cephalopods form a very important source of food. Both *Polypus* (particularly *P. marmoratus* and *ornatus*, to judge from the market specimens before me) and *Sepioteuthis* are frequently offered for sale in the Honolulu markets. The Hawaiian word denoting the *Polypus*, and perhaps other forms as well, is "hee." Cobb (1905, pp. 734, 736, 740) gives the following interesting account of some of the various modes of procedure resorted to by the natives for their capture:

> Spears are frequently used in fishing for the hee (octopus), principally by women. This animal generally makes its home in small circular holes in the rocks on the reefs. When the fisherwoman finds a hole that she thinks is occupied she runs the spear into it gently. Should a hee be there it comes out to see what is the matter, the spear is run through it, and it is brought to the surface. The woman usually carries a smaller spear also, and with this she pricks or hits the animal in the head until it is stunned or killed, otherwise it might twine around her arms or legs and cause serious difficulty.

* * * * * * *

In fishing for hee (octopus) the native dives to the bottom, and, with a stick, pokes around in the small holes in which the animal lives. When he touches one it seizes the stick and allows him to draw it out of the hole. On reaching the surface the native seizes his captive with his hands and bites into its head, thus killing it.

* * * * * * *

The native is a great lover of the hee and has a number of methods of capturing it, one of the most interesting of which is with the cowrie shell. One or more cowrie shells of the Mauritiana or Tiger varieties are attached to a string. When only one is used, an oblong pebble about the size of the shell is tied to the face of it, a hole is pierced in one end of the back of the shell, a line is passed through, and after being fastened here, allowed to hang a few inches below the shell, to which a hook, whose point stands almost perpendicular to the shaft or shank, is attached. Only shells with small red spots breaking through a reddish-brown ground have an attraction for the hee, and it will not rise to any other kind. Shells which have suitable spots but unsuitable background are given the desired hue by steaming them over a fire of sugar-cane husks.

On arriving at the fishing ground the fisherman in pursuit of hee either chews up and spits upon the water a mouthful of candlenut meat, to render the surface glassy and clear, or he uses the water glass, which is described below. He drops the shell into the water, and by means of the line swings it back and forth over a place likely to be occupied by a hee. The greedy animal perceives the shell, shoots out an arm, and seizes it. If the bait is attractive, after a few moments' hesitation another arm is placed around it, and then another, until at last the animal withdraws itself entirely from its hole and hugs the shell closely to its body, oblivious of everything else. The fisherman then draws it rapidly up through the water, and when it raises its head at the surface, pulls it over against the edge of the canoe and delivers a blow between the eyes with a club which is generally fatal. Owing to the hee's quickness with its eight tentacles or arms, the fisherman has to be very rapid in his movements, as the animal would be no mean antagonist should it have an opportunity to seize him with its arms. The natives say that a number of persons have lost their lives in struggles with the octopus. This method of fishing is called by the natives "Lawaia hee me ke leho" (squid catching with cowrie).

Nearly all squids and a good many octopods possess a further economic value in that they comprise one of the chief articles of diet for such birds as the albatross and shearwater, as well as for many of the more important food fishes.

KEY TO THE CEPHALOPODA KNOWN TO INHABIT THE HAWAIIAN ISLANDS AND ADJACENT WATERS.

I. Arms normally eight in number, tentacles being absent; suckers sessile, without a horny ring (OCTOPODA).

1. A pair of lateral oar-shaped fins present; suckers in a single row. (Family Cirroteuthidæ.)

2. Radula present; suckers not flanked by paired cirri..... *Lætmoteuthis lugubris*, p. 275.

1′. No fins.

3. Hectocotylized arm of male involving the entire third arm of one side, developed in a specialized sac, and separable at maturity; animals pelagic. (Family Argonautidæ.)

4. Dorsal arms of female with terminal winglike expansions modified for the secretion of an external "shell;" left third arm of male hectocotylized; no aquiferous pores present on head. (Genus *Argonauta*.)

5. Shell relatively small, compactly coiled, without auricular expansions at sides. *Argonauta böttgeri*, p. 277.

5′. Shell large, more or less auriculate at the sides..... *Argonauta* sp., p. 280.

4′. Dorsal arms of female connected by a broad velum, but without terminal expansions; no external shell; right third arm of male hectocotylized; aquiferous pores present on head. *Tremoctopus violaceus*, p. 281.

3′. No aquiferous pores; no external shell; dorsal arms normal.

6. Body soft and gelatinous; suckers in two rows; hectocotylus of male involving entire right third arm, which is presumably separable..... *Alloposus mollis*, p. 287.

6′. Body soft; suckers in a single row; hectocotylized arm not separable (family *Bolitænidæ*)..... *Eledonella* sp., p. 289.

6″. Body comparatively firm; suckers in two rows; hectocotylus of male confined to tip of one third arm, to which it forms a spoon-shaped extremity. (Family Polypodidæ.)

7. Hectocotylus affecting third arm of right side. (Genus *Polypus*).

8. A conspicuous pigmented oculation obliquely in front of each eye; hectocotylus minute..... *Polypus marmoratus*, p. 291.

8′. No definite ocular markings in front of the eyes.

9. Adult brightly colored, the pigment conspicuously arranged in longitudinal bands or series of spots; arms very long and attenuate... *Polypus ornatus*, p. 294.

9′. No definitely arranged color pattern.

10. Body smooth, without cirri; second arm pair longest; color dark. *Polypus hawaiiensis*, p. 290.

10′. Body finely papillose, rather soft, with blunt cirri over the eyes; mantle opening small; color uniformly pale..... *Polypus hoylei*, p. 296.

7′. Hectocotylus affecting third arm of left side; body bounded by a conspicuous peripheral fold..... *Scæurgus patagiatus*, p. 305.

II. Arms normally 10 in number, one pair being greatly modified to form the "tentacles"; suckers distinctly pedunculate, their apertures usually bounded by a chitinous ring (DECAPODA).

1. Eyes covered by a continuous membrane (division Myopsida).

2. Adult small; body short, rounded posteriorly, with round or ovate lateral fins; gladius much reduced or wanting. (Family Sepiolidæ.)

3. Dorsal margin of mantle fused with head in nuchal region.

4. Fins of moderate size; suckers in four rows on the arms and 16 or more on the tentacle club; left dorsal arm hectocotylized..... *Euprymna scolopes*, p. 312.

4′. Fins very broad and longer than the mantle; suckers on the arms in two rows; a conspicuous shield-shaped patch on the ventral surface of the mantle..... *Stoloteuthis iris*, p. 316.

3′. Dorsal margin of mantle free; funnel covered by a conspicuous forward prolongation of the mantle..... *Heteroteuthis hawaiiensis*, p. 319.

2′. Adult relatively large; body elongate, pointed posteriorly; fins marginal, extending the entire length of the mantle; gladius well developed, its texture horny throughout. *Sepioteuthis arctipinnis*, p. 308.

1′. Eyes with a perforated lid (division Œgopsida).

5. Part of the suckers with their chitinous rings transformed to hooks.

6. Sessile arms with true suckers only; one or more rows of hooks on tentacle club.

7. Adult moderately large; two rows of hooks on the tentacle club. *Onychoteuthis banksii*, p. 322.

7′. Adult small; hooks and suckers of tentacle club in four rows. *Teleoteuthis compacta*, p. 324.

6′. Sessile arms with part of the suckers modified into hooks. (Family Enoploteuthidæ.)

8. All suckers of sessile arms modified into hooks except at the extremity; hooks also present on tentacle club; ventral surface of mantle ornamented with numerous photogenic organs.

9. Buccal membrane pale in color; tips of ventral arms normal.

10. Photophores of mantle distinctly of two types and showing a definite bilateral arrangement; fins comparatively small..... *Abralia astrosticta*, p. 326.

10′. Photophores not conspicuously differentiated into two main types; their bilateral arrangement obscure; fins half as long as the mantle.
Abralia trigonura, p. 329.

9′. Buccal membrane dark reddish or violet in color; ventral arms with a series of three conspicuous heavily pigmented beadlike organs at their tips.
Abraliopsis sp., p. 331.

8′. Tentacle club with suckers only, but few hooks on sessile arms; numerous photogenic organs on the eyeball and within the pallial cavity, but none on the outer aspect of the mantle.....*Pterygioteuthis microlampas*, p. 332.

5′. None of the suckers with their chitinous rings transformed to hooks.

11. Mantle free all round anteriorly (not true of *Symplectoteuthis*, as see below).

12. Numerous photogenic organs on the body, head, and arms. (Family Histioteuthidæ), p. 335.

12′. Photogenic organs few in number or absent.

13. Funnel articulating with the mantle by a ⊥-shaped groove. (Family Ommastrephidæ.)

14. Sucker bearing portion of tentacles greater than half the total length; fixing apparatus poorly developed.*Ommastrephes hawaiiensis*, p.338.

14′. Sucker bearing portion of tentacles less than half the total length.

15. Mantle fused with the funnel on at least one side; fixing apparatus a distinct carpal group of pads and suckers.
Symplectoteuthis oualaniensis, p. 341.

15′. Animal small; clubs of tentacles fused to form an X-shaped or proboscis-like organ.....*"Rhyncoteuthion"*, p. 341.

13′. Funnel articulating with the mantle by a simple pit or groove.

16. Mantle delicate, membranous, transparent; fins sagittate; pelagic.....*Brachioteuthis riisei*, p. 336.

16′. Mantle fleshy, produced to a delicate point posteriorly; fins lanceolate, over half as long as the mantle; ventral arms much the longest.....*Mastigoteuthis* (?) *famelica*, p. 344.

11′. Mantle fused with the funnel on either side and with the head in the nuchal region; mantle ample, thin, transparent; viscera confined to a very small proportion of the pallial cavity. (Family Cranchiidæ).

17. Mantle ornamented with several series of cartilaginous tubercles; mantle greatly inflated..*Liocranchia globulus*, p. 346.

17′. Mantle smooth; only moderately inflated.

18. Eyes enormous, rounded, sessile.*Megalocranchia fisheri*, p. 348.

18′. Eyes much smaller, oval, upon short stalks.
Helicocranchia sp., p. 350.

NOTE.—Except in the case of one or two well-known and widely distributed species, it has been my endeavor in the following pages to make the list of references preceding the description of each species as nearly complete as possible, and it is hoped that the occasional parenthesized comments regarding the nature of particular citations will prevent the confusion which might otherwise accrue through the promiscuous cataloguing of trivial and important references in the same tables. An attempt has been made to economize the time of the reader by printing all citations of special present importance in bolder type than the remainder.

Phylum MOLLUSCA.

Class CEPHALOPODA Cuvier 1798.

Octopodia Schneider 1784, p. 108.
Cephalopoda Cuvier 1798 (*fide* Gray).
Cephalopodia Rafinesque 1815, p. 139 (*fide* Binney and Tryon, p. 14).
Cephalophora de Blainville 1825, p. 364.

Order DIBRANCHIATA Owen 1836.[a]

Antepedia Rafinesque 1815, p. 139 (*fide* Binney and Tryon, p. 14).
Cryptodibranchiata de Blainville 1824, p. 172 (*fide* Verrill).
Acétabulifères d'Orbigny 1835, p. 1.
Dibranchiata Owen 1836, p. 127.
Acetabulifera d'Orbigny 1845, p. 157.
Antepedia Gray 1849, p. 2.
Dibranchia Pelseneer 1906, p. 336.

Arms eight or (inclusive of the tentacles when present) ten in number; furnished with longitudinal rows of acetabulæ or suckers along their inner surfaces. Funnel a closed tube. Normally but a single pair each of ctenidia and renal organs present. Visceral mass naked; shell much reduced and embedded in the tissues of the mantle, frequently absent. Eyes highly developed and with closed cavities; a crystalline lens present. Characteristic and intricately constructed dermal pigment cells called "chromatophores" are developed in the integument.

This order includes all living cephalopods except *Nautilus*.

Suborder OCTOPODA Leach 1817.

Octopia + *Argonautea* Rafinesque 1815, p. 139 (*fide* Binney and Tryon, p. 14).
Octopoda Leach 1817, *fide* Gray.
Octocera de Blainville 1824 (*fide* Verrill); 1825, p. 365.
Octopoda d'Orbigny 1845, p. 163.
Octopia Gray 1849, p. 2, 3.
Octopoda Verrill 1881, p. 360.

Arms normally always eight in number and similar (with the exception of the hectocotylized arm in the male); tentacles absent. Suckers sessile, usually with thickened bases; their apertures not equipped with horny or chitinous rings. Body usually short; always rounded posteriorly; finless, or rarely with one or two pairs of weak oar-shaped lateral fins. Head and mantle broadly continuous in the nuchal region. Cœlom greatly reduced. No gladius. Wherever hectocotylization occurs it is one arm of the third pair which is affected. With the exception of the recently described *Melanoteuthis* Joubin 1912, specialized photogenic organs are unknown in the entire suborder.

Family CIRROTEUTHIDÆ Keferstein 1866 em.

Pteroti Reinhardt and Prosch 1847, p. 38.
Cirrhoteuthidæ Keferstein 1866, p. 1447.
Cirrhoteuthidæ Verrill 1881, p. 382.
Cirroteuthidæ Hoyle 1904, p. 3.

Adult animals commonly of large size. Body equipped with one or sometimes two pairs of lateral oar-shaped fins. A well-developed internal skeleton, comprising a broad saddle-shaped or horseshoe-shaped dorsal cartilage and a few lesser elements. Suckers in a single row which usually alternate with two flanking rows of paired cirri. Radula usually absent.

Genus LÆTMOTEUTHIS Berry 1913.

Laetmoteuthis Berry 1913, p. 563.

Adult of large size. Body rounded, with a small, weakly supported, transversely elongate fin attached to either side of the mantle. Arms moderately long; connected for the greater part of their length by an ample umbrella; intermediate web lacking. Suckers large, little elevated, in a single slightly zigzag row; paired cirri absent, or at best greatly reduced (possibly confined to the tips of the arms). Radula neither wanting nor reduced, but generously developed and with seven rows of teeth.

[a] Date often given as 1832, but the paper upon which such quotation is based is unknown to me.

Type.—Lætmoteuthis lugubris Berry 1913, a species of the Hawaiian Islands.

The genus is closely allied to both *Cirroteuthis* and *Stauroteuthis*, but differs in the absence of paired cirri and the presence of an odontophore.

Lætmoteuthis lugubris Berry 1913. (Pl. XLIX, fig. 1, 2.)

Cirroteuthis (?) sp. Berry 1909, p. 418 (mere record).
Lætmoteuthis lugubris Berry 1913, p. 563.

Body large, rounded posteriorly. Lateral fins situated well back on the mantle, but small, transversely elongate, their greatest dimension (width) about twice as great as their length (fig. 2). Funnel thin walled, very large and broad; interior ample. Eyes probably large.

Arms long, appearing merely as thickenings or soft folds in the broad and ample umbrella and without any intermediate web connecting them thereto. Umbrella longest between the ventral arms, but everywhere extensive though very thin. Suckers large, flattened, distant; in a single series, though frequently somewhat zigzag; slightly, but not much, firmer in texture than the arms or umbrella; round-tubercular in shape; the apertures contracted, their margins crenulate. Paired cirri indistinguishable.

Mandibles large, compressed; but, with the exception of the sharp powerful beaks, thin and comparatively fragile; color black, horny at margin. (Pl. XLIX, fig. 1, 2.)

A very large and perfectly developed radula present; of the seven rows of teeth the tricuspid medians are considerably the largest.

Surface color a livid dark brownish slate, with a somewhat bluish cast over the inner surface of the umbrella in preserved specimens. The label accompanying the type contains a note to the effect that the color of the specimen when captured was chocolate brown. Chromatophores small, numerous, and heavily distributed over the entire surface.

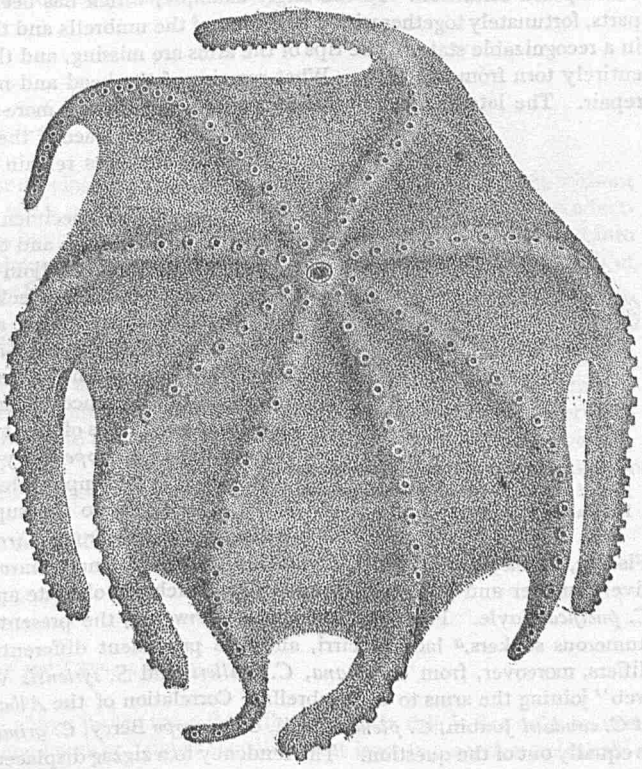

FIG. 1.—*Lætmoteuthis lugubris*, intraumbrellar aspect of type, considerably restored [211], × ⅙. Drawn by R. L. Hudson.

MEASUREMENTS OF LÆTMOTEUTHIS LUGUBRIS.

	Measurement.	Number of suckers.		Measurement.	Number of suckers.
Length of—	*mm.*		Length of—	*mm.*	
Right dorsal arm	430+	18+	Left ventral arm	110+	5+
Left dorsal arm	400+	16+	Umbrella between dorsal arms	300	.....
Right second arm	260+	8+	Umbrella between ventral arms	100	.....
Left second arm	430+	18+	Funnel	72	.....
Right third arm	350+	23+	Diameter of one of largest suckers	9	.....
Left third arm	210+	10+	Length of extracted radula	22	.....
Right ventral arm	330+	29+	Width of toothed portion of radula	8	.....

Type.—Catalogue No. 214385, United States National Museum. [S. S. B. No. 211.]

Type locality.—*Albatross* station 3904, surface, off Mokapu Islet, north coast of Molokai, Hawaiian Islands; one fragmentary specimen, April 30, 1902.

Distribution.—Vicinity of Molokai, Hawaiian Islands (*Albatross*).

Specimens examined.—In addition to the type but one other even more fragmentary specimen has been seen. This was taken in the Pailolo Channel near Molokai, from a depth of 258 to 284 fathoms, *Albatross* station 3898 [S. S. B. No. 212].

Remarks.—Both the specimens mentioned are in extremely fragmentary and indeed partially decomposed condition. In the larger example, which has been chosen for the type, only the mouth parts, fortunately together with a large part of the umbrella and the inclosed portions of the arms, remain in a recognizable state. The tips of the arms are missing, and the viscera as well as the eyes have been entirely torn from the body. What remains of the head and mantle is tangled and lacerated beyond repair. The lateral fins still adhere and are fortunately more or less intact. The funnel is present, but there is no trace of the funnel organ. Large fragments of the internal cartilages remain but defy any accurate description at my hands.

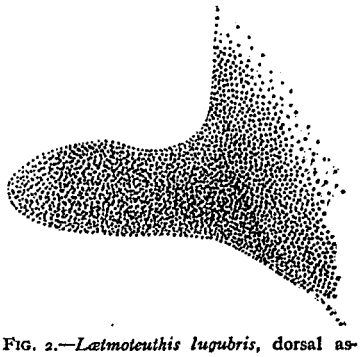

FIG. 2.—*Lætmoteuthis luqubris*, dorsal aspect of left fin of type [211], natural size. Drawn by R. L. Hudson.

The smaller specimen is even more mutilated, so that here only the buccal mass and those portions of the umbrella and arms which immediately adjoin it are left to us.

Even from these wrecks, however, enough has been made out to render it evident that a species is represented which, though closely allied to *Cirroteuthis* and *Stauroteuthis*, differs very markedly in the apparently total absence of cirri on any of the arms as well as the presence of an odontophore, a structure reported to exist in no species of the two genera named except the recently described *C. macrope* Berry from the coast of California. Perhaps, indeed, it is not impossible that the latter species is congeneric.

In addition to the supposed absence of cirri, this species is distinguishable from *Cirroteuthis magna* Hoyle, *C. umbellata* Fischer, *C. megaptera* Verrill, *C. mülleri* Eschricht, and *Stauroteuthis meangensis* Hoyle, by the relatively smaller and differently shaped fins, which are obovate and in outline more nearly like those of *C. pacifica* Hoyle. From the last species, however, the present form differs in the larger, much less numerous suckers,[a] lack of cirri, and less prominent differentiation of the arms from the web. It differs, moreover, from *C. magna*, *C. mülleri*, and *S. syrtensis* Verrill in the lack of an "intermediate web" joining the arms to the umbrella. Correlation of the *Albatross* specimens with the descriptions of *C. caudani* Joubin, *C. plena* Verrill, *C. macrope* Berry, *C. grimaldii* Joubin, or *S. hippocrepium* Hoyle is equally out of the question. The tendency to a zigzag displacement exhibited by many of the suckers might be regarded as a characteristic feature, were it not for the possibility that it is due to distortion. All the basal suckers are relatively very distant from one another, the space between those of the same row being about 25 millimeters, but they gradually become more closely ranked distally.

Of course the possibility must not be overlooked that the apparent absence of cirri may be due to their restriction to the extremities of the arms as above suggested, but to the unfortunate state of preservation of the material. However, the appearance of the specimens in question is such that I have felt obliged to regard the possibility as a remote one, so that the erection of a new group seems expedient.

It is extremely unfortunate that the condition of both specimens is so unsatisfactory, but they belong to a family of abyssal octopods of such elusive habit and tender structure that almost all the described species have been founded upon similar fragmentary material. We have a really complete knowledge of scarcely any of these forms, and it may be that the number of nominal species will have

[a] An appearance which perhaps may be partially due to the loss of the distal portions of the arms, as in quite a number of forms the basal suckers are less crowded than their successors.

to suffer a certain reduction when better methods, better appliances, and more extensive researches have further enriched our museums, but for the present there seems no way of dealing with them except to carefully describe each apparently divergent specimen as it comes in.

The dimensions attained by *L. lugubris* should often be considerable, as when living the larger of the specimens in hand must have had a total arm spread of over 80 centimeters.

Although neither of the Hawaiian specimens was actually obtained from an abyssal depth, there is every reason to believe that such was in reality their place of origin.

Family ARGONAUTIDÆ (Cantraine 1840) Gray 1847.

Argonautides Cantraine 1840, p. 20.
Philonexidæ d'Orbigny 1845, p. 199.
Ocythoina Gray 1847, p. 204.
Ocythoidæ (Argonautidæ?) Gray 1849, p. 3, 28. + *Philonexidæ* Gray, op. cit., p. 3, 29.
Argonautidæ H. and A. Adams 1853, vol. 1, p. 23.
Argonautidæ (pars) Naef 1912b, p. 197, 198.

Octopods of small to moderate size and pelagic habit. Body rounded or slightly elongate; without fins. Sexes conspicuously dimorphic. Males much smaller than the females; hectocotylization affecting one of the ventro-lateral arms, which, having its origin in a specialized sac, becomes developed into a highly modified and detachable copulatory organ, which persists separately for a certain length of time in the mantle cavity of the female. Suckers in two rows on all the arms.

Subfamily ARGONAUTINÆ s. s.

Third right arm of male hectocotylized; outer aspect of hectocotylus smooth. Dorsal arms of female furnished with broadly expanded glandular membranes at their extremities, which serve to secrete and hold in embrace a delicate involute calcareous shell, which latter functions as an ovarium as well as a partial retreat for the animal itself. Articulation between mantle and funnel cartilaginous. Funnel organ comprising a Λ-shaped dorsal cushion and a pair of ventro-lateral pads.

Genus ARGONAUTA Linné 1758.

Argonauta Linné 1758, p. 708.
Nautilus Schneider 1784, p. 120 (not of Linné 1758).
Ocythoe Leach 1817, p. 295 (not of Rafinesque 1814).
Hectocotylus (pars) Cuvier 1829, p. 147.
Todarus Rafinesque 1840, p. 64 (*fide* Binney and Tryon, p. 94).
Argonauta d'Orbigny 1845, p. 210.

For the characters of this genus see above under the subfamily, of which this is the only known group. Here are included the familiar argonauts or "paper nautili." At least two species are inhabitants of the Hawaiian region.

Type.—Argonauta Argo Linné 1758 (the species first mentioned), a characteristic Mediterranean type.

Argonauta böttgeri Maltzan 1881. (Pl. XLVIII, fig. 5.)

Argonauta Böttgeri Maltzan 1881, p. 163, pl. 9, fig. 7.
Argonauta böttgeri Smith 1887, p. 409, pl. 17, fig. 1–6.
Argonauta Böttgeri Hidalgo 1905, p. 9 (*fide* Hoyle 1909).
Argonauta bœttgeri Dall 1908, p. 226, 229.
Argonauta böttgeri Berry 1909, p. 418 (locality record only).

Animal small, pelagic. Male (with the exception noted below) unknown. Body of female smooth, elongate, in general cylindrical, twice as long as broad; posterior part of body with a sharp upward torsion, at least in animals preserved in situ within the shell; rounded below, elevated and bluntly pointed posteriorly, widest in front, much elevated just back of the nuchal region. Mantle margin thin; pallial opening very wide, reaching well above the eyes on either side.

Head small and very indistinctly delimited because so deeply embraced in the mantle. Eyes large, spherical, protruding, a distinct constriction separating them from the head at the base. Funnel of robust proportions, but thin-walled and extremely long, reaching nearly midway of the ventral arms; broad at the base, but thence rapidly tapering to the simple circular aperture at the apex. Funnel organ prominent, of a whitish color; it comprises a large ∧-shaped cushion on the dorsal wall a little anterior of the middle, and a somewhat shorter and narrower elongate-ovate organ on either side of the ventral wall just below it (fig. 5). Locking apparatus well developed; just behind and a little below the eye, the basal margin of the funnel on either side is furnished with a small cartilaginous pit-like depression, which articulates with a posteriorly directed, roughly hook-like nodule on the inner surface of the mantle; just outside this nodule and passing below it parallel to the mantle margin, a shallow, though distinct, groove coincides with a similar sulcus on the outer surface of the mantle, so that the constriction thus formed renders very prominent the thickened band of transverse muscle bordering the mantle opening.

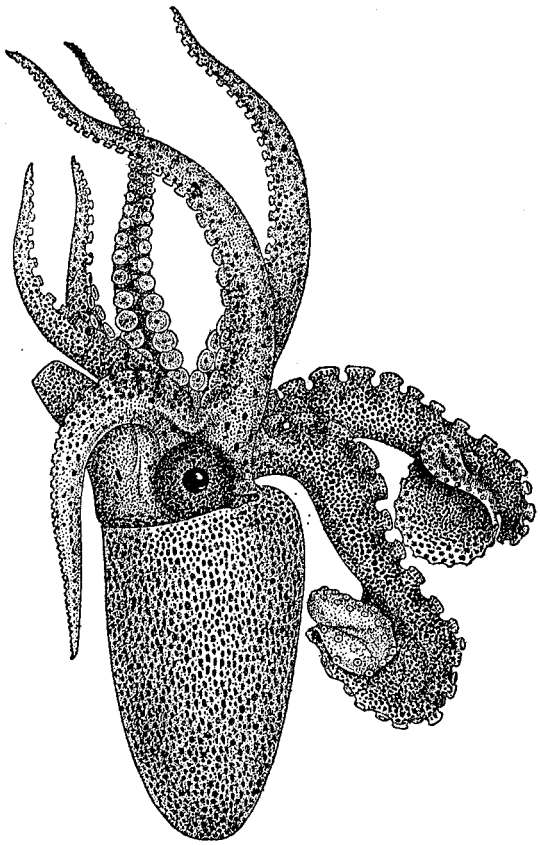

FIG. 3.—*Argonauta böttgeri*, lateral view of female [165], × 2. Drawn by R. L. Hudson. The drawing does not show the characteristic flexures of the body.

Arms of moderate length, perhaps half again as long as body, sharply separated from body at base by a deep sulcus; order of length 1, 2, 3, 4; dorsal arms somewhat the thickest and strongest as well as the longest, their distal portions furnished with the usual conspicuous wing-like expansions of the marginal membrane, much wrinkled and contracted in preserved specimens so that its exact outline is very difficult of determination; remaining arms broad at the base, but rapidly tapering to an attenuate extremity. Umbrella rudimentary, comprising only a short fold interwebbing all the arms for a distance of about three millimeters from their base. Suckers very large, much elevated, 40 to 50 or more in number on each arm (on the dorsal arms over 50 suckers in each row, on the second and third arms about 30 in each row, and on the ventral arms about 18 to 20 in each row); compactly and very regularly ranked in two alternating rows, which on the second arm (and to a very slight degree on the others as well) become ultra-marginal and very widely separated distally (pl. XLVIII, fig. 5); cups flattened and discoid; both rows persistent to the tips of all the arms, though vastly reduced on the

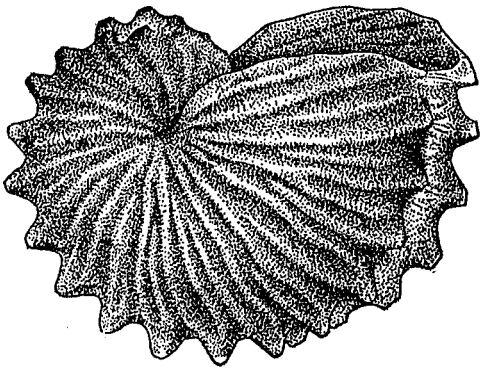

FIG. 4.—*Argonauta böttgeri*, lateral view of shell of female [165], × 2. Drawn by R. L. Hudson.

modified extremities of the dorsal pair, on which latter only the basal 15 to 16 are at all well developed. The funnel is connected to the head dorso-laterally by a pair of delicate bridle-like connective membranes, which are continuous with a delicate keel running along the lower aspect of each ventral arm; otherwise the arms are rounded and devoid of keels or swimming membranes. Dorso-laterally the integument of the head is connected with the dorsal arms by a delicate vertical membrane bridging the sulcus which otherwise separates the arms and head, and two similar but smaller membranes bridge the constriction between the anterior boundary of the eyeball and the lateral arms.

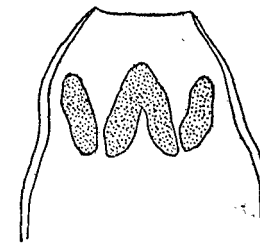

FIG. 5.—*Argonauta böltgeri*, outline drawing of funnel laid open medioventrally to show the funnel organ [165], × 2.

Shell small for the genus, coiled very compactly in an even plane, laterally compressed; the sides ornamented with some 30 or more conspicuous ridges radiating from the shallow depression which is the outward mark of the shell axis; periphery flattened, each angle decorated with a row of bluntly squared tubercles, 17 to 18 of which can be made out on each side; margin of aperture simple, without any trace of lateral expansions or "auricles;" surface finely and quite evenly granulose, the granules most numerous on either side of the shell near the axis and visible without the aid of a lens (fig. 4).

General surface color of animal in alcohol everywhere a pale brownish buff, dotted more or less impartially with numerous fairly large bluish black chromatophores, which are nowhere crowded save on the outer aspect of the dorsal arms and in less degree the dorsal integument of the eyeball. Beak coal black.

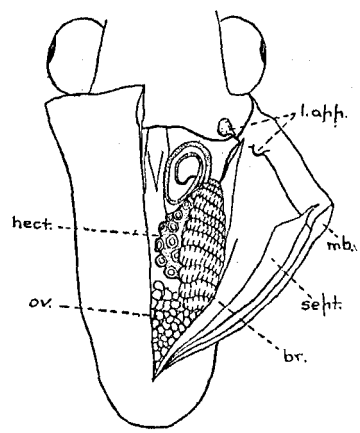

FIG. 6.—*Argonauta böltgeri* [165], ventral aspect of female, with mantle laid partially open to show the detached hectocotylus of the male in situ within the pallial chamber, × 2: br., gill; hect., hectocotylus of male; l. app., locking cartilages of left side; mb., thickened band of muscular tissue bordering mantle margin; ov., gonad; sept., median septum of pallial chamber.

As no male animal of this species has come to hand the above description applies only to the female. However, the mantle of the specimen before me was carefully laid open along the medioventral line; lying within the cavity, its thickened basal portion lodged snugly just above the left gill between the latter organ and the viscera, was found the detached hectocotylus of a male. This condition is well shown in the accompanying sketch, which indicates the position of the structures in question in situ (text fig. 6); see also the more detailed representation of the hectocotylus in figure 7. The organ comprises a thickened basal portion curved in the shape of a horseshoe about 6 mm. in length by a little more than 4 in breadth, with the inner or sucker bearing aspect outermost; widest between the middle and the base, tapering slightly to a rounded point posteriorly, and more gradually to the acute distal extremity which terminates in a very long and slender thread-like process, lying in a loose coil; the basal portion broadly flattened on its inner surface, the margin of the latter armed with a closely placed row of minute much elevated suckers, about 22 on each border, which are connected by a delicate hyaline membrane; the outer aspect (i. e., inner curve of the horseshoe) is keeled and bears a conspicuous marginal membrane, which even continues along the terminal thread, though there becoming extremely thin and delicate. The diameter of the basal portion is 2 mm.; the length of the flagellum about 13 mm.

The shell of this specimen was partly full of eggs and young embryos connected into a loose mass by fine filaments and representing various early stages of development. The total number is several hundred at least, the largest scarcely a millimeter in length.

MEASUREMENTS OF ARGONAUTA BÖTTGERI.

	mm.
Total length (to tip of second arms)	59
End of body to base of dorsal arms	23
End of body to ventral margin of mantle	21
Width of body near middle	10
Width of mantle anteriorly	13
Width across eyes	13
Length of—	
Right dorsal arm to expanded portion (inside measurement)	15
Left dorsal arm to expanded portion (inside measurement)	17
Length of—	
Right second arm (inside measurement)	36
Left second arm (inside measurement)	35
Right third arm (inside measurement)	28
Left third arm (inside measurement)	31
Right ventral arm (inside measurement)	15+
Left ventral arm (inside measurement)	22
Funnel	15
Diameter of largest suckers	2
Diameter of shell	31

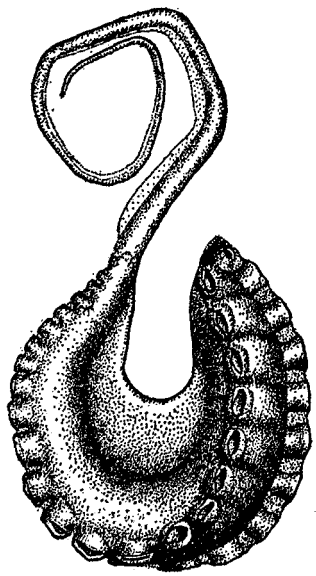

FIG. 7.—*Argonauta böttgeri*, hectocotylus of male [165], × 8.

Type.—?

Type locality.—Unknown.

Distribution.—Mauritius (Smith); Chagos Islands (Smith); Masbate, Philippines (Smith, Hidalgo); China Sea (Smith); Australia (Smith); Hawaiian Islands (*Albatross*).

Specimens examined.—A single adult female containing a hectocotylus and numerous embryos was taken by the *Albatross* in the surface net at station 3927, latitude, 21° 31′ N., longitude, 161° 55′ W., between Honolulu and Laysan Island. The specimen constitutes catalogue No. 214377 United States National Museum [S. S. B. 165].

Remarks.—*Argonauta böttgeri* is not only one of the smallest species of the genus, but one of the most delicately beautiful as well. Its discovery in Hawaiian waters extends its known distribution many thousand miles to the northeast, and further enables me to publish the first detailed description of the animal. When compared with the Mediterranean *A. argo* (see Jatta 1896, p. 191, pl. 8, fig. 3, pl. 18, fig. 15–29), which is the only other form of which I have seen a complete account, important differences are found to be numerous. Most obvious are perhaps the following: In *A. argo* the ventral arms are longest, the third pair shortest; the body is shorter and more inflated; also the suckers are larger and more crowded, and the eyes are larger. Details in the shape and proportions of the funnel organ (narrower in *A. argo*), hectocotylus (also narrower in *A. argo*), and other structures are also noteworthy. The shell of the present species seems unique in its small size, compact coil, and the circumstance that the auricular expansion at the sides of the aperture, so frequently developed in other species of the genus, are here notable only for their entire absence.

With the exception of the detached hectocotylus as above described, the male of this species was not encountered by the *Albatross*, so unfortunately is still unknown.

Argonauta species.

Argonauta (*argo* Linnæus ?) Berry 1909, p. 418 (locality record only).

From a depth of 127–128 fathoms in the Pailolo Channel, *Albatross* station 3857, were obtained a few badly shattered fragments of a shell which is clearly not referable to *A. böttgeri* [S. S. B. 216]. The nearly complete columella shows the shell to have been auriculate in form, which would indicate that the species represented is probably of the group of *A. argo* and possibly close to *A. pacifica* Dall. The surface of the fragments shows a fine, almost obsolete granulation.

Subfamily TREMOCTOPODINÆ.

Philonexidæ H. and A. Adams 1858, vol. 1, p. 21.
Tremoctopidæ Tryon 1879, p. 130.
Tremoctopodidæ P. Fischer 1882, p. 334.
Tremoctopodinæ Berry 1912b, p. 386.

Adult small. Third left arm of the male hectocotylized; its outer surface ornamented with fringe-like papillæ. Dorsal arms of female connected at base by a broad veliform membrane, which extends along their margins, leaving only the very attenuate and frequently decollated extremities free. Remaining arms webbed only at the base, their suckers larger and better developed than those of the dorsal pair. No calcareous egg case or shell. Two large aquiferous pores on the dorsal aspect of the head and a smaller one at either side ventrally just in front of the funnel. Mantle articulating with the funnel by membranous folds; no definite locking cartilages. Funnel organ poorly developed and represented only by a series of longitudinal lamellæ.

Genus TREMOCTOPUS Delle Chiaje 1829.

Tremoctopus Delle Chiaje 1829, T. 70, 71 (*fide* Wülker).
Octopus (*Philonexis*) d'Orbigny 1835, p. 14.
Philonexis d'Orbigny 1845, p. 200.
Tremoctopus Naef 1912b, p. 199.

Since only the single genus of the group is known, its characters are entirely those of the subfamily.

Type.—Tremoctopus violaceus Delle Chiaje 1829 (monotypic), a species originally described from the Mediterranean.

Tremoctopus violaceus Delle Chiaje 1829. (Pl. XLIX, fig. 3, 4.)

? *Tremoctopus violaceus* Delle Chiaje 1829, T. 70, 71 (*fide* Wülker).
Octopus gracilis Souleyet in Eydoux and Souleyet 1852, p. 13, pl. 1, figs. 8–9.
? *Octopus dubius* Souleyet in Eydoux and Souleyet 1852, p. 15, pl. 1, figs. 10–14.
? *Tremoctopus dubius* Tryon 1879, p. 131, pl. 43, fig. 80, 81 (after Souleyet).
Tremoctopus gracilis Tryon 1879, p. 131, pl. 43, fig. 82, 83 (after Souleyet).
Tremoctopus quoyanus Hoyle 1904, p. 12, fig. A.
Tremoctopus sp. (near *quoyanus* d'Orbigny) Berry 1909, p. 418 (locality record only).

Animal small, pelagic. The sexes are so conspicuously dimorphic that a separate description is necessary.

Female: Mantle short; width about equal to length; pouch-shaped, widest anteriorly, and either simply rounded behind or rapidly narrowing to a rounded point; a sharp median longitudinal groove on the ventral surface indicates the position of the median septum of the mantle cavity. Mantle opening very wide and full, extending to a point just above the center of the eye on either side, but well behind it; mantle of scanty extent below, so that its margin barely meets the posterior edge of the funnel.

Head large, flattened; extremely short and broad, the large prominent rounded eyes rendering it usually wider than the body. Eyes not at all pedunculated. Entire surface covered by a loose smooth delicate skin or cuticle of hyaline consistency and unpigmented, which is perforated by four small oval openings—the so-called aquiferous pores—a pair on the dorsal aspect being situated one at the base of each dorsal arm just a little outside the axis of the latter, and another pair about half as large situated one at the base of each ventral arm at either side of the tip of the funnel. Funnel large, compressed, very broad at the base, its outline almost that of an equilateral triangle; only the narrow apex free. Funnel organ composed of a number of longitudinal lamellæ or folds, terminated near the apex by a small acutely pointed valve-like flap. (Pl. XLIX, fig. 4.) The base of the funnel just over the retractor muscles articulates with pocket-like grooves on the inner surface of the mantle by means of a thickened and recurved fold of the posterior margin.

Arms (pl. XLIX, fig. 3) slender, graceful; decidedly unequal, order of length 1, 2, 4, 3; dorsal arms decidedly longest and when perfect terminating distally in a very long delicate thread-like process; second arm pair a little shorter than the first, notably stouter, wider and less attenuate; third arms decidedly

the shortest, usually a very little longer than the mantle in adult specimens and about a third as long a, the dorsal pair; all the arms smooth externally, without keels or carinations. Umbrella thin, delicates hyaline; but little developed between the ventral arms, between these and the third pair, and between the latter and the second pair; very extensive between the four dorsal arms, where it attains its maximum, connecting the first and second arm on each side for nearly half their length, but somewhat more deeply cleft between the dorsal arms; continuous along the dorsal margin of the second pair as a delicate web constantly narrowing distad, but along both borders of the dorsal arms it maintains itself as a promi-

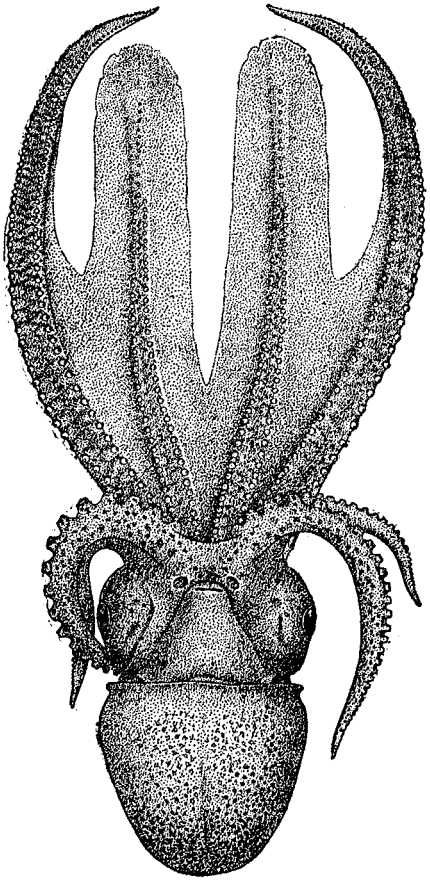

FIG. 8.—*Tremoctopus violaceus*, ventral view of large female [221], from station 3930, × 2. Drawn by R. L. Hudson.

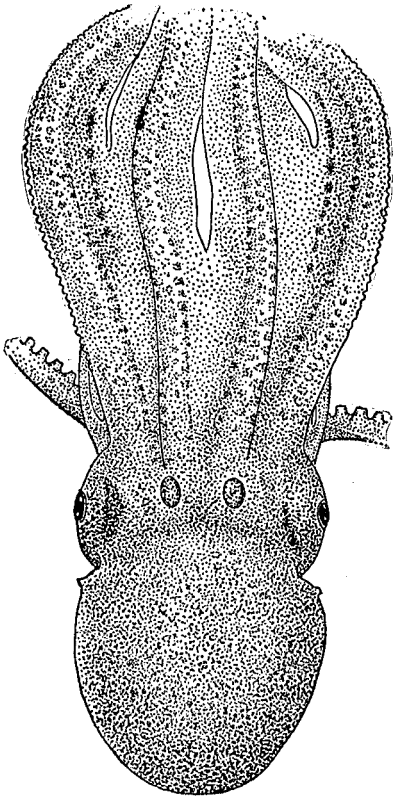

FIG. 9.—*Tremoctopus violaceus*, dorsal view of specimen [221], shown in figure 8, × 2. Drawn by R. L. Hudson.

nent veliform web, ofttimes even broader than the arms themselves, only the filiform extremities of the arms remaining free. In most adult specimens these tips and even the more distal portions of the webbed regions are abruptly decollated.

Suckers small, regularly alternating in two very widely spaced rows, save the basal three which are in a single row and notably larger than any of the remainder except those on the ventral arms which are greatly elevated, cylindrical in shape, much fewer in number, and the rows less widely interspaced. Except at the base the suckers of the four dorsal arms are numerous, much reduced in size, little elevated, and with very small openings; they soon become entirely rudimentary and suddenly crowded laterally

into practically a single row on the distal portion of the dorsal arms, contemporaneous with the general atrophy of the arm itself. The suckers of these arms are ultramarginal except as just noted, and the rows very widely spaced; the suckers of the third arms are somewhat intermediate between this condition and that which prevails on the ventral pair.

Male: Body much smaller, perhaps half as large as that of the female, but quite as variable in shape (figure 10 shows the extreme of rotundity). Arms relatively shorter and more delicate than in the female; the four dorsal arms much less highly specialized, their tips normal, and the very delicate webbing not so well developed. Right ventro-lateral arm hectocotylized, the modification affecting the entire arm, which attains its development in a specialized sac occupying the region which would ordinarily be the base of the arm between the base of the funnel and the eye. (Cf. the account given by Steenstrup, 1857, p. 103–105.) It is visible through the thin overlying integument even in very young specimens as a whitish vermiform body compactly coiled upon itself in such a fashion as to occupy as little space as possible. This arm undergoes a much more rapid growth than the rest of the animal, so that in males measuring about 3 cm. in length (station 4010) the sac is already vigorously crowding the eye and funnel and the animal has consequently a somewhat lopsided appearance; at this stage also the sac has begun to bulge forth by the side of the mouth as a large rounded tumor-like protuberance. In the large mature male from station 4086, the arm had apparently just broken from its sac, but still remained attached by its basal end at the time of capture. At this stage the hectocotylized arm is a highly complex structure as long or longer than the animal itself. It differs very markedly from the hectocotylus of *Argonauta* and may be briefly described as follows:

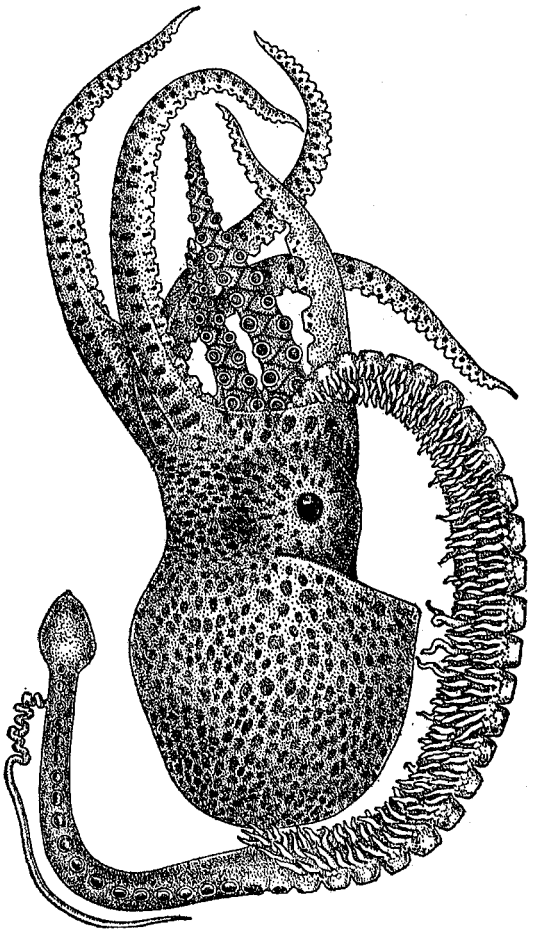

FIG. 10.—*Tremoctopus violaceus*, lateral view of adult male, from station 4086, with nearly ripe hectocotylus [225], × 4. Drawn by R. L. Hudson.

Much flattened; widest about a third of the way above the constricted and bluntly pointed base. Inner surface bearing about 46 pairs of closely placed suckers ranked in two rather widely interspaced marginal rows; outer surface ornamented with a conspicuous double fringe of long acutely conical papillæ, which extend laterally just above the suckers along the proximal two-thirds of the arm; when the distal third of the arm is reached, the papillæ suddenly cease, the outer surface becoming much flattened, naked, and perfectly smooth. Between the rows of papillæ the skin is minutely ridged and tubercled; near the base an irregular series of small rounded tubercles along the median line gives way on the smooth part to a very fine longitudinal costation; on either side a flanking series of low rounded transverse ridges persists along the entire papillate portion of the arm. The apparent differentiation of the arm into regions extends even to the suckers, the 27 pairs arming the papillate portion of the arm being very different from the remainder. Here the suckers are crowded, thickened, massive, elevated,

with swollen bases; at first small, they reach their maximum at about the twelfth to fourteenth pairs, whence they again suffer a gradual diminution in size. The apertures of the first 17 pairs are slitlike and so laterally compressed that the openings are scarcely evident; the next 10 pairs smaller and with more open apertures, the aperture of the twenty-seventh where the papillæ cease being wide open. The following 19 pairs are very differently modified: at this point the interspace between the rows widens, the suckers becoming ultramarginal and facing much more laterally; they are smaller, lower, regularly and gradually diminish in size, and have wide, simple, outwardly flaring apertures. The tip of the arm is occupied by a small bulbous expansion devoid of any armature save a slender pointed filiform process extending distally from its pointed tip. Just proximal to the bulb and about three pairs of suckers from the end, the inner surface of the arm gives rise at its middle to a very long delicate colorless thread, which is so coiled upon itself that it can not be entirely straightened out without danger of breaking. This thread appears to be incased in a tenuous hyaline skin, is thickest beyond the coiled portion, and thence tapers to an attenuate and pointed extremity (fig. 10).

Several of the females were examined to ascertain the possible presence of a free hectocotylus within the mantle cavity, but without success.

The dimensions of the hectocotylus above described are as follows:

	mm.
Total length, exclusive of thread	44
Length of papillated portion	28
Length of terminal bulb and process	4
Length of thread	15+
Maximum diameter	3

Young: The series at hand is replete with immature specimens comprising all the later stages of development, the smallest having a mantle length of about 6 mm. Great variation is evident, especially in the shape and general proportions of the arms and body, but all maintain with great constancy the arm formula 1, 2, 4, 3. The third arms in the smallest specimen (station 3799) are so little developed as to be hardly distinguishable. All the arms are relatively much shorter than in the adult, the suckers fewer and larger in comparison, the umbrella very rudimentary and about equally developed all round, and the eyes rendered more conspicuous through their dark coloration. A slightly later stage (station 3878) shows the arms to have grown rapidly and to be already longer than the body. In males of this size the hectocotylized arm is already well advanced, but in the female the extraordinary development of the umbrella and attenuation of the dorsal arms does not become apparent until the animal has attained a much larger size.

Color of specimens preserved in alcohol everywhere a very pale brownish buff, the eyes with a silvery metallic sheen beneath the integument. Chromatophores fairly numerous, especially just above and behind the eyes, but usually more or less indistinct except in the younger specimens where they are fewer in number and much more conspicuous. A single row of three to five large rectangular chromatophores commences along the base of each dorsal arm, but is soon superseded by a double series of much smaller roundish ones. There is also a pair of rather large chromatophores placed transversely between the eyes, a pair of similar but more widely separated ones behind them, and a single small one near the center of the group. Young specimens show in addition a single line of small dark chromatophores bordering the ventral mantle margin, and sometimes an aggregation of similar chromatophores forms a conspicuous spot on each side of the body just behind the eyes (e. g., the individuals from station 3799, where both males and females appear almost different enough in this and other particulars to constitute a different species; the single individual from station 3929 is the only other specimen seen which shares the foregoing peculiarity).

Type locality.—Of *violaceus*, the Bay of Naples, Italy; of *gracilis*, long. 106° W., lat. 8° N., Pacific Ocean (*fide* Tryon).

Distribution.—Of *violaceus*, Mediterranean (Delle Chiaje, Jatta, etc.); middle Atlantic; Japan (Wülker). Of *gracilis*, eastern mid-Pacific (Souleyet); neighborhood of the Hawaiian and Midway Islands (*Albatross*), eastern tropical Pacific (Hoyle, as *quoyanus*); between Papua and Japan (Hoyle); near Mauritius (Souleyet, as *dubius*).

MEASUREMENTS OF TREMOCTOPUS VIOLACEUS.

Number in author's register	221	221	218	219	218	218	217	223	225	218	224	217	218
Station where taken	3930	3930	3878	3926	3878	3878	3799	4010	4086	3878	4011	3799	3878
	♀	♀	♀	♀	♀	♀	♀	♂	♂	♂	♂	♂	♂
	mm.	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
Total length	64+	51+	48	44+	33	30	6	30	24+	25	21	15	14
Length of mantle (dorsal)	16	13	10	10	9	8	3	10	8	7.5	6	6	4.5
Width of mantle	15	11	10	10	9	7	3	7	10	7	6.5	7	4.5
Width of neck	13	10	8	8	8	6	.....	7	8	5	.....	.....	4
Width of head	15.5	12	11	11	10	8	2.5	8	9	7.5	7	6	4.5
Length of funnel	7	7	5	.....	4.5	3	.....	4	5	3.5	.....	2	2
Length of right dorsal arm	40+	37+	34	28+	22	18	2.5	18	10+	16	14	9	9
Length of left dorsal arm	40+	27+	31	31+	22	20	2.5	.....	10+	16	.....	9	9
Length of right second arm	33+	37	28	27	20	16	1.5	16	.....	14	12	8	6.5
Length of left second arm	45	34+	17+	.....	20	18	1.5	.....	14+	14	.....	8	6.5
Length of right third arm	20	15	11	11	10	7	.....	.....	42	.....	.....	.....	.....
Length of left third arm	20	15	11	.....	10	.....	.....	8	7	4.5	4	3	1.5
Length of right ventral arm	32	25	16	19	14	12	1	.....	14	9	6	2	3.5
Length of left ventral arm	32	25	16	.....	14	.....	1	12	.....	9	6	2	3.5
Length of umbrella between dorsal arms	14	13	9	9	7	3	.....	6	6	3.5	4.5	2	.5
Length of umbrella between ventral arms	3	3	2	2	1	1	.....	1	3	1	1	.....	.....
Length of umbrella between dorsal and second arms	22	17	11	11	9	4	.....	6	5	3.5	4	.....	.....

Material examined.—The 31 specimens examined are of various ages but almost equally males and females:

No. specimens.	Locality.	Depth.	Albatross station No.	Sex.	Author's register No.
4	Lat. N. 29° 22′, long. W. 139° 31′, between Erben Bank and Kaiwi Channel	Surface	3799	1♂3♀	217
5	Off Molokini Islet, Kahoolawe	do	3878	2♂3♀	218
3	Lat. N. 21° 13′, long. W. 158° 43′, between Honolulu and Laysan Island	do	3926	♀	219
1	Lat. N. 23° 19′, long. W. 166° 54′, between Honolulu and Laysan Island	do	3929	♂	220
3	Lat. N. 25° 07′, long. W. 170° 50′, between Honolulu and Laysan Island	do	3930	1♂2♀	221
2	Lat. N. 25° 27′, long. W. 171° 08′, between Honolulu and Laysan Island	do	3931	♂	222
4	Between Kauai and Oahu	do	4010	3♂1♀	223
7	....do	do	4011	3♂4♀	224
2	Off Puniawa Point, Maui	do	4086	♂	225

Remarks.—Owing to the great confusion which prevails in the various published accounts of the species of this genus, the identification of even so excellent a series of specimens as the present is not an easy task and the final conclusion attained is not altogether satisfying. It must be admitted that the temptation is very great to unite practically all the alleged species of *Tremoctopus* under the oldest name of which we chance to have knowledge as applied to a member of this group—the *Tremoctopus violaceus* Delle Chiaje 1829. This is in effect what has been done by Jatta [a] (1896, p. 204) and more

[a] Jatta includes all the following in the synonymy of *T. violaceus:*

Octopus velifer Férussac 1830.
Philonexis Quoyanus d'Orbigny 1835.
Philonexis atlanticus d'Orbigny 1835.
Philonexis microstomus d'Orbigny 1835.
Philonexis hyalinus d'Orbigny 1835.
Octopus (Philonexis) brevipes d'Orbigny 1835.
Octopus semipalmatus Owen 1836.
Octopus velatus Rang 1837.
Octopus Kollikeri Vérany 1847.

recently by Naef (1912*b*, p. 199). Wülker has likewise reported under the same name a species of the genus from Japan (1910, p. 5). Not having any material from other regions available for comparison, I have felt constrained to follow the precedent thus made for me, especially since I have not been able to seize upon any characters of sufficient definiteness to separate the Pacific species from the Atlantic. Nevertheless it should be remembered that our knowledge of the group is still woefully incomplete, and a careful account is needed of all the diverse stages which specimens from the various regions pass through during their life history, before absolute confidence can be felt in such wholesale relegation to the synonymy.

Should it eventually appear that there are more species of *Tremoctopus* than recent writers are inclined to admit, I have no doubt whatever that the Hawaiian specimens are identical with the form described by Souleyet as *Octopus gracilis*. Tryon (1879, p. 131) gives the following brief paraphrase of his very inadequate description: "Body rounded, smooth; head small; eyes large, prominent; arms graceful, the upper very long, lower short, connected by a web. Phosphorescent and with metallic reflections when living. Length 24 mm."

Certainly these few lines contain little which can serve either to prove or to disprove the identity of Souleyet's specimen with those obtained by the *Albatross*, but upon turning to the figure we find a representation which accords very well with Hawaiian specimens of the same size, and as both are from the same general oceanic region and the habit of the animals is admittedly pelagic, we find at once a strong *a priori* reason for uniting them. From the present specimens the figure of *O. gracilis* differs most strikingly in its more inflated body (a character of trifling importance) and somewhat wider web between the ventral arms. The eyes are also represented as being semipedunculate, but I suspect that this appearance may be due to the loss of the delicate integument which usually envelops the head. The proportions of the arms are, however, much the same, and it is further noteworthy that a specimen presumably of this species taken by the *Challenger* in the western Pacific differs in no described character from the *Albatross* specimens (Hoyle 1886, p. 71).

With the same form I would be also disposed to unite the *Octopus dubius*, also of Souleyet, especially since the most immature of the specimens before me is almost a counterpart of his figure and is of similar dimensions (6 mm.).

The two female specimens dredged by the *Albatross* in the tropical Pacific, which Hoyle (1904, p. 12) referred with some doubt to *T. quoyanus*, likewise agree perfectly in all the characters stated, have the same curious arrangement of the chromatophores, and are surely conspecific. The single poorly preserved individual taken by the *Challenger* in the south Pacific (Hoyle 1886, p. 70) also is probably identical, so that on the whole it can be affirmed with certainty that few Hawaiian cephalopods exhibit a wider distribution.

The species is one of the most beautiful and graceful of all cephalopods.

Family ALLOPOSIDÆ Verrill 1881.

Alloposidæ Verrill 1881, p. 365.
Argonautidæ (pars) Naef 1912*b*, p. 197, 198.

Sexes dimorphic, the female larger than the male and often attaining considerable dimensions. Body soft and gelatinous; aquiferous pores lacking. Arms united throughout the greater portion of their length by an extensive umbrella; suckers in 1–2 rows. Hectocotylization affects the whole of the right third arm, which has its origin in a specialized sac in front of the eye, and when mature is most probably caducous.

Genus ALLOPOSUS Verrill 1880.

Haliphron Steenstrup 1859, p. 183 (nomen nudum, *fide* Hoyle).
Alloposus Verrill 1880, p. 393.
Alloposus Verrill 1881, p. 365.
Alloposus Hoyle 1886, p. 72.
Alloposus Naef 1912*b*, p. 198.

This being the only known genus, its characters are entirely those of the family.

Type.—Alloposus mollis Verrill 1880 (monotypic), originally described from off the New England coast.

Alloposus mollis Verrill 1880.

? *Haliphron atlanticus* Steenstrup 1859, p. 183 (*fide* Hoyle).
Alloposus mollis Verrill 1880, p. 394.
Alloposus mollis Verrill 1881, p. 366, 420, 434, pl. 50, 51, figs. 3–4.
Alloposus mollis Hoyle 1886, p. 7, 72.
Alloposus mollis Joubin 1895, p. 4, 13, 55, pl. 5, fig. 1, 3, 10, 11, pl. 6.
Alloposus mollis Joubin 1900, p. 11, 30, 127, pl. 5, fig. 14, 15; pl. 11, fig. 1.
Alloposus mollis Berry 1909, p. 418 (locality record only).

Body large, soft, smooth, semigelatinous in consistency, in shape ovoid, widest in front, narrower and rounded posteriorly.

Head short and very broad; when contracted the lids of the large prominent eyes appear to have distinct openings. Mantle opening very wide and full, extending in two broad pouchlike curves from the median point of union with the ventral commissure to a point just past the eye on either side. Medio-ventral septum or commissure well developed, extending nearly to the anterior margin of the mantle, and thence reaching its dorsal attachment through a sinus in the posterior margin of the funnel. Funnel enormous and almost entirely exposed; its apex reaching slightly past the eyes; fused with the ventral integument of the head for almost its entire length. Funnel organ extremely anterior in position and very large, comprising a broad W-shaped pad of a conspicuous brown ochre color; posterior lobes rounded; anterior lobes acute and almost meeting in the median line below (fig. 12).

Arms moderate, decreasing in length and degree of attenuation from the dorsal to the ventral pair (in the present specimen their extremities are badly mutilated); connected at the base by a broad membranous umbrella, the latter attaining its greatest extent between the arms of the dorsal pair which it interwebs for much the greater portion of their length. Suckers large, elevated, deep, their rims of somewhat more massive consistency than the other tissues of the animal; they are in two rows, or rather in a single more or less zigzag row which most conspicuously approaches the two-rowed condition after reaching the margin of the umbrella (at about the thirteenth sucker on the dorsal arms).

The entire integument is of a somewhat stringy semigelatinous consistency. It does not preserve well and is badly torn away from the right side of the present specimen.

Color of specimen preserved in formalin and alcohol a muddy buff, numerous brownish chromatophores are distributed over the dorsal surface and to a considerably less extent below.

MEASUREMENTS OF ALLOPOSUS MOLLIS.

	mm.		mm.
Total length	147+	Length of—	
Tip of body to base of umbrella between dorsal arms	65	Left second arm	72+
Length of body	50	Right third arm	65
Width of body	46	Left third arm	51+
Width across eyes	51	Right ventral arm	60+
Length of—		Left ventral arm	59+
Right dorsal arm	82+	Umbrella between dorsal arms	54
Left dorsal arm	60+	Umbrella between ventral arms	44
Right second arm	90	Funnel	38
		Diameter of one of largest suckers	4

Type.—In the United States National Museum. A cotype (from *Fish Hawk* station 893) is in the Yale University Museum.

Type locality.—*Fish Hawk* station 880, 252 fathoms, off Newport, Rhode Island, September 13, 1880; three specimens.

Distribution.—Off Newport, Rhode Island (Verrill), off Chesapeake Bay (Verrill); north Atlantic (Hoyle, Joubin), off Marthas Vineyard, Massachusetts (Verrill); off Delaware Bay (Verrill), off the Azores (Joubin).

Pailolo Channel, Hawaiian Islands (*Albatross*).

Verrill gives the bathymetric range of the species as 236 to 1,346 fathoms. Fragments of this species have been obtained from a depth of 1,735 fathoms and likewise from the surface.

Material examined.—One immature female was taken by the *Albatross* in 286 to 290 fathoms, station 4095, northeast approach to Pailolo Channel [S. S. B. 209]. It is catalogue No. 214378 of the United States National Museum.

Remarks.—This interesting species has been described in such excellent detail by Verrill, Joubin, and other writers, that I have endeavored in the above paragraphs to give merely an account of the more salient characters of the species as they appear in the specimen at hand, and to add an account of the funnel organ which has hitherto remained undescribed. The latter is chiefly interesting for its relatively anterior position and great size, for in general outline it does not specially differ from the usual W-shaped type of organ prevalent in most octopod genera.

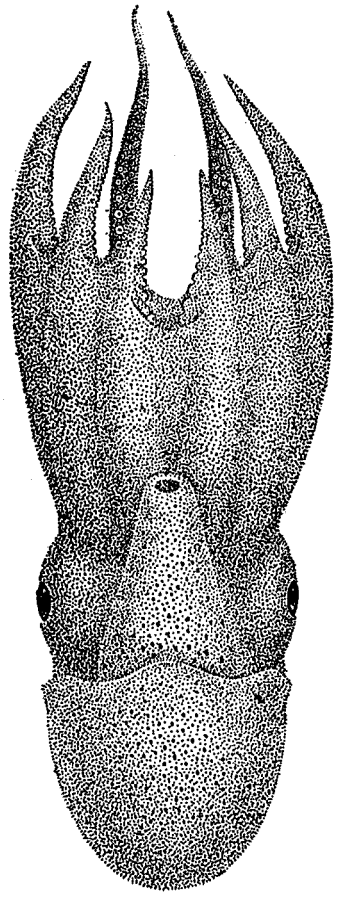

FIG. 11.—*Alloposus mollis*, ventral view of small female, from the Pailolo Channel [209], × ⅔. Drawn by R. L. Hudson.

As this species has not hitherto been reported from the Pacific, there would seem to be strong reasons for doubting its identity with the Atlantic *A. mollis*, if on no other than geographical grounds, yet I have been unable to find any characters which could be used in separately defining it. Perhaps this is due to the obvious immaturity of the present specimen, for an individual observed by Verrill (1881, p. 420) was nearly 79 cm. in length and weighed over 20 pounds, while a single dorsal arm recorded by Joubin (1900, p. 32) is 161 cm. long.

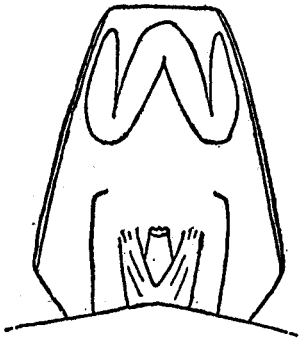

FIG. 12.—*Alloposus mollis* [209], outline drawing of funnel laid open medioventrally to expose funnel organ, natural size.

An allied form—*A. pacificus* Ijima (see Ijima and Ikeda 1902, p. 87, footnote)—has been described from the Sagami Sea, Japan. The chief character advanced by the author to separate this form from *A. mollis* is simply that the suckers "are arranged in a single row for the greater part of the arm length, being biserially arranged only in the free tip." That, unless supported by other structural differences, this feature is of no very weighty importance is readily seen upon examination of the present specimen, for whereas one author might describe the arrangement of the acetabula as unmistakably in two rows, another might as positively assert them to be uniserial. The truth is that, as Hoyle has shown in the case of Polypus (1886, p. 76; 1904, p. 18–19), all the suckers are morphologically to be regarded as ranked in a single row, the component members of which have undergone a greater or less lateral displacement to each side in alternation, the resulting biserial appearance being purely secondary. In this respect *Alloposus* occupies an intermediate position and hence the claims of *A. pacificus* to recognition as a good species can not yet be taken as established, even though in the absence of a complete description of the Japanese form it would be premature to unite the two dogmatically.

Family BOLITÆNIDÆ Chun 1911.

Bolitænidæ Chun 1911, p. 20.

Body semigelatinous. Third arms much the longest and largest; suckers on all the arms in a single row. Right third arm hectocotylized, the chief modification consisting in the enlargement of a part or even all of the suckers. Olfactory organ papilliform.

Genus ELEDONELLA Verrill 1884.

Eledonella Verrill 1884, p. 144.
Eledonella Chun 1911, p. 16.

Body gelatinous, weakly pigmented, semitransparent. Hectocotylization affecting only the distal suckers of the arm.

Type.—Eledonella pygmaea Verrill 1884 (monotypic), a species of the New England region.

Eledonella species (young).

Bolitæna species Berry 1909, p. 418 (locality record only).

Mantle saccular, much wrinkled, longer than broad. Arms short, incompletely webbed; the 4 to 6 large suckers arranged in a single series. Funnel small, little projecting. Head small. The single specimen obtained is too young for safe determination. It is badly contracted and chiefly characterized by its large eyes, wide mantle opening extending well past the eyes, and short arms, the third and fourth pairs being the longest. The specimen was at first referred to *Bolitæna*, but is more probably an *Eledonella*.

	mm.
Total length	15
Length of mantle (dorsal)	10

From *Albatross* station 4039, 670 to 697 fathoms, off Kawaihae Light, Hawaii [S. S. B. 210].

Family POLYPODIDÆ Hoyle 1904.

Octopidæ (pars) d'Orbigny 1838, p. 3; 1845, p. 164.
Octopodidæ H. and A. Adams 1853, vol. 1, p. 18.
Polypodidæ Hoyle 1904, p. 14.
Polypodidæ Naef 1912b, p. 197.

Animals of small to gigantic size. Body short, thick, and usually firm and muscular. Sexes nearly similar. Ventral mantle connection consisting of a pair of shallow folds on the hinder margin of the funnel, with shallow grooves to correspond on the inner surface of the mantle. No aquiferous pores. Arms with one or two rows of suckers and a more or less well-developed basal web. Hectocotylus confined to the extreme tip of either the right or left third arm; a narrow groove or fold in the edge of the marginal membrane terminates in a roughly spoon-shaped copulatory organ at the extremity.

Genus POLYPUS Schneider 1784.

Polypus Schneider 1784, p. 116.
Octopus Lamarck 1799, p. 18 (*fide* Hoyle).
Octopus d'Orbigny, in d'Orbigny and Férussac 1838, p. 17.
Octopus Hoyle 1886, p. 74.
Polypus Hoyle 1901, p. 1–5.

Body short, thick, rounded posteriorly; surface smooth to warty, usually with one or more tubercular cirri over either eye. Arms and umbrella very variable; suckers in two alternating rows, which are perhaps better to be regarded as a single extremely zigzag row. Third right arm hectocotylized.

Type.—Sepia octopodia Linné 1758, a European species perhaps identical with *P. vulgaris* (Lamarck 1799). Schneider designates no type and does not even name a species, but the inference seems clear that the *Sepia octopodia* of Linné is the form which he had in mind, especially since at that time this was the only species of the group which had been characterized by a binomial name. Hoyle, however, arrives at the conclusion that *Octopus vulgaris* Lamarck 1799 is available as the generic type.

Polypus hawaiiensis (Souleyet 1852).

Octopus hawiiensis Souleyet in **Eydoux and Souleyet 1852**, p. 9, pl. 1, fig. 1–5.
Octopus Hawaiiensis Tryon 1879, p. 118, pl. 34, figs. 44, 45 (after Souleyet).
Octopus hawaiensis Hoyle 1886, p. 9, 220 (merely listed).
Polypus hawaiiensis Berry 1909, p. 418 (merely listed).

The original description of this species by Souleyet is verbatim as follows:[a]

"*Octopus, corpore rotundato, lævi; capito magno; brachiis crassis, basi palmatis.*

"Corps petit, globuleux, lisse dans toute son étendree, l'ouverture anterieure du sac ne comprenant pas tout à fait la moitié de la circonférence; l'entonnoir assez long et grêle.

"Tête volumineuse, aussi large que le corps.

"Bras très-forts, proportionellement au volume du corps, et légèrement palmer à leur base; ceux des première, troisième et quatrième paires (1), presque egaux en longueur (quatre fois la longueur du sac); ceux de la deuxième paire, d'une longueur un plus grande; les ventouses atternes peu elevees et très-rapprochées.

"Ce poulpe offere partout une teinte d'un gris bleuâtre, très-finement pointillée de noir, ce qui fait paraitre sa couleur noirâtre; cette couleur est moins foncee en dessous du sac et surtout à la partie inférieure de la tête.

"Il provient de Hawaii, l'une des îles Sandwich; il ne parait pas très-commun das cette localité, car nous n'en avons rapporté qu'un seul individu.

Dimensions.

	Centimetres.
"Longueur totale	13
du sac	2
de la tête	1
des bras (1re, 3e, et 4e paires)	8
des bras (2e paire)	10

"Les charactères qui nous ont paru distinguer surtout cette espèce sont: la petitesse, et la forme arrondie du sac, le volume et la longueur mediocre des bras, enfin l'absence de rugosités et d'eminences sur la peau qui est partout parfaitement lisse. Les espèces dont elle se rapproche le plus sont: le *poulpe tehuelche* (O. tehuelchus), de M. d'Orbigny, et *le poulpe brevitentaculé* (O. brevitentaculatus), de M. de Blainville; mais elle diffère de la première de ces espèces par la grosseur et la brièveté des bras, et de la seconde, par la palmature moins considérable de ces appendices et par leur proportion que est tout à fait différente."

Type locality.—Island of Hawaii (Souleyet).

Distribution.—The species has not been again recorded since its discovery.

Remarks.—I am unable to refer any of the numerous specimens of *Polypus* in either the *Albatross* or Stanford collections to this species. Its special characters seem to be the smooth globose body, without cirri or other tubercles, large head, short umbrella, and short robust arms, the second pair of the latter being longest, the others equal. Of the described Hawaiian species, *P. ornatus* and *P. hoylei* are certainly sufficiently distinct, as is also *P. marmoratus* if the description by Souleyet is to be relied upon. The view that the last-named species may really be identical with *P. hawaiiensis* has been suggested by Ortmann (1891, p. 672), and the fact that in the very large series of the genus before me there are no specimens whatever which approximate to the combination of characters alleged to be diagnostic may indicate that an error has somewhere crept in. On the other hand, Tryon regarded *P. hawaiiensis* as very close to or identical with the *Octopus punctatus* Gabb of California, but I think the resemblance is entirely imaginary.

[a] As the original volume has only once been accessible to me, I must here mention my obligation to Dr. E. J. Nolan, of the Academy of Natural Sciences of Philadelphia, for sending me the copy of the above description which is here transcribed.

Polypus marmoratus (Hoyle 1885).[a] (Pl. XLV; pl. XLVIII, fig. 6.)

Octopus marmoratus Hoyle 1885, p. 227.
Octopus marmoratus Hoyle 1885a, p. 102.
Octopus marmoratus Hoyle 1886, p. 8, 85, 220, pl. 6.
Octopus marmoratus Brock 1887, p. 610, 611.
Octopus marmoratus Ortmann 1891, p. 671.
Octopus marmoratus Joubin ? 1894, p. 35 (*fide* Wülker).
Polypus marmoratus Hoyle 1905, p. 978.
Polypus marmoratus Berry 1909, p. 418 (locality record only).
Polypus marmoratus Wülker 1913, p. 457.

Body of moderate size, rounded pyriform in shape, broadest toward the posterior; not flattened, but with a distinct median longitudinal depression or sulcus on the ventral surface. Integument as a rule quite smooth, but apt to be much wrinkled above, and with a few large, low, longitudinally elongate tubercles on the dorsal surface; notably more conspicuous than the remainder are one of these tubercles at the base of each dorsal arm, one in advance of the center of the head, and a diamond-shaped quadrilateral of four on the dorsum, besides several lateral ones[b]. A series of smaller ridges tends to extend distally from the large tubercles at the base of the dorsal arms out upon the arms, and all show a distinctly bilateral arrangement. In addition to the ridges there is a large conspicuous bluntly conical tubercle just above and behind the center of each eye opening, supplemented by a smaller, more elongated excrescence just in front of the eye, and one other placed diagonally behind. This ornamentation appears to be a reasonably constant feature, at least in the material examined. The mantle opening is not especially wide, extending rather less than halfway from the funnel to the eye.

Head rather small, narrow, rounded, separated from the body by an often slight constriction. Eyes prominent. Funnel small, conical, reaching little more than a third of the distance to the umbrella margin. The funnel organ is well developed and comprises a broad bilobate W-shaped pad on the inner wall of the funnel cavity a little forward of the center. (Fig. 13.)

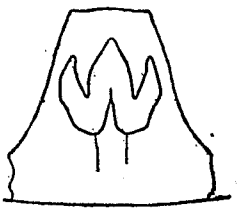

FIG. 13.—*Polypus marmoratus* [175], outline drawing of funnel laid open mediodventrally to expose the funnel organ, natural size.

[a] The principal portion of the description of this species given by Hoyle in the *Challenger* Report (1886, p. 85) is as follows:

"Habitat.—On the Reefs, Honolulu, Sandwich Islands. Three specimens, one ♂, two ♀.

"Sandwich Islands (Copenhagen Museum).

"*The Body* is round, not depressed, and a little longer than wide. The *mantle-opening* extends somewhat less than halfway round the body, terminating nearer to the siphon than to the eye, and considerably behind the latter. The *siphon* is small and acutely conical, and extends about one-third the distance to the umbrella-margin.

"*The Head* is narrow, and the eyes are prominent, where they have not suffered from compression.

"*The Arms* are subequal, eight times as long as the body; they are very long and slender, the last character being more marked in the females than in the male; they taper more rapidly at first than near the extremities, which are much attenuated. The *umbrella* is very wide, especially in the male, where it extends almost one-third up the arms; in the females its extent is only one-sixth. The *suckers* are rather large, and closely set; in the male a few suckers opposite the umbrella-margin are slightly, but not markedly, larger than the others. The extremity of the *hectocotylized arm* is small, and has about 10 small transverse ridges.

"*The Surface* appears to have been smooth, except for a few short ridges placed longitudinally on the back and sides; but the skin is shriveled by the action of the spirit, so that it is difficult to be certain. A conical cirrus is situated above and slightly behind each eye; but in some cases this has been destroyed.

"*The Colour* is a stone-gray, with dark pigment disposed in veins like those of marble on the dorsal surface of the body, head, and umbrella; the male is much darker, so that the marbling is almost concealed. Traces of an oval spot are seen in front of and below the eye on both sides of one female specimen and on one side of the other; but this spot is concealed by the dark colouring in the male even if it exist.

* * * * * * *

"This species presents in some respects a resemblance to *Octopus bimaculatus*, Verrill, namely, in the general form and proportions, in the enlargement of one or more suckers on the lateral arms, and in the small size of the hectocotylus of the male, as also in the presence of the dark spot on either side in front of the eye. Each, too, has a supra-ocular cirrus, but the conspicuously warted upper surface of Verrill's form and the equally marked smoothness of the *Challenger* specimens, as well as the seemingly constant difference of coloration necessitate their separation.

* * * * * * *

"It approaches *Octopus hawaiensis* E. and S., in general form, but differs in the presence of cirri over the eyes."

[b] These structures may very likely represent the "few short ridges placed longitudinally on the back and sides" which are mentioned by Hoyle.

Arms stout and muscular, apt to be heavily recurved and coiled in alcoholic specimens; at first rapidly tapering, but attenuate at the extremities; length moderate, perhaps three to four times that of the body; on the average probably subequal, but variable, in the adult the ventral pair usually a little the longest. Umbrella only moderately developed in the specimens seen; about equal all round, and continued as a prominent contractile web along the outer margins of all the arms. Suckers large, rather flattened, and closely set except along the distal portions of the arms, where the two rows become relatively much more widely separated, a character not shown by the figure in the *Challenger* report; first four suckers at the base in a single row. In the male from two to four suckers opposite the umbrella margin on each arm undergo a slight enlargement.

The third right arm in the male is not very much shorter than its mate and the hectocotylized portion is very small. The calamus is poorly developed and does not show the usual papilliform structure; ligula extremely small, its inner surface excavated and provided with about 10 easily obscured transverse ridges. (Pl. XLVIII, fig. 6.)

Color of preserved specimens everywhere a dull drab or stone gray, lighter below and on the inner surface of the umbrella and arms; dorsally the surface is so heavily clouded with a dark slate as to be almost unicolored, but in the lighter areas and when the folds of the skin are stretched apart the dark pigment is seen to be disposed in narrow anastomosing veins which are here and there very conspicuous.[a] A series of confluent blotches of similar tint extends along the flattened sides of the arms just outside the suckers and in rough alternation with the latter. In well-preserved material there is a large roundish oculation a little way in front of and below the eye on either side; the very dark center is surrounded by a broad ring of lighter tint which is not always easy to make out; the entire spot is often somewhat obscured owing to the heavy pigmentation generally, but as it is conspicuously present in at least one of the male specimens examined, it is clearly not to be looked upon as a sexual character. The color in life is not known.

Beak and radula not examined.

MEASUREMENTS OF POLYPUS MARMORATUS.

Number in author's register	174	175	183	183	183	183	185
Sex	♂	♂	♂	♀	♀	♀	juv.
	mm.	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
Total length	?	a271	59	68	62	59	45
Tip of body to dorsal base of umbrella	95	56	17	20	16	16	13
Width of body	61	38	11	14	13	12	10
Length of body	.....	.....	12	15	12	11	.....
Width of neck	38	26	8	10	9	8	7
Width across eyes	41	29	11	10	11	10	9
Mouth to tip of right dorsal arm	?	a182	37	42	41	40	22
Mouth to tip of left dorsal arm	a310	a185	24+	40	41	40	21
Mouth to tip of right second arm	a340	a188	40+	43	46	43	27
Mouth to tip of left second arm	a335	a190	38	48	45	43	29
Mouth to tip of right third arm	a280	a165	24	.....	44	43	31
Mouth to tip of left third arm	a295	a195	42	47	46	42	38
Mouth to tip of right ventral arm	a345	a210	37	35	43	40	29
Mouth to tip of left ventral arm	a340	a215	39	41	45	40	30
Length of hectocotylus	4	1.5	.....	.....	.....	.....	.....
Length of umbrella between dorsal arms	.....	25	6+	13	11	10	4
Length of umbrella between ventral arms	.....	25	8	8	7	10	4
Length of funnel	40	20	5	6	5	5	4.5

[a] Largely estimated, but figures given for what they may be worth.

	mm.
Total diameter of ocular spot, right side (S. S. B. 175)	12
Total diameter of ocular spot, left side (S. S. B. 175)	11
Diameter of dark center of spot, right side (S. S. B. 175)	8

[a] From this feature arises the significance of the name *marmoratus*.

Type.—In the British Museum (Natural History).

Type locality.—"On the Reefs, Honolulu, Sandwich Islands;" three specimens (*Challenger* expedition).

Distribution.—Honolulu Reef, Oahu (*Challenger, Albatross*, etc.); Hilo, Hawaii (Stanford University collections); Rotuma (Hoyle); Rimatara (Wülker); Buka, Solomon Islands (Wülker); Stewart Islands (Wülker); Amboina (Joubin); Ceylon (Ortmann).

Material examined.—The following 13 specimens have been examined, the majority of them being rather immature:

No. of specimens.	Locality.	Collector.	Sex.	Where deposited.	Author's register.
1	Honolulu, Oahu	Market	♂	Stanford Univ. Coll., Cat. 2089	174
1	Honolulu, Oahu	Jordan and Evermann	♂	Stanford Univ. Coll., Cat. 2088	175
6	Honolulu Reef, Oahu	Albatross	2♀ 4 Juv.		185
4	Honolulu Reef, Oahu	Albatross	1♂ 3♀		183
1	Henshaw's Road, Hilo, Hawaii		Juv.	Stanford Univ. Coll., Cat. 2090	181

Although *P. marmoratus* appears to be a well marked, even if in no way an extraordinary species, it nevertheless exhibits a considerable measure of variability. The four young individuals from Honolulu Reef (S. S. B. 183), which I have assumed to be referable here, indicate this to a remarkable degree, and it may be possible that they are incorrectly determined; they possess a wide flattened head, pale coloration, no ocular markings, and the skin varies from a nearly smooth state to one where the scattered papillæ are erect and bristling. The numerous small chromatophores render the surface finely punctate, and a single slightly zigzag row of somewhat larger chromatophores extends along the outer surface of each arm. The male in this lot is readily distinguishable by its small but well-developed hectocotylus, and by the rather conspicuous enlargement suffered by the seventh and eighth suckers on each of the lateral arms. The remaining suckers are rather small, a little elevated, and equidistant as in the females. The measurements are surprisingly constant, as shown in the above table.

Hoyle compares this species with the Californian *P. bimaculatus* (Verrill) and apparently with justice, although he is undoubtedly correct in regarding the two as distinct. Specimens of the two species placed together have an entirely different aspect and are not likely to be confounded. The divergent pigmentation alone is entirely sufficient for the ready separation of most specimens, and so far as my very limited experience shows the elongate cirri of many *P. marmoratus* do not appear on the Californian form, although the symmetrical arrangement of the tubercles is much the same.

Ortmann (1891, p. 672) has suggested that Hoyle's species may after all be identical with *O. hawaiiensis* Souleyet, in which case the latter name has many years priority and would of course take precedence, but for the present the matter must go over unsettled.

One of the *Challenger* specimens, which is the largest example of the species so far recorded, has a total length of 630 mm. The species is apparently an abundant littoral form occurring in large numbers on the reefs, and is one of the most important of the species used as food. As the most common of the *Polypi* it is likely to be met with in almost any general collection from the region. It is readily distinguishable from the species which usually accompany it by its somber coloration, ridgelike cirri, moderate arms, small hectocotylus, and wide funnel organ, as well as the presence of the three cirri over the eyes and the oculations at the base of the third arms. Being a solid and muscular species, the tissues, particularly of the arms, are apt to undergo a powerful contraction when preserved in alcohol.

Polypus ornatus (Gould 1852).[a] (Pl. XLVI.)

Octopus ornatus Gould 1852, p. 476, figs. 590, 590a.
Octopus ornatus Tryon 1879, p. 112, pl. 30, figs. 29, 30 (after Gould).
Polypus ornatus Berry 1909, p. 418 (locality record).

Body of moderate size, subglobose, more expanded and rounded posteriorly. Mantle opening simple, moderately wide, extending on either side to a point about halfway between the eye aperture and the funnel.

Head fairly large, rounded, not excavated above or below; the eyes fairly prominent, with small openings; head and body separated in the nuchal region by a decided constriction. Funnel long, extending for about two-thirds of the distance to the ventral margin of the umbrella, conical and tapering, with a broad base; adherent to the ventral surface of the head for more than half its length; aperture small. Funnel organ well developed, comprising a large W-shaped pad lying nearly midway of the dorsal wall; the median lobe is decidedly longer than the lateral wings. (Fig. 14.)

Arms extremely long, very graceful (pl. XLVI, fig. 1), dorsal pair perhaps as much as seven times the length of head and body taken together, extremely slender and attenuate, the tips almost filiform; disproportionately unequal, the order of length 1, 2, 3, 4; dorsal arms conspicuously the stoutest and longest, the remaining arms exhibiting a decided but very regular decrease in size as we progress ventrally; the ventral arms very slender, less than three-fifths as long as the dorsal pair. Umbrella of small extent; best developed between the dorsal arms and least ventrally, thus giving the mouth the apparent position noted by Gould; it is continuous with a loose, very narrow fold of membrane which runs distad along the outer margins of the arms for a short distance, soon becoming nearly or quite obsolete. Suckers of moderate size, somewhat elevated, and with discoid but fairly deep cups; very numerous and somewhat crowded, 312 being counted on the left dorsal arm of the medium-sized specimen without the aid of a lens, less than a third of them occurring on the distal half of the arm; they are consistently in two rows even at the base near the mouth and at the extreme tip as well; a conspicuous maximum in size is attained a little distance beyond the margin of the umbrella. Third right arm in the male about a third shorter than its mate of the opposite side; on this arm a shallow marginal fold incloses a groove running along the outer ventral angle of the arm; this fold is barely distinct from the main body of the arm itself and is the sole remaining vestige of the marginal web; beginning at the umbrella margin, it terminates in the hectocotylus as the median groove of the flattened conical basal papilla (calamus) of the latter; the principal portion of the hectocotylus (ligula) is a conspicuously thick-

[a] The original description of Gould (1852, p. 476) is as follows:

"Body subglobose, the length exceeding the breadth about one-twelfth. Head two-thirds as long as the body, and about half its breadth, of nearly equal width throughout, the eyes being but very slightly prominent. Inferior opening broad, the lip transverse and simple; eyes small, the pupil black, with a silvery iris. Mouth small, situated at the lower third of the umbrella, which is rather small, but well-marked, the membrane not prolonged up the arms. Arms compressed, long and slender, attenuated to a thread, comparative length 2, 4, 3, 1, differing much in size, the upper ones being very robust, the second, third, and fourth pairs being successively more slender, the latter being remarkably slender, not half the size of the upper ones. Cupules of medium size, nearly sessile, crowded, very numerous, extending to the tips of the arms; they commence in a double series on the upper arms, while on the lower ones the first six are in a single series. The surface is coarsely reticulate-papillose, with a series of oblong-oval, smooth, and colorless patches along the back of the arms and around the sac, somewhat resembling bullæ. The ground color is deep orange; beneath somewhat clouded with white; above variegated with five longitudinal, buff stripes, the median one extending to between the eyes, the two lateral ones curving on each side, like meridian lines, and extending only to the neck; between these lines, around the middle of the sac, are deep brown patches, and also between the bases of the arms; there are also brown mottlings along the back of the arms. These, with the pale, bubble-like patches around the base of the sac and along the arms, give a very gay and diversified coloring.

"Length of sac to inferior opening, one and a half inches; length along the back to the umbrella, two and a half inches; breadth of sac, one and three-fourths inches; breadth of neck, one inch; breadth of umbrella from side to side, three inches; breadth above mouth, two inches; below mouth, one inch; length of arms, upper pair, twenty inches; upper lateral, twenty-four inches; lower lateral, about twenty inches; lower pair, twenty-one inches.

"Obtained at the Sandwich Islands at Oahu and Maui.

"No other described species approaches [to] this in form and coloration, except *O. macropus* Risso. The comparative length of arms is different (1, 2, 3, 4), the body is more elongated, and there are no cirrhi about the eyes in the latter species, besides a sufficiently well-marked distinctness of coloration. Described from specimens preserved in spirits, and from a coloured drawing."

ened and expanded spoon-shaped organ, its inner surface broadly but not abruptly excavated and ornamented with numerous irregular transverse wrinkles or grooves. (Pl. XLVI, fig. 2, represents the hectocotylus of an immature specimen.)

The surface ornamentation is very distinctive. Body nearly smooth below; above coarsely and irregularly papillose, the papillæ ordinarily arranging themselves in fairly distinct longitudinal lines, most noticeable on the nuchal region, but extending anteriorly over the umbrella and posteriorly over the dorsum before becoming obsolete. Certain of these papillæ are larger than the others, and in preserved specimens they often become confluent with one another in certain regions of the body to form narrow elongate ridge-like folds of great permanency; along the median line are three of these folds, one extending back from the nuchal region for about a third the length of the body, the second some distance posterior to it in the same line, but much shorter, and a third still farther back and representing but little more than a single large papilla. Lateral to these are three series of similar ridges; two short ones, which, in conjunction with the two chief median ridges, inclose a dark quadrangular area in the middle of the dorsum; two longer folds external to these and paralleling the anterior median fold; and outside these, two still longer but more or less interrupted ridges extending from the upper edges of the mantle opening well past the middle of the body. There are three rather small bluntish cirri just above each eye opening.

FIG. 14.—*Polypus ornatus* [179], outline drawing of funnel laid open medioventrally to expose the funnel organ, natural size.

Color of specimens preserved in alcohol a dull buff, much clouded above with a more or less washed out reddish chocolate, and below with dull ocher or a livid brown. Each of the integumentary ridges which have been described is inclosed in a prominent band of buff, and a conspicuous series of areolæ or reticulations of the same pale tint are disposed in pairs along the outer surfaces of the four dorsal arms for the greater portion of their length. Gould states the general ground color of the living animal to be orange, but in alcoholic material this fades, and in some specimens the buff bands and areolæ may appear not lighter (as in the specimen to which particular reference is had above), but actually darker and brighter than the surrounding integument. The chromatophores are excessively small and copiously distributed.

MEASUREMENTS OF POLYPUS ORNATUS.

Number in author's register	382	179	179
Sex	♂	♂	♂
	mm.	*mm.*	*mm.*
Total length	650+	526	263
Tip of body to dorsal base of umbrella	97	61	38
Length of body (dorsal)	68	40	24
Width of body	57	40	25
Width of neck	35	25	17
Width of head	35	28	19
Length of—			
Right dorsal arm	540	305+	224
Left dorsal arm	553+	465	225
Right second arm	415	360	175
Left second arm	480	375	186
Right third arm	234	175	112
Left third arm	380	310	155
Right ventral arm	365	260	126
Left ventral arm	380	270	132
Umbrella between dorsal arms	56	27	21
Umbrella between ventral arms	34	15	13
Hectocotylus	9	2	0.5
Diameter of largest sucker	9	5	3
Length of funnel	40	28	17
Width of mantle opening	38	23	15

Type locality.—Oahu (first locality mentioned), Hawaiian Islands (Wilkes expedition).

Distribution.—Hawaiian Islands: Oahu (Gould); Honolulu Reef, Oahu (*Albatross*); Maui (Gould).

Material examined.—Three specimens, all males, are in the *Albatross* collection. All are in an excellent state of preservation.

No. of specimens.	Locality.	Collector.	Sex.	Author's register.
2	Honolulu Reef, Oahu	Albatross expedition	♂	179
1	Honolulu market	do	♂	382

Remarks.—The above description is drawn throughout from the specimens taken by the *Albatross*, special reference being had to the larger of the two individuals collected on the reef, as the large market specimen did not come into my hands until afterward and has been chiefly utilized in preparing the description of the hectocotylized arm. It will at once be noted that there are several rather astonishing discrepancies between these specimens and Dr. Gould's description. Perhaps the most important of these is the relative length of the arms, which Gould states to be 2, 4, 3, 1, an utterly different formula from that shown by the present material. As the quantitative differences between the arms of the respective pairs seem altogether too great for such variations to be due to inequalities in the methods of preservation, I am at a loss to account for the discrepancy. It is of course possible that an error has crept in somewhere, for the *Albatross* specimens show not the slightest evidence of any abnormality, while Gould's account of the consecutive diminution in bulk of the arms is entirely in accord with the condition I have described, though not at all what would be expected were his statement of their relative order of length correct. It may be that the type specimen was possessed of some unobserved defect, for where the arms are so slender as in the present species a mutilated and regenerating extremity might be readily overlooked were not special care taken to the contrary. The peculiarly definite color pattern is in all the specimens as striking as Gould's careful description would imply and is so utterly unlike that of any other *Polypus* known to me that I think there can be no doubt as to the correctness of the identification.

Granting this correction in the arm formula, it is interesting to note that the resemblance of this species to the *Polypus macropus* (Risso) becomes even more close than Gould supposed and extends even to such structures as the hectocotylus and funnel organ. (Cf. Jatta, 1896, pl. 23, fig. 8.) A comparison with the figures cited shows that the two species are throughout essentially similar in structure and indicates a very close degree of relationship. The geographical distribution of both forms yields additional strong evidence toward the same conclusion and further supports the idea that *P. macropus* is in fact the parent form. Although *ornatus* is thus far known only from the Hawaiian Islands, *macropus* has a remarkably wide and continuous range, extending from the Mediterranean, on the one hand, through the Red Sea and Indian Ocean to the Malay Peninsula and even to Japan, where it is still a hardy and abundant species Small differences between the two are numerous and constant, but perhaps are in no way different from the inevitable changes which should be expected to take place in the island species during the long sojourn which it must have had in so isolated an environment. It is curious that the color pattern and surface ornamentation are the features which have undergone the most extensive modification.

Polypus hoylei Berry 1909 (Pl. XLVII, fig. 1; Pl. XLVIII, fig. 2–4; Pl. LV, fig. 1.)

Polypus hoylei Berry 1909, p. 407, 418, text fig. 1.

Body pouch shaped, rounded, more or less depressed above and below, about as long as broad, widening posteriorly and with an obscure longitudinal groove forming an incipient superficial division of the ventral region into halves. Mantle loose and semigelatinous, very soft to the touch; at

first sight nearly smooth, but upon careful examination revealing a fine regularly granulose papillation, most obscure ventrally. Some examples show indications of low tubercles or cirri on the body, but the only structures of this nature which appear to be at all constant are two soft prominent papilla-like excrescences situated over each eye, one placed just in advance of the eye opening, the other at a slightly greater distance behind this point; when in a state of retraction these eminences are reduced to rounded tubercles having a pore-like pit or indentation at their apex. (Pl. XLVIII, fig. 3.) Mantle opening very small, semicircular, closely embracing the base of the funnel, from which, however, it tends in preserved material to contract away, exposing even the basal folds of the latter. (Pl. XLVII, fig. 1.)

Head large, broad, flattened; separated from the body in the nuchal region by a slight lateral constriction. Eyes large, the integument covering them being usually much puckered about the rather small opening. Funnel large and of robust outline, but short, broad, compressed; broadly adherent above to the head and bound to the latter by loose folds of the integument even as far forward as the basal portion of the umbrella; its extremity is free and reaches a little less than half way to the margin of the latter. Funnel organ well developed and of a very distinctive type; it comprises two narrow but conspicuous V-shaped pads lying on the dorsal inner wall of the funnel cavity, near the tip; they are entirely similar to one another and unconnected. (Text fig. 15, also pl. XLVIII, fig. 4.)

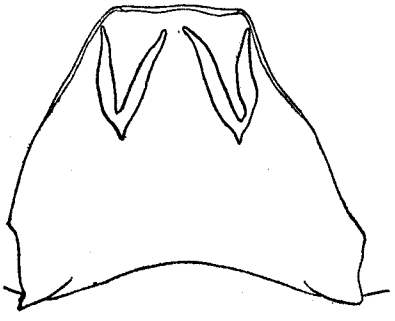

FIG. 15.—*Polypus hoylei* [176], outline drawing of funnel laid open medioventrally to expose the funnel organ, × 2.

Arms quite short for a *Polypus*, only about two to two and one-half times as long as the head and body; stout, rapidly tapering, the extremities little attenuate; dimensions nearly equal, but exhibiting considerable variability, the third pair apt to be slightly the shortest; connected at base by a wide semitransparent membranous umbrella, extending between the arms about equally all round for from one-third to nearly one-half of their length, but usually of slightly less extent ventrally; this interwebbing is continuous with a conspicuous fleshy fold which extends along the outer margins of all the arms to their extremities. Suckers moderately large, numerous, closely set; regularly alternating in two rows, except at the base, where the first three appear in a single row; soft, but well separated; moderately elevated. According to my observations none of the suckers in the male show any appreciable enlargement or other differentiation one from another. (Pl. LV, fig. 1.)

Third right arm in the male notably shorter and stouter than its mate of the opposite side and prominently hectocotylized, the modification affecting only the tip of the arm and the usual sperm canal formed along the edge of the marginal membrane. The organ at the tip is bluntly conical, somewhat spoon shaped, and the broad excavation on its inner face scarcely or not at all ridged; such ridges, if they occur at all in the larger specimen are rendered very obscure by the loose consistency of the integument, and in the smaller male one or two transverse grooves only may be made out. The relative measurements of the hectocotylus are given in the table of measurements below. With age the ligula becomes apparently somewhat more elongate, as in the smaller male it is very short and pyramidal. The sperm canal terminates distally in the usual basal papilla or calamus, which is here acutely conical, with its inner surface deeply grooved. (Pl. XLVIII, fig. 2.)

Color of preserved specimens a brownish red above, slightly paler or more pinkish below and on the inner surface of the umbrella; no definite color pattern or even any mottlings or other ornamentation of the sort. Entire surface closely punctate with small round reddish brown chromatophores, especially on the dorsal aspect, where they are largely distributed in veins or obscure cloudings, the interstices between which appear as pale reticulations or marblings against a darker background, a feature scarcely to be distinguished without carefully and firmly smoothing out the skin by the fingers.

MEASUREMENTS OF POLYPUS HOYLEI.

Author's register	166	176	178	177
Sex	♂ (type.)	♂	?	♀
	mm.	*mm.*	*mm.*	*mm.*
Total length	233	127	108	148
Tip of body to base of umbrella	65	41	41	54
Width of body	45	31	28	26
Width of neck	36	27	26	22
Width of head	41	30	27	24
Length of—				
Right dorsal arm	109+	89	71	91
Left dorsal arm	111+	88	76	49+
Right second arm	[a] 161+	89	76	105
Left second arm	172	82	75	62+
Right third arm	116	75	22+	86+
Left third arm	158	78	66	93
Right ventral arm	104+	85	74	80
Left ventral arm	159	85	75	79
Hectocotylus	6.5	2	.....	.....
Umbrella between dorsal arms	42	30	20	20
Umbrella between ventral arms	41	36	15	17
Diameter of largest sucker	3	2	2	2
Length of funnel	18	17	12	15
Width of mantle opening	22	18	16	16

[a] Through an inadvertence the length of this mutilated arm was given in the original description as that of the second arm pair. In the above table the measurements of all the arms were taken along the inner surface from the mouth to the tip. The umbrella was measured externally.

Type.—Cat. no. 214310 United States National Museum [S. S. B. 166].

Type locality.—Hawaiian Islands (*Albatross*); the exact locality and other data are unknown as this specimen was unfortunately not accompanied by any label when it came into my hands.

Distribution.—Among the Hawaiian Islands, in the archibenthal region (*Albatross*).

SPECIMENS OF POLYPUS HOYLEI EXAMINED.

No. of specimens.	Locality.	Depth in fathoms.	Collector.	Sex.	Where deposited.	Author's register.
[a]1	Hawaiian Islands	?	Albatross	♂	U. S. N. M. Cat. 214310.	166
1	Kaiwi Channel, between Molokai and Oahu.	449-460	Albatross station 4110	?	.....	178
1	Vicinity of Kauai Island	283-309	Albatross station 4130	♂	.....	176
1	.....do	257-312	Albatross station 4132	♀	.....	177

[a] Type.

Remarks.—*P. hoylei* appears to be a characteristic member of the deeper water fauna of this region. Finding no close ally among its neighboring congeners, it is conspicuously characterized by its pale color, soft consistency, unusually small mantle opening, fine surface papillation, short arms, stout hectocotylized arm, and the very unusual shape of the funnel organ. I had originally thought that this species might be a near relative of *P. januarii* (Steenstrup), but a reconsideration of the admirably full description of the latter in the *Challenger* Report has led me to believe that the alliance is not especially close. Both are of deep-water habit and such resemblance as exists between them may well be due to coordination with a similar environment. *P. hoylei* bears a certain resemblance to some of the published figures of *P. sponsalis* (P. and H. Fischer) and one or two similar forms, but it is, I think, sufficiently distinct.

Altogether it is an unusually attractive and interesting species. The specific name is in honor of that master student of cephalopods, Dr. William Evans Hoyle.

[Polypus fontanianus (d'Orbigny 1835).]

Octopus fontanianus d'Orbigny 1835, p. 28, pl. 2, fig. 5.
Octopus fontanianus Tryon 1879, p. 123, pl. 37, fig. 54 (after d'Orbigny).

This species is rather uncertainly listed from the "Sandwich Islands" by Tryon (l. c., p. 124) on the authority of a specimen stated to be in the collection of the Academy of Natural Sciences of Philadelphia. It is a South American species and hence its occurrence in Hawaii needs a confirmation which it is not likely ever to receive.

As the collections before me are unusually rich in immature individuals of this genus, some of which do not seem referable to any of the named species, I have thought it worth while to present a brief description of each of the various types into which as a rule the specimens may be easily separated.

Polypus α (young).

Polypus a Berry 1909, p. 418 (merely listed).

Two juvenile *Polypi* in the *Albatross* collection agree in the following assemblage of characters:

Body relatively large, ovate, saccular; much inflated, especially below; broadest *anteriorly* and terminating in an obtuse point or nipple-like projection behind. Mantle approximately smooth, with no definite papillæ, tubercles, or cirri; mantle opening wide, extending to just below the eyes.

Nuchal constriction prominent, almost furrow-like. Head short, broad, flattened. Eyes inconspicuous, slightly protruding, with very small apertures. Funnel large, but not reaching to the base of the arms; in shape bluntly conical.

Arms long, slender, attenuate; very unequal, the order of length 1, 2, 3, 4; connected at the extreme base by a short, delicate umbrella of nearly equal extent all around. Suckers small, numerous, crowded, in two rows.

Color of preserved specimens everywhere pale, without markings of any kind.

With one of the two specimens mentioned are two much smaller individuals (about 27 mm. long), which may represent an even younger stage of the same species, but they differ from those described in their shorter, more uniform arms, much larger eyes, and more oval body.

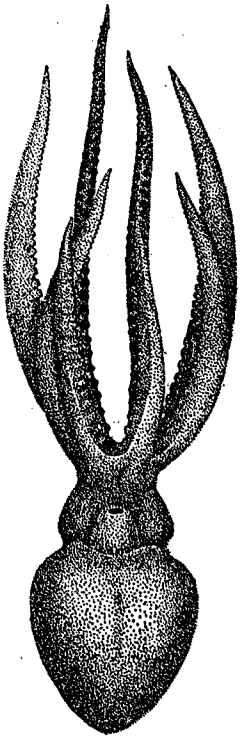

FIG. 16.—*Polypus a* [192], ventral view of immature specimen from station 3843, × 2. Drawn by R. L. Hudson.

MEASUREMENTS OF POLYPUS α.

Number in author's register	191	192	Number in author's register	191	192
	mm.	*mm.*	Length of—	*mm.*	*mm.*
Total length	56	45	Right second arm	34	28
Tip of body to base of dorsal arms	18	15	Left second arm	33	25
Length of body (dorsal)	14	11	Right third arm	29	21
Width of body	11	9	Left third arm	29	22
Width of neck	6.5	6	Right ventral arm	25.5	17
Width of head	8	7	Left ventral arm	25	17
Length of—			Umbrella between dorsal arms	5	3
Right dorsal arm	38	30	Umbrella between ventral arms	4	2
Left dorsal arm	38	25+	Funnel	6	5.5

SPECIMENS OF POLYPUS α EXAMINED.

No. of specimens.	Locality.	Depth.	Collector.	Author's register.
3	Off Diamond Head Light, Oahu	Surface	Albatross station 3921	191
1	Off South coast of Molokai	do	Albatross station 3843	192

Remarks.—The long, graceful arms give this curiously shaped little *Polypus* a most characteristic spidery appearance. As already indicated, the specimens bear all the evidences of immaturity, and I think there is good evidence that they are but the young of *P. ornatus*, the adult of which they resemble in their arm formula and short umbrella. However, as this is not quite certain and they have so unique a facies of their own, it has seemed best to give them provisional consideration by themselves. In recalling the discussion I have given on a preceding page regarding the relationships of *P. ornatus*, it is interesting to note that these young individuals are exceedingly suggestive of the young of *P. macropus* (Risso) as figured by Jatta in his Naples monograph (1896, pl. 24, fig. 2). Should my belief that these are juvenile *ornatus* be correct, another striking bit of evidence of the close affinity of that species with *P. macropus* is afforded.

Polypus β (young). (Pl. XLVIII, fig. 7, 8.)

Polypus β Berry 1909, p. 418 (merely listed).

Body compact, slightly longer than broad, little tapering, squarely rounded posteriorly; flattened above, more inflated below, with a distinct longitudinal sulcus in the middle, and sometimes a curved constriction or groove nearly paralleling the mantle margin and just behind it. Surface almost smooth, but the dorsum very faintly and regularly papillose, especially between the eyes; just above and a little posterior to each eye opening is a small blunt tubercle, with one or two fainter ones sometimes to be distinguished near it. Mantle opening wide, reaching nearly to the eyes.

Head short, broad, compressed, flattened above. Eyes moderately large and prominent. Funnel short, bluntly conical; barely reaching to the base of the arms; broadly adherent above to the head for a large part of its length.

Arms robust, little attenuate; very short, but about half again as long as the head and body; nearly equal, the dorsal pair as a rule slightly the shortest. Umbrella well developed, but only about half as long dorsally as ventrally and attaining its maximum between the arms of the third and fourth pairs, along which it reaches for about one-third of their length; marginal membranes present on the arms as continuations of the umbrella, but much reduced and almost keel-like. Suckers numerous, large, slightly elevated; closely placed, the first two to four in a single row, the remainder alternating and biserial.

Ground color everywhere a brownish buff, rather pale, but closely dotted above with numerous minute slate-colored chromatophores. A double row of very large, irregular, chevron-shaped chromatophores extends from the base along the outer surface of all the arms, but early becomes obscure on the two ventral pairs. In very young individuals (of a length of 12 mm. or less) the ventral surface of the mantle is ornamented by a number of large irregularly ovoid chromatophores arranged in transverse rows, and there is a single very distinct dark-colored series bordering the nuchal constriction. Such specimens are apt to be a little more globose than those further advanced.

MEASUREMENTS OF POLYPUS β.

Author's register	190	196	193	197	Author's register	190	196	193	197
	mm.	*mm.*	*mm.*	*mm.*		*mm.*	*mm.*	*mm.*	*mm.*
Total length	51	36	24	10	Length of—				
Tip of body to base of dorsal arms	19	15	10	6	Left second arm	29	19	13	4
Length of body (dorsal)	15	12	9	5	Right third arm	29	19	14	4
Width of body	12	12	9	3.5	Left third arm	32	21	14	4
Width of neck	11	10	8	3.5	Right ventral arm	31	19	14	4
Width of head	12	11	9	3.5	Left ventral arm	31	19	14	4
Length of—					Umbrella between dorsal arms	5	4	.....	1
Right dorsal arm	28	21	13	3	Umbrella between ventral arms	10	8	.....	2
Left dorsal arm	28	20	13	3	Diameter of largest suckers	1.5	1+	1	.....
Right second arm	29	19	14	4	Diameter of mantle opening	10.5	9	.....	3
					Length of funnel	7	5	.....	.....

Material examined.—Specimens exhibiting essential accord with the above description were very commonly taken by the *Albatross* in surface hauls. In all some 15 individuals are to be recorded.

SPECIMENS OF POLYPUS β EXAMINED.

No. of specimens.	Locality.	Depth.	Collector.	Author's register.
1	Off Lae-o Ka Laau Light, Molokai	Surface	Albatross station 3821	194
1	.....do	.....do	Albatross station 3837	202
2	Off Kalaupapa, Molokai	.....do	Albatross station 3905	200
1	Off Diamond Head, Oahu	.....do	Albatross station 3907	201
1	.....do	.....do	Albatross station 3911	193
1	.....do	.....do	Albatross station 3912	196
2	.....do	.....do	Albatross station 3921	195
1	Honolulu Reef, Oahu	Shore	Albatross expedition	184
1	Between Honolulu and Laysan Island	Surface	Albatross station 3926	199
1	.....do	.....do	Albatross station 3930	190
1	Between Honolulu and Kauai	.....do	Albatross station 3980	198
2	Between Kauai and Oahu	.....do	Albatross station 4011	197

Remarks.—The series of small *Polypi* now under discussion has been the occasion for no little perplexity, especially since it seemed natural to suppose that a species of such apparent abundance ought to be represented in a collection of this size by adults as well, even though I have been utterly unable to bring about such an identification. The more salient characters which separate these specimens, even at a glance, from the other juveniles before me, are the comparative shortness and equality of the arms, the great development of the umbrella, faint papillation, and the prominent chevronlike chromatophores on the arms. It might be safe to propose a new specific name for this form, but in view of the lack of adult material and the unfortunate uncertainty which attaches to *P. hawaiiensis*, it seems the part of wisdom to refrain from adding another name to this already overburdened genus.

Polypus γ (young).

Polypus γ Berry 1909, p. 418 (merely listed).

Several specimens have a different aspect from anything thus far dealt with. The largest of these is the best preserved and may be briefly described as follows:

Body bag-shaped, rather elongate, widest near the middle, without any very prominent ventral groove; length exceeding the width by about one-half. Surface densely papillose above, but nearly smooth below; the papillæ extend thickly over the dorsal aspect of the mantle, head, and umbrella as well as the outer surface of the first two pairs of arms and the dorsal half of the outer surface of the third; they are nearly equal in size, but on the body become longitudinally elongate and appear to be ranked in more or less irregular longitudinal rows, some of them occasionally tending to coalesce to form short

ridges which are usually bilaterally arranged on either side of the body. The most conspicuous of these ridges are two median and two lateral ones, which between them inclose a diamond-shaped space on the dorsum similar to that already described for *P. marmoratus*. There is also a large blunt tubercle above and just behind the center of each eye opening, but this is often so flattened in preserved specimens as to be quite obscure. Mantle opening wide, extending for a little more than half the circumference.

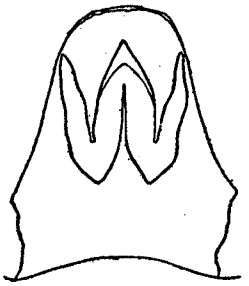

FIG. 17.—*Polypus γ* [180], outline drawing of funnel laid open medioventrally to expose the funnel organ, × 2.

Head large, elevated, rounded, slightly flattened above. Eyes prominent, with rather large openings. Funnel small, conical; aperture narrow. Funnel organ W-shaped (fig. 17).

Arms moderate, about twice as long as the head and body together; connected at the base by a fleshy umbrella which is best developed between the ventral arms, extending between them for about a quarter of their length; subequal, except the dorsal pair, which are a little the shortest, the order of length 3=4=2, 1; marginal membrane well developed. Suckers rather large, elevated, the first two or three in a single line, the remainder placed moderately close together in two alternating rows.

Chromatophores few below; extremely numerous on the dorsal surface where they appear as exceedingly fine dark punctations. Color in alcohol brownish gray, heavily clouded above with a somewhat darker shade. A very dark stripe borders the upper margin of each arm, while a broad triangular area of a pale color just includes the ocular aperture within its apex and is bounded dorsally by a dark wedgeshaped stripe in front of the eye and a similar one just behind, an arrangement which may be roughly represented by the use of a diagram (fig. 18). There are no ocular markings.

The youngest specimen seen (station 3849) differs from that just described in that a few scattered chromatophores are evident on the ventral as well as the dorsal surface, and certain others are evident as two extremely regular rows of distinct round dots extending along the outer surface of each of the four ventral arms; on the arms of the third pair, however, the dorsal row is almost completely hidden by the prevailing dark coloration. In a somewhat larger individual (station 3905) this peculiar arrangement of the chromatophores is still to be made out but has become much more obscure. Both these specimens have a wider head and more globose body than the larger one above described.

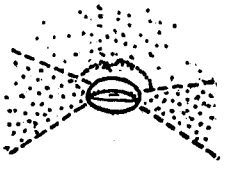

FIG. 18.—*Polypus γ*, diagrammatic representation of color pattern in region of left eye of specimen from Honolulu [180].

Another specimen taken on the reef at Honolulu by Dr. Jenkins is probably the same, the numerous small differences being apparently due to the better preservation of the *Albatross* material. The papillæ are here considerably less prominent so that their arrangement is more difficult to determine, and the umbrella is considerably shorter between the ventral arms than it is above.

MEASUREMENTS OF THREE LARGEST INDIVIDUALS OF POLYPUS γ.

Author's register	180	188	203	Author's register	180	188	203
Sex	♀	♀	♀	Sex	♀	♀	♀
	mm.	*mm.*	*mm.*	Length of—	*mm.*	*mm.*	*mm.*
Total length	143	120	77	Left second arm	92	95	48
Tip of body to base of dorsal arms	46	25	25	Right third arm	94	91	50
Length of body	30	17	18	Left third arm	97	92	47
Width of body	22	17	16	Right ventral arm	93	88	51
Width of neck	17.5	14	13	Left ventral arm	96	90	52
Width of head	20	17	14	Umbrella between dorsal arms	16	18	6
Length of—				Umbrella between ventral arms	22	15	12
Right dorsal arm	87	84	31	Diameter of largest suckers	3.5	3	2
Left dorsal arm	57+	82	40	Diameter of mantle opening	16.5	13	11.5
Right second arm	95	90	51	Length of funnel	13	11	11

SPECIMENS OF POLYPUS γ EXAMINED.

Number of specimens.	Locality.	Depth.	Collector.	Sex.	Where deposited.	Author's register.
1	Honolulu, Oahu	Shore	Wood 1898	♀	Stanford Univ. Coll., Cat. 2091.	180
? 1	Honolulu Reef, Oahu	...do	O. P. Jenkins	♀	Stanford Univ. Coll., Cat. 2092.	188
1	Off Kaluapapa, Molokai	Surface	Albatross station 3905	♀	U. S. Nat. Mus., Cat. 214384.	203
1	Off Lae-o Ka Laau, Molokai	...do	Albatross station 3849	♀	Not preserved	172

Remarks.—These specimens are obviously not the young of either *Polypus ornatus* or *P. hoylei.* In some respects they approach *P. marmoratus*, but differ decidedly in coloration, in shape, the absence of ocular markings, and the double row of small chromatophores on the ventral arms of the very young. The funnel organ also appears to be a little different, being narrower and more deeply cleft in the median line. Were it not for the papillated surface and the cirri over the eyes, a relationship with *P. hawaiiensis* might be suggested, but even here these are not the only difficulties. The most conspicuous features of possibly diagnostic importance in addition to those just noted are the short dorsal arms, the subequal dimensions of the remainder, the elongate body, and the relative shortness of the umbrella dorsally. Some of the specimens have a superficial resemblance to *Scaeurgus patagiatus* in a general way, but of course lack the marginal fold and other distinguishing features. As in the latter species, the body is remarkable for its compactness and solid consistency in alcohol.

Polypus δ (young).

A single badly mutilated *Polypus* taken on the reef at Honolulu by Dr. O. P. Jenkins and now in the Stanford University collections does not seem clearly identifiable with any of the other forms which have been discussed. It is chiefly characterized by its small ovoid body, smooth save for a few small isolated papillæ; broad head; protruding eyes, ornamented above by two or three minute cirri; the very scanty umbrella, which is much shorter than in any other Hawaiian *Polypus*, not even excepting *P. ornatus;* short dorsal arms, and the extremely stout and long arms of the third and fourth pairs. The arms of the second pair are both mutilated, but with this exception the order of relative length is 3=4.1. The suckers are fairly large, very numerous, and close set. The color is cloudy black above, pale beneath.

In some respects this specimen recalls *P. ornatus*, but in most ways the aspect is notably different. It is No. 186 of the author's register.

MEASUREMENTS OF POLYPUS δ.

	mm.
Total length	162
Tip of body to base of dorsal arms	22
Length of body	15
Width of body	14
Width of neck	10
Width of head	12
Length of—	
Right dorsal arm	17+
Left dorsal arm	71
Right second arm	17+
Length of—	
Left second arm	32+
Right third arm	37+
Left third arm	137
Right ventral arm	133
Left ventral arm	140
Umbrella between dorsal arms	5
Umbrella between ventral arms	9
Diameter of largest suckers	3
Diameter of mantle opening	9.5
Length of funnel	9

Polypus ε (young).

Polypus ornatus (pars) Berry, 1909, p. 418 (locality record only).

Two small *Polypi* taken from a depth of 53–230 fathoms, *Albatross* station 4002, vicinity of Kauai Island, constitute catalogue no. 214,383 of the United States National Museum (S. S. B. 182). They agree in the following characters:

Body small, globose, elevated dorsally; surface obscurely and distantly papillose. Head short and very broad; well separated from the body by a rather deep constriction. Eyes prominent, the aperture to each surmounted by a small conical cirrus and surrounded by a number of more or less distinct smaller papillæ. Funnel of moderate length and width, not quite reaching to the base of the arms.

Arms attenuate; fairly stout, but in appearance slender owing to their great length; in preserved specimens often much tangled and twisted; decidedly unequal, the order of length being 3, 4=2, 1; the third pair vastly the stoutest, largest, and longest, attaining a length of over six times that of the head and body. Suckers small, elevated, little flattened; numerous and closely crowded in each row, but the two rows themselves placed quite distantly from one another along the margins of the arm, the inner surface of which between them is broad and flattened. The first four or five suckers appear in a single row, but distal to these the biserial condition prevails. Umbrella of moderate width, but thin; continuing along the outer edge of each arm to its extremity as a delicate contractile membrane.

Ground color of preserved specimens dull buff, heavily mottled above with dark brown, which, except for a very irregular blotch or spot on either side of the body, does not appear to be distributed with any special regularity. The outer aspect of the arms is mottled and reticulated. Chromatophores small and numerous.

MEASUREMENTS OF POLYPUS ε.

	mm.		mm.
Total length	88	Length of—	
Tip of body to base of dorsal arms	12	Right second arm	52
Length of body	7·5	Left second arm	53
Width of body	9	Right third arm	59+
Width of neck	6	Left third arm	76
Width of head	8	Right ventral arm	57
Length of—		Left ventral arm	52
Right dorsal arm	37	Umbrella between dorsal arms	4
Left dorsal arm	37	Umbrella between ventral arms	6
		Funnel	5

Remarks.—Upon the first hasty glance these specimens were thought to be young *P. ornatus* and they were originally so reported. Further study has, however, persuaded me that they represent not that species but some other form, the adult stage of which has not yet been obtained. The most distinctive features are the mottled coloration, the extraordinary development of the third arm pair, the wide separation of the two rows of suckers, and the small size of the latter.

Polypus species?

A single specimen obtained by the *Albatross* party from a fish market in Honolulu is represented only by the body and part of the head. It is too mangled for safe determination [S. S. B. 331].

Genus SCÆURGUS Troschel 1857.

Scæurgus Troschel 1857, p. 51.
Scæurgus Troschel 1858, p. 298.
Scæurgus Jatta 1896, p. 53, 230.

Animal very similar to that of *Polypus*, but in the male the third arm of the *left* side is hectocotylized

Type.—*Scæurgus titanotus* Troschel 1857 (first species named), a Mediterranean species.

Scæurgus patagiatus Berry 1913. (Pl. XLVII, fig. 2, 3; pl. XLVIII, fig. 1.)

Scaeurgus, sp. Berry 1909, p. 418 (locality record only).
Scaeurgus patagiatus Berry 1913, p. 564.

Body short, rounded, firm, compact, nearly or quite as broad as long; widest anteriorly or near the middle, evenly rounded behind; much flattened ventrally, with a conspicuous median longitudinal groove; dorsum arched; sides rounded, often flattened or sunken above the periphery in preserved material giving an angular appearance. Mantle opening wide, reaching a little more than halfway between the funnel and eye. Surface (except on the funnel and ventral aspect of the head and arms) everywhere thickly covered with small distinct rounded papillæ or tubercles; on the ventral surface of the mantle they are in the main separate and irregularly but evenly distributed; on the dorsal surface they have a tendency to run together and arrange themselves in more or less irregular longitudinal series, occasionally forming short low ridges similar to those which have been remarked in *Polypus marmoratus*. These ridges also recall those of *P. marmoratus* in their position and frequent bilateral symmetry; four of them form the usual quadrilateral on the dorsum, besides various others more laterally situated. A conspicuous series of similar but less obscure ridges begins a short distance from the base of the arms (affecting all of them except the ventral pair), and extends along their outer surfaces, reaching its maximum on the third pair, where it results in a nearly continuous fold. A narrow keel-like ridge or fold bounds the periphery of the body from a point on either side opposite the base of the funnel nearly to the posterior; in the gap where the resulting lateral folds are discontinuous on the extreme posterior point of the body is a large soft vertical papilla of elongate-conical shape. A large warted or branched papilla is situated obliquely above and behind each eye, with a smaller one just in front and directly over the eye opening.

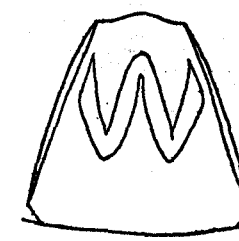

FIG. 19.—*Scæurgus patagiatus* [205], outline drawing of funnel laid open medio-ventrally to expose the funnel organ, female, × 2.

Head broad, but considerably narrower than the body, from which it is separated by a decided but variable constriction; short, rather small. Eyes large and prominent. Funnel large, conical; broadly adherent above to the head for over half its length, the free extremity reaching about halfway to the umbrella margin. Funnel organ well developed as a broad W-shaped band centering on the dorsal wall of the interior cavity anterior to its center (fig. 19).

Arms robust, squarish, rapidly tapering; of moderate length, but over twice that of the body and head taken together; subequal, the second pair usually a very little the longest. Umbrella well developed, especially between the dorsal arms, where it reaches for nearly one-fourth of their total length; it is continued along the outer margin of each arm to the extremity as a narrow contractile webbing; this membrane appears on both dorsal and ventral angles of the arm, but is invariably widest and most persistent ventrally. Suckers numerous and fairly large; the first two to four in a single row, the remainder quite closely ranked in a double series. In the male one of the suckers on each third arm opposite the margin of the umbrella is obviously larger than the rest.

Third left arm in male a little shorter than its mate of the opposite side and prominently hectocotylized; the conspicuous and ample sperm canal in the margin of the ventral membrane terminates in a long slender acutely conical *calamus*, over one-half as long as the entire hectocotylus; *ligula copulatoria* spoon shaped, its inner surface deeply excavated, nearly smooth, and protected by the heavily incurved margin, which may almost completely inclose the cavity. (Pl. XLVII, fig. 3; pl. XLVIII, fig. 1.)

Color of alcoholic specimens, in general a pale brownish buff, clouded or lightly marbled above with a light chocolate of somewhat varying intensity. Chromatophores small and very numerous, indistinguishable ventrally. Specimens preserved in formalin lose every vestige of pigmentation.

The following notes in regard to the color of this beautiful species during life appear on the reverse of the station label accompanying the type specimen, in the handwriting of Dr. W. K. Fisher: "Ventral surface of body opalescent blue and pink. Light emerald green about eyes. Reddish brown chromatophores on dorsum and sepia ones over eyes. General color of animal when chromatophores are contracted is very pale green."

MEASUREMENTS OF SCÆURGUS PATAGIATUS.

Number in author's register	204 type.	207	208	205	207	206	207
Sex	♂	♀	♀	♀	♀	♂	♂
	mm.	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
Total length	152	136	130	104	97	63	60
Tip of body to base of dorsal arms	46	40	40	31	27	21	23
Length of body	34	31	30	22	20	14	13
Width of body	31	31	28	26	19	15	14
Width of neck	20	20	21	18	13	12	11
Width of head	24	20	22	19	13	13.5	12.5
Length of—							
Right dorsal arm	103	92	87	71	59	40	37
Left dorsal arm	91	93	82+	73	60	40	36
Right second arm	106	93	90	73	59	42	37
Left second arm	100+	96	87	72	52+	30+	36
Right third arm	105	90	88	68	58	42	34
Left third arm	90	89	89	70	55	38	33
Right ventral arm	100	86	84	68	53	40	36
Left ventral arm	100	88	87	69	57	27+	35
Hectocotylus	8	.....	.....	.....	.....	.....	.75
Umbrella between dorsal arms	26	25	22	19	16	12	10
Umbrella between ventral arms	13	11	18	13	12	8	8
Diameter of large sucker	4	3	3	2	1.5	1	.....
Diameter of mantle opening	17	18	20	16	11.5	10	9.5
Length of funnel	20	13	15	14	10	10	8

Type.—Catalogue No. 214379 United States National Museum [S. S. B. 204].

Type locality.—*Albatross* station 4079, 143–178 fathoms, bottom of gray sand and foraminifera, off Puniawa Point, Maui, July 22, 1902; one adult male.

Distribution.—Among the Hawaiian Islands in depths of 125 to 165 fathoms as follows: Off Puniawa Point, Maui (*Albatross*); Pailolo Channel (*Albatross*); vicinity of Laysan Island (*Albatross*).

SPECIMENS OF SCÆURGUS PATAGIATUS EXAMINED.

No. of specimens.	Locality.	Depth in fathoms.	Collector.	Sex.	Where deposited.	Author's register.
1	Pailolo Channel	127	Albatross station 3856	♀	.....	205
1	.....do	128–138	Albatross station 3858	♂	.....	206
3	.....do	132–141	Albatross station 4103	♂ 2 ♀	.....	207
1	Off Puniawa Point, Maui	143–178	Albatross station 4079	♂	U. S. Nat. Mus., Cat. 214379	204
[a] 1	Vicinity of Laysan Island	148–163	Albatross station 3938	♀	.....	208

[a] Type.

Remarks.—This superb species is the first representative of the circumscript genus *Scæurgus* to be noted from outside the Mediterranean and the immediately adjacent waters of the Atlantic, so that its occurrence as a common species in the Hawaiian Islands occasioned no little surprise. Not only does the present form belong unmistakably to this genus, but it presents so close an approximation to one of the Mediterranean species—*S. unicirrus* (delle Chiaje)—that the separation of the two has only been accomplished by attention to very small details. I have unfortunately not been able to see any actual specimens of *S. unicirrus*, but to judge from the figures given by Jatta (1896, p. 234, pl. 3, fig. 2; pl. 25, figs. 14–22; pl. 26, figs. 1–3) the body of the latter species is a little more elongate; the funnel organ is somewhat different in shape; and the ornamentation of the integument shows certain dissimilarities, notably in that no ridgelike folds are shown to occur on the dorsum and arms, although indications of such a fold on the third arms of the example figured on plate 26, figure 2, suggests the possibility that their absence in the other figures may be due to insufficient representation. The Hawaiian form also appears

to be slightly the superior in size. The widely separated habitat of the two leads one to believe that as both species become better known numerous other differences will undoubtedly be discovered to exist between them.

Dr. Fisher informs me that when living the animal is an object of great beauty, the sheen of its delicate opalescence approaching that of mother-of-pearl. If it is so common a species in this region, it seems rather remarkable that no member of the genus has been brought to light from any other part of the Pacific.

LARVAL OCTOPOD.

There is a very curious but undetermined larval octopod in the *Albatross* collection from station 3802, 150 fathoms, between the Erben Bank and Kaiwi Channel [S. S. B. 386].

Suborder DECAPODA Leach 1817.

Sephinia Rafinesque 1815, p. 139 (*fide* Binney and Tryon, p. 1).
Decapoda Leach 1817 (*fide* Gray).
Decacera de Blainville 1824 (*fide* Verrill).
Decacera de Blainville 1825, p. 366.
Decapoda d'Orbigny 1845, p. 236.
Decapoda Gray 1847, p. 205.
Sephinia Gray 1849, p. 2, 35.
Decapoda H. and A. Adams 1853, vol. 1, p. 25.
Decapoda Keferstein 1866, p. 1438.
Decacera Verrill 1881, p. 426.

Arms normally 10 in number; the fourth pair originating in special pouches into which they may be more or less completely retractile, and greatly modified to function as highly specialized prehensile organs. Suckers distinctly pedunculate; their apertures equipped with horny or chitinous rings, which may be perfectly smooth, more or less dentate, or with the upper margin greatly enlarged and produced into a long incurved hook. Body short to elongate, rounded or pointed posteriorly, and always with well developed terminal or lateral fins. Head and mantle sometimes continuous in the nuchal region, but more often free and with a cartilaginous articulation. Gladius calcareous or horny; rarely absent; in one genus (*Spirula*) there is an internal coiled and chambered shell. Wherever hectocotylization occurs one or both of either the dorsal or ventral arms undergo the modification.

Highly specialized photogenic organs of many types are of frequent occurrence.

Division MYOPSIDA (d'Orbigny 1845).

Decapoda Myopsidæ d'Orbigny 1845, p. 237.
Myopsidæ Keferstein 1866, p. 1441.
Myopsidæ Verrill 1881, p. 432.
Myopsida Hoyle 1886, p. 16, 110.
Myopsida Pfeffer 1908, p. 15, 24.

Eyes almost invariably covered by a continuous imperforate membrane or foldlike lid. Horny rings of suckers either smooth or dentate, but never falciform.

There are also numerous important visceral characters such as the symmetrically bipartite liver, genital artery springing directly from the heart, etc.

Family LOLIGINIDÆ (d'Orbigny 1845 em.).

Loligidæ d'Orbigny 1845, p. 318.
Loligidæ Gray 1849, p. 36, 66.
Loliginidæ H. and A. Adams 1853, vol. 1, p. 35.
Loliginidæ Verrill 1881, p. 433.
Loliginidæ Pfeffer 1908, p. 24.
Loliginidæ Naef 1912, p. 243; 1912a, p. 741.

Body elongated and cylindric or cylindro-conical. Mantle free from head in the nuchal region but with a cartilaginous articulation. Eyes without lid-folds, the lens uninterruptedly covered by the outer skin. Fins rhombic to sagittate and terminal, or nearly as long as the mantle and marginal; more

or less acute posteriorly. Left ventral arm of male hectocotylized. Tentacle club with four rows of suckers on the median portion. Horny rings of the suckers usually toothed. Funnel supported dorsally by free muscular bridles; its aperture with a large internal valve. Shell a horny, uncalcified, feather-shaped gladius, comprising a thickened midrib and broad lateral wings.

Genus SEPIOTEUTHIS de Blainville 1824.

Sepioteuthis de Blainville 1824 (*fide* Hoyle).
Sepioteuthis d'Orbigny 1845, p. 319.
Sepioteuthis Wülker 1913, p. 460.

Fins very elongate and marginal, bordering the mantle for nearly or quite its entire length. The outline of the entire animal thus becomes elongate-oval, oval, or elliptical.

Type.—*Sepioteuthis sepiacea* de Blainville 1824 (*fide* Hoyle)=*S. sepioidea* (de Blainville 1823), a species of the West Indian region.

Sepioteuthis arctipinnis Gould 1852.[a] (Pl. LIV, fig. 1.)

Sepioteuthis arctipinnis Gould 1852, p. 479, fig. 93.
Sepioteuthis arctipinnis Tryon 1879, p. 152, pl. 62, fig. 211 (after Gould).
Sepioteuthis arctipinnis Berry 1909, p. 418 (merely listed).
Sepioteuthis arctipinnis Wülker 1913, p. 452, 475, 482.

Adult of moderately large size. Body massive, elongate-conical, compressed dorso-ventrally, tapering to a blunt point behind. Mantle very thick and heavy, its anterior margin free, produced forward to a very obtuse and evenly rounded point in the nuchal region; broadly emarginate below the funnel, the emargination bounded by rather acute prominent angles. Fins enormous; attached along the mantle for almost its entire length; widest at about the posterior third, thence gradually tapering anteriorly but ending rather abruptly just before reaching the mantle margin; posteriorly they narrow very rapidly, being not quite continuous around the hinder tip of the body; each fin at its widest point about three-fourths as wide as the body at the same point; thick at base, but with quite thin margins. Entire outline of body, including fins, a very regular ellipse, anteriorly truncate, smoothly curved behind, and broadest at the posterior third as indicated. Cartilaginous articulations of head and mantle as usual in the genus; large and very prominent.

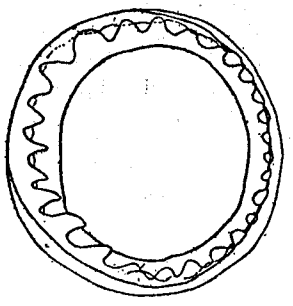

FIG. 20.—*Sepioteuthis arctipinnis* [42], horny ring of sucker from third arm, camera outline, × 12.

Head squarish, of moderate size. Eyes large and prominent; in front of the orbit a pore; behind it the integument is raised into a conspicuous bilobate angled crest, somewhat excavated in front, and with the "olfactory pore" shel-

a The original description of this species is as follows:

"Body elongated, ovate lanceolate, tapering gradually backwards to a blunt point. Fins broadest at about the posterior fourth, where, together, they equal the width of the body, thence tapering in each direction gradually, and without any angle or dilatation. Color dark purple brown above, paler beneath, everywhere finely punctate with dark brown dots. Head narrower than the body, longer than broad. Sessile arms rather short and stout, armed with two rows of cupules; the superior pair shorter than the head; the first lateral pair a third longer than the superior, and somewhat longer than the head; the second lateral pair a little longer than the first; the inferior pair nearly equal to the second lateral; tentacular arms nearly as long as the body, compressed, the distal third having a lanceolate dilatation, bearing four rows of delicately pedunculated cupules, armed at the margin with delicate black crochets. Mouth large, lip folded and projecting, with two or three minute cupules at each fold.

"Length of body, six inches; of head, two inches; of superior arms, two and a half inches; of inferior lateral arms, three inches; of tentacular arms, eight inches; of cup-bearing portion, two and three-fourths inches; greatest width, two and a half inches.

"From the island of Maui, Sandwich Islands.

"It closely resembles *S. loliginiformis*, D'Orb., from the Red Sea, which has a much more decided expansion of the fins at its posterior half, and the tentacular arms are much shorter. The narrow and regularly tapering fin is its distinguishing character. Described from specimens in spirits." (Gould 1852, p. 479.)

tered within the bay of the ventral angle.[a] Funnel very large; broad at the base and tapering bluntly to the wide-valved aperture. Funnel organ enormous, comprising a very large deeply bilobate pad occupying most of the posterior two-thirds of the dorsal wall of the funnel, and a pair of much shorter bean-shaped ventro-lateral pads.

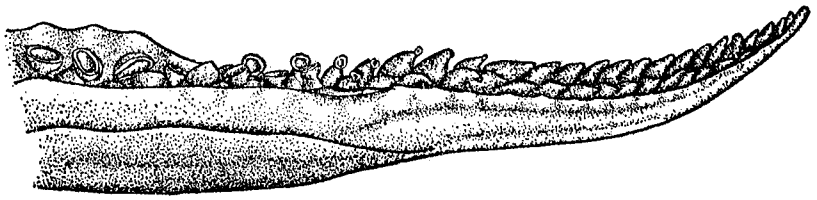

FIG. 21.—*Sepioteuthis arctipinnis* [45], hectocotylized portion of left ventral arm of male, × 3.

Arms of moderate length, stout, squarish, unequal, the order of length 3, 4, 2, 1. All the arms are outwardly keeled and have a broad trabeculated marginal membrane bordering the sucker-bearing area, this membrane reaches its maximum on the central portion of the third arms and is least developed on the ventral pair. Both outer margins of the ventral arms conspicuously keeled, the dorsal keel developed as a broad thickened membrane ensheathing the base of the tentacle. Suckers large, regularly alternating in two rows; the horny rings of the largest armed with 25 to 26 stout acute teeth (fig. 20).

The hectocotylization is as usual in the genus; for about 19 pairs the suckers of both rows are normal; at this point on the left ventral arm the cups become suddenly reduced (although persisting to about the twenty-second pair) and the pedicels correspondingly enlarged; the latter continue as stout conical papillæ to the tip of the arm, those of the dorsal row being considerably larger than their ventral companions (fig. 21).

Tentacles of variable length, laterally compressed; both outer and inner faces subcarinate at the base, the inner becoming flattened and transversely striate distally; on the distal half of the club the outer carina becomes expanded to form a heavy fleshy keel. Club large, expanded; its margins bordered by a crenulate membrane strengthened by rather flattened and illy-defined transverse trabeculæ. Suckers crowded, in four rows; largest at about the middle, especially those of the two central rows, diminishing toward either end; distally all the suckers become very minute, those of the ventral row becoming the largest, of the dorsal smallest; horny ring of a large median sucker armed with 17 to 19 strongly incurved teeth.

Buccal membrane 7-lobed, the lobes pointed and bearing a few very minute suckers near their tips.

Gladius lanceolate; with a heavy midrib and distinct submarginal thickenings (fig. 22).

FIG. 22.—*Sepioteuthis arctipinnis* [45], dorsal aspect of gladius of male from Honolulu, × ½.

Color of preserved specimens a brownish buff everywhere beneath the large slate-colored chromatophores. The latter very variable in size; very numerous and much run together dorsally, fewer and more scattered on the ventral aspect; absent from the ventral surfaces of the fins.

[a] My previously published account of this structure in *S. lessoniana* (1912b, p. 402) is ambiguous and very misleading respecting the position of the olfactory pore. The pore is not really dorsal in position, but sheltered within the ventral lobe of the crest as stated above.

MEASUREMENTS OF SEPIOTEUTHIS ARCTIPINNIS.

Number in author's register	45	42	Number in author's register	45	42
Sex	♂	♀	Sex	♂	♀
	mm.	*mm.*	Length of—	*mm.*	*mm.*
Length of mantle (dorsal)	187	163	Third arm	87	81
Width of mantle anteriorly	54	55	Ventral arm	73	77
Width across fins at widest point	120	90	Hectocotylized portion	23	.....
Width of fin at widest point (ventral)	38	25	Tentacle	.....	184
Width of head	41	38	Tentacle club	.....	60
Length of—			Diameter of largest suckers on tentacle	3	4
Dorsal arm	58	48	Diameter of largest suckers on third arms	3	3
Second arm	71	72			

Type locality.—Island of Maui (Gould).

Distribution.—Honolulu, Oahu (*Albatross*, Jenkins, et al.); Maui (Gould); Bertrand Id., north coast of Papua ? (Wülker).

SPECIMENS OF SEPIOTEUTHIS ARCTIPINNIS EXAMINED.

No. of specimens.	Locality.	Collector.	Sex.	Where deposited.	Author's register.
1	Honolulu, Oahu	Jordan & Evermann	♂	Stanford Univ. Coll., Cat. 2098	45
1	.....do	Brandt	♀	Stanford Univ. Coll., Cat. 2099	44
1	Honolulu Reef	O. P. Jenkins	Juv.	Stanford Univ. Coll., Cat. 2100	43
1	Honolulu Market	Albatross expedition	♂	U. S. Nat. Mus	42

Remarks.—The large male from Honolulu, which is the subject of the major portion of the preceding paragraphs, shows certain differences from the description of Gould. Its fins are proportionately wider (the two taken together considerably more than equaling the body in width at their widest point), and the ventral arms are longer, considerably exceeding the head in length. These divergencies do not seem important, however, and on the whole the specimens indicate that *S. arctipinnis* is probably to be regarded as a good species, even though not a very strongly differentiated one.

As compared with male specimens of a near ally, *S. lessoniana* Férussac, from Wakanoura, Japan, the following differences are presented: The animal is smaller, the body a little more slender, more regularly tapering, and the posterior extremity somewhat more acute. The fins do not extend quite so far forward, they do not possess so symmetrically curving an outline, and the point of their widest expansion is at the posterior third instead of at near the middle. The "olfactory crest" is less developed and its lobes angled rather than rounded. The minutiæ of the hectocotylized arm are slightly different, although this may be due to the method of preservation. Lastly, the suckers of the sessile arms have a decidely fewer number of teeth on their horny rings; the variance between the horny rings of the tentacular suckers is very slight but in the same direction. The marginal thickenings of the gladius are also worthy of note, but these have already been called to attention by Tryon. On the whole the relationship between the species is exceedingly close, but so far as my material goes the two may be readily separated by means of the characters noted.

This is another important edible form.

Genus LOLIGO Schneider 1784.

Loligo Schneider 1784, p. 110.
Loligo Lamarck 1798 (*fide* Hoyle); 1799, p. 11 (*fide* Jatta).
Loligo Verrill 1881, p. 307.

Body elongate, tapering posteriorly. Fins terminal; rhomboidal in the young, in the adult more or less sagittate.

Type.—*Sepia Loligo* Linné 1758. As in the case of *Polypus*, Schneider mentions no type or other species, but the clear inference is that *Sepia loligo* Linné was what he had in mind, a conclusion supported by the fact that this was the only species of true *Loligo* which was at that time possessed of a binomial name. Because of the great uncertainty attaching to Linné's species, Hoyle considers *L. vulgaris* Lamarck 1798 to be the type of Schneider's genus as it is that of Lamarck.

[Loligo gahi d'Orbigny 1835.]

Loligo gahi d'Orbigny 1835, p. 60, pl. 3, fig. 1–2.
Loligo Gahi Tryon 1879, p. 144.

Tryon gives us an alleged record of this species from the Hawaiian Islands in the following words: "Specimens in Mus. Phila. Acad., said to come from the Sandwich Islands, agree well in the dentition of the rings with this species." As this is a characteristic Peruvian and Chilean species there is no doubt that the citation is an error.

Strangely enough the above is the only record I have been able to find of the presence of any member of the cosmopolitan genus *Loligo* in Hawaiian waters, and I am unable even with the aid of the large collection now in hand to affirm its occurrence there.

Family SEPIOLIDÆ Keferstein 1866.

Sepiolini Steenstrup 1861 (*fide* Hoyle).
Sepiolidæ Keferstein 1866, p. 1443.
Sepiolidæ Verrill 1881, p. 347, 416.
Sepiolidæ Joubin 1902, p. 80, etc.
Sepiolidæ Pfeffer 1908, p. 24, 31.
Sepiolidæ Naef 1912, p. 243, 244.

Body short, thick, rounded posteriorly. Fins large, separate, ovate or rounded, attached laterally near the middle of the body. Eyes with a thickened ventral fold or false lid, and sometimes a dorsal fold as well. Median septum of mantle cavity reenforced by a pallial retractor muscle joining the mantle to the body. Internal shell a very rudimentary uncalcified gladius, often entirely absent. Eggs large and few. A photogenic gland is often present in the pallial cavity overlying the ink sac; from it a luminescent secretion is emitted.

Subfamily SEPIOLINÆ Naef 1912.

Sepiolini Appellöf 1898, p. 623.
Sepiolinæ Naef 1912, p. 246, 247.

Mantle margin united with head in nuchal region by a band-like commissure. Left dorsal arm hectocotylized. Photogenic glands often absent; when present of elongate form, well separated, and more or less lateral in position.

Genus EUPRYMNA Steenstrup 1887.

Euprymna Steenstrup 1887, p. 66.
Euprymna Steenstrup 1887a, p. 88–90 (42–44).
Euprymna Hoyle 1904, p. 24.
Euprymna Wülker 1910, p. 9, 26, etc.
Euprymna Naef 1912, p. 247.

Suckers of sessile arms in four rows, except at tip and extreme base; on tentacle club long stalked, very minute, urceolate, and in very numerous (more than 16) rows. Nuchal commissure over one-third as broad as the body. Left dorsal arm of male hectocotylized, the distal suckers closely palisaded together and of very characteristic structure; the remaining arms differ from those of the female in the possession of certain peculiarly enlarged suckers. Large elongate photogenic glands present. Gladius wanting.

Type.—*Inioteuthis Morsei* Verrill 1881 (species first mentioned), a common Japanese species.

Euprymna scolopes Berry 1913. (Pl. XLIX, fig. 5–8, text fig. 23–26.)

Euprymna morsei Berry 1909, p. 418 (locality record only), *not* of Verrill.
Euprymna scolopes Berry 1913, p. 564.

Animal small, sepioliform. Body short, thick, rounded; the transverse diameter usually equal to about two-thirds to four-fifths of the length, but the entire outline and proportions very variable. Fins large, semicircular; attached with a considerable degree of obliquity a little in advance of the middle of the body; broadest posteriorly; anterior lobe conspicuous and abruptly notched at its inward margin, so that the fin is actually attached along only about the posterior two-thirds of its length. Mantle united with the head in the nuchal region by a broad commissure, so that the pallial aperture extends but a very small distance past the eyeball, which it partially encompasses posteriorly. Ventrally the mantle margin is sinuous and somewhat produced forward on either side of the funnel, though with a more or less conspicuous emargination just beneath the latter.

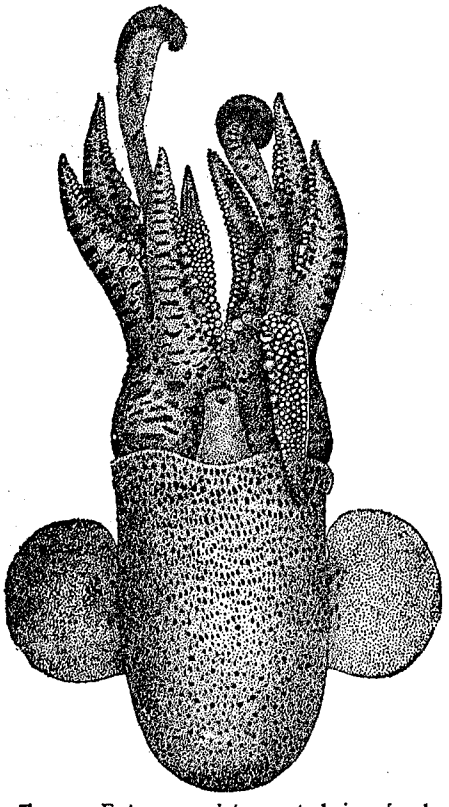

FIG. 23.—*Euprymna scolopes*, ventral view of male [320] type, × 1½. Drawn by R. L. Hudson.

Head somewhat broader than long, its transverse diameter usually a little less than that of the mantle, but sometimes slightly exceeding it; broadly flattened above, somewhat hollowed out below for the accommodation of the funnel. Eyes somewhat swollen, large and prominent. Funnel elongate conical; the extremity nearly cylindrical, with thick walls, and a small apical aperture; tip nearly or quite attaining the base of the ventral arms; interior walls of tip minutely striate longitudinally; the minute spoon-shaped valve is situated on the dorsal wall just back of the striated area and is succeeded posteriorly by a region of strong transverse striation. Funnel organ posterior in position and very similar to that of *E. morsei* (see Berry 1912b, p. 409).

Arms rather short, stout; usually as long as or a little longer than the mantle; unequal, the brachial formula consistently 2, 3, 4, 1, although the dorsal arms are only a little shorter than the ventral; outer surfaces of ventral arms rounded, the others all furnished with a delicate colorless carina or fold of membrane, best developed on the third arms, but sometimes obscure even there. Umbrella rudimentary or lacking (in some specimens) between the dorsal arms as well as those of the ventral pair; better developed between the dorsal and second arms and between these and the third pair; between each third arm and its ventral companion it forms the usual broad sheath inclosing the base of the tentacle. Suckers on all the arms in two rows at the extreme base, but the succeeding pairs soon undergo an alternate lateral displacement, resulting in a four-rowed condition, which prevails practically to the extremities of the arms; pedicels stout, conical; cups spherical, with small apertures, and easily lost through abrasion; horny rings of larger suckers (at least in the female) smooth.

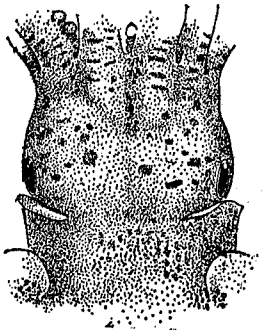

FIG. 24.—*Euprymna scolopes*, dorsal view of head of male [320], × 1½ Drawn by R. L. Hudson.

In the female the suckers of the various arms are relatively minute and of subequal size at homologus regions of the arms, but in the male a number of important modifications occur. In specimens of the latter sex the left dorsal arm is conspicuously hectocotylized; the first four pairs of suckers at the base

are in two rows; at the point where the 4-rowed condition commences the ventral series contains two (sometimes apparently only one) modified papillæ, usually differentiated from the ordinary sucker pedicels, with which they are undoubtedly homologus, by their more slender shape and oblique position. Distal to this point occur about 10 quartets of small globular suckers similar to those of the female, except that those of the dorsal row are a little the largest. Beyond its basal third the arm becomes much swollen, while the suckers of the two ventral rows suddenly give place to a compactly crowded, rather irregular series of massive transversely elongate and compressed papillæ, bearing a mouth-like aperture in place of a true sucker at their inner apex, and continuing in constantly diminishing size to the tip. The suckers of the two dorsal rows continue normally for two or three pairs farther than the ventral, when they too undergo modification, appearing as a crowded alternating double series of swollen tubercles, their pedicels not transversely compressed nor so closely palisaded as those of the ventral papillæ. As in the case of the latter, the suckers themselves are reduced to mere lip-like slits at the apices. In all cases these apertures appear to be guarded by a highly modified very minutely toothed horny ring. Except in minute details, the whole structure is thus seen to offer a close parallel to that which has been described for *E. morsei*.

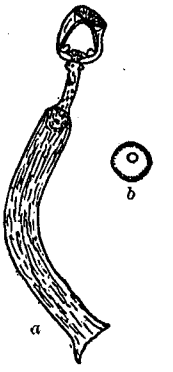

FIG. 25.—*Euprymna scolopes: a*, sucker from tentacle club [323], from a mount in balsam, greatly enlarged; *b*, oral aspect of horny ring from same, same scale.

The right dorsal arm is more slender than the left and approaches more closely than any of the other arms to the condition observed in the female; all the suckers crowded, minute, but those of the median rows rather the more so; the suckers of the ventral row in their turn slightly smaller than those of the dorsal series. On the arms of the second pair the suckers of the outer rows are larger than those of the inner; about six of the basal suckers of the dorsal row are notably larger than the remaining members of the series; in the ventral row about eight suckers along the distal two-thirds of the arm are greatly enlarged (though not to such an extent as in *E. morsei*) and occur in alternation with other suckers of the same row having scarcely a third the diameter. The third arms likewise have their marginal suckers larger than the inner, 8 to 10 alternating suckers of the ventral row being much enlarged. The same condition prevails on the ventral arms and is only a little less conspicuous; here three or four suckers of the dorsal series are similarly affected, though in less degree.

Tentacles very variable in length, elastic, compressed; keeled near the extremity, inner surface flattened. Club little expanded; closely recurved and coiled upon itself at the tip; inner aspect villous in appearance, due to the exceeding minuteness of the numerous suckers. Individual suckers deeply urceolate, slightly oblique, the so-called papillary area very wide, so that the inner aperture is much reduced; pedicels very long, their basal portions columnar and closely packed together, so that the suckers are mobile only by virtue of a much shorter constricted peduncle, which serves to join the cupules to the main stalk.

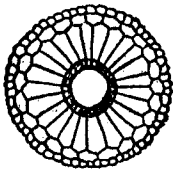

FIG. 26.—*Euprymna scolopes* [323], diagrammatic representation of papillary area of tentacular sucker, greatly enlarged.

Buccal membrane seven-pointed; thickened, with rugose edges.

Gladius, none.

Color of preserved specimens a pale brownish buff, sometimes spotted above with conspicuous well-defined dark dots, sometimes heavily clouded (especially over the dorsal surface) with dark bluish slate, depending upon the state of expansion or contraction of the chromatophores. There is an especially conspicuous series of large transversely elongate chromatophores ranked in close succession along the outer aspect of each of the sessile arms, and a very similar series of smaller chromatophores extends along the distal portion of the tentacle stalk. The following note as to the color of this species during life appears in Dr. Fisher's handwriting on the reverse of one of the original labels: "Sepia: Chromatophores brown yellow and sepia eyeballs and visceral sac tinged with iridescent Nile green and blue."

Larval or young specimens differ most conspicuously from the adult in their shorter more inflated mantle, larger head, and the fewer and more definite chromatophores. The secondary sexual characters begin to become conspicuous at least as early as the stage with an average mantle length of about 10 mm.

MEASUREMENTS OF EUPRYMNA SCOLOPES.

Number in author's register	187	319	321	312	320	323	323	308
Sex	♀	♀	♀	♀	♂ (type)	♂	♂	♂
	mm.	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
Total length	128	54	50	20	63	74	52	44
Tip of body to base of dorsal arms	41	35	32	13	35	36	31	18
Tip of body to tip of second arms	71	54	47	20	59	61	49	32
Tip of body to mantle margin	28	25	23	9	25	24	21	12
Width of mantle	21	20	18	9	16	18	14	11
Length of fins, total	10	13	12	5	12	13	10.5	7
Length of fins along plane of attachment	8	9	8	3	8	9	6.5	4.5
Width across fins	38	35	33	14	29	36	26	19
Width of dorsal commissure	9.5	10	10.5	5.5	10	12	10.5	7
Length of head	13	11	11	4	10	13	10	6
Width of head	18	17	16	8	15	18	15	11
Length of—								
Right dorsal arm	28	16	15	7	20	20	16	11
Left dorsal arm	27	16	14	5.5	20	20	16	8.5
Second arm	38	23	20	9	27	27	21	15
Third arm	34	21	19	8	23	23	20	13
Ventral arm	31	18	15	7	20	21	18	11.5
Tentacle	92	22	22	8	31	43	24	28
Tentacle club	16	6	7	.....	5.5	6	5	4
Funnel	16	11.5	.....	.....	.....	.....	12	.....

Total length of smallest specimen examined 8 mm.; of mantle of same 3 mm.

Type.—Catalogue No. 214380, United States National Museum [S. S. B. 320].

Type locality.—*Albatross* station 3905, surface, off Kalaupapa, Molokai, April 30, 1902; 13 specimens.

Distribution.—Known only from the region of the Hawaiian Islands (*Albatross*, Jenkins, Berndt).

Material examined.—The 64 specimens of this species which have been examined are to be catalogued as follows:

Number of specimens.	Locality.	Depth in fathoms.	Collector.	Sex.	Where deposited.	Author's register.
1	Off Lae-o Ka Laau Light, Molokai.	Surface.	Albatross station 3821	♂		309
1	Off Avalu Point, Lanai	Surface.	Albatross station 3829	♀		311
1	Off Lae-o Ka Laau Light, Molokai.	60–64	Albatross station 3846	♀		318
1	Pailolo Channel	127	Albatross station 3856	♀		319
1	do	127–128	Albatross station 3857	♀		315
1	do	138–140	Albatross station 3859	♂		305
1	Off Mokapu Islet, Molokai	Surface.	Albatross station 3889	♀		312
2	do	Surface.	do	juv.		307
1	Auau Channel	126–130	Albatross station 3896	♂		322
1	Off Kalaupapa, Molokai	Surface.	Albatross station 3905	♂	U. S. Nat. Mus., Cat. 214380; type.	320
12	do	Surface.	do	♂ ♀	Paratypes	323
1	21° 13′ N. lat., 158° 43′ W. long.	Surface.	Albatross station 3926	♀		304
2	25° 27′ N. lat., 171° 08′ W. long.	Surface.	Albatross station 3931	juv.		302
6	Between Oahu and Kauai	Surface.	Albatross station 3980	juv.		317
3	do	Surface.	do	juv.		300
5	do	Surface.	Albatross station 4010	juv.		310
1	Off Puniawa Point, Maui	52–56	Albatross station 4071	♀		306
1	do	69–78	Albatross station 4073	♂		303
1	Pailolo Channel	122–132	Albatross station 4102	♂		308
2	do	122–132	do	♀		313
1	do	132–141	Albatross station 4103	♂		301
1	Vicinity of Modu Manu	Surface.	Albatross station 4152	juv.		314
1	do	Surface.	Albatross station 4153	juv.		316
1	Honolulu Reef, Oahu	Shore.	Albatross expedition	♀		187
1	do	Shore.	do	♀		321
9	do	Shore.	O. P. Jenkins	4 ♂ 5 ♀	Stanford Univ. Coll., Cat. 2094.	299
1	Honolulu Market	.....	Louis Berndt	♂	Stanford Univ. Coll., Cat. 2095.	298
1	Honolulu, Oahu	Shore.	do	♂	Stanford Univ. Coll., Cat. 2096.	297
1	do	Shore.	do	1 ♂ 2 ♀	Stanford Univ. Coll., Cat. 2097.	296

Remarks.—The specimens which have been made the subject of the foregoing detailed description do not appear to offer any features in essential disagreement with Grant's brief account of his *Sepiola stenodactyla* from Mauritius, but with the recent more careful description by Hoyle[a] of some south Pacific specimens which he referred to Grant's species they are not in complete accord. The observed differences are admittedly trivial, but they maintain themselves persistently and with great constancy throughout the large series of specimens which has been examined and hence seem worthy of recognition. As in the case of most closely related sepiolids the chief difference is in the structure of the hectocotylized arm. In Hoyle's figure of *S. stenodactyla* the modified papillæ begin about halfway up the arm. Those of the ventral row are comparatively stout, fairly regular, not very closely appressed, and the figure shows only about fifteen of them. The conspicuous thickening of the arm at the point where the papillæ begin and the strongly recoiled tip exhibited by the Hawaiian specimens do not appear. In *E. scolopes*, moreover, the modified papillæ extend over a much greater proportional area (two-thirds) of the arm, are much more numerous (35 to 40 in the ventral row), and so tightly palisaded together that many of them are squeezed quite out of place. The details regarding the modified suckers of the remaining arms are also different from Hoyle's description, especially in the case of the third pair, where in *E. scolopes* about twice as many of the suckers in the ventral series undergo enlargement. Unfortunately this comparison has been hampered by the lack of actual specimens of *E. stenodactyla* or any other Indo-Malayan representatives of the genus, so that the separate recognition of the Hawaiian race should perhaps be regarded as somewhat provisional.

It is interesting to note that the differences separating the Japanese *E. morsei* from either *stenodactyla* or *scolopes* are not very conspicuously greater than those just dwelt upon, but they appear equally constant, and I regard my original reference of the Hawaiian material to *E. morsei* as clearly erroneous. The males of the last-named species may be distinguished at a glance by the much more conspicuously enlarged suckers of the outer rows on the sessile arms, especially those of the second pair. Apart from secondary sexual characters, however, a description of one species, however detailed, would, so far as I am aware, serve almost equally well for either of the others, and I am at a loss to name any satisfactory criterion for the separation of any of these puzzling forms when represented by females alone.

E. scolopes is one of the most abundant and ubiquitous cephalopods of the Hawaiian Islands. Not only is it a common surface form throughout the surrounding waters but it is to be captured on the reefs and even at considerable depths, as may be seen from the accompanying table. It is, however, a surprisingly constant species, the greatest variation observed being in the general form and proportions of the body, and even this is more probably due to the varying stresses of preservation than to any inherent differences in the animals themselves. It doubtless possesses luminous properties as glandular organs similar to those described by Meyer (1906) for *Sepiola*, and more especially by Wülker (1910, p. 26) for *E. morsei* are very conspicuous in a corresponding position within the mantle cavity.

The specific name *scolopes* has been adopted in reference to the stockade-like appearance of the outer papillæ on the hectocotylized arm.

Subfamily STOLOTEUTHINÆ, new subfamily.

Mantle and head united in the nuchal region by a commissure. Suckers in two rows, for the most part very small. Both dorsal arms hectocotylized, but the modification weak, consisting chiefly in the greater or smaller size and more crowded condition of the suckers. Eyes with a completely circular lidlike fold. Gladius, none.

Genus STOLOTEUTHIS Verrill 1881.

Stoloteuthis Verrill 1881, p. 417.
Stoloteuthis Verrill 1882, p. 375 [165]

Body short and thick, bluntly rounded behind. Fins large. Arms short; all except the ventral pair united by a wide delicate basal web. Suckers for the most part minute. Mantle ornamented ventrally by a sharply delimited and specially pigmented shield-shaped area of the integument.

Type.—*Sepiola leucoptera* Verrill 1878 (monotypic); a species of the New England region.

[a] Hoyle, 1904, p. 24, fig. B-D.

Subgenus IRIDOTEUTHIS Naef 1912.

Iridoteuthis Naef 1912, p. 247.

Body extremely short and rounded; transversely compressed. Nuchal commissure very broad, reaching to a point opposite the anterior margin of the fins. Fins exceedingly large, their basal attachment relatively narrow. Mantle produced far forward ventrally so as to nearly conceal the head and funnel. Head very large, the eyes much swollen and protruding. Arms very unequal; dorsal and second pairs short; third pair considerably longer. Photogenic organs inconspicuous, leaving the greater portion of the ink sac uncovered.

Type.—Stoloteuthis iris Berry 1909 (monotypic); described from the Hawaiian Islands.

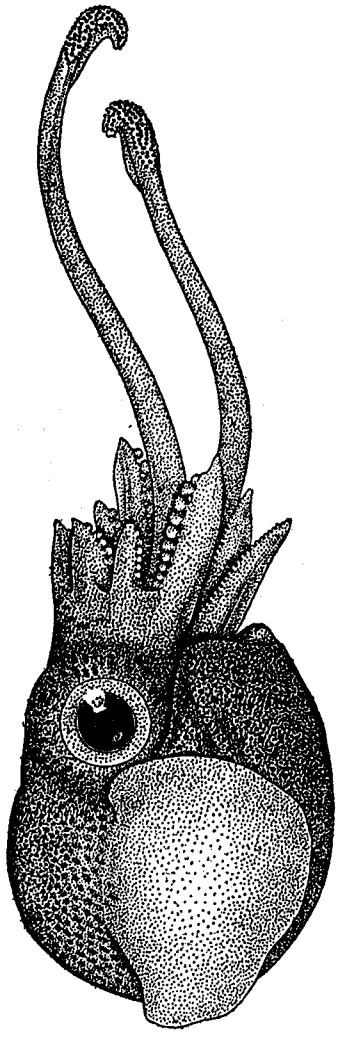

FIG. 27.—*Stoloteuthis iris*, lateral view of type [31]. × 4. Drawn by R. L. Hudson.

Stoloteuthis (Iridoteuthis) iris Berry 1909. (Pl. 1, fig. 1, 2.)

Stoloteuthis iris Berry 1909, p. 410, 418, fig 3.
Iridoteuthis iris Naef 1912, p. 247.

Body small, short, stout; much compressed and flattened laterally, rounded very abruptly behind; width and length dorsally about equal and both greatly exceeded by the depth. Mantle smooth, broadly continuous above with the integument of the head from which it is delimited only by a rather prominent cutaneous line or shallow fold; anterior ventral margin produced forward beneath the eyes and far past them to form a broad, deeply convex lobe, which almost entirely conceals the funnel and ventral surface of the head to which its upturned anterior margin is closely applied. A shallow notchlike indentation in the free anterior edge of the lobe permits the tip of the funnel to be seen; convex central region of lobe differentiated from the rest of the mantle surface as a large, slightly raised and flattened, heart-shaped area. Laterally, as in Verrill's *Nectoteuthis*, the mantle margin "recedes in such a way as to leave the large prominent eyes exposed." Fins relatively enormous, thin, their outline rounded oblong to subcircular; much narrowed at the base; slightly broader and conspicuously longer than the body, exceeding it both anteriorly and posteriorly; anterior margin reaching to the eyes, its extremity rounded; posterior margin obtusely pointed; the plane along which the fins are attached is considerably above the median horizontal plane of the body.

Head extremely large; short, wide, flattened. Eyes large, so swollen and protruded in the only specimen at hand that they have lost all appearance of having free lids, perhaps because in pushing outward they have evaginated the usual circular lid fold; they are situated in the angle of the mantle margin above the ventral lobe. Funnel visible only after the removal of the mantle lobe; very broad at base, thence rapidly tapering to a sudden and deep constriction which occurs just in advance of the middle; entire extremity beyond the constriction swollen and thickened; a secondary gland-like swelling occurs on the dorsal external aspect of the funnel in this region, terminating in a very short blunt papilla which fits in between the true tip of the funnel and the bases of the ventral arms; walls of funnel thick, the interior narrowed and of relatively small capacity; aperture very minute. Funnel organ large, occupying almost the entire interior surface posterior to the median constriction; dorsal cushion with widely flaring lateral wings, almost trilobate in outline; ventro-lateral pads large, wide, and very loosely

adherent. Locking apparatus a slightly curved cartilaginous groove at either side of the base of the funnel with conspicuous ridges to correspond on the inner wall of the mantle considerably posterior to its margin.

Sessile arms short, connected by a well-developed basal web reaching beyond the middle of the dorsal arms, but diminishing ventrally and entirely absent between the ventral pair; conspicuously unequal, the order of length 3, 4, 2, 1; third pair much the stoutest and longest and with somewhat larger suckers than the remainder, also differing in the possession of a prominent membranous keel bordering their outer margins; ventral arms also keeled in somewhat similar fashion, but less prominently. Suckers in two rows on all the arms, crowded; extremely minute, especially on the dorsal and ventral arms; those of the second arms slightly larger, and those on the third pair distinctly the largest of all, although not very conspicuously so (most of the suckers on this pair of arms have been lost through abrasion, so that it can not be determined whether or not any of the more distal ones are subject to enlargement or other special modification; the stumps of the pedicels, however, are entirely similar to one another); individual suckers spherical, with small openings and smooth horny rings; pedicels very short.

Tentacles exceedingly long and slender; tapering; slightly thickened at the base; club but little if any wider than the stalk, velvety in appearance, and under a high power lens seen to be armed with about eight rows (fewer at base) of extremely minute crowded suckers, those near the base somewhat the largest, thence gradually and regularly diminishing in size toward the tip. (Pl. L, fig. 2.)

Ink sac large, by no means covered by the photogenic glands, which, though distinct in the present material, appear to be of small size and very anterior position.

Gladius not observed; probably absent as in *S. leucoptera*.

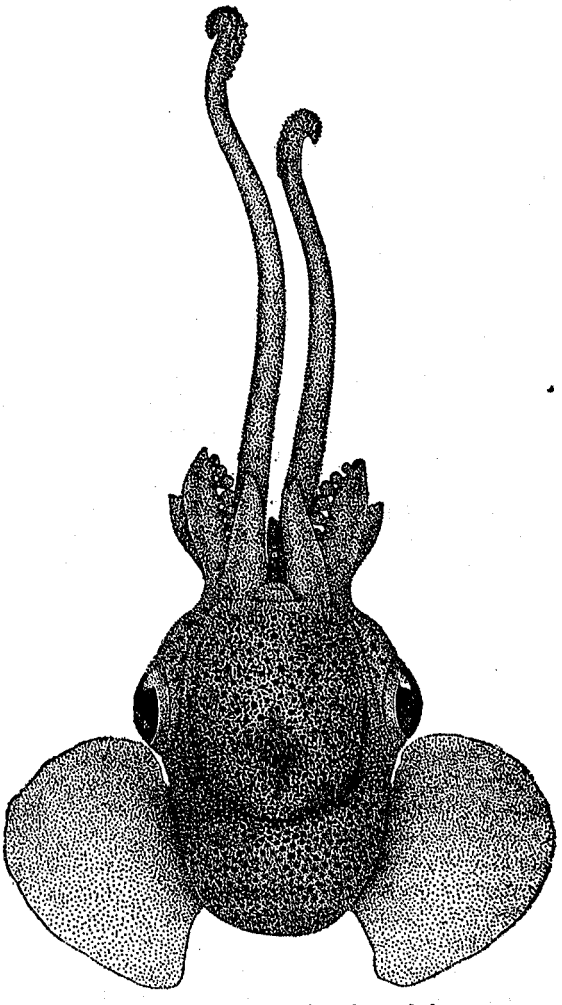

FIG. 28.—*Stoloteuthis iris*, ventral view of type [31], × 4. Drawn by R. L. Hudson.

Color in alcohol for the most part a brownish white; suffused about the eyes, base of the fins, and notably about the ventral shield, with a purplish black; fins unmarked; mantle closely speckled above and below with small brownish chromatophores of two main types, which become rather fewer in number posteriorly and on the sides; those of the one type are paler, larger, more suffused, and more evenly distributed; the others are darker, much smaller, more distinct, and more exclusively confined to certain areas, such as the dorsum and especially the ventral shield, where they are very thickly and evenly distributed; the difference is very apparent, but I am not sure what morphological

significance, if any, is possessed by it. The ventral surface is further ornamented by a dark bluish-gray band bordering the heart-shaped shield.

The following note appears on the reverse of the original station label in the handwriting of Dr. W. K. Fisher and affords important information regarding the appearance of this species in life (colors according to Ridgway's "Nomenclature of Color"): "Tentacles, chromatophores burnt sienna, yellow ocher, and light red. Eye: pupil transparent, iridescent purple, blue, and emerald green; iris reddish burnt sienna. Body (except wings and outer test) iridescent orange, yellow, solferino, green, crimson, purple. Chromatophores of outer test burnt sienna and sepia."

MEASUREMENTS OF STOLOTEUTHIS (IRIDOTEUTHIS) IRIS.

	mm.		mm.
Total length exclusive of tentacles	16	Length of head	4
Medio-dorsal length of mantle	7	Width of head	8
Medio-ventral length of mantle	11	Length of—	
Width of body	7	Dorsal arm	4
Width across fins	18	Second arm	5
Extreme length of fin	9	Third arm	6
Length of same fin at base of attachment	4	Ventral arm	5
Median length of ventral shield	7	Right tentacle (left tentacle missing)	21
Dorsal-ventral diameter of body	10		

Type.—Catalogue No. 214312, United States National Museum [S. S. B. 31].

Type locality.—The type and only specimen of the species known was taken in 153 to 142 fathoms, *Albatross* station 3832, off the island of Molokai, bottom of brown mud and sand.

Remarks.—The sex of the single specimen is unknown, as owing to the brittle texture of its tissues it was deemed inadvisable to attempt to pry the arms far enough apart to ascertain any further details of structure or possible evidences of hectocotylization. It is very possible that the specimen is not quite adult, but its characteristic features have nevertheless attained a high development.

Perhaps the most distinctive features are the extreme development of the dorsal commissure uniting the mantle to the head, and the immense ventral lobe. The former feature is carried to a much further extreme in this species than in either *S. leucoptera* or in *S. nipponensis*, which are the only other described species of the genus, while in the latter respect the only near approach is the *Nectoteuthis pourtelesii* of Verrill. According to information furnished me by Dr. Ad. Naef, *S. nipponensis* differs from the other species mentioned in important anatomical characters, as well as in its size and general aspect, and must henceforth be known as *Sepiolina* Naef. Its exact systematic position still seems a matter of more or less uncertainty, although Naef refers it to the *Sepiolinæ*. All three of the remaining species, *S. leucoptera*, *S. iris*, and *N. pourtelesii*, are characterized by the possession of a conspicuous pigmented shield on the ventral surface similar to that above described, have large fins, and are delicate gaily colored creatures of doubtless similar habits. *N. pourtelesii*, however, stands quite alone in having the dorsal border of the mantle entirely free, and *S. iris* likewise is in many ways very different from its congener. Because of this fact it also has recently been made by Naef the type of a separate genus, *Iridoteuthis*, but because its most important characters (nuchal commissure, ventral shield, webbed arms, etc.) are shared equally with *Stoloteuthis* s. s., I believe their probable relationships are for the present expressed better by grouping them together. The distinctive features adduced by Naef are the integumentary fold in the nuchal region, the large head, protruding eyes, immense fins, ventral protraction of the mantle, and unequal arms, but none of these features seem sufficient of themselves to be regarded as of more than subgeneric value. A more complete knowledge of either *S. iris* or *S. leucoptera* than we at present possess might, however, indicate differently.

Subfamily HETEROTEUTHINÆ Appellöf 1898.

Heteroteuthinæ Appellöf 1898, p. 624.
Heteroteuthinæ Joubin 1902, p. 111.
Heteroteuthinæ Naef 1912, p. 246.

Mantle margin free all around; a cartilaginous articulation in the nuchal region, but the mantle and body fused farther back. Right dorsal arm hectocotylized. Photogenic glands large and conspicuous, nearly covering the ventral surface of the ink sac; closely conjoined along the median line.

Genus HETEROTEUTHIS (Gray 1849).

Rossia (*Heteroteuthis*) Gray 1849, p. 90.
Heteroteuthis Steenstrup 1900, p. 287.
Stephanoteuthis Berry 1909, p. 408.
Heteroteuthis Naef 1912, p. 246.

Body plump, compact; obtusely pointed posteriorly. Fins large, more posterior than anterior in position. Ventral mantle margin produced forward beneath the head so as to almost or even entirely conceal the funnel. Arms short, webbed all around except between the ventral pair. Right dorsal arm hectocotylized and united at base with the second arm of the same side; a few suckers on the third arms of the male greatly enlarged.

Type.—*Sepiola dispar* Rüppell 1844 (monotypic); a species of the Mediterranean region.

Heteroteuthis hawaiiensis (Berry 1909) Naef 1912. (Pl. 1, fig. 3–8.)

Stephanoteuthis hawaiiensis Berry 1909, p. 409, fig. 2; p. 418.
Semirossia (?) sp. Berry 1909 p. 418 (merely listed).
Heteroteuthis hawaiiensis Naef 1912, p. 246.
Heteroteuthis hawaiiensis Berry 1912c, p. 645.

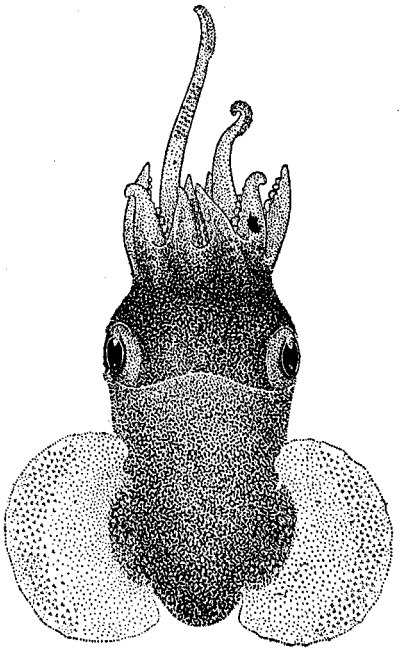

FIG. 29.—*Heteroteuthis hawaiiensis*, dorsal view of type [30], × 1¼. Drawn by R. L. Hudson.

Female (type specimen): Body short, plump, compact, very firm and solid; dorsal aspect tapering posteriorly and terminating past the fins in an obtuse point; ventral half of body more rounded, scarcely tapering, and abruptly surpassed above by the pointed dorsal portion, from which it is separated by a short curved horizontal groove, as though the dorsal and ventral halves of the body were slid upon one another beneath the integument like the two divisions of a large bean; dorsum less convex than the venter, which is full and rounded. Mantle margin free all around, sinuous; slightly projecting above, thence sweeping backward, downward, and then far forward again, broadly curving beneath the eyes to form a conspicuous ventral lobe, which, though slightly emarginate in front, entirely conceals both the funnel and the ventral surface of the head. In the nuchal region a little way behind the margin the mantle is united to the body by an indistinct cartilage and a delicate membrane which is easily torn away. Ventral locking apparatus essentially as in other Sepiolids; an elongated groove with a raised and reflexed margin articulates on either side of the base of the funnel with a thickened ridge on the inner surface of the mantle, the ridge bent at its anterior end so as to inclose a small pitlike depression. The very tight adhesion of the ventral lobe of the mantle to the head is secured in two ways: First, by the strong upward flexion and close application of the margin to the ventral surface of the head, and, secondly, by the insertion of this margin into two deep curved grooves extending obliquely along the under surface of the head from a point about midway of the lower eyelid, nearly but not quite to the cleft between the ventral arms; on the eyelid the groove is shallowest, deepest at its inner end, and bounded anteriorly by a heavy raised margin. (Pl. 1, fig. 7 and 8.)

Head very large, due to the large rounded eyes; broader than the body; flattened above, much excavated beneath. Eyes prominent, with large white pupils and a very deep ventral lid fold. Funnel very stout and thick; flattened; outline bluntly conical; extremity rounded; aperture small.

Sessile arms short, stout, thick; unequal, the order of length 3, 4, 2, 1; dorsal pair shortest, third pair longest,[a] but the ventral almost as long as the third and even longer if measured along the cleft separating their inner ventral margins; connected at base by a fleshy umbrella, best developed between the dorsal arms, between these and the second pair, and between the third pair and the ventral pair; between the second and third arms the web is very short, and is totally lacking between the arms of the ventral pair, which are divided from one another by a deep cleft extending as far back as the tip of the funnel; second arms rounded, the remainder with a distinct keel along their outer margins distal to the webbed portion. Suckers small, spherical, oblique; in two rows extending nearly or quite to the tips of the third arms, but leaving the final distal extremities of all the other arms bare; this circumstance becomes especially conspicuous in the case of the second pair, where the distal portion of the arm is not only devoid of suckers, but is minutely ridged transversely and exhibits a strong tendency to recoil upon itself (pl. L, fig. 5); horny rings of suckers smooth.

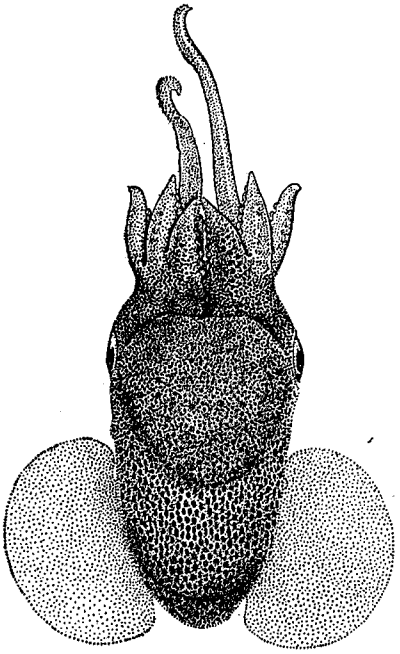

FIG. 30.—*Heteroteuthis hawaiiensis*, ventral view of type [30], × 1½. Drawn by R. L. Hudson.

Tentacles rather short, stout, angled, slightly tapering, with a flattened and somewhat grooved out inner surface. Club small, of considerably less diameter than the stalk; inner aspect with a velvety appearance, due to the great multitude of exceedingly minute suckers with which it is armed (pl. L, fig. 3).

Surface everywhere smooth.

Color of the living animal unknown; in alcohol a brownish buff; fins and arm tips unmarked; dorsum and head heavily dotted and clouded with the blackish chromatophores which appear as open reticulations about the bases of the fins; ventral surface of mantle less densely pigmented, except for a shield-shaped area occupying the ventral lobe and extending back therefrom, over which the chromatophores are very numerous and distinct, being apparently of two main sizes, somewhat as noted in the case of *Stoloteuthis iris;* the marginal delimitation of this area is by no means so distinct and conspicuous as the corresponding region of *Stoloteuthis* and was hence overlooked by the artist when the first drawings were made (pl. L, fig. 7). Chromatophores appear also upon the ventral aspect of the head and funnel, even extending upon the dorsal surface of the latter, but are not to be distinguished upon the tentacles.

Gladius apparently wanting.

MEASUREMENTS OF HETEROTEUTHIS HAWAIIENSIS.

	mm.
Total length, exclusive of tentacles	38
Medio-dorsal length of mantle	22
Medio-ventral length of mantle	27
Width of body	14
Width across fins	32.5
Extreme length of fins	17
Length of fins at base of attachment	9.5
Anterior mantle margin to base of dorsal arms	8.5
Width between eyes	10
Length of—	
Dorsal arms	8
Second arms	9
Third arms	10
Ventral arms	9–12
Tentacle	21

[a] Owing to an inadvertence the original description states the reverse to be true.

In addition to the specimen above described, the *Albatross* collection contains three other individuals which are so badly macerated (as though taken from the digestive cavities of larger animals, as was undoubtedly the case) that their true identity was not ascertained for a considerable length of time. One of these is a male and has been made the subject of the following notes:

Male: Third arm pair very much larger than the others, bearing two or more very greatly enlarged basin-shaped suckers (pl. L, fig. 4) at their distal ends. No evidence of hectocotylization visible except that the left dorsal arm is much smaller than the right and is closely united with its neighbor of the second pair by a very narrow basal webbing; no true fusion of the arms on either side can be made out after the fashion described for *H. dispar*.

The firm adherence of the mantle and body just back of the nuchal cartilage is very clearly evident in this specimen.

The extremely desiccated condition of the specimen precludes the giving of more accurate or complete details.

Type.—Catalogue No. 214311, United States National Museum [S. S. B. 30].

Type locality.—*Albatross* station 3989, 733 to 385 fathoms depth, in the vicinity of the island of Kauai, coral sand and rock bottom, June 11, 1902; 1 ♀.

Distribution.—Vicinity of the Hawaiian Islands (*Albatross*).

SPECIMENS OF HETEROTEUTHIS HAWAIIENSIS EXAMINED.

No. of specimens.	Locality.	Depth in fathoms.	Collector.	Sex.	Remarks.	Author's register.
1	Vicinity of Kauai.....	385–733	Albatross station 3989.....	♀	U. S. Nat. Mus.; type, Cat. 214311.	30
1	Pailolo Channel.....	280–283	Albatross station 3900.....	♀	Fragmentary.....	34
1	.....do.....	297–306	Albatross station 4088.....	♂	.....do.....	33
1	.....do.....	297–304	Albatross station 4089.....	?	.....do.....	333

Remarks.—The only other species of this genus which are at present recognized are the *H. dispar* (Rüppell) of the Mediterranean region and *H. weberi* Joubin from the Dutch East Indies, from each of which *H. hawaiiensis* appears clearly distinct. Its nearer relationships are certainly with *H. dispar*, but it is to be differentiated on the following grounds:

1. Indications of the presence of a ventral shield similar to that already familiar in *Nectoteuthis* and *Stoloteuthis*, but much less clearly defined.
2. The complete concealment of the funnel by the ventral lobe of the mantle.
3. The heavy oblique folds on the under surface of the head which apparently function to secure a more perfect application of the mantle margin to the head and thus serve as a secondary locking apparatus.
4. The curious nonconformity between the dorsal and ventral halves of the body in mature females.
5. The shorter arms.

The adults of this species are very neat, compact little creatures of pleasing appearance, and like all their near allies are probably quite brilliantly colored when living. They also possess luminous properties, the photogenic glands overlying the ink sac in the present species being in all respects closely similar to those described for *H. dispar* and very conspicuous even in the macerated specimens.

DIVISION ŒGOPSIDA (d'Orbigny 1845).

Decapoda Oigopsidæ d'Orbigny 1845, p. 367.
Chondrophora Gray (pars) 1849, p. 36, 37.
Œgopsidæ Keferstein 1866, p. 1444.
Oigopsidæ Verrill 1881, p. 427.
Œgopsida Hoyle 1886, p. 32, 162.
Œgopsidæ Pfeffer 1900, p. 151.
Œgopsida Chun 1910, p. 3.
Œgopsida Pfeffer 1912, p. 1.

Eyelids perforate over the cornea; their margins free all around and continuous except for the usual presence of a notch or sinus in front. Suckers on either the sessile arms or tentacles or both frequently

transformed into hooks. Complex photogenic organs of polymorphic structure and undoubtedly polyphyletic origin are of repeated occurrence.

Family ONYCHOTEUTHIDÆ Gray 1849.

Onychoteuthidæ Gray 1849, p. 36, 45.
Onychoteuthidæ Pfeffer 1900, p. 152, 154; 1908, p. 62, 63; 1912, p. 39.

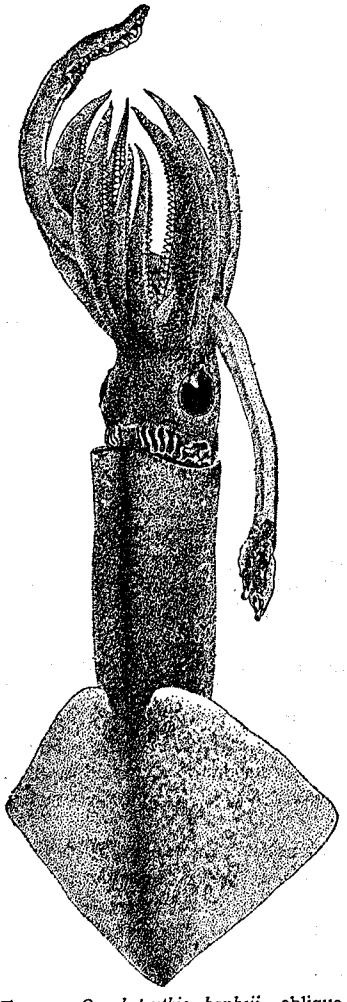

FIG. 31.—*Onychoteuthis banksii*, oblique dorsal view of specimen [227] from near Laysan Island, × ¼. Drawn by R. L. Hudson.

Animals of small to gigantic size; body stout, loliginiform. Suckers on sessile arms in two rows and normal throughout. Tentacle club with part of the suckers unmodified, the remainder transformed into hooks; fixing apparatus a compact carpal group of suckers and pads.

Genus ONYCHOTEUTHIS Lichtenstein 1818.

Onychoteuthis Lichtenstein 1818, p. 1591 (*fide* Hoyle); 1818a, p. 223.
Onychoteuthis d'Orbigny 1845, p. 383.
Onychoteuthis Pfeffer 1900, p. 156, 158; 1908, p. 64; 1912, p. 70.

Body of moderate size, cylindrical, tapering. Fins broadly sagittate. Head with a conspicuous "olfactory crest" made up of series of broad longitudinal lamellæ. Arms stout, bearing true suckers only. Tentacles stout, the clubs armed with two rows of hooks on the central part; fixing apparatus a very definite compact rounded group of small suckers and pads on the carpus. No hectocotylization. Gladius narrow and slender, showing through the integument as a well-defined dark streak; a small spoon-shaped cone at the posterior extremity. Hoyle has recently discovered the existence of photogenic organs within the mantle cavity.

Type.—Onychoteuthis Bergii Lichtenstein 1818=*O. banksii* (Leach 1817), a cosmopolitan species.

Onychoteuthis banksii (Leach 1817) Férussac 1826.

Loligo Banskii **Leach 1817, p. 141.**
Onychoteuthis Banksii Férussac in d'Orbigny 1826, p. 151.
Onychoteuthis Banksii **d'Orbigny 1845,** p. 386, pl. 26, figs. 1–7.
Onychoteuthis Banksii **Schauinsland 1899,** , p. 92 (locality record).
Onychoteuthis Banksii **Pfeffer 1912,** p. 70, 758, pl. 3, fig. 13–25, pls. 4–6.
Onychoteuthis banksii Berry 1912, p. 83, figs. 44–46.

This is such an abundant and universal species that I have given above only some of the more particularly relevant references regarding it. For similar reasons the following description is made only complete enough to afford sufficient means for its ready identification.

Body of moderate size, loliginiform, with a pair of large broadly sagittate fins extending a little more than half the length of the mantle. Head small, squarish; ornamented just below the nuchal region with a conspicuous series of about a dozen stout longitudinal lamellæ on either side. Eyes large, with capacious openings.

Arms moderate, stout, outwardly keeled; armed with two rows of small oblique hood-shaped suckers, produced at the upper margin. Tentacles long and stout, the club not expanded except for

the broad marginal membrane; armed with two rows of 9 to 12 hooks each, those of the ventral row in the main conspicuously the larger. Fixing apparatus a compact rounded group of suckers and pads in approximately equal numbers on the carpus. There is a compact cluster of minute suckers at the tip of the club.

Color in alcohol a brownish buff, mottled with slate; a very irregular dark streak on the dorsal aspect marks the position of the gladius.

MEASUREMENTS OF ONYCHOTEUTHIS BANKSII.

	mm.	Length of—	mm.
Total length	315	Right second arm	69
Tip of body to dorsal margin of mantle	150	Left second arm	69
Width of mantle	33	Right third arm	71
Width across fins	112	Left third arm	68
Extreme length of fins	87	Right ventral arm	70
Length of fins at plane of attachment	80	Left ventral arm	43+
Length of head	16	Right tentacle	141
Width across eyes	30	Right tentacle club	34
Length of—		Left tentacle	125+
Right dorsal arm	57	Left tentacle club	27+
Left dorsal arm	54	Carpal fixing apparatus	5

Distribution.—"Distribution nearly universal; collected in all the oceans at numerous localities, equally in Arctic and tropical waters." (Tryon 1879, p. 168.)

Neighborhood of Laysan Island (Schauinsland; Stanford University collection).

Material examined.—But a single Hawaiian specimen of this species has been examined. This is no. 2101 of the Stanford University invertebrate series and was taken off Laysan Island by Mr. Max Schlimmer [S. S. B. 227].

Remarks.—I can not find that this Laysan Island specimen exhibits any particular differences from the *O. banksii* I have seen from the Atlantic and elsewhere. So far as can be determined, there appear to have been 11 hooks in each row on the right tentacle club and more than likely on the mutilated left tentacle as well. The fixing apparatus of each tentacle contains 10 suckers and an exactly equal number of pads, a feature which appears to be subject to great variation in this species.

It seems clear that the original spelling of the specific name was the result of an accidental transposition of type, so that the emended version seems preferable. *O. banskii*, *O. banski*, *O. banksii*, and *O. banksi* are abundantly appearing variants in the extensive literature.

This is one of the species of squid preyed upon by the Laysan albatross, and has been previously reported in this connection by Schauinsland.

Genus TELEOTEUTHIS Verrill 1882.

Onykia Lesueur 1821, p. 98.
Onykia Lesueur 1822, p. 296.
Onychia Latreille 1825 (*fide* Gray), not *Onychia* Hubner 1816.
Teleoteuthis Verrill 1882, p. 279, 280.
Teleoteuthis Pfeffer 1900, p. 155, 156; 1912, p. 42, 43.

Animals of small or very moderate dimensions. Tentacle club of young with four rows of suckers, the two median of which become typically modified into hooks in the adult, but in some cases only one of the median rows is noticeably modified, and one of the marginal rows is often very weakly developed. Gladius with broad wings as in *Loligo*.

Type.—*Onykia Carriboea* Lesueur 1821 (species first named); a widespread species originally described from the West Indies.

Teleoteuthis compacta Berry 1913. (Pl. LII, fig. 4, 5.)

Teleoteuthis appellöfi Berry 1909, p. 419 (locality record only), *not* of Pfeffer 1900.
Teleoteuthis compacta Berry 1913, p. 565.

Animal small, loliginiform. Mantle almost cylindrical anteriorly; slightly swollen a little in advance of the middle, thence tapering rapidly to a very acute point. Fins enormous, broadly sagittate in outline, their total width about equal to the length of the mantle; length a little more than half that of the mantle. Mantle margin slightly produced in the medio-dorsal line to form an obtuse point, and a little more prominently in the same way on either side of the funnel; emarginate below the funnel.

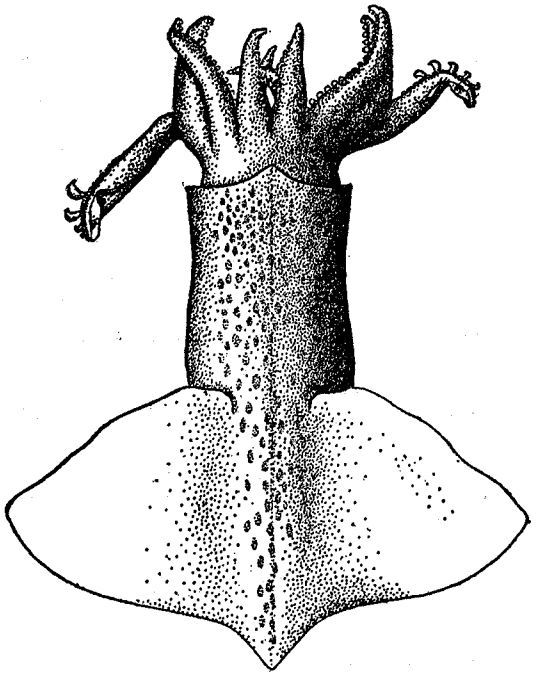

FIG. 32.—*Teleoteuthis compacta*, dorsal view of type [238], × 3.

Head squarish, narrower than the mantle, into which it may be almost completely withdrawn. Eyes little prominent; their lid openings small, notched in front.

Arms short, stout, little attenuate; unequal, their order of length 3, 2, 4, 1; the dorsal arms clearly shorter than those of the second and third pairs. Suckers on all the arms small, rotund, closely ranked in two widely interspaced series. (Pl. LII, fig. 5). Umbrella wanting, but all the arms well angled, and the third pair furnished externally with a strong membranous keel.

Tentacles short, stout, but little exceeding the arms; clubs not thickened, but broadly keeled above and slightly so along the ventral margin; both suckers and hooks present on the club; hooks sessile, 10 to 11 in number and in a single longitudinal series, comprising the more ventral of the two median rows of acetabula; first five hooks quite small, the next three much larger, the distal ones diminishing again; the two dorsal rows of suckers irregular, the first five pairs small and closely placed, the succeeding ones slightly larger and more distant, becoming smaller again distally; the suckers of the inner dorsal row persist in alternation with the hooks to the tip of the club, but the marginal row becomes obsolete distally and comprises only about eight suckers in all; suckers of the ventral row exceedingly minute, especially distally where they are placed very far apart. The extreme tip of the tentacle is occupied by a group of excessively minute suckers, which are scarcely visible as such with an ordinary hand lens. Fixing apparatus well developed, comprising a quadruple series of small suckers and pads in alternation; about 8 pads and 12 suckers can be made out. (Pl. LII, fig. 4.)

Gladius delicate, the expanded wings greatly narrowing in front of the hollow terminal cone.

Color in alcohol a brownish buff. Chromatophores light brown, scarcely visible below.

MEASUREMENTS OF TELEOTEUTHIS COMPACTA.

	mm.	Length of—	mm.
Total length including tentacles	28	Dorsal arms	4·5
Tip of body to dorsal mantle margin	21	Second arms	5·5
Width of body	6	Third arms	6
Width across fins	20	Ventral arms	5
Extreme length of fins	12	Left tentacle	7
Length of fins at base	11	Tentacle club	3·5
Width across eyes	5		

Type.—Catalogue No. 214381, United States National Museum [S. S. B. 238].

Type locality.—*Albatross* station 3989, 385 to 733 fathoms, vicinity of Kauai Island, coral, sand and rock bottom, June 11, 1902; one specimen.

Distribution.—Hawaiian Islands (*Albatross*).

Specimens examined.—The type is unique.

Remarks.—It was at first thought that this specimen might be referable to the *T. appellöfi* of Pfeffer and was indeed so listed in a preliminary paper, but a more careful study of details, particularly those of the tentacular armature, has convinced me that the present species is distinct and stands rather nearer to M. Joubin's *T. caroli* (1900, p. 64), from which it differs in the relatively larger fins and shorter and differently armed tentacle club.

The latter structure is a curious affair and is better to be understood from the figure than from my description. It offers several apparent divergencies from that of *T. caroli* as figured by Joubin (1900, pl. 11, fig. 10), especially in the fixing apparatus, for *T. caroli* is represented as having but seven suckers (pads are omitted from the drawing but mentioned in the text). Furthermore, the suckers of the club itself are very different in number and arrangement, although the two forms agree in the presence of but a single series of hooks.[a] In *T. caroli* the fifth hook from the base attains the maximal proportions, while in our species it is the sixth, and the change in size at this point is conspicuously more abrupt.

It is, however, not at all impossible that the single row of hooks and the broad fins are juvenile characters, the former being intermediate between the hookless condition described by Pfeffer as *Steenstrupiola* (cf. Pfeffer 1900, p. 156) and the normal adult, in which case the Hawaiian specimen may after all prove to be closer to the *T. peratoptera* d'Orbigny, a Chilean species which was indeed originally figured with three rows of suckers and but one series of hooks (d'Orbigny 1835, pl. 3, fig. 6), though since united by d'Orbigny himself with the *T. platyptera* of the same region.

T. appellöfi has fins of somewhat similar proportions, but the structure of the tentacle club is totally different.

Family ENOPLOTEUTHIDÆ Pfeffer 1900.

Enoploteuthidæ Pfeffer 1900, p. 152, 163.
Enoploteuthidæ Chun 1910, p. 52.
Enoploteuthidæ Pfeffer 1912, p. 118.

Animals of small to moderate size. Arms with two rows of suckers, part of which typically are modified into hooks. Tentacles with clubs little or not at all expanded; their suckers in four rows (one or more of these often suppressed in the adult) and usually part of them transformed into hooks; a carpal fixing apparatus present comprising a few suckers and pads. Buccal membrane eight-pointed. Gladius feather-shaped; with broad somewhat angular wings and no end cone. Photogenic organs are almost invariably present on the ventral aspect of the eyeball, and in addition may occur within the mantle cavity or scattered over the ventral surface of the outer integument.

Subfamily ENOPLOTEUTHINÆ (Chun 1910) Pfeffer 1912.

Enoplomorphæ Chun 1908, p. 86.
Enoploteuthinæ Tribus *Enoplomorphæ* Chun 1910, p. 56, 78.
Enoploteuthinæ Pfeffer 1912, p. 124, 125.

Body more or less pointed posteriorly but not spitlike. Fins large and usually sagittate. Buccal membrane free; dorsal lappets well separated. Photogenic organs occur, often in large numbers, on the ventral aspect of the mantle and usually the head and arms as well; in most genera a conspicuous single series of large organs is found on the ventral periphery of the eyeball; no luminous organs in the pallial chamber.

[a] Joubin (op. cit., p. 65) states that the hooks of *T. caroli* are in two rows, but it seems to me that the "première série" described as "très petits, longuement pédonculés" are better interpreted as suckers as I have done.

Genus ABRALIA Gray 1849.

Abralia Gray 1849, p. 46, 50.
Abralia Pfeffer 1900, p. 166, 167.
Asteroteuthis Pfeffer 1908a, p. 292.
Abralia Chun 1910, p. 57.
Asteroteuthis Pfeffer 1912, p. 124, 128.
Abralia Pfeffer 1912, p. 762.

Fins large, sagittate; more or less pointed posteriorly, and not exceeded by the tip of the pointed body. Arms with two rows of hooks throughout the greater part of their length, but with true suckers at their tips; extremities of ventral arms normal. Left ventral arm hectocotylized. Dorsal row of suckers on proximal portion of tentacle club suppressed in adult, leaving one row of hooks and two rows of suckers which give way to four rows of suckers distally. Buccal membrane in preserved specimens pale and scattered over with reddish chromatophores.

Type.—Onychoteuthis armata Quoy and Gaimard 1832 (species first mentioned); described from near the island of Celebes.

Abralia astrosticta Berry 1909. (Pl. LI.)

Abralia astrosticta Berry 1909, p. 412, 419, fig. 4–7.
Abralia astrostricta Weindl 1912, p. 271–275.
Abralia (Compsoteuthis) astrosticta Pfeffer 1912, p. 149, 151, 163.

Animal of small size. Mantle firm, fleshy, cylindrical in shape, little compressed; tapering at first gradually, then more abruptly to a bluntish point posteriorly. Anterior edge of mantle smooth, emarginate below the funnel, and with a very slight obtuse medio-dorsal angle. Fins moderately large and very wide in proportion to their length; about one-third as long as the mantle, and each one about as broad as long; subterminal, triangular; attached firmly along the inner margin for most of their length; anterior lobes prominent, but posterior margins nearly straight and converging at a very obtuse angle.

Head rather large, but decidedly narrower than the body, squarish, flattened above and below; "olfactory crest" comprising a series of four oblique fleshy folds behind the eye on either side. Eyes large; the circular lid opening with a minute rounded sinus in front. Funnel large, subtriangular, very firm and thick-walled, its center rounded and conspicuously swollen ventrally. Funnel organ well developed, posterior in position; comprising a V-shaped median pad on the interior dorsal wall, and a small elongate-ovate pad placed ventro-laterally to it on either side. The tip of the funnel is furnished with a wide shallow flaplike valve. (Pl. LI, fig. 8.)

On its inner surface the edge of the mantle articulates with the head in the nuchal region and with the base of the funnel on either side by cartilages of the form usual in the genus. The dorsal apparatus consists of a simple longitudinal ridge on the mantle and a corresponding plate on the neck. The funnel cartilages are elongate, slightly widest near the base, have a thickened, raised and reflexed margin, and their grooves are simple, narrow, deep, and elongate (pl. LI, fig. 7); they fit over a slender linear ridge on either side of the inner surface of the mantle.

Sessile arms stout, little attenuate; nearly of a length, but the second arms slightly the longest and stoutest, and the dorsal pair a little shorter and more slender than the others, so that the formula of their relative length is in general 2, 4, 3, 1; outer edge of arms angled and furnished with a keel, membranous and poorly developed on the four dorsal arms, but increased to a fleshy carina on the arms of the third pair and more particularly along the outer aspect of the ventral arms, where it is so heavy and conspicuous as to cause these arms to appear almost twice their true diameter when viewed ventrally. For the greater part of their length all the arms are armed with two widely spaced alternating rows of small hooks which are replaced on the extreme distal portions by a double series of minute crowded suckers; the tips of the ventral arms bear suckers similar to those of the other arms and are indeed entirely normal in every particular; the number of pairs of hooks on the ventral arms is about eight.

Tentacles slender, over half as long again as the arms, cylindrical, little tapering. Club but little expanded, armed with four rows of acetabulæ which respectively may be described as follows: (1) On the distal half of the club all four rows consist of small suckers of about equal size at any given transection

of the arm, but regularly diminishing to the tip; (2) the two dorsalmost rows continue down the club proximally for its entire length, attaining their maximum dimensions near the middle; the two ventral rows on the other hand abruptly cease and are replaced on the proximal half of the club by (3) a single series of five rather large hooks which stand opposite the five proximal pairs of suckers in the dorsal rows; (4) at the base of the club, upon the carpus, is a very definite fixing apparatus comprising a double row of some four to five suckers alternating with a similar number of small whitish pads. (Pl. LI, fig. 2, 6.)

Buccal membrane eight-pointed (as correctly surmised by Pfeffer, my original assertion that there are but seven lappets is erroneous); coarsely papillose within.

Photophores of the outer integument exceedingly numerous and readily perceivable to be in two main sizes, the grouping of the larger of which is distinctly bilaterally symmetrical and varies on different regions of the body as follows:

(1) On the ventral aspect of the mantle appear about ten rather ill-defined longitudinal series of these organs, including (*a*) two nearly median rows of relatively large organs extending without interruption from the anterior mantle margin to the posterior extremity; (*b*) two similar series succeeded laterally by two or three others, composed of organs constantly diminishing both in size and number, occur parallel to these anteriorly, but all converge posteriorly in such a way that in addition to the two central series but one other row persists on each side to the tip. The organs of the various series are very regularly and equally interspaced so that there is a certain tendency evident for the grouping to occur in a transverse as well as a longitudinal direction. Aside from the effect which might well be expected to result from such a tendency, no specially definite line of photophores is found bordering the margin of the pallial aperture. The smaller organs are much more numerous than the larger and occur scattered between and among them in a much more irregular fashion. On the dorsal surface of the mantle photogenic organs are almost entirely wanting, but there is a fairly regular series of about seven small distant organs close to the median longitudinal line on either side, and some distance lateral to these a few (3 to 4) isolated organs, perhaps representing the rudiments or forerunners of other longitudinal series.

(2) The ventral aspect of the funnel exhibits a little in front of its middle a transverse line of four large organs of equal size, in front of and behind which occur a number of smaller ones in such a way as to form four longitudinal series containing one of the large organs and two to three of the smaller ones each. A few scattered organs occur in addition, but all are bilaterally arranged. A clear space down the center of the funnel separates the photophores of each side into two triangular patches. This space, like the extreme tip of the funnel, is colorless and devoid of organs.

(3) There are no photophores upon the upper surface of the head, but upon the lower aspect they appear with perfect symmetry in five longitudinal rows with an additional series bordering each ocular aperture. Here also the larger organs are relatively few in number compared with the smaller, there being only two of the former in the median row, and two to three in each of the lateral series. The median row bifurcates at the apex of the funnel groove (one large organ on either side), and also anteriorly, where either branch parallels a continuation of the first lateral series along each ventral arm to its extremity. The outer lateral series continues for a distance along the border of the membranous keel, so that the basal half of each ventral arm bears in all three rows of photophores. The arms of the third pair have a series of these organs near the base along their ventral aspect, and there are evidences of a second row of smaller ones along the dorsal margin as well. No such structures have been identified upon any of the other arms or upon the tentacles.

All of the photophores appear as minute, but definite, faintly elevated, circular, bluish rings, surrounding a white dotlike center, and having much the appearance of minute eyes. The bluish rings are relatively heavier and more conspicuous in the larger organs, while the smaller organs are by this means again separable into two types, the one much less heavily pigmented than the other.

In addition to photogenic organs of the general type described above, there are to be observed a very conspicuous series of five large reddish bead-like structures upon the ventral periphery of each eyeball. They are placed very close together, are of circular outline and subequal in size (pl. LI, fig. 3). The two terminal organs are considerably lighter in color than the three median ones.

Prevailing color of animal preserved in alcohol, a pale buff brown; the gladius showing through the dorsal integument as a very prominent medio-longitudinal line. Chromatophores brownish; most numerous on the upper surface of the head, which is thus rendered very dark in color; much less numerous on the dorsal aspect of the mantle and below largely replaced by the bluish photophores which are strongly contrasted with the chromatophores in color. Buccal membrane almost uniformly pale, with only a few scattered chromatophores.

Gladius with a thickened midrib; wings unthickened, very delicate, and with distinctly angular margins.

MEASUREMENTS OF ABRALIA ASTROSTICTA.

	mm.	Length of—	mm.
Total length	65	Left dorsal arm	11
Length exclusive of tentacles	56.5	Right second arm	13
Length of mantle, dorsal	34	Left second arm	15
Extreme length of fins	11	Right third arm	12
Length of fins at base	9	Left third arm	12
Width across fins	22	Right ventral arm	13
Width of mantle	10	Left ventral arm	13.5
Width of head	9	Tentacle	23
Length of—		Tentacle club	4
Head	8	Funnel	6.5
Right dorsal arm	11		

Type.—A female; catalogue No. 214313, United States National Museum [S. S. B. 171].

Type locality.—*Albatross* station 4122, 192 to 352 fathoms depth, off Barbers Point Light, Oahu, bottom of coarse coral sand and shell, July 26, 1902; one ♀ specimen.

Distribution.—Hawaiian Islands (*Albatross*).

Material examined.—No other specimens than the type are known.

Remarks.—This very beautiful little squid is a member of a rare and exceedingly curious group of cephalopods which have been sparsely taken at divers times and in many widely separated localities, and the interrelationships of which are by no means as yet clearly understood. They are Enoploteuthids chiefly characterized by the double row of hooks on the arms supplanted distally by suckers, and the extensive development of photogenic organs over the entire ventral surface of the head and body, though not within the mantle cavity, as in the case of certain forms similar to some which will be described later. The peculiar features of the group were first recognized (although only partially) by Gray, who in 1849 founded the genus *Abralia* for their reception. Many years later (Joubin 1896) a second genus, *Abraliopsis*, was erected for the reception of certain *Abralia*-like forms, unique in the possession of a conspicuous series of pigmented swellings at the tips of the ventral arms, and further distinguished by the deep violet color of the buccal membrane, somewhat different structure of the tentacle club, bilaterally symmetrical arrangement of the photophores, and the presence of three instead of two series of these organs upon the ventral arms. A few years ago Pfeffer, on the supposition that the type species of Gray (*A. armata* Quoy and Gaimard) would be found congeneric with *Abraliopsis*, replaced that term by *Abralia* and advanced the new name *Asteroteuthis* for the group thus left without a cognomen. More recently, however, he has once more returned to the older and more familiar arrangement, for upon examination the type specimen of *A. armata* proved that species to be after all an *Asteroteuthis* or true *Abralia* in the accepted sense.

The position of the Hawaiian species now under consideration is in many respects anomalous. Since the tips of the ventral arms are entirely normal, bear suckers at their extremities, and lack all indications of terminal pigmented organs, it is most decidedly not an *Abraliopsis* and Pfeffer's suggestion that the specimen represents a very large *Compsoteuthis* stage of that genus is quite untenable. This is further borne out by the fact that the buccal membrane is not deep violet in color, but pale and dotted with chromatophores, while the main features of the armature of the tentacle club are those of a typical *Abralia*. On the other hand no previously described *Abralia* shows so strikingly symmetrical an arrangement of the photogenic organs on the mantle, or possesses more than two series of these structures on the ventral arms, or has such extremely short and wide fins. In almost every respect, therefore,

A. astrosticta is a remarkably distinct species and is not closely approached by any other known form excepting possibly the very recently described *A. steindachneri* Weindl 1912 of the Red Sea, which is thought by its author to be somewhat nearly related. A complete account of the latter species has not yet reached me, but from the preliminary notice above cited it would seem that this is the case, although the two forms differ in enough particulars to be sufficiently distinct. In Weindl's species the fins are not quite so short and wide, there are seven to eight hooks on the tentacle club, and the median photophore on the eyeball is said to be much the smallest.

It has seemed worth while to make the account of this species as full as possible, firstly on account of the special interest attaching to forms of this group, and secondly because of the unusually fine condition of the present specimen which renders the chance for misinterpretation correspondingly slight.

Abralia trigonura Berry 1913.

Abralia species Berry 1909, p. 419 (locality record only).
Abralia trigonura Berry 1913, p. 565.

There is a second specimen of *Abralia* in the *Albatross* collection, which, although not very well preserved, is clearly not referable to *A. astrosticta*, but belongs rather to the typical section of the genus.

Animal of small size, in general loliginiform, but the mantle rather short, wide, inflated, and rapidly tapering to a point posteriorly. Fins large, a little over half as long as the mantle; their total width about approximates the length of the mantle.

Head rather small, squarish; olfactory crests low (crushed, and not distinct). Eyes large and prominent. Funnel large, triangular, compressed. Funnel organ well developed; similar in general arrangement to that of *A. astrosticta*, except that the lobes of the median (dorsal) pad are broader, and the ventro-lateral cushions are ovate and conspicuously larger (fig. 33). The funnel has a delicate foldlike valve at the tip.

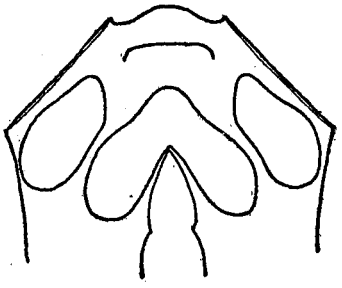

FIG. 33.—*Abralia trigonura*, outline drawing of funnel organ [275], × 3.

Arms quite long, over two-thirds the length of the body; subequal, but the dorsal pair distinctly the shortest; order of length in general 2, 4, 3, 1. The arms bear two rows of small alternating hooks, which are replaced by suckers at the extremities.

Tentacles very long and slender, the clubs little expanded. The armature is almost entirely effaced, but a single hook persisting on one of the clubs is much longer, more slender, and much more curved than those of *A. astrosticta*.

Buccal membrane large; eight-pointed; papillose and uniformly pale within; its outer surface conspicuously dotted with many small, distinct, dark reddish chromatophores.

The gladius as compared with that of *A. astrosticta* is similar in general shape, but is relatively much flatter and less slender, with, however, a wider and more robust midrib; the lateral expansions are conspicuously broader and their angles more pronounced and more anterior in position.

The photophores of the ventral integument are of a very different aspect than those of *A. astrosticta*, but here also they are apparently of two main types. The larger appear as small whitish tubercles, which, under the microscope, show a lenslike core of chalky white color inclosed by a pale bluish gray ring. The smaller organs are either (1) conspicuously darker, comprising a light bluish core surrounded by a narrow dark ring distinctly composed of separate bodies of pigment, or (2) but slightly darker and resembling the large organs in miniature. The integument of the mantle has mainly sloughed away, but from the portions remaining there appear to have been two very definite parallel rows of the larger organs running down the medio-ventral line, with at least two other series on either side more or less parallel to them. The smaller organs are exceedingly numerous and heavily distributed among the larger all over the ventral surface.

The funnel shows two large triangular groups of numerous organs symmetrically disposed. As in *A. astrosticta* four of these only are of the larger type, but in this species they do not lie in a single transverse line. The tip of the funnel is colorless and devoid of photophores. The number of these organs on the head and arms is no longer to be made out.

Subocular organs are present, but the eyes are so damaged that their exact number and position can not be made out with certainty. They appear, however, to be relatively small and distant from one another.

Color everywhere a brownish buff, heavily clouded with dark reddish chromatophores which are numerous even over the ventral surface. These combine with the bluish photophores to give a purplish cast to the entire animal.

MEASUREMENTS OF ABRALIA TRIGONURA.

	mm.	Length of—	*mm.*
Total length	93	Head	11
Length excluding tentacles	68	Dorsal arm	18
Length of mantle, dorsal	28.5	Second arm	22
Extreme length of fins	17	Third arm	20
Length of fins at base	15	Ventral arm	21
Width across fins	29	Tentacle	49
Width of mantle	13	Tentacle club	8?
Width of head	11	Funnel	9

Type.—Catalogue no. 214387, United States National Museum [S. S. B. 275].

Type locality.—*Albatross* station 4087, 306 to 308 fathoms, off Mokuhooniki Islet, northeast entrance to Pailolo Channel, fine gray sand bottom, July 21, 1902; one specimen.

Distribution.—Hawaiian Islands (*Albatross*).

Material examined.—The unique type is the only specimen known.

Remarks.—Although in a rather badly macerated condition, as though taken from the stomach of some larger animal, the single specimen seen still retains enough of its original appearance to show features which forbid its reference to any of the previously described species of either *Abralia* or *Abraliopsis*. The lack of terminal organs on the ventral arms and the pale red-dotted buccal membrane alone serve to establish its identity as an *Abralia*, while the large fins indicate that it will prove to belong to the typical section of that genus. The species to which *A. trigonura* most closely approximates seems to be the *A. andamanica* Goodrich from the Bay of Bengal. The mantle of the Hawaiian species, however, appears to be relatively shorter and much more rapidly tapering, and such of the photogenic organs as can be made out fail to coincide in their arrangement with the description given by Goodrich, who fails to mention the definite series of these organs which here adorn the ventral aspect in so conspicuous a fashion that they can scarcely have been overlooked.

From the other known Hawaiian species, *A. astrosticta*, it is widely different. The short conical body, larger fins, more numerous small luminous organs on the ventral surface, and much smaller subocular organs are sufficient to distinguish it at a glance. As the specimens obtained of the two species are not very far from one another in size, it is evident that one can not be regarded as but a younger stage of the other.

Genus ABRALIOPSIS Joubin 1896.

Abraliopsis Joubin 1896, p. 19.
Abraliopsis Pfeffer 1900, p. 166, 168.
Abralia Pfeffer 1908a, p. 289–292.
Abraliopsis Chun 1910, p. 57, 78.
Abralia Pfeffer 1912, p. 124, 137.
Abraliopsis Pfeffer 1912, p. 764.
juv.=*Compsoteuthis*+*Micrabralia* Pfeffer 1900, p. 165, 167.
juv.=*Nepioteuthion*+*Prodromoteuthis* Pfeffer 1912, p. 149, 151, 165, 167.

Fins large, sagittate; acutely pointed posteriorly, and not exceeded by the tip of the equally pointed body. Arms with two rows of hooks throughout the greater part of their length, but with true suckers

at the tips of all the arms, as in *Abralia*, except the ventral pair which bear only hooks; extremities of ventral arms with a conspicuous series of heavily pigmented black bead-like organs probably photogenic in function. Left ventral arm hectocotylized, but distinguished chiefly by its very wide web with broad lappets at the margin; no glandular swellings. Two rows of suckers on proximal portion of tentacle club suppressed in adult, leaving either two rows of hooks or one row of hooks and one row of suckers, which give way distally to four rows of suckers. Buccal membrane deep violet in color. Photogenic organs of the mantle usually showing a definite bilateral arrangement; three rows of these organs present on the lower aspects of the ventral arms, two occurring on the arm itself, the other upon its marginal web. A single series of five large photophores occurs upon the ventral periphery of the eyeball, the terminal organs of this series being somewhat larger than the remainder.

Type.—Enoploteuthis Hoylei Pfeffer 1884 (designation); described from the Mascarene Islands.

Abraliopsis species (young).

Abraliopsis species Berry 1909, p. 419 (mere locality record).

Animal small. Mantle short, acutely conical, widely flaring in front. Fins relatively enormous, over two-thirds the length of the mantle and notably wider when taken together than the latter is long, anterior lobes prominent and angular.

Head small; only broader than long because of the large conspicuous eyes. Funnel flattened, little projecting.

Arms rather long, very slender and attenuate; decidedly unequal, their formula 4, 2, 3, 1; the ventral arms conspicuously longer than the others, the dorsal pair notably the shortest. Armature consisting of two alternating series of small elevated hooks, the latter persistent nearly to the tips of the arms, so that the usual suckers at the extremities are very small and obscure and have not in the present case been actually observed by me.

Buccal membrane eight-pointed; its coloration violet throughout except for the paler and more whitish trabeculæ.

Photogenic organs of mantle conspicuous and exhibiting a very definite grouping, not even the smaller ones being very irregularly scattered; on the ventral surface of the mantle occur six very definite rather distant converging series, with traces of another row as represented by three or four widely spaced organs lateral to these. On the head three conspicuous rows (the only ones shown in the figure) with another weaker row lateral to these and a rather weak circle around the eyelid opening, making seven rows in all. Along the ventral aspect of the ventral arms there are two rows and one row on the third pair.

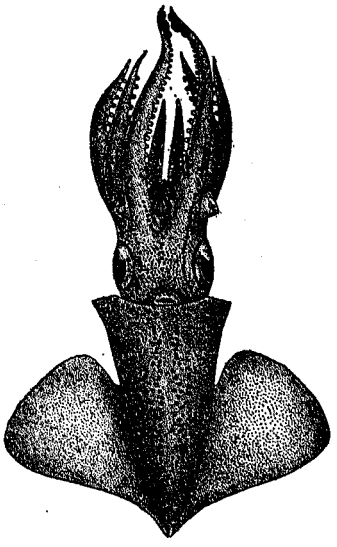

FIG. 34.—*Abraliopsis* sp., young, ventral view [276], × 2. Drawn by R. L. Hudson. The representation of the photogenic organs is incomplete.

The ventral arms bear at their extremities a bead-like series of three distinctly separate smooth black ovoid swellings, the median one notably the largest.

The subocular organs are yellowish in color but too badly damaged to be made out very clearly.

Color in alcohol a brownish buff; the chromatophores darker but comparatively few in number. Photophores bluish with paler centers.

MEASUREMENTS OF ABRALIOPSIS SPECIES (YOUNG).

	mm.		mm.
Total length exclusive of tentacles	35	Length of—	
Length of mantle, dorsal	16	Head	5
Extreme length of fins	11	Dorsal arm	7
Length of fins at base	9	Second arm	12
Width across fins	19	Third arm	11
Width of mantle near anterior margin	7	Ventral arm	15
Width of head	6	Funnel	5

Material examined.—The single specimen was taken from the surface at *Albatross* station 3926, latitude 21° 13′ N., longitude 158° 41′ W., between Honolulu and Laysan Island [S. S. B. 276].

Remarks.—This specimen is clearly immature and withal very poorly preserved. The tentacles are missing and the integument disfigured with a whitish deposit, badly obliterating some of the important features. It is undoubtedly a young *Abraliopsis*, however, and is very close to the stage described by Pfeffer as *Micrabralia*.

Subfamily PYROTEUTHINÆ Pfeffer 1912.

Pterygiomorphæ Chun 1908, p. 86.
Pterygiomorphæ Chun 1910, p. 58, 108.
Pyroteuthinæ Pfeffer 1912, p. 124, 189, 773.

Body sharply pointed posteriorly, notably exceeding the large round separate fins. Buccal membrane joined with the basal web of the arms; dorsal lappets close together and coherent at base. Photogenic organs lacking from the outer integument, but numerous and polymorphic on the eyeball as well as within the pallial chamber.

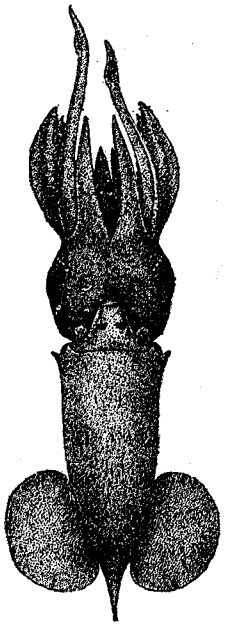

FIG. 35.—*Pterygioteuthis microlampas*, ventral view of female [278]. × 2. Drawn by R. L. Hudson.

Genus PTERYGIOTEUTHIS H. Fischer 1895.

Pterygioteuthis H. Fischer 1895, p. 205.
Pterygioteuthis Pfeffer 1900, p. 165, 166.
Pterygioteuthis Hoyle 1904, p. 39.
Pterygioteuthis Chun 1910, p. 58, 108.
Pyroteuthis (*Pterygioteuthis*) Pfeffer 1912, p. 193, 204, 774.

Ventral arms naked or with suckers only; remaining arms with a few of the middle suckers transformed to hooks. Tentacle club with four rows of suckers and no hooks; fixing apparatus composed of a very few suckers and pads. Left ventral arm hectocotylized, and furnished with a conspicuous glandular fold or swelling.

Type.—*Pterygioteuthis Giardi* Fischer 1895 (monotypic); described from off the coast of Morocco.

Pfeffer has placed this genus under *Pyroteuthis* Hoyle 1904 as a subgroup; but even should this arrangement be accepted as zoologically correct, the name *Pterygioteuthis* has nine years' priority and should therefore be given precedence.

Pterygioteuthis microlampas Berry 1913. (Pl. LII, fig. 1-3.)

Pterygioteuthis giardi Berry 1909, p. 419 (locality record only).
Pterygioteuthis microlampas Berry 1913, p. 566.

Animal small, fragile, with a cylindro-conical body terminating posteriorly in a sharp spinelike process, which extends between the fins and well past them; mantle about one-third as wide as long. Fins rather large, prominent, longer than broad, circular, not adnate, attached along their inner margins for less than half their total length; anterior and posterior lobes about equal.

Head large, rounded, but little narrower than the mantle. Eyes large, prominent. Funnel large, broadly conical in outline; aperture small.

Arms short, nearly of a length, their order of relative length 3, 2=4, 1; outwardly keeled by a very fragile trabeculated membrane (most conspicuous on the arms of the third pair). Dorsal arms bare for the basal one-fourth of their length; at this point occur two very minute somewhat distant suckers, succeeded distally by six pairs of much larger suckers alternating in two series; the ventral members of the succeeding three pairs are transformed into hooks, after which the remaining suckers (about eight in number) steadily diminish in size to the extremity of the arm, there being 14 pairs of suckers or their homologues on the entire arm; distally a wide delicate trabeculated membrane (mostly torn away) occupies the ventral margin of the sucker-bearing area; the larger suckers have about four large long bluntly squarish teeth along the upper border of their horny rings. Arms of second and third pairs essentially similar in all respects to the dorsal arms, although larger and stouter. Ventral arms squarish,

much more slender, more acutely tapering; hooks entirely lacking; suckers exceedingly minute, occurring in two distant narrowly spaced rows of 10 to 14 suckers each, which are confined to the more distal portion of the arm.

Tentacles short, stout, cylindrical, but little longer than the arms; near the base of the stalk a conspicuous circular constriction, beyond which the stalk swells out again, attaining a diameter even greater than that of the proximal portion, thence tapering gradually to the short blunt unexpanded club. Suckers on inner surface of club minute, in four rows; the five proximal members of the dorsal row distinctly the largest, even exceeding in size the two suckers on the carpus, which together with two small pads constitute the fixing apparatus. (Pl. LII, fig. 3.)

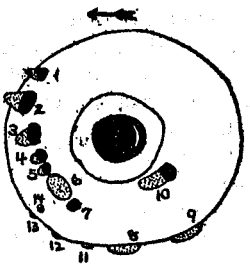

FIG. 36.—*Pterygioteuthis microlampas*, diagram to show arrangement of photogenic organs of left eyeball [277], × 5.

Subocular photophores numerous, at least 14 on each eyeball, but in the present material exceedingly difficult to locate with certainty, due to the ease with which they become detached upon the removal of the outer lid. Most conspicuous are two very large circular organs situated one just behind the other on the ventral periphery of the eyeball, just in front of the funnel (fig. 36, no. 8 and 9). Well anterior to these and more or less in line with them are four very much smaller organs (nos. 11–14). Just posterior to the lens is a large conical organ (no. 10), while a conspicuous series of seven moderately large organs form an oblique curve in front (nos. 1–7). Of the latter the three upper (nos. 1–3) are very large and conical in outline: the next two and the last one are smaller, but the next to the last one (no. 6) is large flattened, of ovate outline, and pale in color, very different in appearance from any of the other organs. (See also pl. LII, fig. 1.)

Color in alcohol a grayish buff, the chromatophores somewhat darker. Buccal membrane purplish, with paler trabeculae. The gladius shows through the dorsal integument as a prominent median line.

MEASUREMENTS OF PTERYGIOTEUTHIS MICROLAMPAS.

Number in author's register	277	278	Number in author's register	277	278
Sex	♀	♀	Sex	♀	♀
	mm.	*mm.*		*mm.*	*mm.*
Total length	31	.....	Length of—		
Tip of body to tip of arms	28	.....	Head	4	.....
Length of mantle, dorsal	18	.....	Dorsal arm	6.5	7
Width of mantle	6	6	Second arm	7.5	8
Extreme length of fins	8	.....	Third arm	8	8
Length of fins at base	3.5	.....	Ventral arm	7.5	7.5
Width across fins	14	.....	Tentacle	12	.....
Width across eyes	5.5	7			

Type.—Catalogue No. 214386, United States National Museum [S. S. B. 277].

Type locality.—*Albatross* station 4105, in 314 to 335 fathoms, Kaiwi Channel, bottom of fine coral sand and foraminifera, July 24, 1902; one ♀ specimen.

Distribution.—Hawaiian Islands (*Albatross*).

SPECIMENS OF PTERYGIOTEUTHIS MICROLAMPAS EXAMINED.

No. of specimens.	Locality.	Depth in fathoms.	Collector.	Sex.	Where deposited.	Author's register.
[a] 1	Kaiwi Channel	314–335	Albatross Sta. 4105	♀	U. S. Nat. Mus. Cat. 214386	277
1	No locality	(?)	Albatross Sta. (?)	♀	Fragmentary	278

[a] Type.

Remarks.—Only two species of *Pterygioteuthis* have been recognized previous to the present one. The first of these and type of the genus is the *P. giardi* Fischer, originally described from a specimen taken by the *Talisman* at a depth of 1105 meters off the coast of Morocco. In 1904 Hoyle published a much more detailed account of some specimens thought to represent the same species which were captured by the *Albatross* in the eastern tropical Pacific at depths ranging from 551 to 1,201 fathoms. In 1908 Chun issued a brief diagnosis of a second species, *P. gemmata*, which was secured by the *Valdivia* expedition in the South Atlantic. When the present specimens from the *Albatross* Hawaiian collections were first being examined by the writer, Chun's paper had not yet come to hand, so that they were, after a little hesitation, referred to *P. giardi* and were indeed recorded under this name in a preliminary publication. Since that time the appearance of the great monograph of the *Valdivia* Oegopsids by Chun has greatly increased and simplified our understanding of the genus, so that upon a reexamination of the specimens and a patient working out of the details (often seriously obscured by the woeful preservation of the material) the conclusion was reached that a new species is represented, which though in many respects very close to *P. giardi*, in some ways shows an approach to *P. gemmata*, and in others is somewhat different from either. The relationship of the three species is well shown by a consideration of their more important diagnostic characters grouped in parallel columns.

DIAGNOSTIC CHARACTERS OF THE SPECIES OF PTERYGIOTEUTHIS.

P. giardi.	P. microlampas.	P. gemmata.
15 subocular organs; the 5 small anterior ones nearly in line with one another.....	14 subocular organs; arrangement similar to *P. giardi*, but 4 instead of 5 small anterior organs, and the last of these not in line with the others.	14 subocular organs; arrangement very different.
Dorsal arms with 3 hooks near middle of arm (both rows affected) and about 5 pairs of suckers proximally; 2d and 3d arms with 2–3 hooks (both rows). No suckers at tips of any arms save dorsal pair.	Dorsal arms with 3 hooks near middle of ventral row, with 6–7 pairs of suckers proximally; 2d and 3d arms with 3 hooks in ventral row and 7 suckers proximally; suckers continuing distally to tips.	Dorsal, 2d, and 3d arms with 4–5 hooks near middle of ventral row.
Ventral arms devoid of both hooks and suckers.	Ventral arms with no hooks; suckers minute and confined to distal half of arm.	Ventral arms with no hooks; but with small suckers throughout their length.
Two suckers in fixing apparatus.....	Two suckers in fixing apparatus.....	Three suckers in fixing apparatus.
Chitinous plate between the glandular ridges of the hectocotylus bidentate.	Hectocotylus unknown.....	Chitinous plate between the glandular ridges of the hectocotylus finely toothed.

It is an unfortunate but curious fact that practically all of the specimens of this genus which have been obtained have been defective in one way or another. As a rule either the eyes have burst or the arms are badly damaged or both types of mutilation have occurred. This appears to be due to the fragile and incoherent nature of the tissues, which seem unable to withstand the great changes in pressure which they are forced to undergo in being pulled up from the depths in which they live. According to present evidence it appears that even in a preserving medium they are apt to gradually disintegrate, and despite the utmost vigilance and care the handling necessarily incidental to a thorough examination is often fatal. This was the case with the specimen which was the subject of Mr. Hudson's excellent drawing, for though evidently perfect at that time, it was in such fragmentary condition when it came into my hands that no accurate description of it could be given and it became necessary to utilize the second individual as the type, although the account of the photogenic organs of the eye has been mainly drawn from the former specimen.

I can not forbear adding that there are certain discrepancies in the various descriptions given by Fischer, Joubin, Hoyle, and Chun for *P. giardi* which cause me to feel some doubt as to whether all their specimens are really referable to the same species, an uncertainty which is by no means diminished when the localities furnishing the respective specimens are taken into consideration.

Family HISTIOTEUTHIDÆ Verrill 1881.

Histioteuthidæ Verrill 1881, p. 431.
Histioteuthidæ Pfeffer 1900, p. 152, 168.
Histioteuthidæ Pfeffer 1908, p. 75.
Histioteuthidæ Chun 1910, p. 147.
Histioteuthidæ Pfeffer 1912, p. 243.

Body short, barrel-shaped; mantle thickened and fleshy. Fins relatively small, subterminal. None of the suckers on either arms or tentacles modified into hooks; two rows of suckers on sessile arms; on tentacle club more than four rows. Fixing apparatus a series of small suckers and pads extending across the carpal region of the tentacle and well down its stalk. Funnel locking cartilages simple linear grooves and ridges. Gladius simple, loliginiform, with broad wings. Photogenic organs of very characteristic structure plentifully developed over almost the entire outer surface of the mantle, head, and arms.

Histioteuthid species (young).

Ommastrephid (young) Berry 1909 (pars), p. 419 (mere locality record).

Body small, ovate, considerably over half as broad as long. Fins very small, subterminal, and decidedly dorsal in position, with a nearly circular outline; practically continuous posteriorly. Anterior margin of mantle obtusely angled in the median line above; slightly emarginate below the funnel.

Head about half as large as the body; flattened above and below. Eyes rounded, prominent; their apertures small, angled in front but otherwise entire. Funnel rather large, little projecting. Mantle connectives a pair of simple grooves with thickened and reflexed margins at the base of the funnel articulating with narrow linear ridges on the inner surface of the mantle.

Arms over half as long as the mantle; rather stout; unequal, the order of length 2, 3, 1, 4. Suckers minute, spherical, biserial; horney rings well developed.

Tentacles but little longer than the arms. Club slightly expanded and armed with four rows of minute crowded suckers, the two outermost of which continue down the stalk nearly to its base.

Color in alcohol a dull brownish buff. The chromatophores are large, slate colored, thickly distributed above, but not without certain hints of a symmetrical arrangement in seven to eight more or less obscure transverse rows; much paler and less crowded below. Pigmentation on dorsal surface of head extremely dense. A single series of large chromatophores extends along the outer surfaces of all the arms, dark in color on the dorsal pair, but so pale as to be scarcely visible below. There are two distinct chromatophores placed opposite one another on the ventral aspect of the funnel not far from the middle.

Total length of largest specimen, 11 mm.; of mantle, 5 mm.; of head, 2.5 mm.; of arm of second pair, 3 mm.; of tentacle, 3.5 mm.; width of mantle, 3 mm. Length of smallest specimen, 9 mm.; of mantle, 4 mm.

Three specimens of this curious larval form were taken by the *Albatross* in the surface net at station 4190, latitude 34° 39′ 18″ N., longitude 132° 04′ W. [S. S. B. 254].

Although minute and offering no very conspicuous characters of their own, the above specimens undoubtedly represent larval stages of some Histioteuthid, perhaps *Calliteuthis* or some nearly related form. Although in all essential features they resemble the young Histioteuthid described by Pfeffer in Hoyle 1907, p. 1–2, sufficient minor differences are evident to render it probable that they belong to another species, even if referable to the same genus. From the young Ommastrephids with which they were at first confounded, the strong pigmentation, larger head, and longer arms are sufficient for their ready separation.

Family BRACHIOTEUTHIDÆ Pfeffer 1908.

Tracheloteuthidæ Pfeffer 1900, p. 152, 174.
Brachioteuthidæ Pfeffer 1908, p. 62, 78.
Tracheloteuthidæ Chun 1910, p. 205.
Brachioteuthidæ Pfeffer 1912, p. 345.

Body slender, loliginiform. Fins large, rhombic. None of the suckers on either arms or tentacles transformed to hooks; arms with two rows of suckers; tentacles with four or more rows. No fixing apparatus. Funnel locking cartilages simple and linear. Gladius slender, consisting for the most part of little but the rhachis; terminating in a long pointed cone.

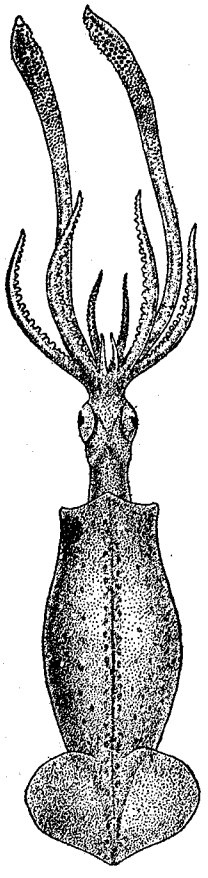

FIG. 37.—*Brachioteuthis (Trachelateuthis) riisei*, dorsal view of specimen [280], from station 3878, × 2. Drawn by R. L. Hudson.

Genus BRACHIOTEUTHIS Verrill 1881.

Brachioteuthis Verrill 1881, p. 405.
Brachioteuthis Pfeffer 1900, p. 174, 176.
Brachioteuthis Chun 1910, p. 206.
Brachioteuthis Pfeffer 1912, p. 346.

Characters af genus identical with those of the family, for the latter becomes monogeneric upon the union of *Tracheloteuthis* with *Brachioteuthis*, as is now very generally advocated.

Type.—*Brachioteuthis Beanii* Verrill 1881 (designation); a species of the New England region.

Subgenus TRACHELOTEUTHIS Steenstrup 1882.

Tracheloteuthis Steenstrup 1882, p. 294.
Verrilliola Pfeffer 1884, p. 22.
Entomopsis de Rochebrune 1884, p. 15.
Tracheloteuthis Hoyle 1886, p. 163.
Tracheloteuthis Pfeffer 1900, p. 174, 175.
Tracheloteuthis Pfeffer 1908, p. 78.
Brachioteuthis (pars) Chun 1910, p. 206.
Brachioteuthis (*Tracheloteuthis*) Pfeffer 1912, p. 355.

Mantle very thin, membranous. Entire animal nearly colorless except for a few chromatophores on the head and a very few scattered ones on the body. Fins large, rhombic, but never as long as half the mantle length.

Type.—*Tracheloteuthis Riisei* Steenstrup 1882 (species first mentioned); a species of almost cosmopolitan distribution.

Brachioteuthis (Tracheloteuthis) riisei (Steenstrup 1882).

Tracheloteuthis Riisei Steenstrup1882 p. 294.
Tracheloteuthis Behnii Steenstrup 1882, p. 294.
Tracheloteuthis riisei Hoyle 1886, p. 36, 164, 213, 221, pl. 28, fig. 6–12.
Tracheloteuthis Behnii Weiss 1888, p. 85, pl. 10, fig. 1–4.
Tracheloteuthis riisei Lönnberg 1897, p. 603 (account of funnel organ).
Tracheloteuthis riisei Pfeffer 1900, p. 175.
Tracheloteuthis Riisei Hoyle 1905a, p. 93, pl. 14, fig. 1–5.
Tracheloteuthis riisei Pfeffer 1908, p. 79, fig. 93–95.
Tracheloteuthis Riisei Massy 1909, p. 30.
Tracheloteuthis riisei Berry 1909, p. 419 (mere locality record).
Brachioteuthis Riisei Chun 1910, p. 207.
Brachioteuthis (*Tracheloteuthis*) *Riisei* Pfeffer 1912, p. 355, pl. 26, fig. 1–20; pl. 27, fig. 1–9.

Animal small, pelagic, hyaline, extremely slender and graceful. Mantle very thin, inflated, elongate-cylindrical; swollen at the middle and tapering to an acute slightly attenuate point posteriorly; pallial chamber capacious, very scantily occupied by the delicate viscera. Mantle opening very wide, due largely to the extreme length and narrowness of the neck; anterior margin sharply angled in the medio-dorsal line, the ventro-lateral projections also well marked but somewhat less pronounced.

Fins fairly large, a little over one-fourth as long as the mantle; each one taken singly, a little longer than broad; barely separated in the medio-dorsal line by the narrow membrane covering the slender gladius, which extends past them as an acute point.

Head small, flattened, elongate, distinctly wider than the stalklike neck. Eyes large, little projecting; their apertures ample, with a slight obtuse anterior sinus. Funnel large, thin-walled, only its tip protruding beyond the mantle margin; valve minute. Funicular locking cartilages simple, with nearly straight grooves.

Arms conspicuously unequal, their order of length 2, 3, 4, 1; the lateral arms not only immensely longer than those of the dorsal and ventral pairs, but also more robust in every way; dorsal arms exceedingly short and weak, slightly recurved; the length of the second arms is about 5 to 6 times that of the dorsals, the third arms about 4½ times, and the ventrals 2½ to 3½ times; lateral arms usually a little more than half as long as the body, exceedingly slender and graceful, with a delicate narrow membrane or keel along their outward aspect. Suckers small, not crowded; pedicels conical; horny rings toothed.

Tentacles more robust, thicker, and much longer than any of the arms, attaining approximately twice the length of the second pair. Club little expanded; distal portion tapering and with a conspicuous dorsal keel; at this region the inner face of the club bears four rows of minute suckers (horny rings toothed), which increase regularly in size from the dorsal to the ventral row, the latter suckers long pediceled and with a diameter about three times that of the dorsal ones; distally all the acetabula regularly diminish in proportion, but proximally to this region those of the dorsal row about maintain their size, the remaining rows diminishing in size but greatly increasing in number so that we henceforth find at least eight closely crowded series of minute subequal suckers extending for perhaps a third the length of the tentacle, after which they again thin out; two of the rows continue down the stalk in distantly placed alternating series for another third of its length.

Gladius long, slender, consisting chiefly of the rhachis, and terminating in a delicate hollow cone; midrib visible through the dorsal integument as a narrow horn-colored line.

Color in alcohol everywhere a very pale brownish buff, the head and eyes darker; head brown, eyes with a slaty tone. Chromatophores sparse, pale, indistinct; a longitudinally-arranged series extends along the dorsal aspect of the mantle on either side of the gladius.

MEASUREMENTS OF TRACHELOTEUTHIS RIISEI.

Number in author's register	280	280	280	280	280	280	280
	mm.	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
Total length	60	59	58	58	55	55	45
Length, excluding tentacles	46	45	46	45	41	41	33
Tip of body to base of dorsal arms	32	31	32	31	31	30	26
Length of mantle, dorsal	25	24	25	23	23	23	17
Extreme length of fins	6.5	6.5	7	6	6	5.5	3
Width across fins	10	10	11	10	9.5	8.5	7
Width of mantle	7.5	6	7.5	7	7	7	6
Width of head	2.5	2.5	3	2.5	2.5	2.5	2
Length of—							
Head	4	3.5	4.5	3.5	3.5	4	3
Dorsal arm	3	2.5	2.5	2.5	2	2	1.5
Second arm	15	14	14	13	12	11	7
Third arm	11	11	12	11	9	9.5	6
Ventral arm	7	7	7	8	7	5	3
Tentacle	27	25	28	27	24	24	21

Type.—In the Copenhagen Museum.

Type locality.—Latitude 34° 40′ S., longitude 7° W. (*fide* Hoyle).

Distribution.—North Atlantic (Lönnberg); off coast of Ireland (Hoyle, Massy); Faeroe Channel (Fowler); Messina, Sicily (Weiss, Hoyle); Gulf of Naples (Jatta); coast of Morocco (Joubin); St. Paul Island (de Rochebrune); Zanzibar (Pfeffer); Indian Ocean (Hoyle); west coast of New Guinea (Hoyle); Solomon Islands (Pfeffer); Hawaiian Islands (*Albatross*); between Honolulu and San Francisco, California (*Albatross*); Chile (Pfeffer).

SPECIMENS OF TRACHELOTEUTHIS RISEI EXAMINED.

No. of specimens.	Locality.	Depth.	Collector.	Author's register.
7	South of Lanai	Surface	Albatross station 3878	280
1	34° 39′ 18″ N. lat., 132° 04′ W. long	...do	Albatross station 4190	281

Remarks.—These specimens, all of which are of approximately the same size and developmental stage as the one selected for figuring, are of interest here chiefly because they serve to extend the known range of this curious pelagic species over a much greater area of ocean it was previously reported to inhabit. There is small doubt that it will eventually prove to have an almost universal dispersion in the warmer currents of the ocean.

Family OMMASTREPHIDÆ Gill 1871.

Ommastrephini Steenstrup 1861, (*fide* Hoyle).
Ommastrephidæ Gill 1871, p. 1.
Ommastrephidæ Verrill 1881, p. 428.
Ommastrephini Hoyle 1886, p. 32, 162.
Ommatosrephidæ Pfeffer 1900, p. 153, 176.
Ommatostrephidæ Pfeffer 1908, p. 62, 87.
Ommatostrephidæ Pfeffer 1912, p. 369.

Animal usually of moderate size, but often of considerable dimensions; loliginiform. Fins large, sagittate, subterminal. Suckers in two rows on the arms, usually four rows on the clubs of the tentacles; none of the suckers modified into hooks. Fixing apparatus a single series of modified suckers and pads at the base of the club. Funicular cartilages highly developed, complex; their major outlines ⊥-shaped. Gladius consisting of little but the rhachis throughout the greater portion of its length; terminating posteriorly in a deep hollow cone. The occurrence of photogenic organs has not been described in any of the genera except *Hyaloteuthis*.

Genus OMMASTREPHES d'Orbigny 1835.

Ommastrephes d'Orbigny 1835, p. 45.
Ommastrephes d'Orbigny 1845, p. 412.
Ommatostrephes Lovén 1846 (*fide* Hoyle).
Ommastrephes (pars) Verrill 1880a–1881, p. 267, 385.
Todarodes Steenstrup 1880, p. 83 (13).
Ommatostrephes Pfeffer 1900, p. 178, 179.
Ommastrephes Hoyle 1902, p. 198.
Ommatostrephes Pfeffer 1908, p. 89, 92.
Ommatostrephes Pfeffer 1912, p. 388, 438.

Funnel groove with a foveola. Horny rings of large tentacular suckers with the teeth either nearly subequal, or with one or more of the apical denticles somewhat enlarged. Fixing apparatus very poorly developed. Sucker bearing portion of tentacle extending for more than half the total length.

Type.—*Loligo sagittata* Lamarck 1799 (species first mentioned); a common Atlantic species.

Ommastrephes hawaiiensis Berry 1912. (Pl. LIV, fig. 2.)

?*Ommastrephes sloanei* Schauinsland 1899, p. 92 (listed from Laysan Island).
Ommastrephes sagittata near *sloanei* Berry 1909, p. 418 (mere locality records).
?*Ommatostrephes Sloanei Sloanei* (pars) Pfeffer 1912, p. 458.
Ommastrephes hawaiiensis Berry 1912b, p 434, 437.

Animal loliginiform, moderate in size. Mantle cylindro-conical, widest somewhat in advance of the middle, thence tapering very rapidly to an acute point between the fins; margin smooth and entire above, slightly emarginate below the funnel. Fins only moderately large, triangular when taken

singly, together broadly sagittate; posterior outlines nearly straight, anterior ones arcuate and lobed at the inner margin; total length a little less than two-fifths that of the mantle.

Head large, a little broader than the body; flattened above and below; bounded posteriorly by raised thickened fleshy ridge, which is continuous with the three ear-like folds behind the eye composing the so-called olfactory crest. Eyes large, the large lid apertures with a small indented sinus in front.

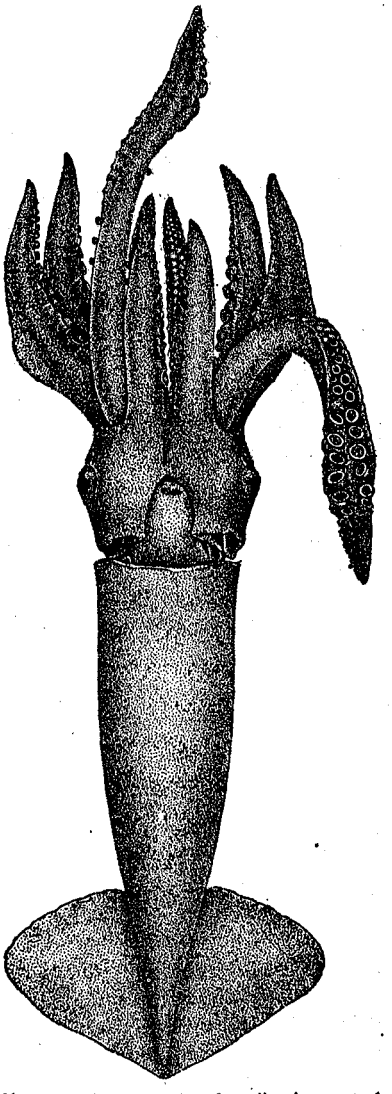

FIG. 38.—*Ommastrephes hawaiiensis*, ventral view of type [243]. × ½. Drawn by R. L. Hudson.

Arms moderate, stout, squarish, little attenuate, their average length about half that of the mantle; order of length in general 2, 3, 1, 4, or in younger specimens 2, 3, 1=4; not webbed at the base, but all strongly keeled along the outer angle, and with a narrow trabeculated membrane bordering the margins of the sucker-bearing area; the latter attaining its maximum along the ventral margins of the third arms, but scarcely developed on the ventral pair. Suckers large, distant; regularly alternating in two series so closely appressed together that they have rather the appearance of a single zigzag row; those of the dorsal arms distinctly smaller than the others; those of the lateral pairs largest, some of those near the middle of the arm attaining a diameter almost as great as that of the arm itself; on the arms of the second pair only about 36 to 40 suckers in all can be readily counted. Horny rings of the larger suckers with 19 to 21 teeth, the upper median tooth conspicuously the largest and more regularly conical in shape than the others; those of the lower margin blunt and much reduced (obsolete in the smaller suckers), the remainder acutely pointed; an occasional very minute denticle may be interpolated among the teeth of the upper margin.

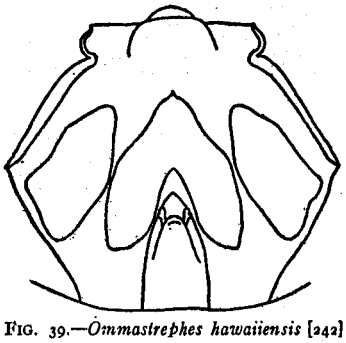

FIG. 39.—*Ommastrephes hawaiiensis* [242] outline drawing of funnel organ, natural size.

Tentacles stout, of moderate length, some two-thirds or more as long as the mantle; outer margin carinate; club slightly expanded, large, the sucker bearing area including 64 to 70 per cent of the total length of the tentacle. Suckers in four rows; all of small size at the extremity, the ventral row largest, thence very regularly decreasing in size dorsally; at the middle of the club the dorsal and ventral series about equal, but still very small and widely spaced, the suckers of the two median rows immensely larger (and therefore more crowded) and basin shaped, but proximally again showing a diminution in size; at the base of the club the central rows terminate, the marginal series continuing past them for a short distance down the stalk. The horny rings of the large median suckers are toothed all round, the 13 to 16 acutely-pointed curved teeth occurring in regular alternation with an equal number of wide, low, very thin arcuate plates; upper median tooth much larger and more pointed than the others, very much as already noted in the case of the suckers of the sessile arms. The small marginal suckers are much

deeper above and bear about 20 teeth, which are very long, slender and acute on the upper margin (obtuse and reduced below) and occur in alternation with minute bluntish denticles; none of the teeth in these suckers notably larger than the others. I can not make out any pads or specially differentiated suckers which could be construed as constituting a fixing apparatus.

Color in alcohol the usual brownish buff dotted with brown chromatophores.

MEASUREMENTS OF OMMASTREPHES HAWAIIENSIS.

Number in author's register	242	243 (type)	244	245	248
	mm.	*mm.*	*mm.*	*mm.*	*mm.*
Total length	285	282	195	151	207
Tip of body to tip of arms	249	239	179	131	172
Length of mantle, dorsal	147	138	107	81	105
Width of mantle near middle	31	33	23	21	22
Width across fins	76	76	54	42	.....
Extreme length of fins	56	52	37	27	.....
Length of fins at base	50	45.5	33	22	.....
Length of head	35	28	22	18	18
Width of head	50	37	25	22	23
Length of—					
Right dorsal arm	60	62	41	26	35
Right second arm	76	77	50	33	42
Right third arm	78	76	48	32	50
Right ventral arm	58	60	41	26	41
Right tentacle	118	118	67	48	80
Sucker-bearing portion of right tentacle	81	80	43	32	43?
Left tentacle	.....	119	66	50	74
Sucker-bearing portion of left tentacle	.....	81	44	35	43?

Type.—Catalogue no. 214382, United States National Museum [S. S. B. 243].

Type locality.—*Albatross* station 4177, 253 to 282 fathoms, off Kahuku Point, northwest coast of Oahu, bottom of coral sand and foraminifera, July 25, 1902; one specimen.

Distribution.—Hawaiian and Midway Islands (*Albatross*).

SPECIMENS OF OMMASTREPHES HAWAIIENSIS EXAMINED.

No. of specimens.	Locality.	Depth in fathoms.	Collector.	Remarks.	Author's register.
1	Honolulu	.....	Albatross expedition	Young; badly desiccated	247
1	Honolulu market	.....	....do	.....	383
1	Pailolo Channel	256–283	Albatross station 3865	.....	242
1	Off Kahuku Point, Oahu	253–282	Albatross station 4177	Type; U. S Nat. Mus., Cat. 214382.	243
1	Off Hanamaulu, Kauai	257–312	Albatross staion 4132	.....	244
1	Off Puniawa Point, Maui	220–238	Albatross station 4082	.....	245
1	Laysan Island	.....	Albatross hydrographic station 4353.	From stomach of *Sula piscator*.	248

Remarks.—This is one of the commonest Hawaiian squids and probably a species of considerable economic value in its food relations to many sea birds and the larger fishes. Because it is so abundant and characteristic a member of the fauna of this region, I have little doubt that the specimens listed by Schauinsland and more recently Pfeffer from Laysan Island as *O. sloanei* are the same form. The true *O. sloanei*, however, appears to be a somewhat different creature, as Gray expressly states that the horny rings of the suckers have the "higher side with *regular* acute teeth, lower *smooth*" (italics mine), while the remainder of Gray's diagnosis is so sadly incomplete or even silent regarding what should prove to be features of the highest importance, that there seems every likelihood that other even more striking differences will eventually appear. *O. hawaiiensis* is undeniably a near relative of the Japanese *O. pacificus* Steenstrup, considered by many to be a synonym of *O. sloanei* (cf. Berry 1912b, p. 436–437), but the specimens before me differ consistently in their more rapidly tapering body, slightly shorter fins, much larger and wider head, very much fewer and larger suckers on the sessile arms (especially

the second and third pairs), and the fact that the teeth of the latter are not subequal but the middle tooth on the upper side is conspicuously larger than its neighbors, showing in this last character an approach to the condition prevailing in the Atlantic *O. sagittatus*. From this résumé it would appear that *O. hawaiiensis* is in some respects intermediate between *O. sagittatus* and *O. pacificus*, while in a few particulars it is somewhat different from either.

The position of *O. sloanei* I am now disposed to regard as more doubtful than ever, for undoubtedly the union of *O. pacificus* with it was more premature than the meager evidence would justify. The habitats of all three of the Pacific forms are still widely separated, and further material, particularly from southern localities, is an important desideratum.

Genus SYMPLECTOTEUTHIS Pfeffer 1900.

Symplectoteuthis Pfeffer 1900, p. 178, 180.
Symplectoteuthis Pfeffer 1912, p. 388, 501.

Funnel groove with a foveola. Funicular locking cartilages fused with those of mantle on at least one side. Horny rings of large tentacular suckers with one tooth in each quadrant much enlarged. Sucker-bearing portion of tentacle comprising less than half the total length. Fixing apparatus composed of a few heavy pads and smooth-ringed suckers.

Type.—*Loligo oualaniensis* Lesson 1830 (monotypic); a species of the tropical Pacific.

Symplectoteuthis oualaniensis (Lesson 1830) Pfeffer 1900.

Loligo oualaniensis Lesson 1830, p. 240, pl. 1, fig. 2.
Ommastrephes oualaniensis d'Orbigny 1845, p. 427.
Ommastrephes oualaniensis Tryon 1879, p. 186, pl. 81, fig. 368 (after d'Orbigny).
Ommastrephes oualaniensis Schauinsland 1899, p. 92 (listed from Laysan).
Symplectoteuthis oualaniensis Pfeffer 1900, p. 180.
Symplectoteuthis oualaniensis Hoyle 1904, p. 32, fig. F.
Symplectoteuthis oualaniensis Berry 1909, p. 419 (merely listed).
Symplectoteuthis oualaniensis Pfeffer 1912, p. 502, pl. 40, 41; pl. 42, fig. 1–4.

I have seen no specimens of this species, but include it here on the authority of Schauinsland, who found it one of three species of squid which compose a chief food for the Laysan albatross. It is an abundant species of wide distribution, having been reported from the Red Sea, Laccadive Islands, Japan, Australia, the Cocos Islands, and Laysan. It may be readily recognized by the compressed arms, short tentacle club, and the fusion of the ventral mantle locking cartilages with those of the funnel.

Genus RHYNCOTEUTHION Pfeffer 1908.

Rhyncoteuthis Chun 1903, p. 716 (not of d'Orbigny 1847).
Rhyncoteuthis Hoyle 1904, p. 32.
Rhyncoteuthion Pfeffer 1908, p. 88.
Rhyncoteuthis Chun 1910, p. 201.

This is a name which has been applied to various larval *Ommastrephidæ* during the curious stage when the tentacles are fused along a portion of their inner faces, to form in some cases an elongate proboscis-like organ, or in others a pincer-shaped organ. The development and relationships of the different forms which have been described is still so insufficiently known that it is impossible to refer them to the proper adult form, so that it is convenient to give them provisional consideration by themselves.

Type.—No type has ever been given and but one species (*R. chuni* Hoyle 1904) has received a specific name.

Rhyncoteuthion α. (Pl. LIII, fig. 1.)

Cf. *Rhyncoteuthis chuni* Hoyle 1904, p. 32, fig. G.
Ommastrephid (young) Berry 1909 (pars), p. 419 (mere locality records).

Animal small, pelagic. Body rather short, robust, cylindrical, tapering to a blunt point posteriorly; width of mantle in largest specimens less than half its length, in smaller examples considerably more than half its length. Fins extremely short and broad in the larger specimens (mantle length of 20 mm.), more rounded and very minute in the smaller, with all variations between; subterminal to terminal. Locking cartilages typically Ommastrephid.

Head short, broad, flattened, averaging about the same width as the mantle. Eyes large and in all but the largest specimens prominently protruding; lid openings with a small sinus in front.

Arms very short and stout; second and third pairs longest, ventrals shortest, a condition especially apparent in the more minute specimens; lateral arms (especially the third pair) outwardly keeled, but true umbrella wanting. Suckers minute, spherical, in two series.

Tentacles but little longer than the arms, but their appearance very variable. In the smallest specimen seen (mantle length of 5 mm.) they are slender, fused along their inner faces for the greater portion of their length, but free at the extreme base and at the extremities, which bear a few suckers (3 to 4 each), one of the latter being so conspicuously larger than the remainder as to be barely visible to the unaided eye. In slightly larger specimens (mantle length of 6.5 to 7 mm.) the tentacles are more completely separated but are yet fused for a short diatance near the base of the small recurved pointed club (this is the condition typical of Hoyle's *R. chuni*), and minute swellings, the rudiments of future suckers, are now visible on the club distal to the large sucker and group of smaller ones mentioned above. Soon after this (mantle length of 9 mm.) the tentacles become entirely free of one another, though still bent strongly inward and with the tips still recurved. Further development is now rapid and the largest specimens show four longitudinal series of extremely minute suckers, those of the two outer rows much smaller than the central ones and already extending down onto the short robust stalk. The four carpal suckers are still separately distinguishable, but are now no larger than the median ones farther distad.

Color in alcohol a pale brownish buff, the chromatophores brown. The latter show a very constant disposition, forming (1) a broad transverse girdle around the middle of the body, shading paler at its anterior and posterior margins, and (2) an irregular dotting over the dorsal surface of the head, with a tendency to concentrate into two dark roundish spots, one over either eye.

MEASUREMENTS OF RHYNCOTEUTHION *α*.

Number in author's register...	255	255	253	Number in author's register...	255	255	253
	mm.	*mm.*	*mm.*	Length of—Continued.	*mm.*	*mm.*	*mm.*
Total length	35	23	11	Dorsal arms	7	5.5	2
Length of mantle, dorsal	21.5	15	6	Second arms	8+	6.5	2+
Length of fins	4.5	3	1.5	Third arms	8—	6	2—
Width across fins	11.5	8.5	3	Ventral arms	6	4	1
Width of mantle	9	7.5	5	Tentacles	10	7	.....
Width of head	9.5	8	4	Sucker bearing portion of tentacles	6.5	5	.....
Length of—							
Head	5	4	2				

SPECIMENS OF RHYNCOTEUTHION *α* EXAMINED.

No. of specimens.	Locality.	Depth.	Collector.	Remarks.	Author's register.
2	Off Mokapu Islet, Molokai	Surface	Albatross station 3889	Tentacles of 1 fused; others free.	249
1	Off Diamond Head, Oahu	do	Albatross station 3912	Tentacles free	250
5	Between Honolulu and Laysan	do	Albatross station 3926	do	255
1	Between Oahu and Kauai	do	Albatross station 3980	do	251
1	do	do	Albatross station 4010	Tentacles fused	252
1	Off Modu Manu	do	Albatross station 4152	do	253

Remarks.—This is a very interesting series and very beautifully shows the ontogenetic transition from the small larva with proboscidiform tentacles similar to that originally figured by Chun to the normal juvenile stage with free tentacles. Originally fused throughout practically their entire length, these organs begin to separate at the base as growth ensues, and then gradually split apart, the carpal region of the clubs marking the point of most persistent adhesion. Microscopical preparations show that the integument is truly continuous at the area of junction and that therefore the union is not merely a mechanical one.

Individuals of the corresponding stage in the degree of separation of the tentacles approximate very closely to the brief account and figure of *R. chuni* as given by Hoyle, and may very well be congeneric with it, although only the identification of the adults will show whether they are referable to the same species. The fact that the suckers extend more than half way along the tentacles of the largest specimen affords a certain suggestion that the present series are larval *Ommastrephes hawaiiensis*.

Rhyncoteuthion β.

Animal small, pelagic; mantle elongate, less than half as wide as long; nearly cylindrical, slightly tapering, bluntly pointed posteriorly. Fins almost continuous above, minute, rounded, subterminal. Anterior margin of mantle with a faint medio-dorsal angle; very weakly emarginate below the funnel. Locking appartus typically Ommastrephid.

Head small, flattened; a little wider than the body. Eyes large, rounded; apertures angled in front. Funnel short, broad, not reaching to the eye openings.

Arms very short, unequal, the ventral pair decidedly the shortest; suckers moderately large, biserial, obliquely placed on short pedicels; horny rings minutely toothed.

Tentacles shorter than the arms, and remarkable in that their inner faces are fused with one another for only a short space below the free recurved tips. When examined with a high-power lens each tentacle is seen to be furnished with a number of small suckers just distal to the point of fusion, one of which is greatly larger than the others, hood shaped, distinctly pediceled, its horny ring minutely toothed, median in position, and placed in close opposition to its mate of the other tentacle.

Color in alcohol a pale brownish buff, the chromatophores considerably darker. There is a pair of large rather conspicuous chromatophores transversely placed on the dorsal aspect of the head.

MEASUREMENTS OF RHYNCOTEUTHION β.

	mm.		mm.
Total length	12.5	Width across fins	3
Length of mantle, dorsal	8	Length of fins	1.5
Width of mantle	3	Length of second arms	2.5
Width of head	3.5	Length of tentacles	1.5
Length of head	2		

Material examined.—The single specimen was taken from the surface *Albatross* station 3930, latitude 25° 07′ N., longitude 170° 50′ W., between Honolulu and Laysan Island (S. S. B. 246).

Remarks.—The unique specimen forming the subject of the foregoing account is a minute squid at once distinguishable from the preceding by its elongate more pointed body and entirely different arrangement of the chromatophores. The curious pair of large opposite suckers on the tentacles may merely represent the first of these structures to become fully differentiated, but their entire aspect is rather that of some temporary larval adaptation.

Family CHIROTEUTHIDÆ Gray 1849.

Chiroteuthidæ Gray 1849, p. 36, 42.
Chiroteuthidæ Verrill 1881, p. 430.
Chiroteuthidæ Pfeffer 1900, p. 153, 183.
Chiroteuthidæ Chun 1910, p. 216.
Chiroteuthidæ Pfeffer 1912, 539.

Body soft and semigelatinous or somewhat membranous. Mantle elongate, terminating in an acute and often slender point. Fins large. Head elongate; "olfactory tubercle" stalked. Arms with two rows of suckers, the ventral pair usually conspicuously the longest and largest. Tentacles very long, the stalk without suckers; club with four or more rows of suckers; none of the suckers on either arms or tentacles modified into hooks. Funicular locking cartilages broad, deeply grooved, usually more or less ear-shaped. Gladius slender, with weak narrow wings and a long cone. Photogenic organs may occur over the outer surface of the body, on the eyeball, or within the pallial chamber; frequently absent.

Subfamily MASTIGOTEUTHINÆ (Verrill 1881) Chun 1908.

Mastigoteuthidæ Verrill 1881a, p. 100.
Mastigoteuthinæ Chun 1908, p. 87.
Mastigoteuthinæ Chun 1910, p. 219, 220.
Mastigoteuthinæ Pfeffer 1912, p. 540, 608.

Olfactory tubercle or papilla short-stalked. Tentacles long and slender; club not expanded and without glandular swellings at tip. Photogenic organs in some cases numerously developed over the entire integument, sometimes lacking; no photophores upon the eyeball or within the pallial chamber.

Genus MASTIGOTEUTHIS Verrill 1881.

Mastigoteuthis Verrill 1881a, p. 100.
Mastigoteuthis Pfeffer 1900, p. 184, 187.
Mastigoteuthis Chun 1910, p. 220.
Mastigoteuthis Pfeffer 1912, p. 609.

The characters of this genus coincide with those of the subfamily of which it is the only known representative.

Type.—Mastigoteuthis Agassizii Verrill 1881 (monotypic); a North Atlantic species.

Mastigoteuthis (?) famelica (Berry 1909) Pfeffer 1912. (Pl. LII, fig. 6–8.)

Chiroteuthis famelica Berry 1909, pp. 414, 419, fig. 8.
Mastigoteuthis (?) famelica Pfeffer 1912, p. 624.

Animal small, graceful, its outlines attenuate. Mantle cylindrical, extremely long and narrow; gradually tapering for a little more than half its length, then becoming suddenly constricted to continue as an exceedingly slender and delicate spit extending between the fins and somewhat exceeding them posteriorly; anterior margin sinuous, inflated, projecting in an obtuse point in the medio-dorsal line. Fins enormous, leaflike, not lobed; at the base relatively thick and fleshy, but thin at the margins; each one about three times as long as wide and extending for a little more than half the length of the mantle; separated only by that portion of the slender posterior extension of the mantle which covers the delicate gladius; in front the attached margins extend well forward on the dorso-lateral surfaces of the main body.

Head small, narrower than the body except across the eyes, whence it rapidly tapers to the narrow elongate neck (the neck is rather longer than wide); dorsal and ventral surfaces flattened. Eyes large, rounded, conspicuous, somewhat protruding; very anterior in position. "Olfactory papilla" short, but possibly not well represented in the present specimen. Funnel small, broadly conical, not quite reaching to the eyes. Funicular locking cartilages deep, ear-shaped, with ridges to correspond on the inner surface of the mantle.

Arms, except the ventrals, extremely short in proportion to the length of the body; decidedly unequal, the order of relative length being 4, 2, 3, 1. Ventral arms enormously developed, about three times as long as the others and half as long as the body; squarish; sucker-bearing surface very narrow in proportion to the total diameter of the arm and furnished with two alternating rows of distant minute slender pediceled suckers, the horny rings of the latter minutely toothed. Remaining arms more nearly of a length, the dorsal pair a little the shortest and weakest; their suckers slightly larger and more crowded. All the arms obscurely keeled. Umbrella and lateral membranes wanting.

Tentacles missing.

Gladius extremely long and slender, the posterior cone terminating in a long needle-like point; visible through the dorsal integument as a dark medio-longitudinal line.

Color in alcohol a pale brownish buff; chromatophores brown but very sparsely distributed. Such portions of the outer integument as remain intact are devoid of photogenic organs, and I have not succeeded in identifying any of these structures upon the eyeball.

MEASUREMENTS OF MASTIGOTEUTHIS (?) FAMELICA.

	mm.
Tip of body to tip of ventral arms	64
Tip of body to base of dorsal arm	44
Tip of body to medio-dorsal margin of mantle	39
Extreme length of fins	21
Length of fins at base	21
Width across fins	14.5
Width of mantle	4
Width of head	4
Length of—	
Head	5
Dorsal arm	5
Second arm	6.5
Third arm	5.5
Ventral arm	20

Type.—Catalogue no. 214314, United States National Museum [S. S. B. 260].

Type locality.—*Albatross* station 3989, 385 to 733 fathoms, bottom of coral sand and rock, vicinity of Kauai Island, June 11, 1902; a single specimen.

Material examined.—The type is unfortunately unique.

Remarks.—Although the whole aspect of this species is suggestive of *Chiroteuthis* rather than *Mastigoteuthis*, the short olfactory papilla and the apparent absence of photophores on either the eyes or the ventral arms preclude its reference to that genus as I had originally placed it. On the other hand, it seems to have little in common with the remarkable *M. agassizii* Verrill, which is the type species of the latter genus. Verrill's species is notable for the extremely rich development of photogenic organs over the entire outer integument, and possesses other features which induce me to believe that it will eventually prove generically distinct from almost all the more recently described species usually associated with it. Even from the latter forms the present species is strikingly different, and as the condition of the single specimen is confessedly not all that might be desired, besides being very likely immature, it may be that better material may after all accomplish its restoration to *Chiroteuthis*.

In purely superficial characters *M. famelica* seems nearer to *C. pellucida* Goodrich of the Bay of Bengal than to any other form of either genus known to me, but differs in the much larger fins, shorter neck, more poorly developed arms, and a number of other characters. Both species are remarkable for their gaunt slender body, and to this feature is due the specific name of the Hawaiian form.

Family CRANCHIIDÆ (Prosch 1847).

Cranchidæ Prosch 1847, p. 19.
Cranchiadæ Gray 1849, p. 37.
Cranchiaeformes Steenstrup 1861 (*fide* Hoyle).
Desmoteuthidæ Verrill 1881, p. 300.
Cranchiidæ P. Fischer 1882, p. 340.
Cranchiidæ Pfeffer 1900, p. 154, 188.
Cranchiidæ Chun 1906, p. 82.
Cranchiidæ Pfeffer 1908, p. 63, 101.
Cranchiidæ Chun 1910, p. 299.
Cranchiidæ Pfeffer 1912, p. 636.

Mantle border firmly fused with the head in the nuchal region and with the base of the funnel on either side. Body usually membranous and transparent; nearly colorless. Eyes usually large, often pedunculate. Sessile arms with two rows of suckers only; tentacles with four rows of suckers, which frequently extend down the stalk for the greater portion of its length; hooks may occur on the tentacle club, but only in one or two genera. Photogenic organs may be numerously developed on the ventral aspect of the eyeball, may occur within the pallial chamber, or may be entirely absent.

Genus LIOCRANCHIA Pfeffer 1884.

Liocranchia Pfeffer 1884, p. 25.
Liocranchia Chun 1906, p. 84.
Liocranchia Chun 1910, p. 303, etc.
Liocranchia Pfeffer 1912, p. 644, 665.

Mantle thin, saccular; often much inflated. Fins of rounded outline, terminal, small to moderate in size. Two diverging series of small conical cartilaginous tubercles extend back from the ventral point of fusion of the mantle and funnel on either side; in some forms a similar series may be present

along the medio-dorsal line of the mantle. Eyes large, sessile; a row of four large oval photophores on the ventral aspect. Left ventral arm hectocotylized.

Type.—Liocranchia Brockii Pfeffer 1884 (species first named)=*L. reinhardtii* (Steenstrup), a species of very wide distribution.

Liocranchia globulus Berry 1909. (Pl. LIII, fig.2–4.)

Cranchia (Liocranchia) globula Berry 1909, p. 415, 419, fig. 9.
Liocranchia reinhardtii (pars) Chun 1910, p. 336, 337.
Liocranchia globulus Pfeffer 1912, p. 666, 674.

Animal small, pelagic. Body almost completely spherical; short, rounded, the maximum diameter almost but not quite equal to the length; mantle truncate in front, suddenly constricted posteriorly and tapering rapidly to an acute point which forms the base of attachment for the fins. Mantle mainly smooth; very thin and membranous; anterior margin passing in three even nearly equal curves from each point of attachment to the next; the latter three in number and about equidistant, the ventral points of fusion with the base of the funnel being about as far separated from one another as either is from the nuchal attachment. At the extreme mantle margin the position of each point of attachment is marked externally by a series of small projecting cartilaginous tubercles of acutely conical shape; the dorsal series is a close succession of at least 48 tubercles in single file, forming a narrow cartilaginous ridge along the anterior two-thirds of the medio-longitudinal line, a wedge-shaped area forming the posterior continuation of this ridge being hyaline and bare; the ventral series are each double, forming a Λ-shaped ridge having its apex at the margin, and with about 20 minute tubercles of two sizes in more or less irregular alternation in each line, flanked at the anterior end by parallel rows of two or three smaller tubercles on each side (pl. LIII, fig. 2). The divergence between the diverging arms of these ventral series is somewhat less than 90 degrees.

Fins small, thin; very short and broad, so that the outline of each is roughly circular; separated only by the minute posterior protrusion of the mantle, beyond which they extend for perhaps a third of their length; base of attachment only about one-half the total length.

Head minute; exceedingly short and broad; little projecting beyond the mantle. Eyes large, prominent; lid apertures very small, constricted; a series of four rather large oval photophores is visible on the inner ventral periphery upon the removal of the outer integument; they are subequal in size, very closely placed, and to all appearances essentially similar under a low power lens. A very large transparent fingerlike "olfactory papilla" has its origin from the outer integument just back of the eyelid opening. Funnel short, broad, well projecting beyond the mantle, and with a noticeable ventral flexion not far from the tip.

Arms short, poorly developed; unequal, the relative order of length 3, 4, 2, 1; dorsal pair decidedly the shortest and weakest, bearing only 6 to 8 pairs of suckers (largest near the base); second and fourth pairs more nearly equal, each second arm with about 9 pairs of suckers; third pair much the largest and longest, bearing 12 or more pairs of suckers. Umbrella present but poorly developed; extending between the dorsal arms for nearly half their length, and not exceeding this width between any of the arms; apparently absent between the arms of the ventral pair, and nearly so between these and the third pair. Suckers exceedingly minute, pedunculate; in two regularly alternating rows; horny rings apparently smooth, but this feature is somewhat difficult to ascertain.

Tentacles stout, smoothly cylindrical, much thicker and heavier than the arms; nearly as long as the mantle. Clubs little expanded, tapering to a bluntish point, lightly keeled, and furnished with a narrow delicate swimming membrane along each margin. Suckers minute, pedunculate; on the club in four rather crowded rows; largest near the middle of the club, very minute distally, and also proximally, where they gradually become more widely spaced, each row in the meanwhile tending to press in toward the center, so that there soon appear to be but two rows which continue down the stalk for about two-thirds of its entire length;[a] aperture of suckers small; horny rings apparently smooth, but surrounded by radial papillæ.

[a] In the smallest specimen these suckers extend practically to the base of the stalk.

Color of preserved specimens a semitranslucent grayish white, probably colorless or opalescent in life. Chromatophores light brown in color; few in number; minute; most evident are a number of very small ones scattered over the posterior portion of the ventral surface of the mantle in advance of the fins; there is also a transverse series forming a slightly irregular semicircle on the ventral aspect a little distance back of the mantle margin. Two longitudinal series of distantly placed chromatophores extend along each tentacle.

MEASUREMENTS OF LIOCRANCHIA GLOBULUS.

Number in author's register	262	282	Number in author's register	262	282
	mm.	*mm.*		*mm.*	*mm.*
Total length (mantle distended)	45	22	Width across fins	7	4
Tip of body to tip of third arms (mantle distended)	26	14	Width of head	4.5	.....
Dorsal length of mantle, exclusive of fins (distended)	20	11	Length of—		
Dorsal length of mantle, exclusive of fins (not distended)	25	.....	Head	2	.....
Maximum width of mantle (distended)	19	10	Dorsal arms	1	.....
Extreme length of fins	4	2	Second arms	1.5	.....
Length of fins at base	2	.....	Third arms	3	.....
			Ventral arms	2	.....
			Tentacle	19	9
			Tentacle club	4	.....

Type.—Catalogue No. 214315, United States National Museum [S. S. B. 262].

Type locality.—*Albatross* station 3878, surface, south of Lanai and west of Kahoolawe, April 14, 1902; two specimens.

Distribution.—Hawaiian Islands (*Albatross*).

SPECIMENS OF LIOCRANCHIA GLOBULUS EXAMINED.

Number of specimens.	Locality.	Depth.	Collector.	Remarks.	Author's register.
1	Off Molokini Islet, south of Lanai and west of Kahoolawe.	Surface....	Albatross station 3878.....	U. S. Nat. Mus., Cat. 214315; type.	262
1	.....do.....	...do.....	.....do.....	Cotype.....	282
1	Between Kauai and Oahu.....	...do.....	Albatross station 4009.....	.....	263

Remarks.—Should this curious form prove to be a valid species, it adds one further member to the very remarkable group of aberrant squids which comprise the family *Cranchiidæ*. The inflated saccular mantle here reaches practically the greatest attainable maximum of rotundity, so that a specimen looks not unlike a bubble having a few appendages of small size at either pole. The nearest ally of our species is self-evidently the *L. reinhardtii* (Steenstrup), with which indeed it is united by Chun, but the latter possesses the characteristic inflation only in vastly less degree. Lönnberg (1897, p. 611) has considered rotundity to be a condition in *L. reinhardtii* attendant upon immaturity and has given figures of an unusually large specimen which is almost loliginiform. However, the largest of the *Albatross* specimens is no whit less spherical than the youngest, and in this feature no figures or measurements of *L. reinhardtii* which I can find on record show close approach to any of them. On the other hand our knowledge of the limits of variation in these forms, either living or after preservation, is still very far from complete, and Chun's suggestion that this extreme state of inflation is due to a sharp contraction of the circular muscles around the mantle opening at the moment the animals were killed may prove to be the true explanation. Should this be so, it is somewhat curious that all three of the specimens before me chanced to be overwhelmed by the preserving fluid at exactly the same moment of contraction. It is believed that the drawings show the true condition with a very fair degree of accuracy, as in each case the mantle of the specimen was carefully distended by means of a pipette without the exertion of undue pressure, and an attempt was even made to keep the specimens so inflated suspended freely in the alcohol while the more important measurements were being taken.

In all other respects the Hawaiian form is essentially similar to *L. reinhardtii* except that (1) the number of cartilaginous tubercles in the dorsal series is somewhat less than given by Lönnberg for the specimen described by him, although more numerous in the ventral series; (2) the fins are conspicuously smaller; and (3) according to Pfeffer the statement that the latter are "flanked near the anterior end by parallel rows of two or three smaller tubercles on either side" does not hold with respect to the older species.

Genus MEGALOCRANCHIA Pfeffer 1884.

Megalocranchia Pfeffer 1884, p. 24.
Desmoteuthis Pfeffer 1900, p. 191 (not of Verrill 1881).
Desmoteuthis Chun 1906, p. 85.
Desmoteuthis Chun 1910, p. 304, 356.
Megalocranchia Pfeffer 1912, p. 645, 711.
Megalocranchia Berry 1912c, p. 644

Body cask-shaped, membranous, transparent, very weakly pigmented. Fins oval, longer than broad, overreaching the extremity of the body. Eyes large, rotund, protruding, sessile; on the ventral surface of each a very large semicircular photogenic organ, with a smaller crescent-shaped organ just in front. Arms with two rows of suckers; tentacles with four rows of suckers which extend along the greater portion of the stalk; none of the suckers modified into hooks; no fixing apparatus. Photogenic organs wanting except on the eye as stated.

Type.—Megalocranchia maxima Pfeffer 1884 (monotypic); described from the Cape of Good Hope.

Megalocranchia fisheri (Berry 1909) Pfeffer 1912. (Pl. LIII, fig. 5, 6; pl. LV, fig. 2.)

Helicocranchia fisheri Berry 1909, p. 417.
Xenoteuthis fisheri Berry 1909, p. 419 (error).
Megalocranchia fisheri Pfeffer 1912, p. 718.
Megalocranchia fisheri Berry 1912c, p. 644.

Animal small, body somewhat barrel-shaped. Mantle smooth, tough, membranous, saccular, thin, very much inflated; largest at a point nearly midway between the head and fins; somewhat tapering anteriorly and to a greater degree posteriorly, where it becomes at last suddenly constricted, terminating in a short, slender, spitlike point extending between the fins and serving as their base of attachment; maximum width of mantle probably about half its length.[a]

Fins rather small, thin; each semicircular, almost exactly half as wide as long, and a little over a quarter the length of the mantle; almost continuous posteriorly and separated along the median line only by the thread of integument covering the slender hinder extremity of the gladius.

Head very short and broad; slightly concave above and below; relatively very large, due to the enormous globular eyes which are only faintly constricted at the base; lid openings very small, puckered, so elevated as to appear almost papilliform. Mantle attached firmly to the head in the nuchal region and also to the base of the funnel on either side. Funnel large, thin-walled, conical, broad at the base; extremity not quite reaching the base of the ventral arms; aperture ample, with a caplike upper lip. Funnel organ difficult to distinguish with certainty.

Arms short, robust, fleshy, the longest less than one-third the length of the mantle; unequal, the order of length 3=4, 2, 1; umbrella wanting; all the arms outwardly keeled and provided with a very delicate trabeculated marginal membrane, which attains by far its best development on the arms of the third pair; the latter in every way larger than the others and with larger suckers. Suckers biserial, closely placed, regularly alternating to the tip; oblique, hood-shaped; apertures wide; horny rings (at least on third arms) scarcely dentate, but very minutely and beautifully crenulate on the upper border, nearly smooth below.

[a] The mantle is much wrinkled and contracted in this specimen, especially ventrally (where the distance from the tip of the body to the mantle margin is much less than it is dorsally), thus precluding the possibility of accurate measurement or exact statement of relative proportions. This condition is probably wholly due to the action of the preserving fluid.

Tentacles rather short, stout, about twice as long as the arms, as compared with which they are larger and heavier in every way; stalks nearly cylindrical. Clubs large, well expanded; bordered by a narrow frill-like web or keel along either margin of the sucker-bearing area, supplemented dorsally by a wider gracefully crenulate membrane which has its origin outside the former and lies parallel to it along the distal two-thirds of the club. Suckers small, in four distinct but rather crowded rows on the club; the two median series slightly the larger, but the suckers in all four rows attaining their maximum near the middle of the club; distally they gradually diminish in size, and also proximally, where they steadily become more widely spaced, extending down the flattened inner surface of the stalk for about half its length (exclusive of the club); the four-rowed condition really persists throughout, but on account of the tendency of the various series to press in toward the center at the same time with the increase in interspacing of the suckers, the arrangement soon appears to be biserial and maintains this appearance throughout most of the length of the stalk. Proximal to the point where the marginal membrane of the club comes to an end some 20 to 23 of these alternating pairs of suckers may be counted. Horny rings of the larger suckers minutely dentate on the upper margin with 12 to 14 sharp-curved elongate teeth, which become nearly or quite obsolete below.

Color of preserved specimen a soiled semitranslucent white. Chromatophores very minute and sparsely distributed; they apparently exhibit no very definite arrangement.

Two large photogenic organs form a conspicuous brownish patch nearly covering the ventral surface of each eyeball and visible even through the outer integument which overlies them. The larger is roughly semicircular in outline, its flatter anterior margin somewhat concave, and with the convex side of the crescent-shaped smaller organ closely applied within it. The outline of both organs is in the main similar to those of *D. pellucida* as figured by Chun, but considerably more elongate.

MEASUREMENTS OF MEGALOCRANCHIA FISHERI.

	mm.
Total length	73
Length of mantle (dorsal)	47
Maximum width of mantle	23
Extreme length of fins	12.5
Width across fins	12.5
Length of head (median)	4
Width of head across eyes	15
Length of—	
Right dorsal arm	6
Left dorsal arm	6
Right second arm	8
Left second arm	8
Right third arm	13
Left third arm	12
Right ventral arm	12
Left ventral arm	12.5
Tentacle	27
Sucker-bearing area of tentacle	18
Tentacle club	8
Funnel	8

Type.—Catalogue No. 214316, United States National Museum (S. S. B. 106).

Type locality.—*Albatross* station 3883, 277 to 284 fathoms, bottom of globigerina ooze, off Mokuhooniki Islet, Pailolo Channel, April 16, 1902; one specimen.

Distribution.—Hawaiian Islands (*Albatross*).

Material examined.—The type is unique.

Remarks.—This species is a typical *Megalocranchia*, showing exceedingly close affinity to both the *M. maxima* Pfeffer and the more recently described *M. pellucida* (Chun). The latter species is peculiar in that the horny rings of the tentacular suckers are bluntly toothed, lacking the long acute teeth which are characteristic of both the other species. The following rather trivial features distinguish *M. fisheri* from *M. maxima*: (1) The longer tentacles. (2) The longer ventral arms. In his description of *M. maxima* Pfeffer says regarding the arms that "4 und 2 sind wenig verschieden," while in the present species the disproportion between the arms of these pairs is conspicuous. In my first diagnosis I gave the arm formula as 4, 3, 2, 1. In reality this is true of the left side only, the right arms standing 3, 4, 2, 1, but in both cases the difference between the third and ventral arms is so slight as scarcely to be worth

mentioning, so that the formula is perhaps preferably stated as 3=4, 2, 1. (3) The horny rings of the tentacular suckers have 12 to 14 instead of 10 teeth on the upper margin. These are none of them very great differences, but seem sufficient, together with the widely separate habitats of the two forms, to render their union unjustifiable until a better representation of each is available for study.

My original reference of this species to *Helicocranchia* was certainly ill advised, our species differing conspicuously in the larger, more elongate nonpedunculate fins, spitlike posterior continuation of the mantle, much smaller funnel, and very much larger unstalked eyes.

The discovery of this species very greatly extends the known geographical range of the little group of typical *Megalocranchia*, but even yet the distribution of the various species is of interest because of the continuity of the respective regions occupied by them. Beginning with *M. pellucida* in the south Atlantic, the remaining species form a geographic chain extending more than halfway around the globe. *M. maxima* is known only from the Cape of Good Hope, *M. abyssicola* Goodrich from the waters of the Indian peninsula, and the present species from the Hawaiian Islands. Because of its occupancy of so distant and isolated a region, the Hawaiian species might be expected to be the most highly differentiated member of the group, but such is very far from being the case. On the other hand *M. abyssicola* seems in many ways peculiar and not so closely allied to any of the other three forms as they are to one another.

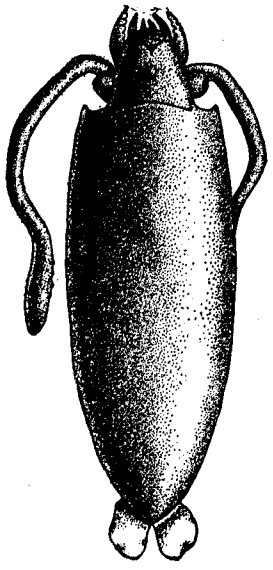

FIG. 40.—*Helicocranchia* sp., ventral view of specimen [261] from the vicinity of Kauai, partially restored. × 2. In this figure the mantle is scarcely represented as sufficiently elongate and the arms are probably shown as much too short and stocky.

It has been a pleasure to associate with this interesting species the name of my friend, Dr. Walter K. Fisher, who, as a member of the staff of the *Albatross* during the Hawaiian explorations, had no small part in the duties of caring for and preserving the present material.

Genus HELICOCRANCHIA Massy 1907.

Helicocranchia Massy 1907, p. 382.
Helicocranchia Massy 1909, p. 34.
Desmoteuthis (pars) Chun 1910, p. 302, 357.
Teuthowenia (*Helicocranchia*) Pfeffer 1912, p. 742, 750.

Body elongate, bag shaped. Fins small, oval; narrowed or even pedunculate at base; little or not at all united posteriorly. Eyes large, elevated on short stalks. Arms rather long, with two rows of suckers; no hooks. Funnel enormous, extending well past the head and eyes.

Type.—*Helicocranchia Pfefferi* Massy 1907 (monotypic); described from off the coast of Ireland.

Chun has referred this genus to *Desmoteuthis* (i. e., *Megalocranchia*), but it seems to me to be rather nearer to *Owenia* (*Teuthowenia* Chun), from which it differs most conspicuously in the more rounded eyes and enormous development of the funnel.

Helicocranchia species?

Cranchiid species, Berry 1909, p. 419 (mere locality record).

A single sadly dilapidated specimen of some cranchiid approaching very close to this genus was taken at *Albatross* station 4001, 230 to 277 fathoms, off Kapuai Point, Kauai [S. S. B. 261]. It is too fragmentary for satisfactory determination, but has been made the subject of the following notes:

Mantle much wrinkled and distorted; its outline in general elongate, swollen, cask-shaped; tapering behind to a point; anterior margin fused with head in the nuchal region and on either side of the funnel as usual in the group; width of mantle about a third the length. Fins very small, separate, delicate; attached for the anterior half of their inner margins to the minute and sharp membranous point which forms the posterior termination of the mantle.

Head small. Eyes moderately small, projecting forward upon very short club-shaped stalks. Funnel enormous, reaching far beyond the head and more conspicuous than any other structure in the anterior region of the body; heavy walled and inflated; aperture large.

Sessile arms very slender and delicate; the third pair much the longest, the second pair next in length, and the dorsal and ventral pairs very minute. Suckers small, but not in relation to the size of the arms; biserial; umbrella and swimming membranes absent.

Tentacles decollated; the stumps heavy, fleshy, brittle, without traces of suckers.

MEASUREMENTS OF HELICOCRANCHIA SPECIES?

	mm.		mm.
Length of mantle, dorsal	36	Length of dorsal arm	4
Width of mantle	11 ?	Second arm	9
Extreme length of fins	4	Third arm	11
Length of fins at base	2.	Ventral arm	4
Width across fins	7	Funnel along medio-ventral line	9.5

The specimen is minus the major portion of both tentacles, the eyes and arms have become detached (although preserved in the bottle), and the remaining portions otherwise mutilated, so that it does not seem wise to attempt to attach any specific name, although a new species is undoubtedly represented. The great resemblance in general form to *Helicocranchia pfefferi* as described and figured by Miss Massy (1909, p. 34) is such that I have little hesitation in assuming that the present specimen is referable to the same genus, although the more broadly attached fins, lack of suckers on the stumps of the tentacles, and various minor details indicate that at any rate the two are not conspecific. If this identification be correct, the genus is now reported for the first time from the Pacific, the type species being known only from a single specimen dredged off the coast of Ireland. Were it not for the immense funnel the aspect would be almost that of an *Owenia*. The accompanying drawing is very unsatisfactory because of the difficulty and uncertainty pursuant to any endeavors to straighten out the wrinkled mantle and reconstruct fragmentary parts, but it seems worth while to offer it for whatever it may be worth. The mantle is probably not represented as sufficiently elongate, and the arms are considerably too short and stout.

LARVAL OEGOPSID.

An undetermined larval oegopsid of minute size is in the collection from *Albatross* station 3803, from a depth of 50 fathoms, between the Erben Bank and Kaiwi Channel [S. S. B. 387].

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TABLE IV.

STATIONS AT WHICH CEPHALOPODS WERE TAKEN DURING THE 1902 HAWAIIAN CRUISE OF THE "ALBATROSS", WITH AN INVENTORY OF THE SPECIES COLLECTED AT EACH.

Station number.	Locality.	Date (1902).	Depth.	Surface temperature.	Bottom temperature.	Character of bottom.	Species taken and number of specimens.
			Fathoms.	° *F.*	° *F.*		
3799	29° 22′ N., 139° 31′ W., between Erben Bank and Kaiwi Channel.	Mar. 18	Surface.	65	.....	.....	4 Tremoctopus violaceus.
3802	27° 4′ 15″ N., 144° 18′ 30″ W., between Erben Bank and Kaiwi Channel.	Mar. 20	150	.....	.....	.....	1 larval Octopod.
3803	25° 39′ 45″ N., 147° 41′ 45″ W., between Erben Bank and Kaiwi Channel.	Mar. 21	50	.....	.....	.....	1 larval Decapod.
3821	South coast of Oahu.....	Mar. 31	Surface.	76	.....	.....	1 Polypus β, 1 Euprymna scolopes.
3829	Off Avalu Point, Lanai....	Apr. 1	Surface.	75	.....	.....	1 Euprymna scolopes.
3832	South Coast of Oahu.....	Apr. 2	153–142	76	.....	Brown mud, sand.....	1 Stoloteuthis iris.
3837	South coast of Molokai.....	Apr. 3	Surface.	76	.....	.....	1 Polypus β.
3843	.....do.....	Apr. 4	Surface.	75	.....	.....	1 Polypus α.
3846	.....do.....	Apr. 8	Surface.	76	.....	.....	1 Euprymna scolopes.
3849	.....do.....	...do.....	Surface.	76	.....	.....	1 Polypus γ.
3856	Pailolo Channel between Maui and Molokai.	Apr. 9	127	74	66.5	Fine sand, yellow mud..	1 Euprymna scolopes, 1 Scæurgus patagiatus.
3857	.....do.....	...do.....	127–128	74	62.5	.....do.....	1 Argonauta sp., 1 Euprymna scolopes.
3858	.....do.....	...do.....	128–138	74	61.5	Fine sand, gray mud....	1 Scæurgus patagiatus.
3859	.....do.....	...do.....	138–140	74	60.2	Fine sand, mud.....	1 Euprymna scolopes.
3865	.....do.....	Apr. 10	256–283	76	45	Fine volcanic sand, rock.	1 Ommastrephes hawaiiensis.
3878	South of Lanai and west of Kahoolawe.	Apr. 14	Surface.	77	.....	.....	5 Tremoctopus violaceus, 7 Brachioteuthis riisei 2 Liocranchia globula.
3883	Pailolo Channel between Maui and Molokai.	Apr. 16	277–284	76	45.2	Globigerina ooze.....	1 Megalocranchia fisheri.
3889	North coast of Molokai.....	Apr. 17	Surface.	74	.....	.....	3 Euprymna scolopes, 2 Rhyncoteuthion α.
3896	Auau Channel between Maui and Lanai.	Apr. 29	126–130	74	63.1	Sand, pebbles, broken shells.	1 Euprymna scolopes.
3898	Pailolo Channel between Maui and Molokai.	...do.....	258–284	74	44.1	Brown globigerina mud, fine sand.	1 Laetmoteuthis lugubris.
3900	.....do.....	...do.....	283–280	75	43.9	.....do.....	1 Heteroteuthis hawaiiensis.
3904	North coast of Molokai.....	Apr. 30	Surface.	75	.....	.....	1 Laetmoteuthis lugubris.
3905	.....do.....	...do.....	Surface.	75	.....	.....	2 Polypus β, 1 Polypus γ, 13 Euprymna scolopes.
3907	South coast of Oahu.....	May 5	Surface.	75	.....	.....	1 Polypus β.
3911	.....do.....	...do.....	Surface.	76	.....	.....	1 Polypus β.
3912	.....do.....	...do.....	Surface.	76	.....	.....	1 Polypus β, 1 Rhyncoteuthion α.
3921	.....do.....	May 6	Surface.	75	.....	.....	3 Polypus α, 2 Polypus β.
3926	21° 13′ N., 158° 43′ W., between Honolulu and Laysan.	May 10	Surface.	75	.....	.....	3 Tremoctopus violaceus, 1 Polypus β, 1 Euprymna scolopes, 1 Abraliopsis (juv.), 5 Rhyncoteuthion α.
3927	21° 31′ N., 161° 55′ W., between Honolulu and Laysan.	May 11	Surface.	76	.....	.....	1 Argonauta böttgeri.
3929	23° 19′ N., 166° 54′ W., between Honolulu and Laysan.	May 13	Surface.	75	.....	.....	1 Tremoctopus violaceus.

TABLE IV—Continued.

Stations at which Cephalopods were taken during the 1902 Hawaiian cruise of the "Albatross", with an inventory of the species collected at each—Continued.

Station number.	Locality.	Date (1902).	Depth.	Surface temperature.	Bottom temperature.	Character of bottom.	Species taken and number of specimens.
			Fathoms.	°F.	°F.		
3930	25° 07′ N., 170° 50′ W., between Honolulu and Laysan.	May 15	Surface.	74	.....	.....	3 Tremoctopus violaceus, 1 Polypus β, 1 Rhyncoteuthion β.
3931	25° 27′ N., 171° 08′ W., between Honolulu and Laysan.	...do.....	Surface.	74	.....	.....	2 Tremoctopus violaceus, 2 Euprymna scolopes.
3938	Vicinity of Laysan.....	May 16	148–163	76	60.3	White sand, broken shells.	1 Scæurgus patagiatus.
3980	Between Honolulu and Kauai.	June 9	Surface.	77	.....	.....	1 Polypus β, 9 Euprymna scolopes, 1 Rhyncoteuthion α.
3989	Vicinity of Kauai.....	June 11	733–385	78	37.5	Coral sand, rock.....	1 Heteroteuthis hawaiiensis, 1 Teleoteuthis compacta, 1 Mastigoteuthis (?) famelica.
4001	.....do.....	June 16	277–230	78	44.3	Coral sand.....	1 Helicocranchia sp.
4002	.....do.....	...do.....	230–53	78	47.1	Fine coral sand, globigerina, coral.	2 Polypus ε.
4009	Between Kauai and Oahu.	June 17	Surface.	76	.....	.....	1 Liocranchia globula.
4010	.....do.....	...do.....	Surface.	76	.....	.....	4 Tremoctopus violaceus, 5 Euprymna scolopes, 1 Rhyncoteuthion α.
4011	.....do.....	...do.....	Surface.	77	.....	.....	7 Tremoctopus violaceus, 1 Polypus β.
	Honolulu Reef, Oahu.....	(?)	.....	.....	.....	.....	10 Polypus marmoratus, 3 Polypus ornatus, 1 Polypus β, 2 Euprymna scolopes.
	Honolulu market.....	(?)	.....	.....	.....	.....	1 Polypus sp., 1 Sepioteuthis arctipinnis, 2 Ommastrephes hawaiiensis.
4039	West coast of Hawaii.....	July 10–11.	670–697	76	38.7	Gray mud, foraminifera.	1 Eledonella (juv.).
4071	Northeast and north coast of Maui.	July 19	52–56	76	72.9	Fine coral, volcanic sand, foraminifera.	1 Euprymna scolopes.
4073	.....do.....	...do.....	69–78	76	71.9	Coarse coral sand, foraminifera.	1 Euprymna scolopes.
4079	.....do.....	July 21	143–178	76	60.8	Gray sand, foraminifera.	1 Scæurgus patagiatus.
4082	.....do.....	...do.....	220–238	76	48.8	Gray sand.....	1 Ommastrephes hawaiiensis.
4086	.....do.....	...do.....	Surface.	76	.....	.....	2 Tremoctopus violaceus.
4087	Northeast approach to Pailolo Channel.	...do.....	308–306	76	43.6	Fine gray sand.....	1 Abralia trigonura.
4088	.....do.....	...do.....	306–297	75	43.8	.....do.....	1 Heteroteuthis hawaiiensis.
4089	.....do.....	...do.....	297–304	75	43.8	.....do.....	1 Heteroteuthis hawaiiensis.
4095	.....do.....	July 22	290–286	76	43.9	Brown mud, fine sand, globigerina.	1 Alloposus mollis.
4102	Pailolo Channel between Maui and Molokai.	July 23	122–132	79	.....	Fine gray sand, foraminifera.	3 Euprymna scolopes.
4103	.....do.....	...do.....	132–141	78	61.7	Fine gray sand.....	3 Scæurgus patagiatus, 1 Euprymna scolopes.
4105	Kaiwi Channel between Molokai and Oahu.	July 24	314–335	76	43.8	Fine coral sand, foraminifera.	1 Pterygioteuthis microlampas.
4110	.....do.....	...do.....	449–460	76	40.3	Gray sand.....	1 Polypus hoylei.
4117	Northwest coast of Oahu..	July 25	282–253	77	45.6	Coral sand, foraminifera.	1 Ommastrephes hawaiiensis.
4122	Southwest coast of Oahu...	July 26	192–352	79	64.6	Coarse coral sand, shells.	1 Abralia astrosticta.
4130	Vicinity of Kauai.....	Aug. 1	283–309	77	46.1	Fine gray sand.....	1 Polypus hoylei.
4132	.....do.....	...do.....	257–312	77	46.8	Fine gray sand, mud....	1 Polypus hoylei, 1 Ommastrephes hawaiiensis.
4152	Vicinity of Modu Manu....	Aug. 5	Surface.	79	.....	.....	2 Euprymna scolopes, 1 Rhyncoteuthion α.
4153	.....do.....	...do....	Surface.	79	.....	.....	1 Euprymna scolopes.
4190	34° 39′ 18″ N., 132° 04′ W., between Honolulu and San Francisco, Cal.	Aug. 27.	Surface.	69	.....	.....	3 larval histioteuthids, 1 Brachioteuthis riisei.

EXPLANATION OF PLATES.

Except where otherwise stated in the context, all the drawings were prepared by Miss Lora Woodhead, of Stanford University. The photographs were made by J. H. Paine.

The numbers in brackets have reference to the author's register of examined specimens.

PLATE XLV.

Polypus marmoratus, dorsal view of large male from Honolulu, ×⅞; [174]. Drawn by R. L. Hudson.

PLATE XLVI.

Fig. 1. *Polypus ornatus*, dorsal view of a medium sized male from Honolulu, [179]. ×¾.

Fig. 2. *Polypus ornatus*, tip of hectocotylized arm of same specimen [179]; as yet not well developed, ×12.

PLATE XLVII.

Fig. 1. *Polypus hoylei*, ventral view of male, type, ×¾; [166]. Drawn by R. L. Hudson.

Fig. 2. *Scæurgus patagiatus*, dorso-lateral view of male (type), ×1½; [204]. Drawn by R. L. Hudson.

Fig. 3. *Scæurgus patagiatus*, tip of hectocotylized arm of same specimen, ×2½; [204]. Drawn by R. L. Hudson.

PLATE XLVIII.

Fig. 1. *Scæurgus patagiatus*, hectocotylized portion of left third arm of male (type), ×7; [204].

Fig. 2. *Polypus hoylei*, hectocotylized portion of right third arm of male (type), ×4; [166].

Fig. 3. *Polypus hoylei*, region surrounding right eye of same specimen, showing the supraocular cirri, considerably enlarged; [166].

Fig. 4. *Polypus hoylei*, funnel of male from the vicinity of Kauai, laid open along the medio-ventra line to show the funnel organ, ×2½; [176].

Fig. 5. *Argonauta böttgeri*, inner aspect of left second arm of female, ×2⅓; [165].

Fig. 6. *Polypus marmoratus*, hectocotylized portion of right third arm of large male from Honolulu, ×7; [174].

Fig. 7. *Polypus β*, left dorsal arm of small specimen from off the south coast of Oahu, ×5; [194].

Fig. 8. *Polypus β*, dorsal view of specimen from off the south coast of Oahu, considerably enlarged; [195].

PLATE XLIX.

Fig. 1. *Lætmoteuthis lugubris*, lateral view of mandibles of specimen from the Pailolo Channel, nearly natural size; [212]. Drawn by J. H. Paine.

Fig. 2. *Lætmoteuthis lugubris*, apical view of same, same scale. Drawn by J. H. Paine.

Fig. 3. *Tremoctopus violaceus*, inner aspect of all arms of left side of female not quite adult, ×3; [221].

Fig. 4. *Tremoctopus violaceus*, funnel of same specimen laid open along medio-ventral line, ×4; [221].

Fig. 5. *Euprymna scolopes*, left tentacle club of male (type), inner aspect, greatly enlarged; [320].

Fig. 6. *Euprymna scolopes*, outer aspect of left dorsal arm of male (cotype) showing hectocotylization, much enlarged; [323]. The suckers of the innermost row along the basal portion of the arm are considerably larger than they should be in the figure.

Fig. 7. *Euprymna scolopes*, inner aspect of middle portion of same arm of same specimen, showing modified suckers, greatly enlarged; [323].

Fig. 8. *Euprymna scolopes*, right lateral arm of same specimen (several suckers missing from ventral row and not supplied in drawing), ×4; [323].

PLATE L.

Fig. 1. *Stoloteuthis iris*, dorsal view of type, ×3; [31]. Drawn by H. V. Poor.

Fig. 2. *Stoloteuthis iris*, tentacle club of type, inner aspect, greatly enlarged; [31].

Fig. 3. *Heteroteuthis hawaiiensis*, tentacle club of type (female), greatly enlarged; [30].

Fig. 4. *Heteroteuthis hawaiiensis*, large sucker from third arm of male from station 4088, greatly enlarged; [333].

Fig. 5. *Heteroteuthis hawaiiensis*, inner aspect of second right arm of type (female), ×4½; [30].

Fig. 6. *Heteroteuthis hawaiiensis*, photogenic organs of specimen from station 4089, ×2½; [333]. Drawn by J. H. Paine.

Fig. 7. *Heteroteuthis hawaiiensis*, lateral view of type (female), ×1¾; [30]. Drawn by H. V. Poor.

Fig. 8. *Heteroteuthis hawaiiensis*, ventral view of type (female), with mantle partially laid open to expose the locking cartilages and funnel, ×2; [30].

PLATE LI.

Fig. 1. *Abralia astrosticta*, ventral view of type (female), ×2; [171]. Drawn by H. V. Poor.

Fig. 2. *Abralia astrosticta*, inner aspect of right tentacle club of type, ×15; [171]. Drawn by H. V. Poor.

Fig. 3. *Abralia astrosticta*, ventral view of right eye of type and surrounding region, ×3; [171]. Drawn by H. V. Poor.

Fig. 4. *Abralia astrosticta*, dorsal view of type, ×1¾; [171]. The extremities of the fins are represented as curved under, their true outline being more as indicated by the dotted line. Drawn by H. V. Poor.

Fig. 5. *Abralia astrosticta*, ventral aspect of funnel, showing the distribution of the photogenic organs, ×5; [171].

Fig. 6. *Abralia astrosticta*, fixing apparatus of left tentacle club of type, much enlarged; [171].

Fig. 7. *Abralia astrosticta*, lateral aspect of head and funnel of type, showing locking cartilage of left side of funnel, ×4; [171].

Fig. 8. *Abralia astrosticta*, funnel of type laid open medio-ventrally to expose the funnel organ, ×4; [171].

PLATE LII.

Fig. 1. *Pterygioteuthis microlampas*, ventral aspect of right eye of type and surrounding region, ×6; [277].

Fig. 2. *Pterygioteuthis microlampas*, funnel locking cartilage, much enlarged; [278].

Fig. 3. *Pterygioteuthis microlampas*, inner aspect of left tentacle club of type, much enlarged; [227]. Drawn by J. H. Paine, from a mount in balsam.

Fig. 4. *Toleoteuthis compacta*, inner aspect of left tentacle club of type, ×16; [238].

Fig. 5. *Toleoteuthis compacta*, inner aspect of right third arm of type, ×13; [238].

Fig. 6. *Mastigoteuthis* (?)*famelica*, ventral view of head of type, ×5; [260].

Fig. 7. *Mastigoteuthis* (?)*familica*, ventral arm of type, inner aspect, ×5; [260].

Fig. 8. *Mastigoteuthis* (?)*familica*, dorsal view of type, ×2½; [260]. Drawn by H. V. Poor.

PLATE LIII.

Fig. 1. *Rhyncoteuthion α*, dorsal view of well advanced specimen with free tentacles, from station 3926, ×2; [255].

Fig. 2. *Liocranchia globulus*, anterior (apical) portion of left latero-ventral series of tubercles, showing the small flanking tubercles (type), much enlarged; [262].

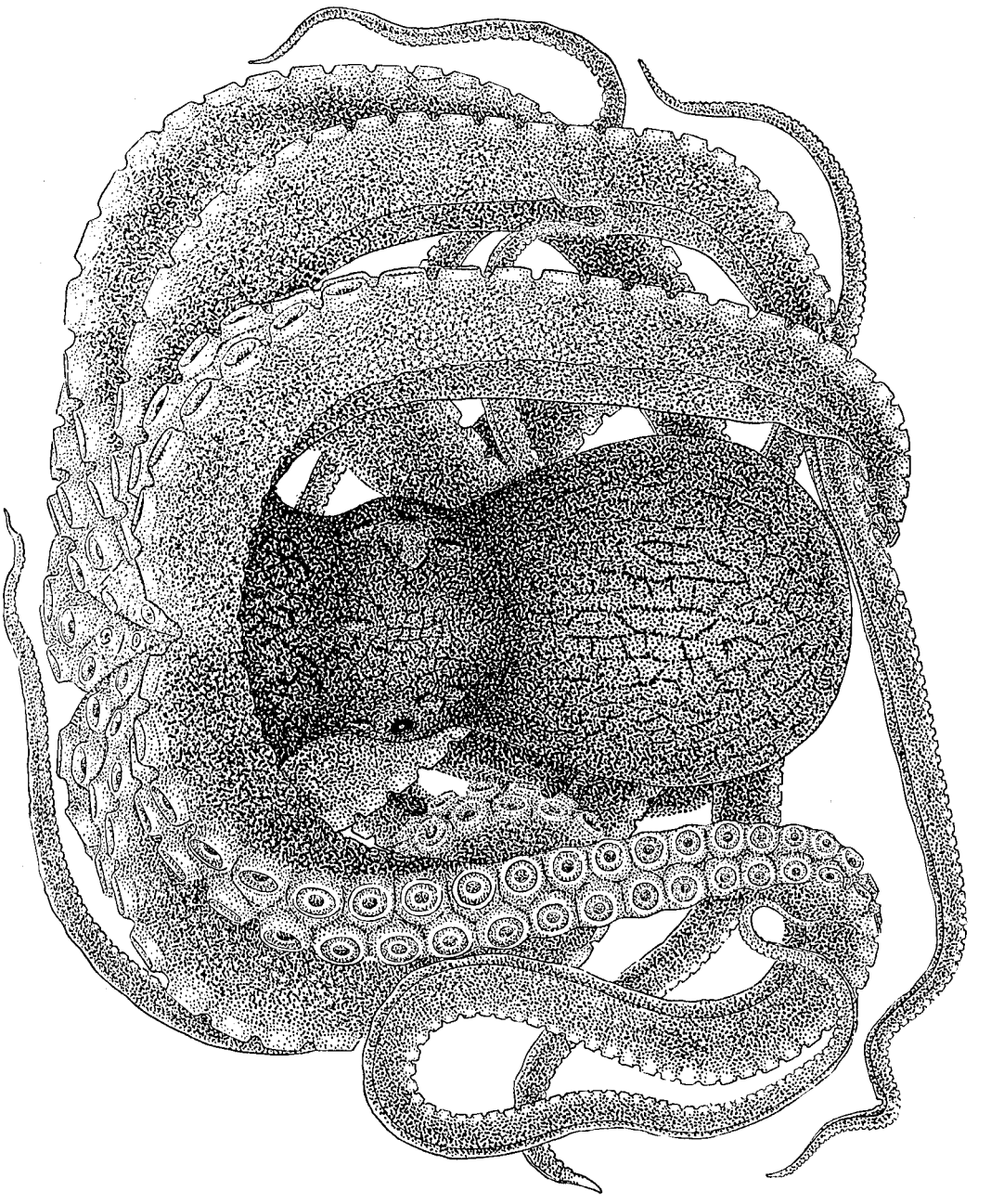
Fig. 3. *Liocranchia globulus*, tentacle of type, ×8; [262].
Fig. 4. *Liocranchia globulus*, dorsal view of type, ×2¾; [262]. Drawn by H. V. Poor.
Fig. 5. *Megalocranchia fisheri*, inner aspect of right tentacle club of type, ×4; [106].
Fig. 6. *Megalocranchia fisheri*, lateral aspect of same, ×4; [106].

PLATE LIV.

Fig. 1. *Sepioteuthis arctipinnis*, ventral view of male from market at Honolulu, ×½; [42]. Photograph.
Fig. 2. *Ommastrephes hawaiiensis*, inner aspect of right third arm of type, ×1⅔; [243]. Photograph.

PLATE LV.

Fig. 1. *Polypus hoylei*, inner aspect of arms and umbrella of type (male), ×½; [166]. Photograph.
Fig. 2. *Megalocranchia fisheri*, ventral view of type, ×1⅔; [106]. Photograph.



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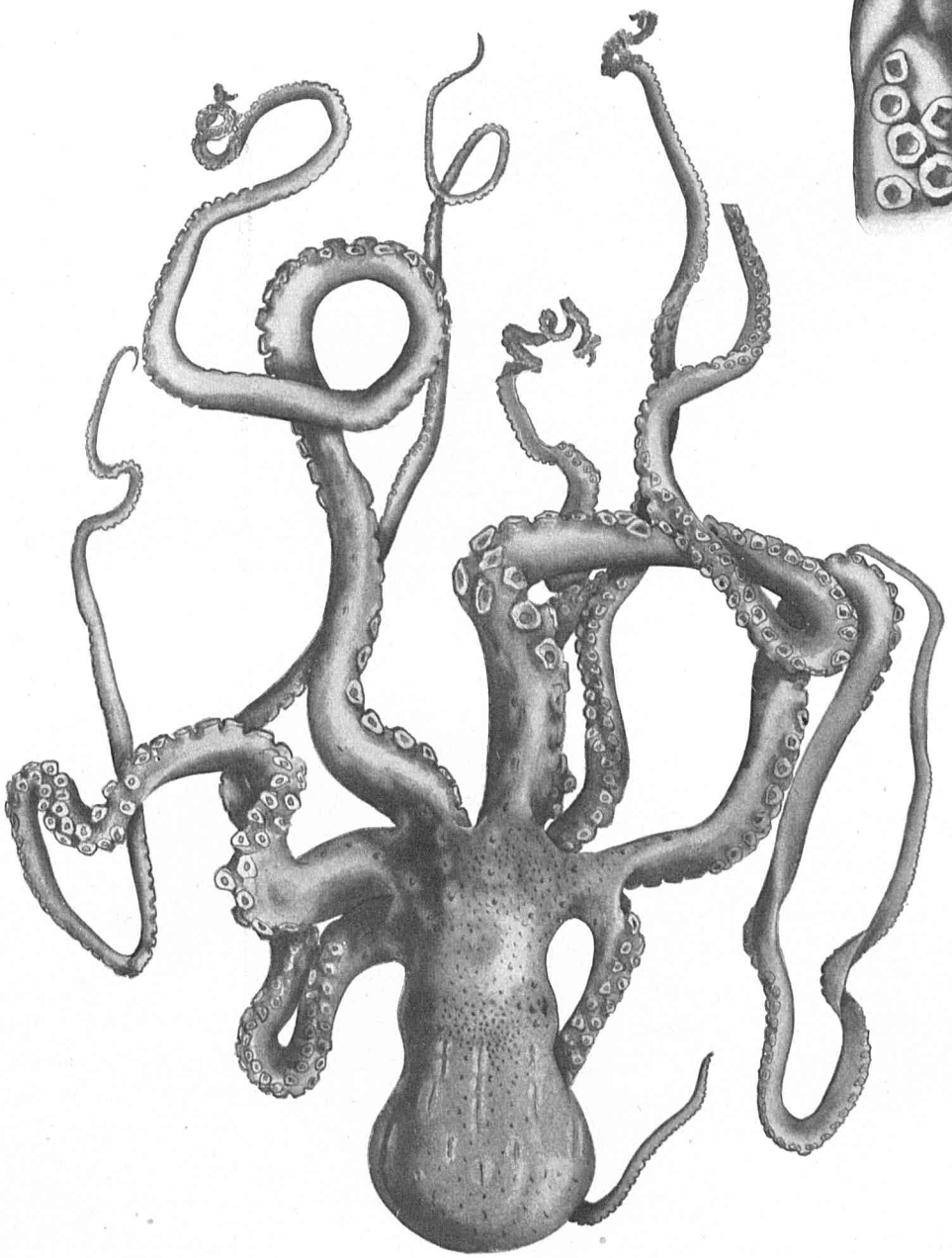

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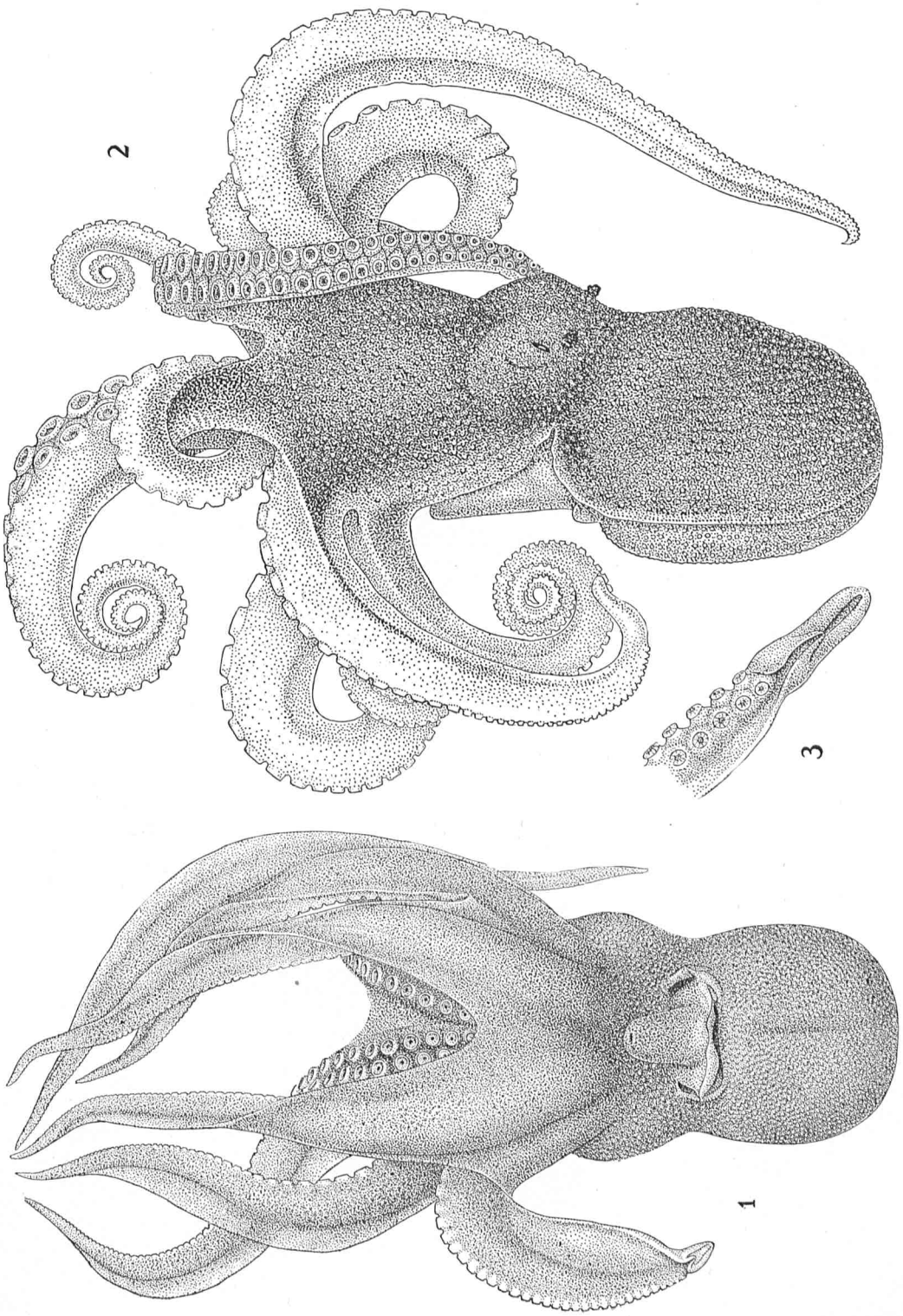
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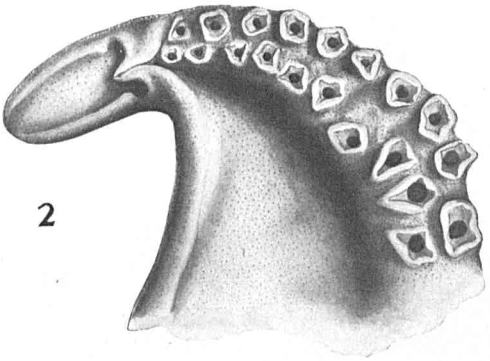
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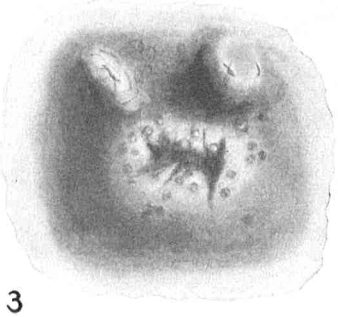
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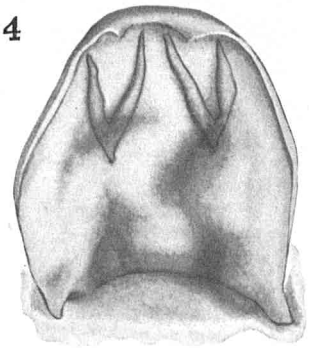
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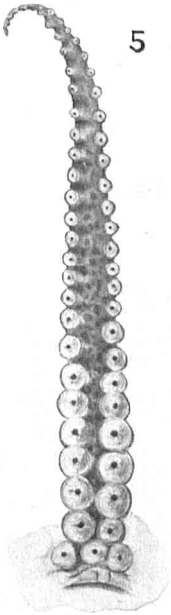
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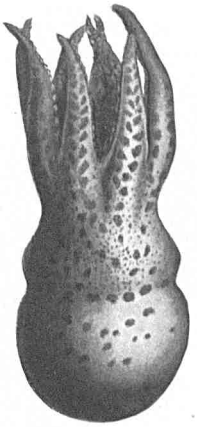
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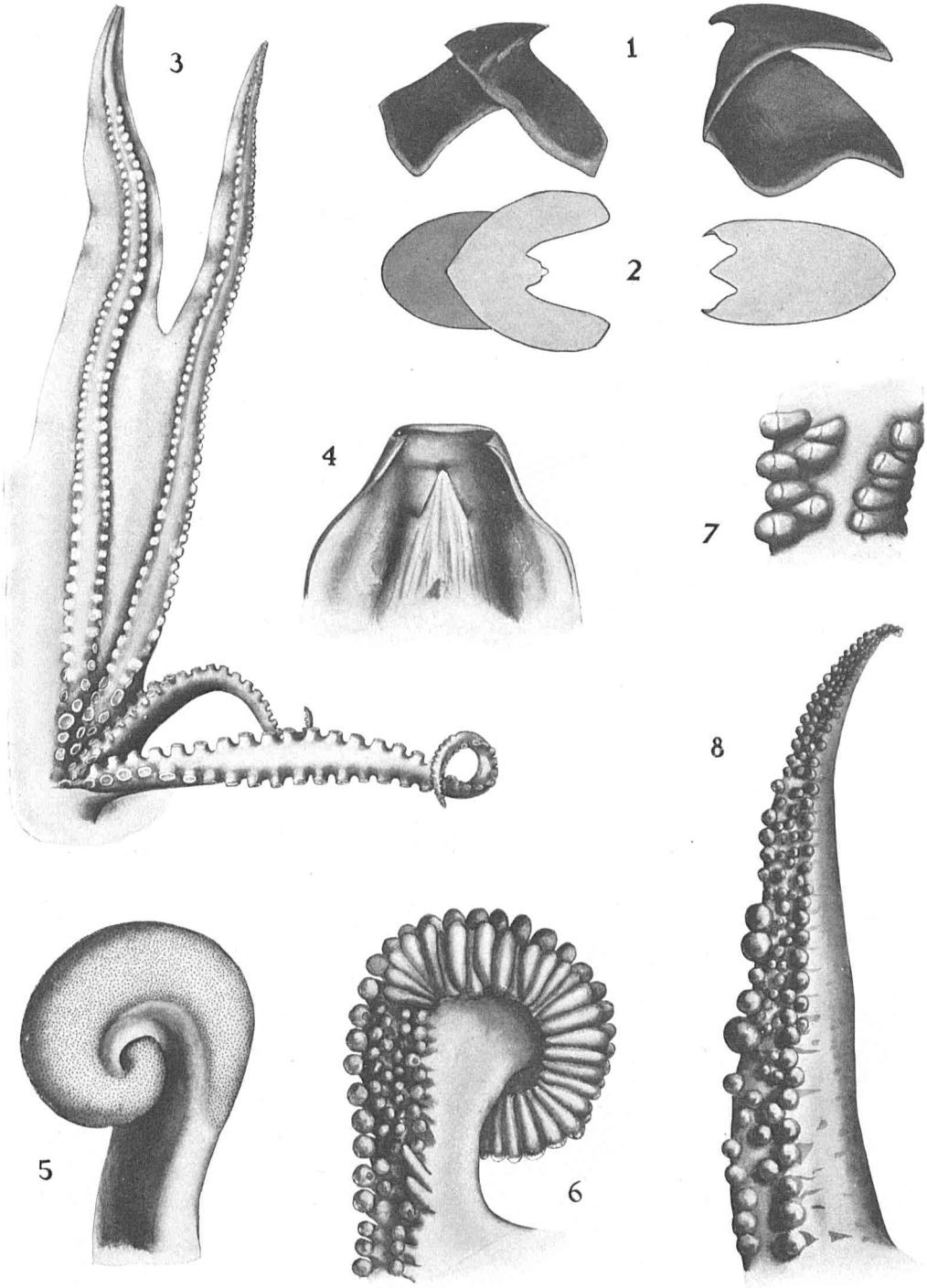
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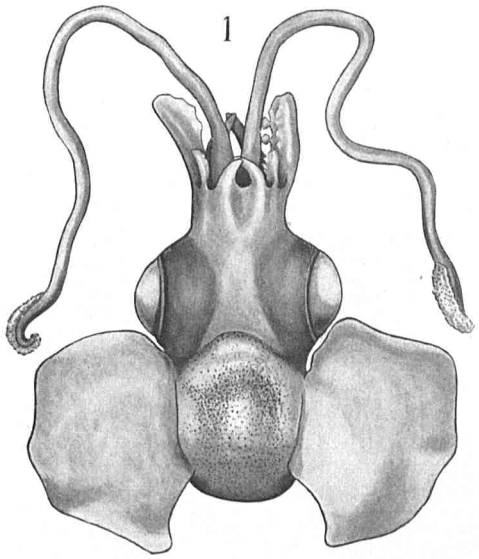

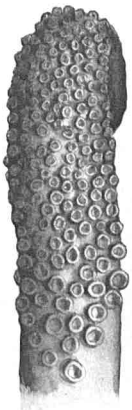

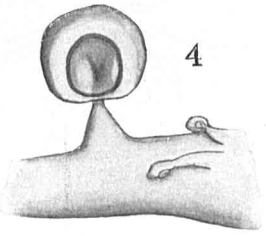

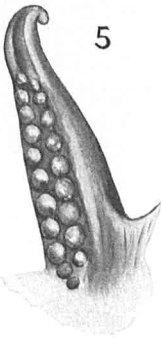

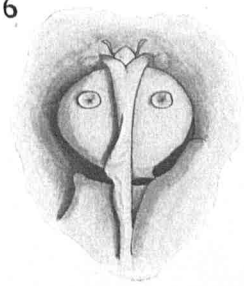

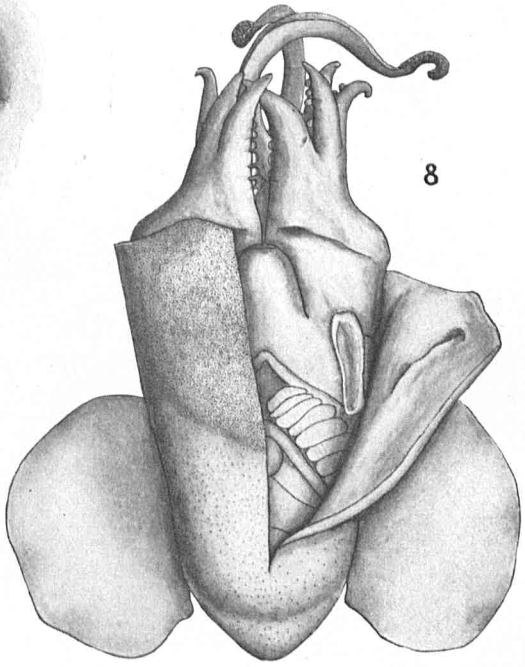

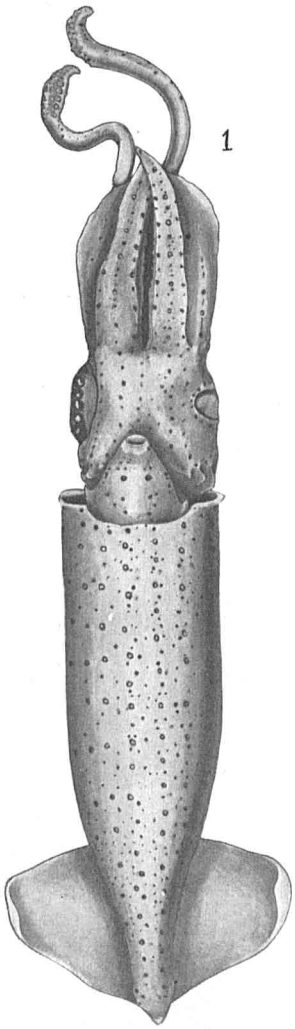
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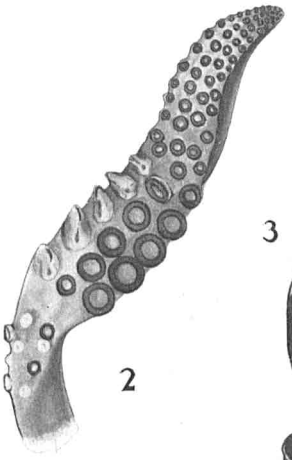
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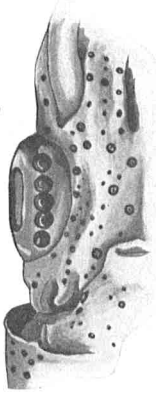
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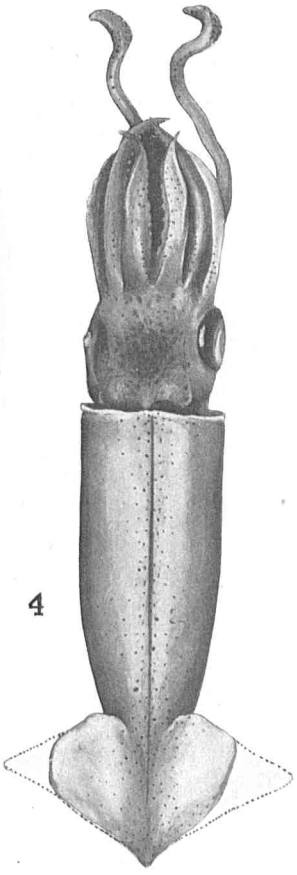
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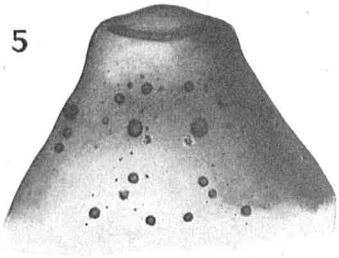
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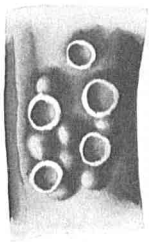
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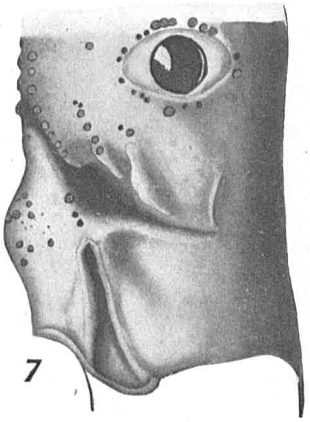
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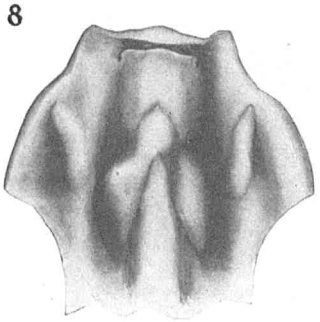
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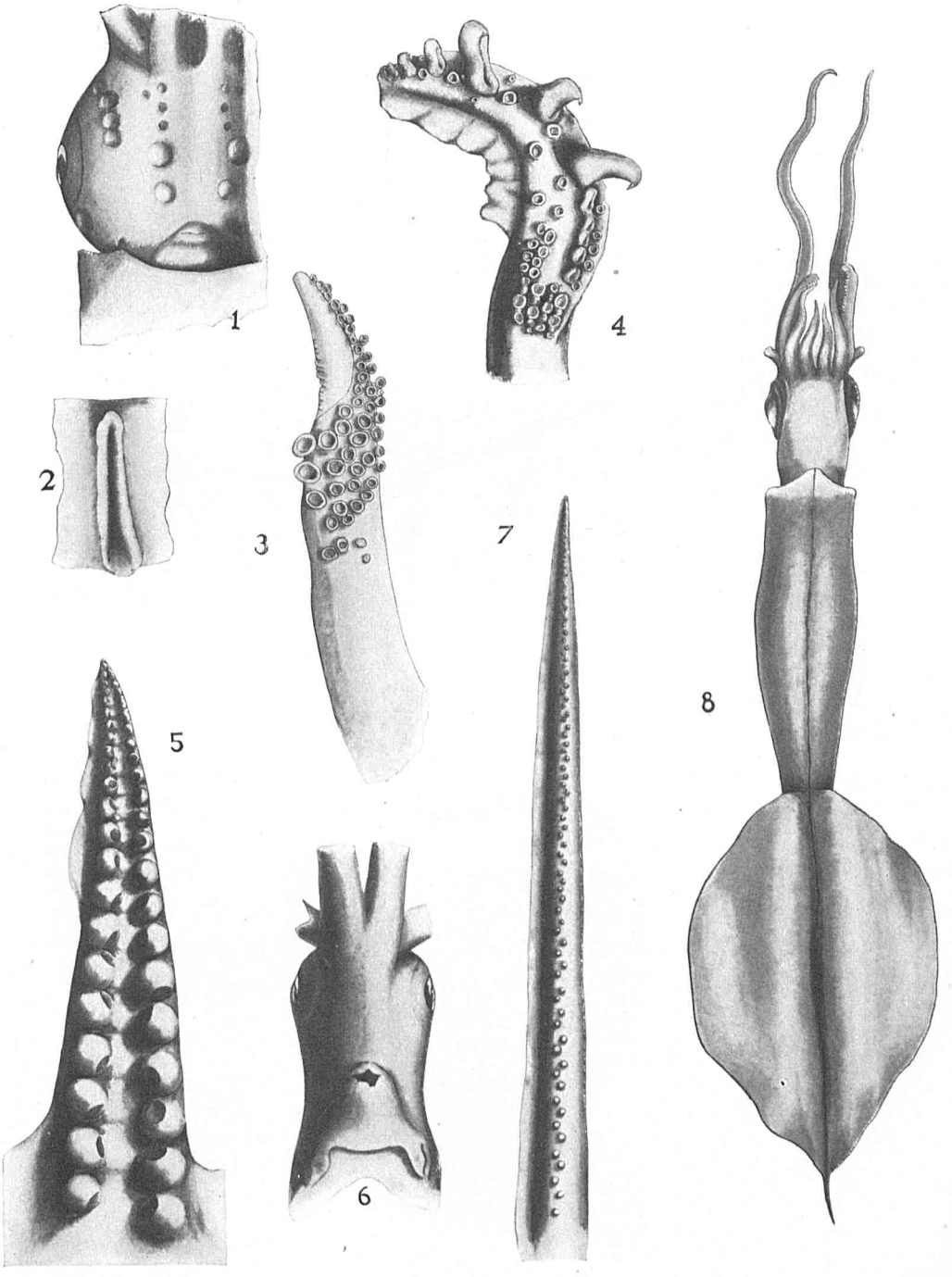
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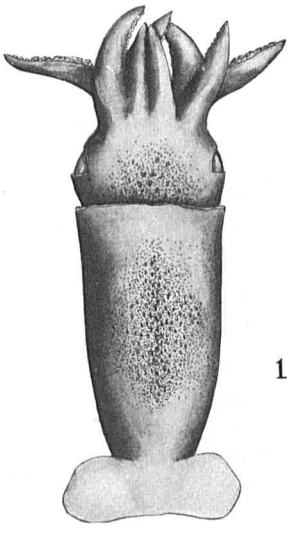

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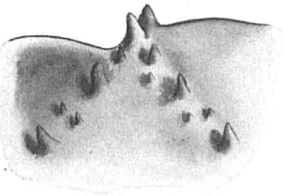

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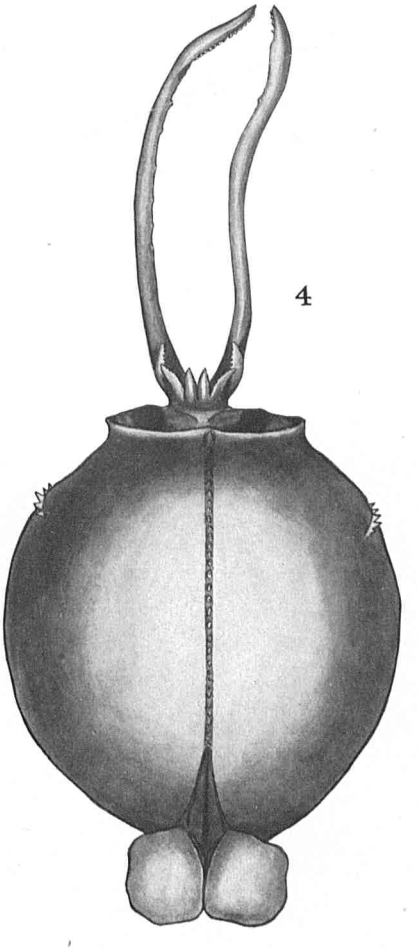

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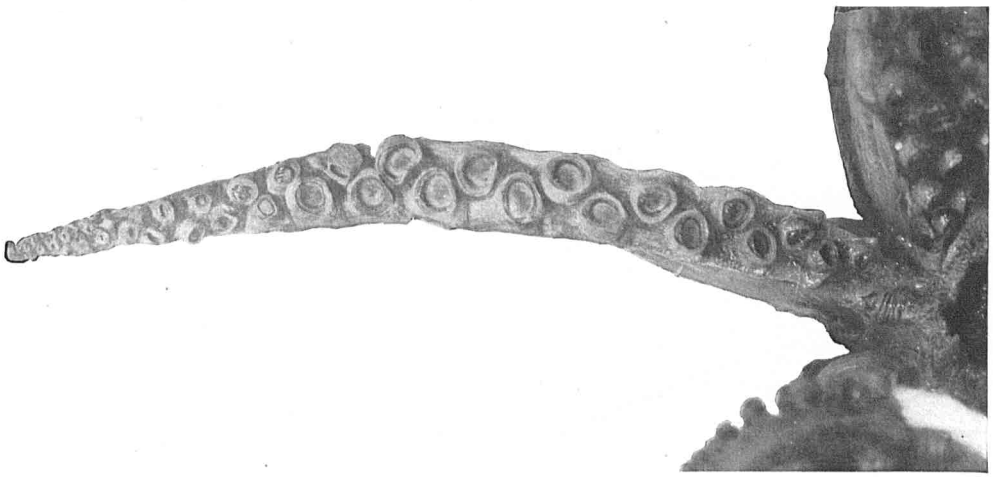

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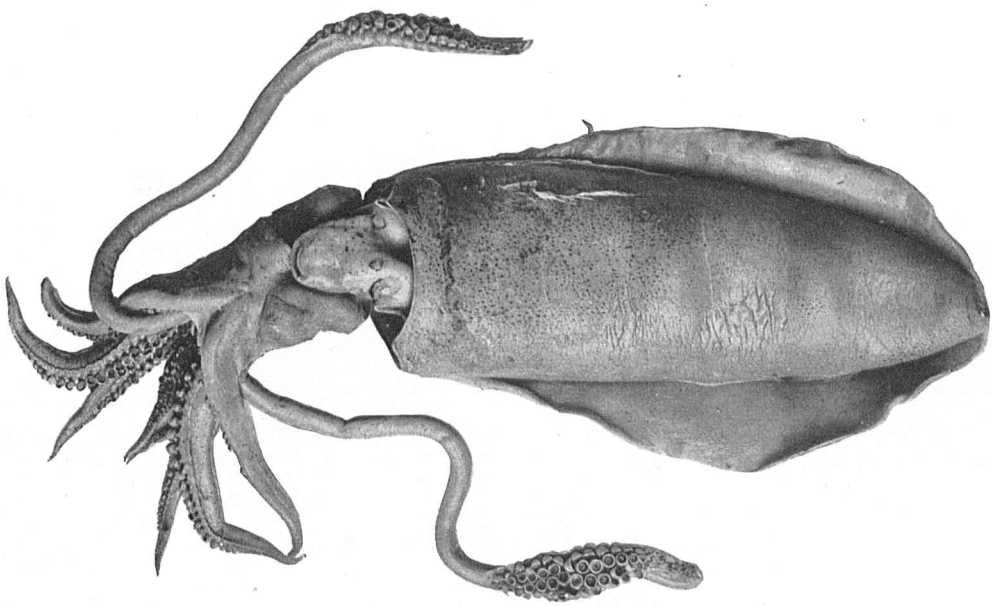

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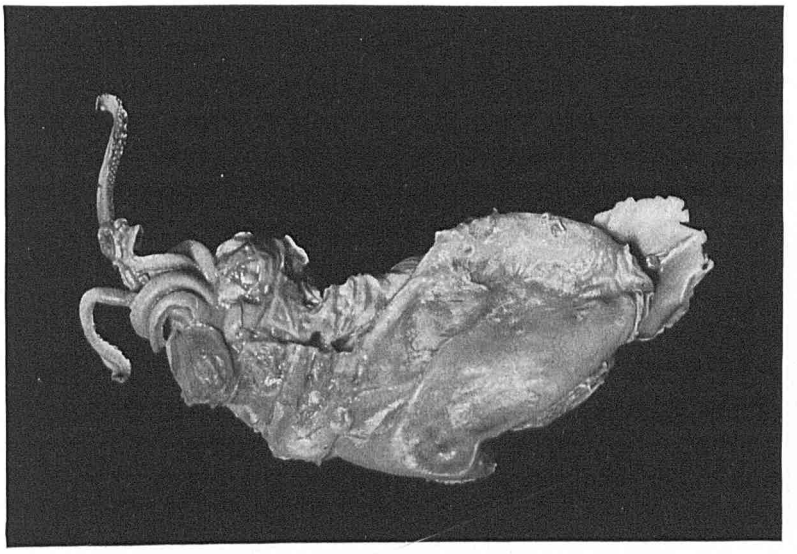

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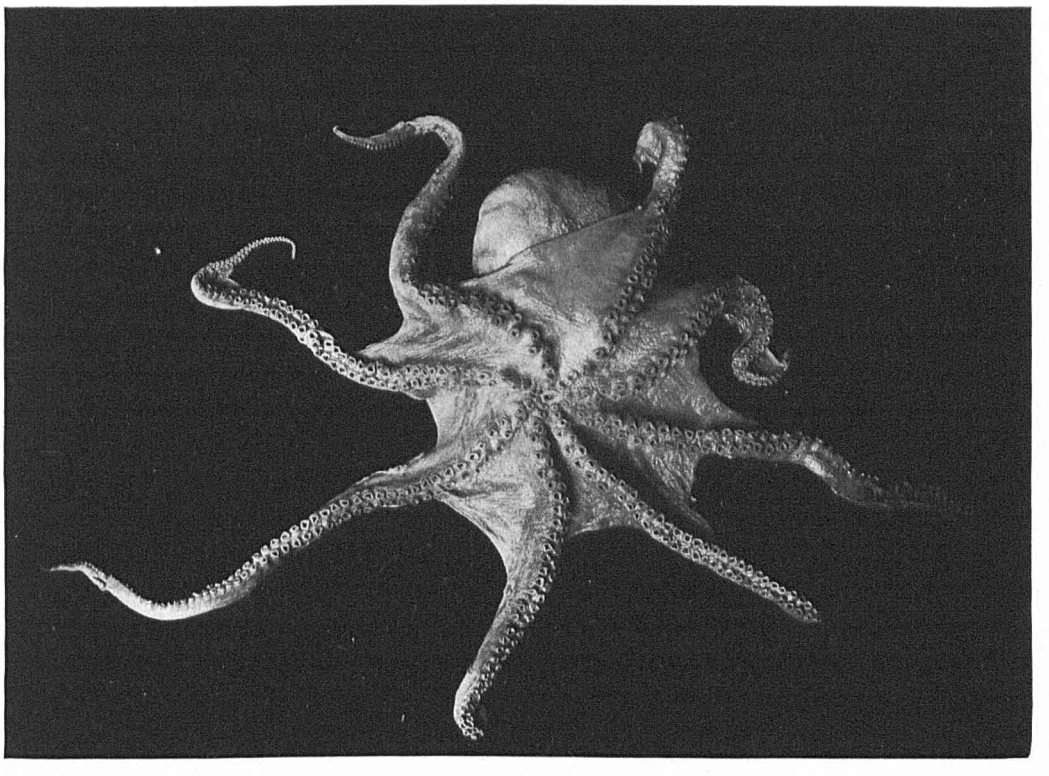

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