

5.—REPORT OF OPERATIONS AT THE LABORATORY OF THE
U. S. FISH COMMISSION, WOOD'S HOLL, MASS.; DURING
THE SUMMER OF 1888.

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The biologists who worked in the laboratory of the U. S. Fish Commission at Wood's Holl, Mass., during the season of 1888 were as follows: The Commissioner, Prof. Marshall McDonald, Prof. W. K. Brooks, Dr. E. A. Andrews, Mr. S. Watase, Mr. T. H. Morgan, Mr. C. F. Hodge, Mr. H. H. Field, Mr. W. McM. Woodworth, Mr. C. H. Eigenmann, Mrs. Rosa Smith Eigenmann, Mr. C. F. W. McClure, Mr. J. Warne Phillips, Dr. H. N. Mateer, Professor Miller, Prof. Spencer Trotter, Mr. Geo. H. Parker, Mr. W. S. Marshall, and the writer.

The laboratory was not formally opened for investigation until about July 1st. On that date the writer arrived, as the representative of the University of Pennsylvania, and began making collections of the larval and post-larval stages of fishes which have been preserved in about 150 vials and jars for further study. The actual investigations conducted by the assistant in charge relate to the development of the sea bass and the development and anatomy of the sturgeon. Brief preliminary notices of this work have appeared in the *American Naturalist* for the months of July and August, 1888. The general results on the sturgeon will be published as a monograph by the writer, and will deal with the scientific and economic questions related to the inquiry.

In the matter of collections the writer would acknowledge the important assistance which he has received from Mr. V. N. Edwards, collector of the Commission at Wood's Holl, whose familiarity with the haunts and habits of the native fishes is most extensive. Many of the series collected serve to bring the earlier stages figured and described by Mr. Agassiz and the writer into connection with the final form and coloration assumed by the adult. This work is one of the most important which can be undertaken by the Commission, as it will bring to light many very remarkable facts in connection with the life history and habits of marine species and afford the means of continuing and extending the very valuable investigations undertaken by Lütken and published in that author's *Spolia Atlantica*. Many fishes undergo such startling and

profound changes of color in the course of their metamorphosis into the adult stage that it seems desirable that a pictorial record of such changes should be undertaken. The only way in which it is possible to carry out this plan is to have the young fishes figured by a competent artist from living specimens kept in the system of aquaria now in operation in the hatching rooms of the station. A beginning has been made in preparing a series of colored sketches of the young and the sexes of the sea bass by Mr. S. F. Denton, a water-color artist of very marked ability; these sketches prove that a great deal still remains to be worked out for any one species, as regards the changes from youth to adolescence and the equally great differences existing in many cases in the form and coloration of the sexes, and when published in connection with the development of a given species, they will constitute monographs of the most enduring economic and scientific value as contributions to fish-cultural literature, while their value as purely scientific productions will in no way be diminished.

Little is known of the histological details of the structure of the alimentary canals of fishes, and it affords the writer great pleasure to state that during the present season from July 17 to August 23 Mr. C. F. W. McClure, a fellow in biology in Princeton College, made a collection of the viscera of the common fishes as a basis for an extended study in this direction. These materials were prepared with great care and will no doubt afford valuable scientific results, especially as to the structure and functions of the regions of the alimentary tract in different forms. The economic bearings of such investigations in comparative histology and physiology are obvious.

Equally important collections of the brains of fishes have been made by another fellow in biology from Princeton College, Mr. J. Warne Phillips. Sixty-nine brains of fishes were exposed in the skull by him and carefully hardened in Müller's fluid for sectioning according to the formula of Weigert. These sixty-nine include twenty-two species, of which six are Selachians and one a Ganoid. This series will be of great value in working out the architecture of the brain in these types and, in conjunction with results already obtained or under way at the hands of Dr. H. F. Osborn, will be of great service in making further comparisons with higher types, and possibly some light may be thus obtained as to the psychology of fishes.

Mr. Phillips also secured a series of sponges, 4 species; coelenterates, 5 species; échinoderms, 7 species; worms, 15 species; mollusca, 6 species; fishes, 21 species; a series of the eggs of *Limulus* and also of the squid; and a large number of starfishes, sea-urchins, holothurians, and skates for dissection.

Mr. C. F. Hodge, of Johns Hopkins University, Baltimore, made a series of injections of the vascular system of the common sand shark, flounder, and hake, and also prepared a skeleton of the flounder for the purpose of study in connection with a series of embryos of the common

species, collected by Mr. V. N. Edwards, and which it is hoped will furnish some of the material for a monograph upon the life history or development and curious metamorphosis of this type of fishes. This monograph it is proposed to put into the hands of a competent investigator, who has already applied for the material.

Mr. Hodge also carried on a series of experiments upon starfishes, to determine the enemies which prey upon them, the *Libinia*, or spider crab, being one of these. Experiments were also tried with the king crab, or *Limulus*, which it is strongly suspected is also an enemy of starfishes. These researches have a bearing upon the questions now presented to the Commission in relation to the best means of preventing the ravages of the starfish upon the oyster beds of Long Island Sound, that work being now in progress under the direction of J. A. Smith, mate U. S. N., of the U. S. Fish Commission steamer *Fish Hawk*, with Mr. Hodge as the scientific observer and expert, to determine the conditions of temperature and the necessary conditions of density of the sea water in which the starfish thrives.

Mr. H. H. Field, representing Harvard College, took up the special study of the genesis of the Wolffian body, or kidney, in fishes from its first appearance in the embryo. For this purpose, the eggs of the common barred killifish (*Fundulus*) were laid under contribution, these ova being obtained by artificial fertilization and developed in the hatching apparatus in the hatching room. The pelagic ova of other species were obtained by Mr. Field with the use of the tow net.

Mr. and Mrs. C. H. Eigenmann occupied a table in the laboratory during the month of August as representatives of Harvard College. They took up the study of the general development of fishes. For this purpose the eggs and embryos of four species were laid under contribution. Besides these results Mr. and Mrs. Eigenmann devoted some part of their time to the study of the osteology of the bluefish (*Pomatomus*), the flounder, and other forms in connection with their work on systematic ichthyology. They made a representative collection of the fishes native to Wood's Holl waters for comparison with the forms found in other regions and in the fish faunas of which they are interested.

Mr. W. S. Marshall, of the University of Pennsylvania, was engaged during the month of September in making a series of preparations of the brains of the common fishes to determine the variations in the form of the organ and the arrangement of the cranial nerves by macerating the whole in 20 per cent. nitric acid, which softens everything but the nerve tissue. Following a method which has given very good results in the hands of Mr. C. F. Hodge, it is believed that interesting and important results may be obtained through such a study of the configuration of the brain and the arrangement of the cranial nerves of fishes, which will supplement those obtained by Mr. Phillips by another method. This method of maceration also makes it possible to isolate the dermal trunks of the lateral nerves, which are very important in

connection with the system of lateral sense organs. These latter it is very important to study, as a knowledge of their function will doubtless enable us to understand to some extent how a fish is impelled to escape from its enemies through warnings sent in to the motor centers from this singular peripheral system of sense organs.

Mr. Marshall also collected a series of starfishes and crustaceans for purposes of dissection.

Special investigations upon the lateral system of sense organs of fishes were undertaken by students in the Boston marine laboratory at the suggestion of the writer. Two ladies, Miss Clapp and Miss Harris, worked on this subject, under the direction of Dr. C. O. Whitman. The former took up the study of the development of the lateral lines in the toad-fish (*Batrachus tau*), a form upon which the writer of this had made some studies in a similar direction. Miss Harris took up the study of the special differentiation of the three free rays of the pectoral of the Gurnards (*Prionotus palmipes* and *evolans*), upon the structure and anatomy of which Prof. H. A. Allen and the writer made some anatomical and histological investigations four years ago. Professor Allen also at that time undertook some physiological investigations. These organs in *Prionotus* are among the most singularly and highly developed known to occur in fishes. They are provided with very large nerve trunks, a specialized motor apparatus, and a most singular system of terminal sensory organs. Their function, there is reason to think, is tactile and may enable the animal to determine the presence of its favorite food on the bottom.

Mr. S. Watase, a fellow of Johns Hopkins University, continued his elaborate studies upon the development and anatomy of the king crab (*Limulus*) and the squid (*Loligo pealii*). Of these studies it is not too much to say that they are among the most beautiful and thorough ever carried out in America, and when completed and published will undoubtedly be regarded as classical. The masterly thoroughness and patience with which the details have been worked out under the microscope, the exquisite and careful finish of the drawings which illustrate those details, are only equaled by the insight of Mr. Watase into the comparative merits of his facts in reaching general conclusions.

Mr. Watase has obtained an abundance of material for the study of the development and anatomy of the king crab. He has confirmed the discovery of Drs. Brooks and Bruce as to the invagination of the median eyes from the under surface of the head and their migration through to the upper surface. He has also made important discoveries in the mode of innervation and structure of the lateral eyes, and has cleared up some of the intricate questions respecting their development. The central nervous system of the adult has also received a careful and thorough study at his hands. He has made an unrivaled collection of embryological and anatomical materials. All students will certainly await the publication of his results with interest.

His studies upon the early history of the germinal area of the squid are without doubt the most exhaustive yet undertaken, as he has been able to trace the origin of the individual cells and their relations to a median plane of symmetry which bisects the germinal area. This has been made possible by the clearness with which the phenomena of karyokinesis manifest themselves. Other aspects of the subject will also be dealt with by him, especially the phenomena of fertilization, the formation of polar cells, the development of the ciliated areas on the embryo, etc. The development of the eye will also form the subject of special treatment at his hands. The habits of the adults during the breeding season have also been studied by Mr. Watase.

The value of these studies on account of the economic importance of the squid as bait and as food is not to be lost sight of. They are an important article of food in China, very large quantities of an allied species being salted, dried, and shipped to that country annually from our west coast. On the eastern coast they are scarcely less valuable as bait to the New England fishermen.

Dr. Wm. Patten, of the Lake laboratory at Milwaukee, Wisconsin, spent part of June and July in the Fish Commission laboratory, collecting and studying materials for further work on the minute structure of the eyes of the king crab (*Limulus*) and other arthropods. He secured a large series of embryos for this purpose along the shores of the harbor, which will no doubt enable him to add essentially to the very important results which he has already obtained in this direction, and which have been published in the *Mittheilungen* of the zoological station at Naples and in the *Journal of Morphology*.

Mr. W. McM. Woodworth, representing Harvard University, during part of July and August took up the study of the planarians parasitic upon the gills of *Limulus*. For this purpose he secured a large suite of materials and made a series of careful studies upon the nervous system and general structure of these singular parasites. New results of great interest with respect to the structure of the nervous system of these organisms were obtained by Mr. Woodworth.

Dr. E. A. Andrews, a fellow in Johns Hopkins University, was engaged during July, August, and September in a series of investigations upon one of the gephyrean worms (*Phascolosoma*) and upon *Diopatra*, one of the common annelids. He also devoted some time to the study of the structure, the histology, and the physiology of digestion of *Phascolosoma*, and also its embryology. The development of the very remarkable ova of *Diopatra* occupied another portion of his time. A large number of finely executed drawings were made by him in the course of his work.

Mr. T. H. Morgan, another fellow in biology in Johns Hopkins University, devoted his attention to the study and collection of Ascidians or Tunicates. Of these he has investigated six genera in the laboratory during the summer, *Salpa*, *Botryllus*, *Amouraccium*, *Molgula*, *Appendicularia*, and *Perophora*. Mr. Morgan has been on a number of expedi-

tions with the steam launch and tow net to the vicinity of Gay Head and Penikese to collect living examples of *Salpa*, besides one trip on the U. S. Fish Commission schooner *Grampus* as far out as the Gulf Stream for the same purpose. The last of these expeditions was partially successful. The object of collecting this material is to get a basis for comparison with the life history of the simpler forms of Tunicates and to work out the precise method of the budding and development of the young *Salpa*, a problem to which Dr. Brooks has devoted much attention, as may be learned from the very important memoirs which he has published on the subject. Mr. Morgan has made sections of the reproductive organs and sexual products in relation to the parent of the other five genera for comparison with *Salpa*, and will doubtless reach important conclusions upon completing his studies.

Prof. W. K. Brooks, of Johns Hopkins University, Baltimore, has continued his extensive and elaborate studies upon the medusæ and hydro-medusæ of the Atlantic coast at the U. S. Fish Commission Station at Wood's Holl. Prof. Brooks's studies have hitherto been confined in the main to those upon the southern coast of the United States from Maryland to Florida and the West Indies, especially the Bahamas. During the 10 years of his work as director of the Chesapeake Zoological Laboratory of Johns Hopkins University he has accumulated several thousand sketches and beautifully finished studies from life of this group from materials obtained over the very wide marine area mentioned above. These results have enabled him to compare the northern and southern forms, for the first time at Wood's Holl, on the basis of a wider acquaintance with the different types ranging over this area than is probably possessed by any other student of these groups. Several common forms found about Wood's Holl, usually regarded as the same as the southern ones, have been found to represent allied but different species, with either a different habit of growth or a somewhat different life-cycle.

Professor Brooks has made studies of the life histories of the following genera of medusæ and hydro-medusæ: *Cyanea*, *Dactylometra*, *Mnemiopsis*, *Pinnaria*, *Pelagia*, *Hydractinia*, *Tubularia*, *Physalia*, *Campanularia*, *Margelis*, *Lafaxa*, *Dipurina*, *Regmatodes*, *Clava*, and *Eudendrium*, all collected near the station. Not only have careful drawings of the adults of most of these been made, but studies of their life-cycles or metamorphoses and development have been carried out. Suites of very carefully preserved materials have also been collected for further investigation of the embryology, histology, and minute anatomy of these animals. The drawings by Dr. Brooks, illustrating the life-cycle and metamorphosis of the individual species, are not surpassed for accuracy and attention to details by any recent work, and can only be brought into comparison as respects the thoroughness and beauty of illustration with the classical monographs of Agassiz, Allman, and Haeckel.

Dr. Brooks accompanied the expedition of the U. S. Fish Commission

schooner *Grampus* to the Gulf Stream to obtain data respecting the existence of the tile-fish, which was so mysteriously destroyed in such inconceivably vast numbers a few years since. While the search for tile fish again proved fruitless, collections of *Salpa*, heteropods, pteropods, and *Sagitta* were obtained in fine condition, besides several well-preserved *Physalia* and *Discomedusæ*.

During these expeditions Dr. Brooks also experimented very successfully with entirely new methods of preserving such delicate organisms as jelly-fishes. The method, which is a very simple one, consists in adding glycerine to Perenyi's fluid until a solution is obtained of the specific gravity of sea water. In this the jelly-fish is killed. The specimen, after the killing is completed, is transferred to a mixture of alcohol and glycerin of the same specific gravity as the first; in this it is preserved, and remains flexibly transparent and preserves its form as well as its histological structure admirably. The results so far obtained show that the method will be a most useful and convenient one.

A complete series of the early stages of the small viviparous lamellibranch, *Spharium sphericum*, was also obtained by Dr. Brooks from the fresh-water pools in the vicinity of Wood's Holl. Some interesting facts regarding the manner in which the young mollusk is nourished by and inclosed in capsules between the gills of the parent have been obtained by Dr. Brooks from the preliminary study of these animals.

Workers from other institutions have also availed themselves of the facilities afforded by the station for the collection of materials for class work. Among those who have been there for that purpose are Prof. S. F. Clarke, of Williams College; Prof. J. S. Kingsley, of the Indiana University, Bloomington, Indiana; Prof. Spencer Trotter, of Swarthmore College, Swarthmore, Pennsylvania; Professor Miller, of Princeton; Prof. H. N. Mateer, of Wooster University, Wooster, Ohio; Mr. W. S. Marshall, of the University of Pennsylvania, and Mr. Geo. Howard Parker, instructor in biology, Museum of Comparative Zoölogy, Harvard College, Cambridge, Massachusetts.

Substantial assistance has also been rendered the Marine Biological Station established at Wood's Holl by the efforts of citizens of Boston in giving the investigators and students connected with that institution facilities in collecting, in company with the naturalists of the U. S. Fish Commission, on the expeditions made with the steam-launch and the U. S. Fish Commission steamer *Fish Hawk*. In this way teachers and students who were not previously familiar with the methods used in deep-sea dredging were enabled to witness the most modern appliances in operation and obtain useful material not otherwise accessible. Similar courtesies were also extended by Commissioner McDonald to Professor Dwight, of Vassar College, and his pupils, who were engaged in scientific explorations and biological studies at Cottage City, Martha's Vineyard.

Summarizing, Johns Hopkins University was represented by five

workers; the University of Pennsylvania by three; Harvard University by five; Princeton College by three; Wooster University, Wooster, Ohio, by one; Swarthmore College by one. Eighteen workers therefore availed themselves of the facilities afforded by the laboratories of the U. S. Fish Commission during the season, these eighteen representing six well known institutions of learning. The Boston Marine Biological Laboratory, Williams College, the University of Indiana, Harvard University, Vassar College, Swarthmore College, Johns Hopkins University, and the University of Pennsylvania have obtained collections for biological work through the facilities offered by the U. S. Fish Commission. About thirty teachers and students availed themselves of these advantages.

Of the monographic work in the widest sense undertaken and carried on to a more or less advanced stage of completion, the work on the sturgeon and the iconography and life histories of the food-fishes is either well advanced or in progress. The proposed monography of the medusæ and the hydromedusæ by Prof. W. K. Brooks (for which he has been gathering materials for several years not only here but in many other localities) is the most extensive and, from a purely morphological view, perhaps the most important. The next are the two monographs by Mr. S. Watase on the squid and the king crab, which will vie with anything produced abroad as respects the thoroughness with which the work will be carried out. Finally, the work on the ascidians by Mr. Morgan, that on the worms by Dr. Andrews, and that on the oyster by Mr. C. F. Hodge, and by Dr. Brooks on *Sphaerium*, will add four more monographs or papers of important economical or scientific value. Eight important monographs or papers at least may be expected to be the outgrowth, wholly or in part, of the work of some seven of the workers engaged in study in the laboratory of the U. S. Fish Commission during the season of 1888.

Sundry improvements, such as dividing the main laboratory in part into stalls for individual workers, have been proposed, so as to make it possible to have more shelf room for reagents, materials, and apparatus. A new self-regulating paraffin bath has been purchased for general use by the workers engaged in research requiring the use of the microtome. A more complete set of glassware, adapted to the requirements of modern biological research, is much needed for the laboratory, and will be added during the next year. These and minor changes in the arrangement of facilities, such as the extension of the system of aquaria now in use, will render the laboratory of the U. S. Fish Commission at Wood's Holl, with its means for obtaining materials by the aid of launches and steam-vessels, the most thoroughly equipped marine station in the United States. As it is, there is now no other place where marine life may be studied with such facilities as here, since the introduction of wooden and rubber pipe for conveying the sea water from the supply tanks to the aquaria. Furthermore, there is

no place where the development and life histories of species, such as the lobster, cod, bluefish, mackerel, and sea bass, can be more advantageously studied than in the hatching rooms connected with the laboratory of this station.

The Commissioner, Professor McDonald, has been engaged, during a considerable part of the time which he has been able to spare from his official duties, in devising improvements in the methods of displaying living objects in the aquaria under the best conditions. This has been accomplished by allowing the light to pass down through the water from above and cutting off the view from the upper surface entirely. This, with tastefully arranged rock work, algæ, polyps, and a limited number of fishes, gives picturesque effects of marvelous beauty, and also renders the organisms confined in the aquaria capable of being studied under conditions natural to them. Sea-anemones, with their flower-like disks of tentacles fixed to the rocks, active stickle-backs, the gorgeously colored sea bass, scup, crevalle, and mackerel swimming back and forth through the grottoes in these aquaria, make a combination of most beautiful objects, which have been sources of perennial interest and instruction to the many hundreds of visitors who have passed through the hatching rooms of the station during the past summer. These displays have also afforded the naturalists very valuable opportunities for studying some of the comical habits of the common denizens of the waters in the vicinity of the station. Some very important and significant habits have thus been made out as characteristic of given types. The tautog, for example, has the habit of lying over on its side, first digging out a bed for itself in the sand or gravel; here it rests as contented as a pig in a puddle till some unwary victim comes along to tempt the fish from his lair. Some such habit as this may have given rise to the flounders, which have unquestionably descended from fishes with an eye symmetrically placed on either side of the head.

The Commissioner has also been experimenting, with most promising results, with new methods of aëration, so as to maintain life in the aquaria without a change of seawater. The presence of the water supply in the tanks is utilized in such a way as to form an aërating apparatus which carries a stream of air divided into fine bubbles through some of the aquaria, from which the supply of water is entirely cut off. The water used in effecting aëration in this manner can be used to operate other overflow aquaria, or such as are fed by constantly renewed supplies of sea water. A plan such as this will make it possible to have marine aquaria operated at the Central Station at Washington, the aëration of the salt water being easily effected by the utilization of the supplies of fresh water used in the operation of fresh-water aquaria. This will make that station doubly valuable in conducting experimental work, and give increased interest to the display of fresh-water fishes, to which it will then be possible to add many marine forms for exhibition in the

living state. This may be made a most important display supplementary to the exhibits in the zoölogical garden to be established in Washington under the direction of the Smithsonian Institution. The fresh-water and marine aquaria, the great national museums of art, science, medicine, and anatomy, the great libraries, botanical and zoölogical gardens situated so near together, will thus doubtless become centers of great public interest and afford a most useful educational influence in Washington.

The adaptation of an aquarium for the convenience of the artist in delineating the fishes has also been devised by the Commissioner. A movable diaphragm of glass is suspended so as to make it possible to restrict at will the space in which a live fish is confined while being sketched. This serves to keep the animal quiet in a narrow space, and enables the artist to work more confidently in catching details of form and color. The same device will be used in conducting experiments in photographing the living fishes in the water.

It is most earnestly to be hoped that a continuance of the liberal coöperation of Congress with the Fish Commission may be maintained, in order that the present Commissioner, Prof. Marshall McDonald, may be enabled to further develop the interests of practical fish-culture in America. The policy of the Commissioner is simply to continue in the line of work originally proposed by Professor Baird, and to call to his aid, in the work of elucidating the economico-biological problems which call for answers from time to time, the leading biologists of the country. This makes the maintenance of a great seaside laboratory near the fishing interests of the country a necessity, if the fullest significance is to be given to the economical work which still remains to be carried out. The marine organisms which man uses as his food prey upon each other and upon such living things as are not directly available as food for man. It thus comes about that when the life-history of any form used as food is to be fully known, the habits, habitats, or natural history of hundreds of forms which have no direct relation to man's wants must also be studied. This can nowhere be so well done as in a properly equipped and maintained seaside laboratory or zoölogical station, which should aim to achieve the preëminence so deservedly attained by the world-famous establishment founded by Professor Dohrn at Naples. Dr. Dohrn, besides devoting a large private fortune to organizing his establishment, has had the assistance of the German and Italian Governments, and of that most enlightened and liberal-minded prince, the late Frederick III, Emperor of Germany, while several learned societies and institutions have also rendered him other important aid. If individual enterprise, aided by some of the governments, princes, and academies of Europe, can take pride in pursuing biological investigation for its own sake and quite irrespective of any economic bearings it may have, it is surely not too much to expect this great country to support researches which have the most direct and immediate bearing upon the food-supply of a nation of fifty millions of people.