(Reprinted from The Collecting Net, Vol. IX, No. 1, June 30, 1934)

RESEARCH IN BIOLOGICAL SUBJECTS AT THE SCRIPPS INSTITUTION OF OCEANOGRAPHY

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The editor of THE COLLECTING NET has invited me to contribute an article on the kinds of biological material available for study at the Scripps Institution, on the work accomplished at it during the last year, and on the researches in progress.

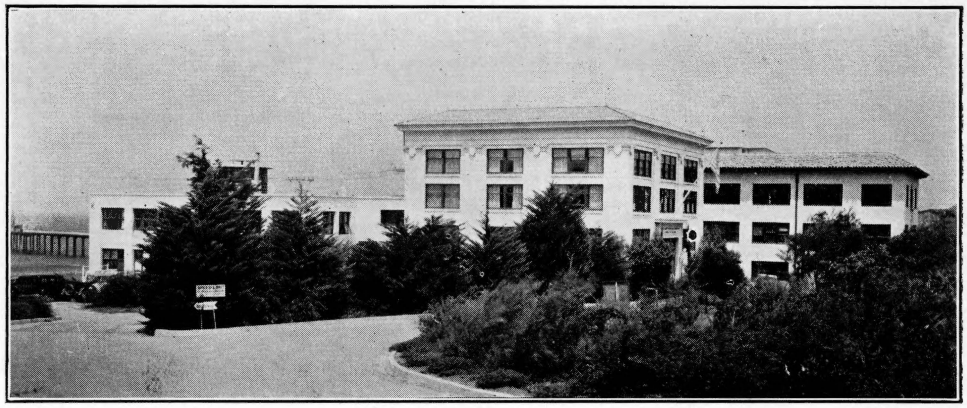
With reference to the biological material available for study at the Scripps Institution, about all that can be said is that representatives of virtually all groups of marine organisms can be found either along the sea coast near the Institution, in the adjacent ocean waters, or at localities which are accessible from the Institution by means of automobile. There are representatives of all the important groups of marine plants from bacteria to giant kelp, and of all the principal groups of marine animals, protozoa, sponges, actinozca, echinoderms, various kinds of worms, molluscs, crustacea, tunicates, and vertebrates, from blind gobies to sea-lions, porpoises, and whales. The whales are not easy to catch, but the sea lions and porpoises are inclined to be friendly. The sea-lions come when called. As regards any particular kind of organism on which an investigator may wish to work, it is advisable to address an inquiry beforehand to the Director of the Institution. Some groups of organisms are not well represented, for example, the larger echinoids, but there are several local species of star fishes and a species of sand dollar, *Dendraster excentricus,* is common. Stony corals are not available for study along the coast of southern California. A few species are found in shallow water at some places, but the polyps are small and specimens are not numerous. In moderately deep water, several species have been found, but it is doubtful if material could be maintained alive in the laboratory. There are, however, species of sea-anemones, which may be obtained in quantity.

Since the Institution has a good salt-water supply system, the facilities are good for culture studies and other kinds of experimental investigations.

It is desirable to have for the waters adjacent to the Scripps Institution a catalogue of the various marine organisms found in its vicinity, like that published for Plymouth, and the preparation of such a list is being considered. A great deal of systematic work has been done on the organisms in the waters off southern California. Studies have been made of the bacteria by ZoBell, the diatoms by W. E. Allen, larger marine algae by Setchell and Gardiner, several groups of marine protozoa by C. A. Kofoid, foraminifera by J. A. Cushman, M. L. Natland and others, medusae by H. B. Torrey, arrow worms by E. L. Michael, copepods by C. O. Esterly, tunicates by W. E. Ritter, appendicularia by Christine E. Essenberg, and other groups have been specially studied. A list of many of the principal publications on Pacific coast marine invertebrates is given in Johnson and Snook's "Seashore Animals of the Pacific Coast," pages 607-620, a valuable book for those who wish a general idea of the marine invertebrates of the region with which it deals.

Regarding the biological researches at the Scripps Institution, it is difficult to separate them from other kinds of oceanographic research. An attempt will be made to illustrate what is meant. It is known that planktonic organisms are abundant in places, if not continuously, along the west coast of America from southern California to Valparaiso, Chile. This does not mean that planktonic organisms are not abundant in other places. Marine animals are dependent on phytoplankton for food. The question immediately presents itself as to why phytoplanktonic organisms should be abundant in the strip of water indicated. The abundance is due to the circulation of the ocean waters, a problem of dynamical oceanography. Along much of the California coast, and in places along the coast of Central America and in the Gulf of Panama, and along the coast of South America, the phenomenon known as upwelling occurs. The upwelling water contains abundant supplies of plant nutrients upon which the development of the phytoplankton depends. The phytoplankton is eaten by smaller animals and the smaller animals are eaten by larger ones, ultimately reaching the carnivorous marine mammals. The upwelling is caused by winds, which along the coast of California and farther south, and along the west coast of South America within the trade wind belt, shove water from near the shore seaward and cause water from below the surface to move upward to take the place of the water which had been pushed away from the shore. Therefore, the atmospheric circulation of the region is a cause of the abundance of life in the sea.

Now to consider for a moment some of the chemical aspects of sea water. The growth of phytoplankton in the sea depends upon the presence of plant nutrients. The only means whereby the distribution of plant nutrients in the sea may be ascertained is by chemical investigations of sea water. The chemical properties of sea water, necessary for the growth of plants, are influenced by many factors, some of which are organic and some inorganic. For animal life in the sea, oxygen is necessary. In order to ascertain the amount of oxygen available for animal life chemical investigations are needed. In the eastern Pacific there is a layer, which



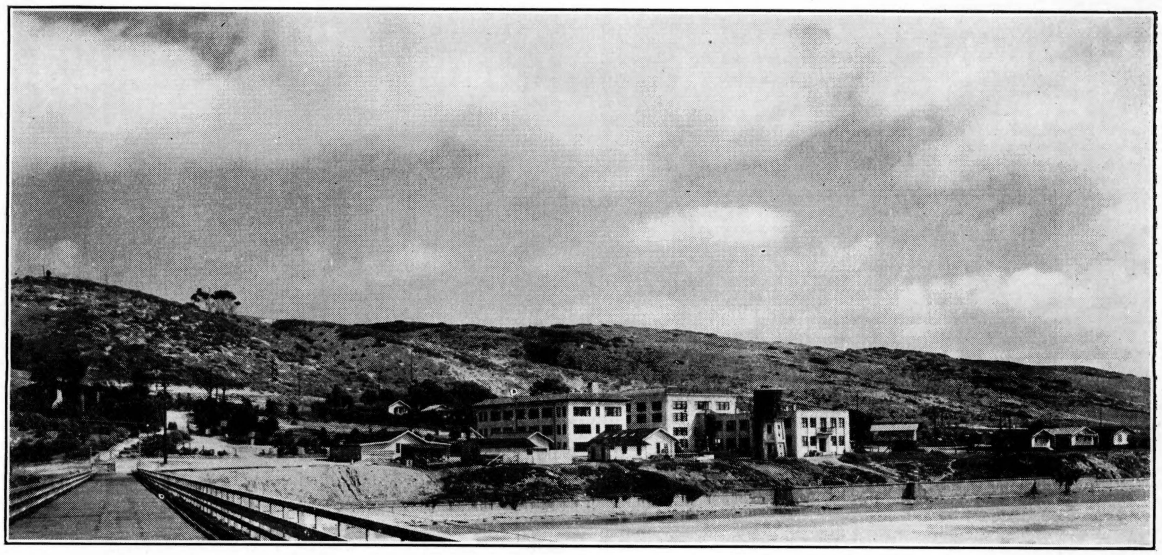
THE SCRIPPS INSTITUTION OF OCEANOGRAPHY

View of the three principal buildings looking northwest. In the center is the Library-Museum building; at the right is part of the new laboratory, Ritter Hall; at the left behind the Museum-Library building is the old George H. Scripps Laboratory. At the extreme left may be seen part of the pier.

varies in depth from 100 to 800 or 1000 meters, in which there is almost no, or actually no, oxygen. Oxygen is not uniformly distributed in the ocean. In order to understand the adaptations of organisms to different oxygen tensions in the sea, both studies in the field and physiological investigations in the laboratory are required.

A geological problem will now be mentioned. It is known that a considerable proportion of the deposits found on the bottom of the ocean is composed of the remains of organisms. From a study of the composition of the marine bottom deposits along the Florida Coral Reef Tract and in the shoal waters of the Bahamas, E. M. Thorp has shown that the calcium carbonate bottom deposits of the two regions are composed of 95% or more of the remains of organisms. That important deep-sea marine deposits are largely composed of organic remains is indicated by the names of some of the deposits, such as Globigerina Ooze, Diatom Ooze, and Radiolarian Ooze. It has been pretty well established that the principal difference between Globigerina Ooze and Red Clay is that calcium carbonate remains, which may have started to fall to the bottom over areas of Red Clay, were dissolved before they reached the bottom. This presents a problem in the chemistry of sea water and the variation in the properties of sea water under different conditions.

Additional illustrations might be given, but enough has been said to show that if we are to understand conditions in the sea, each of the different disciplines developed for the study of the



THE THREE PRINCIPAL BUILDINGS LOOKING SOUTHEAST FROM THE PIER

At the left is the new building, Ritter Hall; in the center is the Museum-Library building; at the right behind the Museum-Library building is the George H. Scripps Laboratory.

sea must be utilized. There is no biology of the sea independent of the physics, chemistry, and geological aspects of the ocean.

The biological program at the Scripps Institution, therefore, may be said to begin with the physics and chemistry of the ocean, after which its various biological and geological aspects follow. A brief account will now be given of some of the recent biological investigations at the Scripps Institution, taking up the subjects more or less topically.

The investigations in microbiology at the Institution are in charge of Dr. C. E. ZoBell, assisted by Mrs. C. B. Feltham. Several papers have been published during the year and others are in press. Studies of water samples along and off the coast of southern California show that a large proportion of the contained bacteria are able to ammonify numerous substances. Eight new species have been isolated which produce ammonia from low concentrations of urea in sea water, and in cultures containing 2% urea raise the pH to 9.4. Nitrosofiers and nitrifiers have been recovered with regularity from bottom deposits in relatively shallow water, but similar methods have failed to reveal their presence at depths greater than 500 meters. Nitrate-reducers are encountered very infrequently and they are functional only under unusual conditions. Observations on the influence of temperature, organic matter, pH, redox potentials, and salinity on the activities of nitrifying and denitrifying bacteria indicate that in the sea the redox potential is perhaps the most important factor.

Analyses of over 40 bottom deposit samples from depths to as great as 1300 meters show the existence of a large and varied microflora which is clastically active against cellulose, starch, and proteinaceous substrates. Aerobes predominate, but the ratio of anaerobes to aerobes increases with the depth of the core strata. The reduction potential of most of the cores approaches that of the hydrogen-electrode and *in vitro* hydrogen overvoltages may be produced by microbial action. Sulphate-reducing bacteria are common in the mud samples.

It has been found that, while immediately following initial isolation marine bacteria have specific sea-water requirements, they are readily acclimatized to become physiologically indistinguishable from fresh-water species. At least 88 new bacterial types from the sea have been characterized.

Dr. ZoBell and Miss Esther C. Allen have noted that the usual sequence of events in the fouling of submerged surfaces is first the adherence of bacteria and kindred growths, followed by the attachment of barnacles, Bryozoa, hydroids, and other organisms. Bacteria and, to a lesser extent, diatoms play an important rôle in the fouling of marine structures. One paper on the subject has been published and another is in preparation.

In collaboration with Dr. Nelson A. Wells, the etiological agent of a highly fatal infectious dermatitis of *Fundulus parvipinnis* and other marine fishes has been isolated and identified as *Achromobacter ichthyodermis*, n. sp., and a paper published on the results. A second paper dealing with the pathology of the disease has been accepted for publication in the *Journal of Infectious Diseases*.

Professor W. E. Allen has continued his studies of phytoplankton of the La Jolla region, devoting most of his time to the preparation of the manuscript of a report on the results of daily collections for ten years at the end of the Institution's pier. Professor Allen has also continued studies of fouling organisms along the lines initiated at the Institution several years ago by Professor Wesley R. Coe of Yale University. Dr. Easter E. Cupp has completed a manuscript entitled, "A critical study of certain distinguishing characters in three closely allied plankton species of the diatom genus *Nitzschia* and their relations to certain environmental conditions," and she has prepared a report on the plankton samples collected by the *Velero III* between San Diego and Panama.

Dr. T. W. Vaughan during the year published a number of papers on fossil foraminifera, and he has directed the work on foraminifera and marine bottom-deposits. A publication of the Scripps Institution Bulletin, technical series, entitled, "The temperature-and depth-distribution of some recent and fossil foraminifera in the southern California region," by Mr. M. L. Natland, is one of significance both to students of the ecology of marine organisms and to geologists. During the year Dr. Earl Myers succeeded in completely working out the life history of a local species of foraminifera known as *Patellina corrugata*. A short note entitled, "Multiple tests in the foraminifera," was published in *The Proceedings of the National Academy of Sciences* (vol. 19, no. 10, pp. 893-899, 1933). The complete report, entitled, "The life history of *Patellina corrugata*, a foraminifer," is now ready for publication. The results were presented by Professor C. A. Kofoid at the last meeting of the National Academy, April, 1934.

During the last twelve months an investigation has been made by Dr. D. L. Fox, the Institution's physiologist, and Dr. G. W. Marks, research associate, on the digestive enzymes of the plankton feeding *Mytilus californianus*, with a view to determining the food that it can utilize and must remove from the sea. Its fecal ribbons have been examined for correlative information. The findings from these investigations will be correlated with Buley's studies, in manuscript, of the gastric contents, and Miss Austin's studies, also in manuscript, of other features of this mollusc. Studies on the effect of oxygen in the inactivation of the enzyme, catalase, are being continued, using a number of marine animals and plants. A paper dealing with the subject entitled, "The inactivation of mussel catalase by

oxygen," appeared in the *Journal of Biological Chemistry* (Vol. 103, p. 269, 1933).

Another investigation in progress is concerned with the amounts of dissolved copper in sea water, the tolerance of a number of marine molluscs for this toxic cation, and the possible accumulation of it by the animals.

The mussel has in its digestive tract an enzyme or enzymes capable of hydrolyzing the poisonous glucoside amygdalin, with the production of a reducing sugar (glucose) and free hydrocyanic acid. Out of 69 bacteria, 6 actinomyces, 3 molds, and 2 yeasts investigated, two-thirds of the bacteria, and all the other forms except one of the yeasts, possess the ability while living to produce HCN from amygdalin. The mussel enzyme hydrolyses amygdalin in the absence of microorganisms. A paper dealing with the subject has been prepared.

In cooperation with Dr. F. B. Sumner an investigation of considerable length concerning the carotenoid pigments in certain marine fishes has been completed and published under the title, "A study of the variations in the amount of yellow pigment (xanthophyll) in certain fishes and of the possible effects upon this of colored backgrounds" (*Jour. Exp. Zool.,* Vol. 66, pp. 263-301, 1933).

During the year seven articles have been published from the section of physiology, two are in press, another has been prepared for publication, and three are in the process of preparation.

The work in fish biology, in charge of Professor F. B. Sumner, who published several papers during the year, consisted in a continuation of studies of the relations of marine fishes to their environment. The chief subjects of investigation were as follows:

The yellow (carotenoid) pigment of fishes, which is partly responsible for the striking adjustments of these animals to the color of their surroundings in nature, was investigated by him, in cooperation with Dr. Fox of the physiology section.

Studies were carried out upon the relations of different parts of the visual field to the color responses of fishes. A new technique was devised, whereby the animals were forced to look through transparent caps which were fitted over the eyes, these caps being variously colored or partly obscured by opaque areas.

Investigations of the oxygen consumption of fishes were continued by Dr. N. A. Wells. The relations of the metabolic rate of activity, to temperature, season, size, sex, and some other factors were determined in part, and certain phases of the work were brought to a definite conclusion. Dr. Wells completed the manuscript of a paper entitled, "Variations in the rate of respiratory metabolism on the Pacific killifish, *Fundulus parvipinnis,* in relation to temperature, season, age, and sex."

Certain diseases of fishes were investigated by Dr. Wells in collaboration with Dr. ZoBell of the section of microbiology, as has already been stated.

During the year two rather large studies of marine bottom deposits have been brought to completion. One of them is a study by Dr. E. M. Thorp entitled, "Calcareous shallow water marine deposits of Florida and the Bahamas," and the other is an investigation by Mr. Roger Revelle of the deep-sea bottom samples collected in the Pacific by the *Carnegie.* It is expected that the results of both of these investigations will be published by the Carnegie Institution of Washington. It has been stated in the introductory remarks to these notes, that the organic remains contained in the sediments have been quantitatively evaluated. Mr. Revelle has also prepared a paper entitled, "The physico-chemical factors affecting the solubility of calcium carbonate in sea water," which will be published in the *Journal of Sedimentary Petrology.* During the year much attention has been paid by several members of the staff of the Institution to oxidation and reduction in the ocean. This subject is a meeting ground of physical oceanography, geology, chemistry, and a considerable range of biological phenomena, therefore members of the staff of the Institution representing each one of those disciplines have cooperated in the investigation.

Dr. Robley D. Evans, assisted by Mr. Arthur Kip, is making a study of the radioactive substances in sea water, in marine plants and animals, and in the bottom deposits off the coast of southern California. They are also making similar analyses of core samples of deep-sea sediments kindly supplied by Dr. Ph. H. Kuenen from the collections made by the *Willebrord Snellius* in the East Indies, and on samples supplied by the Hydrographic Department of the Japanese Imperial Navy, collected by the ship *Mansyu* in the southwest part of the North Pacific. It is generally known that there is concentration of radium in marine sediments, but it is not known how the concentration is effected. It looks as if it might be accomplished by organisms. In order to test such an hypothesis the inorganic constituents of many organisms are being analyzed for their content of radio-active substances.

In the foregoing notes account has been taken of the work of about fourteen people, ten of them members of the Institution staff, one a temporary assistant, and three associated with the Institution in its research program. During the year about fourteen visiting investigators utilized the facilities of the Institution for biological research and about as many more came to it for conference or advice regarding biological investigations. Many teachers and students from colleges and high schools also came to inspect the work of the Institution, its museum, and aquarium.

During the year about thirty papers dealing with biological subjects were published by those connected with the Institution and about nineteen are awaiting publication.