9.—BIOLOGICAL RESEARCH IN RELATION TO THE FISHERIES.

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There is no longer any questioning the fact that when we consider the economic relations of one organism, the economic relations of multitudes of others are at once involved. It may be that those others, thus brought under consideration, may, as single individuals, be of no appreciable economic value to man; only when very minute beings are gathered together in great numbers by other and useful organisms as their staple of nourishment does their value become palpable. For example, a very large and widely distributed group of plants found in fresh and salt water, the diatoms, are very minute as individuals. Some of these diatoms have long been used as test-objects in the trial of the power of resolution of the object-glasses of microscopes. By many amateurs in science this is supposed to be their sole use. The botanist, however, finds in them a wonderful exhibition of the power of a very minute simple organic type to manifest the most manifold variations of the form and superficial sculpturing of its siliceous envelope. To the economist and fish-culturist the diatoms have a totally different significance. Probably more than one-half of the food of the oyster consists of these minute vegetable organisms. Therefore, one-half of the sapid parts of the oysters used as the food of man represents an equal volume of minute organisms transubstantiated into the flesh of this bivalve. These almost infinitesimal vegetable motes that swarm in the sea-water, wherever oysters thrive, are integrated into oyster-flesh by the milliards by means of the wonderful processes of prehension and assimilation manifested by this mollusk. An indefinitely little and apparently useless organism is thus aggregated and transformed so as to build up by infinitesimal increments another palpably large organism that is useful and valuable to man as food. The oyster, as one part of the harvest of the seas, is in reality largely a harvest of these apparently useless diatoms transformed into something useful.

Oysters that are found in different places differ wonderfully in their rates of growth, conditions of flesh, etc. Why should this be so? It is hardly to be doubted that these differences in the growth and conditions of oysters at different places is correlated with the character and abundance of their food supply. If this is true, the kind and relative abundance of diatoms must be studied at these different places if we expect to find out the causes of the differences in flavor and quality of oysters from different beds. We are thus brought to realize the fact that the scientific and accurate study of an apparently useless minute organic type has direct and useful bearings upon the production of an important element of food supply. The very existence of oysters in a given locality is therefore dependent upon the abundant production of a few types of microscopic organisms at that place. Whatever, therefore, impairs the power of these minute organisms to reproduce themselves in such places must impair the productiveness of the oyster beds in the same situations. It is also obvious that, if we would most profitably study the welfare of the oyster beds on our coasts, we

shall be obliged to consider the conditions of life under which this microscopic oyster food is produced.

Similar relations are sustained by many other large aquatic to other microscopic organisms. For example, it has been shown by the writer that the food of the sturgeon, during its larval life, is microscopic. In fact, were it not for this capacity of the larval sturgeon to obtain other living organisms of small size, it could not reach those stages of growth at which it is possible for it to feed upon larger organisms, and thus be enabled to reach the adult condition. In short, were it not possible for the very small larval sturgeon to find living forms small enough for it to capture and swallow entire, it would not be possible for it to grow to those stages which lead to the adult state. We thus realize that were there no microscopic organisms there could be neither caviare nor smoked sturgeon.

The same is true of the larval oyster. It is exceedingly probable that were there no bacteria and monads still more minute than the diatoms upon which the adults feed, the very young larval oyster could not find living food small enough to pass into its exceedingly small mouth. The lowest and minutest organisms known, therefore, probably enable the very young oyster to pass into the next larger stages of growth, and thus absolutely secures this important mollusk against extinction. The bacteria and monads seem, in fact, to be a kind of baby food for young oysters that enables them to pass the critical stage of their very young infancy with safety. Bacteria should therefore not always be condemned. In the form of the yeast plant, and as the bacterium of the butyric ferment, microscopic organisms may be vitally connected in the production of bread and butter, no less than in the production of oysters. While some bacteria, such as the cholera *Spirillum*, may be an agency concerned in decimating the human family, other harmless species may be the means of indefinitely continuing the supply of the necessaries as well as the luxuries of the tables of mankind. It may not be amiss to remind an all too thoughtless public that, whether one enjoys an after-theater supper in a splendid restaurant or a modest oyster "stew" at a cheap lunch counter, the despised bacteria may be indirectly the means of ministering to the mere enjoyments of the palate as well as the necessities of existence.

The same is true of still more costly luxuries. Were there no microscopic organisms upon which the larvæ of the pearl-oyster could feed to carry them over the critical stages of their infancy, there would be no pearls to ornament the show loving human animal, since there would then be no true pearl-forming animal to produce those gems.

Coming to more prosaic and useful things, the fish-oil used in dressing leather, in like manner, is largely the accumulation of the oleaginous matters once forming part of the bodies of microscopic organisms, upon which oil-producing fishes and cetacea feed. Dr. Peck has lately shown that the much-abused menhaden, from which oil and guano are produced, is a living filter that literally strains all its microscopic diatomaceous and protozoan food out of the waters of the ocean wastes that it inhabits. The oil-producing basking-sharks do the same. Whales that may produce upward of two hundred barrels of oil live exclusively upon small pelagic organisms that must themselves live upon still smaller ones. A single whale was found by Mr. Edwards to have made its last meal upon shrimps, of which several barrels were taken from its stomach. These shrimps had fed upon still smaller creatures that had been feeding upon the microscopic life of the sea. Infinitesimal volumes of food are thus gathered together in ocean wastes and assimilated in succession through a series of organisms

gradually increasing in dimensions, man at last reaping the benefits of their industry, incident to the struggle for existence, in the pursuit and capture of prey as food.

In this way it may be shown that on every hand we are vitally dependent upon the lower worlds of life. Even the beefsteak that is to-day being transubstantiated, as the case may be, into either the clown or the sage, may have been part of an animal that was feeding a week ago upon clover that was partly supported with nourishment from the soil by the intermediation of bacteria. The interdependence of the large and the very small forms of life seems to be almost universal. There is such a thing, therefore, as biological economics, as well as a specific human political economy.

Other microscopic marine organisms, such as the foraminifera, have been in the past and are still engaged in world-building. Strata of the earth hundreds of feet thick and thousands of square miles in area are the products of the agglomeration and deposit of the skeletons of untold myriads of these microscopic organisms that once lived in the oceans of the past ages of the world. Of the rocks so formed the Pharaohs built the pyramids to serve as their tombs. The "bones" of microscopic organisms have thus been made to enshrine the bones of men. Some organisms of this same group, at the present time, furnish a part of the living food-supply not only of existing surface fishes, but also of those found at great depths, as I have found.

In every age do we find, therefore, that man has been vitally related to that lower world of life which ranks so far below him in powers and organization. The modern demands upon the sources of the world's food have not yet impelled investigators to study these microscopic organisms as thoroughly as their importance demands. Some, it is true, as the sources or vehicles of human disease, have been carefully studied, thanks to the inspiration of the genius and patience of Pasteur. The fact, however, that this ubiquitous microscopic life is one of the most important of the ultimate sources of the food supply of the world, is only beginning to attract the attention it deserves. The minute forms of life in their bearings upon the interrelations that subsist between the larger and higher forms of life have hardly yet been seriously considered. Even the life-histories of the great majority of the microscopic forms of life are not fully known. Even the relative abundance of the different species of protozoa and protophyta in the ocean, is not known; nor is it more than approximately known to what extent temperature and ocean currents affect their rates of multiplication, and consequently their abundance and distribution. In a large proportion of cases, also, we are ignorant of the nature of the food of many large marine and fresh-water species of great economic value. Again, we do not know to what extent animals that are of no economic value prey upon those that are; or, to what extent useless forms rob useful ones of the microscopic food upon which the latter subsist. Since it is also a fact that the young or larvæ of many useful animals are very minute, as the oyster, for example, it is not known to what extent such minute young stages of useful animals are preyed upon by useless animals. I have found the entire contents of the alimentary canal of a useless mollusk to consist of the remains of the minute young stages of other mollusks, to the number of many thousands, that may have been the embryos of useful species. Nor, again, is it known how many microscopic organisms are hurtful or poisonous to large ones that are useful to man.

It is perfectly evident, then, that the field for research in this branch alone of biological economics is almost unlimited. Its cultivation would achieve most startling and valuable results. Many of these results would be found to have the most unexpected economic and scientific applications. In fact, the thorough investigation of

the biology of the lower and minuter forms of life would probably disclose many hints of the method of the origin of life itself, to say nothing of the practical value of such inquiries. It would also disclose hints as to the methods of operation of the process of organic evolution or the transformation of species. It is opportune for naturalists all over the world to protest against the manner in which the study of the simplest forms of life is dealt with in many of our colleges and universities. No sound conceptions of the nature of the processes of life in the higher organisms can be obtained without a study of those of the simplest ones. Nowhere else do the processes of life present such simplicity in contrast with the appalling complexity of the life processes of the higher types. Nowhere else do we find it possible to so closely approach nature by way of experiment, to inquire what life is and what is the nature of its ultimate machinery. Nowhere else can we hope to get such prompt reactions when these minute beings are subjected to the action of drugs. Whether very dilute deleterious chemical bodies when brought into relation with such microörganisms produce their effects by dynamical and chemical agencies, or by means of endosmosis only, would have profound bearings upon therapeutics and might be the means of laying the foundations of the scientific principles of that science. This we assume to be probable because the higher organisms are composed of aggregates of bodies, the so-called *cells* of their tissues, which are, taken singly, the morphological equivalents of the unicelular microscopic forms of life.

The steps by means of which the infinitely little and seemingly useless beings are integrated or developed into the indefinitely great and useful can be understood only through prolonged observation and experiment. Germany has made a scientific beginning in the study of the minuter as well as the greater life of the sea. America can not afford to lag behind with the splendid equipment already in her possession in the laboratories and vessels of the U. S. Fish Commission, which could be made a hundredfold more efficient than at present if the enlightened policy and aims of Commissioner McDonald could be carried out. If an adequate permanent endowment could be had for the great Government laboratory and hatching station at Woods Holl, Mass., researches of the most far-reaching and valuable economic and scientific importance could be conducted throughout the entire year. Here specialists, such as physicists, chemists, biologists, morphologists, and physiologists should be employed on the great economic and scientific problems presented by the fishery industries. Here the sea, the mother of the primæval life of the world, is accessible under the best conditions. Here what still survive of the primæval types can be had. Here the processes of the development and survival of the useful species could be studied in a way never before approached.

Here, also, there would be the stimulus of research work that exists nowhere else in America, since the Marine Biological Laboratory, close by, has been so successfully developed by Dr. C. O. Whitman and his associates. Climatal, faunal, and other conditions coëxist that render Woods Holl probably the most advantageous locality for these purposes that could be found on the eastern coast of the United States. An endowment of one million dollars could not be more wisely bestowed than by using it to place the great Fish Commission station at Woods Holl on a permanent basis, with the United States Government as trustee. How judiciously and wisely such a trusteeship has been conducted under the Government is sufficiently attested by the unequaled scientific and economic results achieved under such an endowment and under the administration of the three distinguished and successive secretaries of the

Smithsonian Institution, Professors Henry, Baird, and Langley. As the fostering mother of the most momentous scientific enterprises, from which incalculably valuable economic benefits have been derived for the whole country, that institution stands without a rival on the American continent.

Emerson has remarked that "to a sound judgment the most abstract truth is the most practical." This remark has been frequently verified in the course of scientific progress. The development at the time of apparently useless truths by Faraday, Henry, and others, in their laboratories, has led to the evolution of the most wondrous practical developments in applied electrical science. The same remark holds good in respect to biological research. The seemingly useless facts gathered to-day by the disinterested, truth-seeking biological investigator will, if not to-morrow, become useful next year or even ten years hence. Those of us who have watched the progress of biological research for a quarter of a century can speak with assurance that, in proportion to the complexity of the phenomena and the difficulty of dealing with the subject-matter, biology has made as creditable a showing as any other science whatever.

The very complexity of the phenomena involved and the tedious and patient manner in which results must be awaited are only additional reasons why biological science should receive the encouragement it deserves in working out abstract truths in order to give them practical bearings. The scientific investigation of the interrelations of the members of the aquatic world of life, from the lowliest to the most complex of its form, is what the U. S. Fish Commission has undertaken to do with the all too meager means at its command. Practical results the Fish Commission has achieved under the administrations of Profs. Baird and McDonald. It now remains to increase the efficiency of that work by adding to its duties, as desired by the present Commissioner, those of pure research under endowment, so that the great laboratory, in connection with the hatching station at Woods Holl, can be made productive for the entire year instead of only for a few months out of the twelve.

We might then begin to hope that the foundation for a theory of the economics of ocean life would be laid, since, with the unequaled facilities for the study and capture of the life of the surface and bottom of the sea, possessed by the Commission, a vast system of organized research might be conducted that would be beyond anything in value yet undertaken by any country of the world. With abundant means to defray the expense of the costly illustrations and experiments incident to the work, such an establishment would be an enduring monument to some generous, liberal-spirited donor. Such a system of biological investigation in connection with the many stations possessed by the Fish Commission all over the country might be made the most comprehensive in existence. As shown at the outset of this paper, it is a knowledge of the life-history of the seemingly useless and infinitesimally small forms that must lie at the foundation of a knowledge of the growth and development of the useful and practically valuable forms of life. It would, therefore, seem that no stronger argument should at this late day be needed in behalf of the utility and wisdom of an extension of research in connection with the fishery industries of our country. Will some generous friends of science permanently link their names with one of the grandest enterprises and opportunities of modern times? It would be most fitting if the fifth century of the Columbian era might witness the permanent establishment of a great biological laboratory on our coast, the sole business of which would be to foster research and economic study in relation to the fisheries of our country.