13.—THE ORIGIN OF THE FOOD OF MARINE ANIMALS.

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In a picture of the land, the mind calls up a vast expanse of verdure, broken only by water, and stretching through forest and meadow from high up on the mountains, over hills and valleys and plains, down to the sea.

Our picture of the ocean is an empty waste, stretching on and on, with no break in the monotony except, at long intervals, a floating tuft of sargassum or a flying-fish or a wandering sea bird, and we never think of the ocean as the home of vegetable life. It contains plant-like animals, "zoöphytes," in abundance, but while they resemble plants or flowers in form and color and in their mode of growth, they are true animals and not plants.

At Nassau, in the Bahama Islands, the visitor is taken in a small boat, with windows of plate glass set in the bottom, to visit the "sea gardens" at the inner end of a channel through which the pure water from the open sea flows between two coral islands into the lagoon. Here the true reef corals grow in quiet water where they may be visited and examined.

The bottom of the boat is below the surface ripples and reflections. When illuminated by the vertical sun of the tropics and by the light which is reflected back from the white bottom the pure, transparent ocean water is as clear as air, and the smallest object, 40 or 50 feet down, is seen distinctly.

As the boat glides over the great mushroom-shaped coral domes which arch up from the depths, the dark grottoes between them and the caves under their overhanging tops are lighted up by the sun far down among the flower animals or anthozoa and the animal plants or zoöphytes, which are seen through the waving thickets of brown and purple sea fans and sea feathers as they toss before the swell from the ocean.

There are miles of these "sea gardens" in the lagoons of the Bahamas, and it has been my good fortune to spend many months studying their wonders; but no description can convey any conception of their beauty and luxuriance, and I never spent a day among the reefs without longing, at every turn, for the skill to copy with a brush the new beauties which never ceased to present themselves.

The general effect is very garden-like, and the beautiful fishes of black and golden yellow and iridescent cobalt blue hover like birds among the thickets of yellow and lilac gorgonias. The parrot fishes (*Diodon* and *Ballistes*) seem to be cropping the plants like rabbits, but more careful examination shows that they are biting off the tips of the gorgonias and branching madrepores or hunting for the small crustacea

which hide in the thicket, and that all the apparent plants are really animals. The delicate star-like flowers are the vermilion heads of boring annelids or the scarlet tentacles of actinias, and the thicket is made up of pale lavender bushes of branching madrepores and green and yellow and olive masses of brain coral, of alcyonarians of all shades of yellow and lilac and purple and red, and of red and brown and black sponges. Even the lichens which incrust the rocks are hydroid corals, and the whole sea garden is a dense jungle of animals where plant life is represented only by a few calcareous algæ so strange in shape and texture that they are much less plant-like than the true animals.

The scarcity of vegetation becomes still more noticeable when we study the ocean as a whole.

On land herbivorous animals are always much more abundant and prolific than the carnivora, as they must be to keep up the supply of food. Insectivorous birds are very abundant, but they are not numerous enough to keep the plant-eating mollusks and insects in check, and the devastation which is caused every year by the armies of grasshoppers and locusts and herbivorous beetles and by other less conspicuous insects shows that their natural enemies are not numerous enough to overtax their productive power.

The birds which feed upon grain and seeds and fruits are very abundant indeed, and they sometimes gather at their breeding-grounds or places of assembly in innumerable multitudes, but the hawks and owls which prey upon them are not very numerous.

The small rodents, such as the rats, mice, squirrels, and rabbits are the most abundant and prolific of animals; but the small carnivora are so rare that their very existence is known to few except naturalists and trappers.

The homes of the wild sheep and goats, deer, antelopes, cattle, and horses support these large mammalia in incredible numbers, but their carnivorous enemies are never abundant. It is clear that if the destruction of the plant-eaters exceeded their productive power, both herbivora and carnivora would disappear and terrestrial life would come to an end.

The animal life of the ocean shows a most remarkable difference, for marine animals are almost exclusively carnivorous.

The birds which live upon the ocean (the terns, gulls, petrels, divers, cormorants, tropic birds, and albatrosses) are very numerous indeed, so numerous that in many parts of the ocean some are always visible in calm weather around the vessel wherever it may be. The only parallel to the pigeon roosts and rookeries of the land is found in the dense clouds of sea birds around their breeding-places; but these sea birds are all carnivorous: most of them are fishers, and others, such as the petrels, scoop up the copepods and pteropods from the surface. Even the birds of the sea-shore subsist almost exclusively upon animals, such as mollusks, crustacea, and annelids.

The seals pursue and destroy fishes; the sea-elephants and walruses live upon lamellibranchs; the whales, dolphins, and porpoises and the marine reptiles all feed upon animals, and most of them are fierce beasts of prey. The manatee is a vegetable feeder, but it is not strictly a marine animal, since its home is in the mouths of great rivers.

There are a few fishes which pasture in the fringe of seaweed which grows in the littoral zone of the ocean, and there are some which browse among the floating tufts of algæ upon its surface, but most of them frequent these places in search of the

small animals which live among the plants. All the floating fishes whose home is the floating sargassum—the file-fishes and trigger-fishes (*Ballistida*), the trunk-fishes (*Ostracion*), the frog-fishes (*Antennarius*), and the puffing-fishes (*Tetradon* and *Diodon*)—are carnivorous, living upon the barnacles and mollusks and hydroids which grow upon the sargassum, or upon the crustacea, young fishes, and the floating larvæ which seek its shelter.

In the Chesapeake Bay the sheepshead (*Archosargus probatocephalus*) browses among the algæ upon the submerged rocks and piles like a marine sheep, but its food is exclusively animal, and I have lain upon the edge of a wharf watching it crush the barnacles and young oysters until the juices of their bodies streamed out of the angles of its mouth and gathered a host of small fishes to snatch the fragments as they drifted away with the tide.

Many important fishes, like the cod, pasture on the bottom, but their pasturage consists of mollusks and annelids and crustacea, instead of plants.

The vast majority of marine fishes are fierce hunters, pursuing and destroying smaller fishes, and often exhibiting an insatiable love of slaughter, as in the case of our own bluefish and the tropical albacore and barracuda. Others, such as the herring, feed upon smaller fishes and the pelagic pteropods and copepods; and others, like the shad, upon the minute organisms of the ocean, but all, with few exceptions, are carnivorous.

In the other great groups of marine animals we find some scavengers, some which feed upon microörganisms, and others which hunt and destroy each other; but there is no group of marine animals which corresponds to the herbivora and rodents and plant-eating birds and insects of the land. The pelagic copepods are, of all the marine metazoa, the ones whose place in the economy of nature is most like that of the terrestrial plant-eaters. They swarm in innumerable multitudes at the surface of the ocean, and also below it down to a depth of a mile or more, and they furnish the chief food for most young fishes, and for great armies of herrings and pteropods and jelly-fishes and siphonophores, and for most pelagic larvæ.

There are plant-eating mollusks and echinoderms and annelids in the ocean, but not in sufficient numbers to play any conspicuous part in its economy, and the copepods are the only plant-eaters which exist in sufficient numbers to be compared with those of the land, and the food of the copepods is only partially vegetable, for they devour microscopic animals as well as microscopic plants, and probably to an equal amount.

The group crustacea as a whole is a carnivorous one, however, for while a few subsist on algæ, their number is inconsiderable. Others chew the mud of the bottom and extract its organic matter, but this is chiefly animal and consists of foraminifera and rhizopods and infusoria.

The mollusks as a whole are carnivorous, and while there are many exceptions, such as the nudibranchs, for example, many nudibranchs feed on hydroids.

The cephalopods and pteropods and heteropods and many of the gasteropods pursue and destroy their prey, and other gasteropods are scavengers, while the lamellibranchs gather up the microscopic organisms which are drawn into their gills with the water.

The majority of the worms and echinoderms are animal-feeders. Some of them, like the common starfish, are actively predaceous; others, like the crinoids, gather

up microscopic organisms from the water; others, such as most holothurians, eat the mud of the bottom and digest out of it the foraminifera and small mollusks and annelids and crustacea which it contains, while others, such as the sea-urchins of the coral reefs, grind away and swallow the living coral. The universal presence of a poisoning apparatus in the cœlenterates shows that the food of this great and important group of marine animals must consist, in the main, of animals which are able to resist or to escape, and observation shows that this is true. Floating jelly-fishes and siphonophores are often found fastened to the half-digested carcasses of sagittas or heteropods or fishes larger than their captors, and they consume enormous numbers of copepods, pteropods, young fish, and pelagic larvæ of all sorts. So far as we know, all the sea-anemones and coral polyps and alcyonarians and hydroids are carnivorous. Some of the discomedusæ, the rhizostomes, feed upon microscopic organisms, but this mode of life is exceptional, and some recent observations, as yet unpublished, by Dr. R. P. Bigelow, show that the food of the rhizostomes consists of copepods.

Except for a few plant-eating fishes and mollusks and worms and echinoderms, all the animals of the ocean fall into two classes, those which subsist on microscopic organisms and those which prey upon each other and correspond to the rapacious animals of the land.

There is practically nothing in the ocean corresponding to the terrestrial herbivora, and nothing like terrestrial vegetation, except the fringe of seaweeds in the shallow water along the coast, and a few floating islands of algæ like the Sargasso Sea. While these tracts of vegetation are pretty extensive, they are totally inadequate to support the animal life of the ocean, and as the whole animal world is dependent directly or indirectly upon plants, we must ask what takes the place of terrestrial vegetation?

There is so much room in the vast spaces of the ocean, and the part which is open to our direct observation is such an inconsiderable part of the whole, that it is only when great multitudes of pelagic animals are gathered together at the surface that the abundance of marine life becomes visible and impressive; but some faint conception of the boundless wealth of the ocean may be gained by observing the quickness with which marine animals become crowded at the surface in favorable weather.

On a cruise of more than two weeks from Cape Hatteras to the Bahama Islands I was surrounded continually, night and day, by a vast army of dark-brown jelly-fishes (*Linerges mercutia*), whose dark color made them very conspicuous in the clear water. They were not densely crowded, although they were so abundant that nearly every bucketful of water we dipped up contained some of them. We could see them at a distance from the vessel, and at noon, when the sun was overhead, we could look down into the water to a great depth through a well in the middle of the vessel where the centerboard hung, and as far down as the eye could penetrate, 50 or 60 feet at least, we could see the brown spots drifting by like motes in the sunbeam. We cruised through them for more than 500 miles, and we tacked back and forth over a breadth of almost a hundred miles, and they were everywhere in equal abundance.

The fishes in a school of mackerel are as numerous as the birds in a flight of wild pigeons. Goode, in his History of Aquatic Animals, tells of one school of mackerel which was estimated to contain a million barrels, and of another which was a windrow of fish half a mile wide and at least 20 miles long; but while the pigeons are

plant-eaters, the mackerel are rapacious hunters, pursuing and devouring the herrings, as well as the pteropods and pelagic crustacea.

Herring swarm like locusts, and a herring bank is almost a solid wall. In 1879 300,000 river herring were landed by a single haul of the seine in Albemarle Sound; but the herrings are also carnivorous, each one consuming myriads of copepods every day. In spite of this destruction and the ravages of armies of medusæ and siphonophores and pteropods, the fertility of the copepods is so great that they are abundant in all parts of the ocean, and they are met with in numbers which exceed our powers of comprehension.

On one occasion the *Challenger* steamed for two days through a dense cloud formed of a single species, and they are found in all latitudes from the Arctic regions to the equator, in masses which discolor the water for miles. We know, too, that they are not restricted to the surface, and that the banks of copepods are sometimes a mile thick. When we reflect that thousands would find ample room and food in a pint of water, we can form some faint conception of their universal abundance.

As the result of our view, we find that the organisms which are visible without a microscope in the water of the ocean and on the sea bottom are almost universally engaged in devouring each other, and many of them, like the bluefish and the albacore, are never satisfied with slaughter, but kill for mere sport.

Insatiable rapacity must end in extermination unless there is some unfailing supply, and as we find no visible supply in the water of the ocean we must seek it with a microscope. By its aid we find a wonderfully rich and diversified fauna made up of innumerable larvæ of all sorts of marine animals, together with a few minute and simple metazoa, but these things can not form the food supply of the ocean. It is clear that a single carnivorous animal could not exist very long by devouring its own children, and the result must be the same, however great the number of individuals or species.

The total amount of these organisms is inconsiderable, however, when compared with the abundance of a few forms of protozoa and protophytes, and both observation and deduction force us to recognize that the most important element in the total amount of marine life consists of some half a dozen types of protozoa and unicellular plants, of globigerinæ and radiolarians, and of trichodesmium, pyrocystis, protococcus, and the coccospheres, rhabdospheres, and diatoms.

Modern microscopic research has shown that these simple plants, and the globigerinæ and radiolarians which feed upon them, are so abundant and prolific that they meet all demands and supply the food for all the animals of the ocean. This is the fundamental conception of marine biology. The basis of all the life in the modern ocean is to be sought in the microörganisms of the surface.

This is not all. The simplicity and abundance of the microscopic forms and their importance in the economy of nature show that the organic world has gradually shaped itself around and has been controlled by them. They are not only the fundamental food supply, but the primeval supply, which has determined the whole course of the evolution of marine life.

The pelagic plant-life of the ocean has retained its primitive simplicity on account of the very favorable character of its environment, and the higher rank of the littoral vegetation and that of the land is the result of hardship.

On the land the mineral elements of plant-food are slowly supplied as the rains dissolve them; limited space brings crowding and competition for this scanty supply; growth is arrested for a great part of each year by drought or cold; the diversity of the earth's surface demands diversity of structure and habit, and the great size and complicated structure of terrestrial plants are adaptations to these conditions of hardship.

The conditions of the surface of the ocean; the abundance and uniform distribution of mineral food in solution; the area which is available for plants; the volume of sunlight and the uniformity of the temperature, are all favorable to the growth of plants, and as each plant is bathed on all sides by a nutritive fluid, it is advantageous for the new plant cells, which are formed by cell multiplication, to separate from each other as soon as possible in order to expose the whole of their surface to the water. Cell aggregation, the first step towards higher evolution, is therefore disadvantageous to the pelagic plants, and as the environment is so homogeneous at the surface of the ocean that there is little opportunity for an aggregation of cells to gain a compensating advantage by seizing upon a more favorable habitat, the pelagic plants have retained their primitive simplicity.

The list of pelagic microörganisms is a long one, but a few forms are so predominant that the others have little significance at the present day in comparison, and we may regard the great primary food-supply as made up of two simple protozoa, globigerina and the radiolarians, and some five or six unicellular plants.

Of these only two, the radiolarians and the diatoms, show any great diversity of species; and while the radiolarians are so diversified that the *Challenger* collection alone furnished more than 4,000 species, this variety does not obscure the primitive simplicity of the type, and the most distinctive peculiarity of the microscopic food supply of the ocean is the very small number of the forms which go to make up the enormous mass of individuals.