II. THE NATURAL HISTORY OF THE OYSTER.

U. GENERAL NATURAL HISTORY.

60. THE GROWTH AND HABITS OF THE AMERICAN OYSTER OF THE ATLANTIC COAST.

NUMBER OF SPECIES ON THE ATLANTIC COAST.—The question of the specific unity of all the oysters of our Atlantic coast has probably been placed beyond dispute now, and it is settled that the name *Ostrea virginiana* includes the whole. Says Verrill, in his *Invertebrates of Vineyard Sound:*

All the various forms of this species, upon which the several nominal species, united above, have been based by Lamarck and others, often occur together in the same beds in Long Island sound, and may easily be connected together by all sorts of intermediate forms. Even the same specimen will often have the form of *borealis* in one stage of its growth, and then will suddenly change to the *virginiana* style, and, perhaps, later still, will return to the form of *borealis*. Or these different forms may be assumed in reverse order. Great variations in the number and size of the costæ and undulations of the lower valve occur, both in different specimens from the same locality, and even in the same specimen, at different stages of growth. All these variations occur in precisely the same way in the shells taken from the ancient Indian shell-heaps along our entire coast, from Florida to Maine.

In another place he alleges:

I am unable to find any specific differences between the northern and southern oysters, such differences as do exist being due merely to the circumstances under which they grow, such as the character of the water, abundance or scarcity of food, kind of objects to which they are attached, age, crowded condition, etc. All the forms occur both among the northern and southern ones, for they vary from broad and round to very long and narrow; from very thick to very thin; and in the character of the surface, some being regularly ribbed and scalloped, others nearly smooth, and others very rough and irregular, or scaly, etc. When young and grown under favorable conditions, with plenty of room, the form is generally round at first, then quite regularly oval, with an undulated and scalloped edge and radiating ridges, corresponding to the scallops, and often extending out into spine-like projections on the lower valve. The upper valve is flatter, smooth at first, then with regular lamellæ or scales, scalloped at the edges, showing the stages of growth. Later in life, especially after the first winter, the growth becomes more irregular and the form less symmetrical; and the irregularity increases with the age. Very old specimens, in crowded beds, usually become very much elongated, being often more than a foot long, and perhaps two inches wide.* In the natural order of things this was probably the normal form attained by the adult individuals, for nearly all the oyster-shells composing the ancient Indian shell-heaps along our coast are of this much-elongated kind. Nowadays the oysters seldom have a chance to grow to such a good old age as to take this form, though such are occasionally met with in deep water. The young specimens on the rocks are generally mottled or irregularly radiated with brown.

GEOGRAPHICAL DISTRIBUTION.—The geographical distribution of the oyster along our coast has already been learned in detail, and need only be sketched. It is to be found almost without interruption—except at wholly unsuitable localities—from Florida, and the northern shores of the Gulf of Mexico, to Massachusetts bay; local farther north, off Damariscotta, Maine, and in the southern part of the Gulf of St. Lawrence, at Prince Edward island, in Northumberland straits, and bay of Chaleur. "Not found along the eastern shores of Maine, nor in the bay of Fundy. Abundant in the ancient Indian shell-heaps on the coast of Massachusetts, on the islands in Casco bay, and at Damariscotta. The shells, in a semi-fossil state, have been dug up from deep beneath the mud in the harbor of Portland, Maine, in large quantities, but native oysters appear to be entirely extinct in Casco bay. Very abundant in Long Island sound; in the upper part of Buzzard's bay; rare and local in Vineyard sound; very abundant on the shores of Maryland and Virginia. Mouth of St. John's river, and in Tampa bay, Florida (Conrad). Texas (Rœmer)."

FOSSIL OYSTERS.—In the history of the world, as shown by the record of the rocks, the oyster has long played a part. The oldest fossil of this family known was discovered by Professor Winchell in carboniferous strata, and

* "The large oyster taken by Xavier François, while oystering on Monday last, was brought up from the wharf on a dray last evening. An oyster measuring 3 feet 1 inch in length, and 23¾ inches across the widest part of it, is a curiosity."—*Mobile* (Ala.) *Register*, April, 1840.

"An East river oyster," says De Voe, "was opened by Braisted, of Jefferson market, New York, January 27, 1865, which contained a butter-fish [*Poronotus triacanthus?*] measuring 6 inches in length. It was quite dead."

named *Ostrea patercula*. Ascending to the Jurassic, oysters are found to have been somewhat plentiful, and, in the Cretaceous, the family reached its culmination. Never before nor since have these mollusks been more abundant in point of species or numbers of individuals, or more widely differentiated in their characteristics. They are of large size, also. In subsequent ages the *Ostreadæ* were abundant, but the kinds were few, many genera, for example *Gryphæa* and *Exogyra*, disappearing altogether with the close of the Mesozoic era. The fossil remains of these old oysters are found everywhere throughout the world where the ancient oceans had their margins, and in the United States coextensively with the range of brackish-water formations, from the Cretaceous upward.

ANATOMY OF THE OYSTER.—The brief sketch of the anatomy of the oyster which follows, was written by my friend Dr. W. K. Brooks, of the Johns Hopkins University, of Baltimore. It prefaced his account of his successful embryological studies upon the oysters of Chesapeake bay, and is the best and most recent description of this mollusk with which I am acquainted. Therefore I prefer quoting it to writing an imperfect duplicate of the facts. As Dr. Brooks says, it is hardly possible to write such a description without using a few technical words, such as "anterior", "posterior", "dorsal", and "ventral", but these can all be found in any dictionary, and will present no difficulty to any ordinary reader, however unaccustomed to scientific terms. "As the end of the body where the mouth is placed is not marked by a head, it must be spoken of as the *anterior end*, not as the 'head', and the opposite end as the *posterior*. As the oyster lies on one side, the top and bottom of its body do not correspond to the regions which occupy these positions in an upright mussel or clam, and it is most convenient to speak of that part of the oyster's body which answers to the upper surface of a clam as *dorsal*, and the opposite as *ventral*."

Dr. Brooks' anatomical outline sketch* is as follows:

The general structure of an oyster may be roughly represented by a long narrow memorandum book, with the back at one of the narrow ends instead of at one of the long ones. The covers of such a book represent the two shells of the oyster, and the back represents the hinge, or the area where the two valves of the shell are fastened together by the hinge ligament. This ligament is an elastic, dark-brown structure, which is placed in such a relation to the valves of the shell that it tends to throw their free ends a little apart. In order to understand its manner of working, open the memorandum book and place between its leaves, close to the back, a small piece of rubber to represent the ligament. If the free ends of the cover are pulled together the rubber will be compressed and will throw the covers apart as soon as they are loosened. The ligament of the oyster-shell tends, by its elasticity, to keep the shell open at all times, and while the oyster is lying undisturbed upon the bottom, or when its muscle is cut, or when the animal is dying or dead, the edges of the shell are separated a little.

The shell is lined by a thin membrane, the mantle, which folds down on each side, and may be compared to the leaf next the cover on each side of the book. The next two leaves of each side roughly represent the four gills, the so-called "beard" of the oyster, which hang down like leaves into the space inside the two lobes of the mantle. The remaining leaves may be compared to the body or *visceral mass* of the oyster.

Although the oyster lies upon the bottom, with one shell above and one below, the shells are not upon the top and bottom of the body, but upon the right and the left sides. The two shells are symmetrical in the young oyster, but after it becomes attached, the lower or attached side grows faster than the other, and becomes deep and spoon-shaped, while the free valve remains nearly flat. In nearly every case, the lower or deep valve is the left. As the hinge marks the anterior end of the body, an oyster which is held on edge, with the hinge away from the observer and the flat valve on the right side, will be placed with its dorsal surface uppermost, its ventral surface below, its anterior end away from the observer, and its posterior end toward him, and its right and left sides on his right and left hands, respectively.

In order to examine the soft parts, the oyster should be opened by gently working a thin, flat knife-blade under the posterior end of the right valve of the shell, and pushing the blade forward until it strikes and cuts the strong adductor muscle, which passes from one shell to another and pulls them together. As soon as this muscle is cut the valves separate a little, and the right valve may be raised up and broken off from the left, thus exposing the right side of the body. The surface of the body is covered by the mantle, a thin membrane which is attached to the body over a great part of its surface, but hangs free like a curtain around nearly the whole circumference. By raising its edge, or gently tearing the whole right half away from the body, the gills will be exposed. These are four parallel plates which occupy the ventral half of the mantle cavity and extend from the posterior nearly to the anterior end of the body. Their ventral edges are free, but their dorsal edges are united to each other, to the mantle and to the body. The space above, or dorsal to the posterior ends of the gills, is occupied by the oval, firm, adductor muscle, the so-called "heart". For some time I was at a loss to know how the muscle came to be called the heart, but a friend told me that he had always supposed that this was the heart, since the oyster dies when it is injured. The supposed "death" is simply the opening of the shell when the animal loses the power to keep it shut. Between this muscle and the hinge the space above the gills is occupied by the body, or *visceral mass*, which is made up mainly of the light-colored reproductive organs and the dark-colored digestive organs, packed together in one continuous mass.

If the oyster has been opened very carefully, a transparent, crescent-shaped space will be seen between the muscle and the visceral mass. This space is the pericardium, and if the delicate membrane which forms its sides be carefully cut away, the heart may be found without any difficulty, lying in this cavity, and pulsating slowly. If the oyster has been opened roughly, or if it has been out of water for some time, the rate of beating may be as low as one a minute, or even less, so the heart must be watched attentively for some time in order to see one of the contractions.

The heart is made up of two chambers, a loose, spongy, transparent *auricle*, which occupies the lower part of the pericardium, and receives blood from the gills through transparent blood-vessels, which may usually be seen without difficulty, running from the gills toward the heart, and a more compact white *ventricle*, which drives the blood out of the pericardium through transparent arteries, which are usually quite conspicuous.

The visceral mass is prolonged backward over the pericardium and the adductor muscles, and here contains the rectum, surrounded by prolongations of the white reproductive organs. Still farther back, on the middle of the posterior face of the adductor muscle, is the anus, a long, vertical slit, opening into the space between the lobes of the mantle and above the posterior ends of the gills.

* *Report of the Commissioners of Fisheries of Maryland*, January, 1880; Annapolis, W. T. Inglehart & Co., State Printers, 1880, pp. 5–10.

In front of the gills, that is, between them and the hinge, there are four fleshy flaps—the lips—two on each side of the body. They are much like the gills in appearance, and they are connected with each other by two ridges which run across the middle of the body close to the anterior end, and between these folds is the large oval mouth, which is thus seen to be situated, not at the open end of the shell, but as far away from it as possible. As the oyster is immovably fixed upon the bottom, and has no arms or other structures for seizing food and carrying it to the mouth, the question how it obtains its food at once suggests itself. If a fragment of one of the gills is examined with a microscope, it will be found to be covered with very small hairs, or *cilia*, arranged in rows. Each of these cilia is constantly swinging back and forth, with a motion something like that of an oar in rowing. The motion is quick and strong in one direction and slower in the other. As all the cilia of a row swing together, they act like a line of oars, only they are fastened to the gill, and as this is immovable, they do not move forward through the water, but produce a current of water in the opposite direction. This action is not directed by the animal, for it can be observed for hours in a fragment cut out of the gill, and if such a fragment be supplied with fresh sea-water, the motion will continue until it begins to decay. While the oyster lies undisturbed on the bottom, with its muscle relaxed and its shell open, the sea-water is drawn on to the gills by the action of the cilia, for although each cilium is too small to be seen without a microscope, they cover the gills in such great numbers that their united action produces quite a vigorous stream of water, which is drawn through the shell and is then forced through very small openings on the surfaces of the gills into the water-tubes, inside the gills, and through these tubes into the mantle cavity, and so out of the shell again. As the stream of water passes through the gills the blood is aerated by contact with it. The food of the oyster consists entirely of minute animal and vegetable organisms and small particles of organized matter. Ordinary sea-water contains an abundance of this sort of food, which is drawn into the gills with the water, but as the water strains through the pores into the water-tubes, the food-particles are caught on the surface of the gills by a layer of adhesive slime which covers all the soft parts of the body. As soon as they are entangled the cilia strike against them in such a way as to roll or slide them along the gills toward the mouth. When they reach the anterior ends of the gills they are pushed off and fall between the lips, and these again are covered with cilia, which carry the particles forward until they slide into the mouth, which is always wide open and ciliated, so as to draw the food through the œsophagus into the stomach. Whenever the shell is open these cilia are in action, and as long as the oyster is breathing, a current of food is sliding into its mouth.

The cilia and particles of food are too small to be seen without a microscope, but if finely powdered carmine be sprinkled over the gills of a fresh oyster, which has been carefully opened and placed in a shallow dish of sea-water, careful observation will show that as soon as the colored particles touch the gills they begin to slide along with a motion which is quite uniform, but not much faster than that of the minute-hand of a watch.

This slow, steady, gliding motion, without any visible cause, is a very striking sight, and with a little care the particles may be followed up to and into the mouth.

In order to trace the course of the digestive organs, the visceral mass may be split with a sharp knife or razor. If the split is pretty near the middle of the body, each half will show sections of the short, folded œsophagus, running upward from the mouth, and the irregular stomach, with thick semi-transparent walls, surrounded by the compact, dark-greenish liver. Back of the liver and stomach the convoluted intestine will be seen, cut irregularly at several points by the section.

The coils of the intestine are imbedded in a light-colored mass of tissue—the reproductive organ—which forms the greater part of the visceral mass. The reproductive organ varies greatly according to the season, and forms most of what is known as the "fat" of the oyster.

There are no accessory organs of reproduction, and the position, form, and general appearance of the reproductive organ is the same in both sexes. There is no characteristic by which a male oyster can be distinguished from a female, without microscopic examination. As the reproductive organ has an opening on each side of the body, it is usually spoken of as double, but in the adult oyster it forms one continuous mass, with no trace of a division into halves, and extends entirely across the body and into all the bends and folds of the digestive tract.

REPRODUCTION AND EMBRYOLOGY.—An account of the life-history of the oyster should begin with the beginning—the egg—out of which this mollusk, like everything else from mussel to man, is born. And in this matter of oyster-breeding, I must rely upon and again quote at length the researches of Dr. Brooks, since he is easily in advance of all students in his knowledge of this subject. During the summer of 1880, at his seaside laboratory, Crisfield, Maryland, and subsequently, Dr. Brooks made microscopic studies on the embryology of the oyster, which were published, with figures, in the Report of the Maryland Fisheries Commission for 1880, and in the Memoirs of the Johns Hopkins University. These investigations were of the most painstaking description, and may be accepted as satisfactorily portraying the true method of reproduction of the American oyster, *Ostrea virginiana*, although showing it to be essentially different from that of the oyster of Europe *Ostrea edulis*. It is my duty as well as pleasure, consequently, to set forth with as great accuracy as condensation and a popular treatment of the subject will permit, the statements of Dr. Brooks.

If several oysters are opened during the breeding-season, which varies, as will hereafter be shown, a few will be found with the reproductive organ greatly distended and of a uniform opaque white color. These are oysters which are spawning or ready to spawn, that is, to discharge their eggs. Sometimes the ovaries will be so gorged that the ripe eggs will ooze from the openings of the oviducts before the mass is quite at the point of being discharged. If the point of a knife be pushed into the swollen ovary, a milk-white fluid will flow out of the cut. Mixing a little of this with sea-water and placing it on a slide underneath a cover, a lens of 100 diameters will show, if the specimen is a female, "that the white fluid is almost entirely made up of irregular, pear-shaped, ovarian eggs (Figure 49), each of which contains a large, circular, transparent germinative vesicle, surrounded by a layer of granular, slightly opaque yolk." Perfectly ripe eggs will be seen to be clean, sharply defined and separate from each other. If the specimen be male, a glance through the microscope shows something quite different from the fluid of a female. "There are no large bodies like the eggs, but the fluid is filled with innumerable numbers of minute granules (Figure 48), which are so small that they are barely visible when magnified one hundred diameters. They are not uniformly distributed, but are much more numerous at some points than at others, and for this reason the fluid has a cloudy or curdled appearance. By selecting a place where the granules are few and pretty well scattered, very careful watching will show that each of them has a lively dancing motion, and examination with a power of 500 diameters will show that each of them is tadpole-shaped (Figure 50), and consists of a small, oval, sharply defined 'head', and a long, delicate 'tail', by the lashing of which the dancing is produced." These are the *spermatozoa*, or "male cells", whose union with the eggs or *ova* of the female is necessary to the fertilization of the latter, and the consequent hatching of living oysters.

Again quoting from Dr. Brooks:

The number of male cells which a single male will yield is great beyond all power of expression, but the number of eggs which an average female will furnish may be estimated with sufficient exactness. A single ripe egg measures about one five-hundredth of an inch in diameter, or five hundred laid in a row, touching each other, would make one inch; and a square inch would contain five hundred such rows, or 500 by 500=250,000 eggs. Nearly all the eggs of a perfectly ripe female may be washed out of the ovary into a beaker of sea-water, and as they are heavier than the sea-water, they soon sink to the bottom, and the eggs of a medium-sized female will cover the bottom of a beaker two inches in diameter with a layer of eggs one-twentieth of an inch deep. The area of the bottom of a beaker two inches in diameter is a little more than three square inches, and a layer of eggs one-twentieth of an inch deep, covering three square inches, is equal to one three-twentieths of an inch deep and two square, and as a single layer of eggs is one five-hundredth of an inch thick, a layer three-twentieths of an inch thick will contain seventy-five layers of eggs, with 250,000 eggs in each layer, or 18,750,000 eggs. It is difficult to get the eggs perfectly pure, and if we allow one-half for foreign matter and errors of measurement, and for imperfect contact between the eggs, we shall have more than nine millions as the number of eggs laid by an oyster of average size, a number which is probably less than the true number.

Möbius estimates the number of eggs laid by an average European oyster at 1,012,925, or only one-ninth the number laid by an ordinary American oyster, but the American oyster is very much larger than the European, while its eggs are less than one-third as large, so the want of agreement between these estimates does not indicate that either of them is incorrect.* Another estimate of the number of eggs laid by the European oyster is given by Eyton (*History of the Oyster and Oyster Fisheries*, by T. C. Eyton, London, 1858). He says, p. 24, that there are about 1,800,000, and therefore agrees pretty closely with Möbius.

An unusually large American oyster will yield nearly a cubic inch of eggs, and if these were all in absolute contact with each other and there were no portions of the ovaries or other organs mixed with them, the cubic inch would contain 500^3, or 125,000,000. Dividing this, as before, by two, to allow for foreign matter, interspaces and errors of measurement, we have about 60,000,000 as the possible number of eggs from a single oyster.

Although each male contains enough fluid to fertilize the eggs of several females, there does not seem to be much difference in the number of individuals of the two sexes. When a dozen oysters are opened and examined, there may be five or six ripe females and no males, but in another case a dozen oysters may furnish several ripe males but no females, and in the long run the sexes seem to be about equally numerous. Oystermen believe that the male may be distinguished from the female by certain characteristics, such as the presence of black pigment in the mantle, but microscopic examination shows that these marks have no such meaning, and that there are no differences between the sexes except the microscopic ones. It is not necessary to use the microscope in every case, however, for a little experience will enable a sharp observer to recognize a ripe female without the microscope. If a little of the milky fluid from the ovary of a female with ripe or nearly ripe eggs, be taken upon the point of a clean, bright knife-blade, and allowed to flow over it in a thin film, a sharp eye can barely detect the eggs as white dots, while the male fluid appears perfectly homogeneous under the same circumstances, as do the contents of the ovary of an immature female, or one which has finished spawning. When the eggs are mixed with a drop of water, they can be diffused through it without difficulty, while the male fluid is more adhesive and difficult to mix with the water. By these indications I was able, in nearly every case, to judge of the sex of the oyster before I had made use of the microscope.

SEXUAL DIFFERENCES.—This question of sex, and the condition under which impregnation takes place in oysters, must next be considered. To this question Dr. Brooks devoted himself with special attention.

About all the published information upon the subject referred to the European species, and stated that, by means of spermatozoa, discharged into the water by neighboring oysters, and sucked within the shell, the eggs are fertilized inside the body of the parent, and that the young are carried inside the parent shell until they are quite well advanced in development and provided with shells of their own; that they swim about after they are discharged from the parent until they find a place to attach themselves, but that they undergo no change of structure between the time when they leave the parent and the time when they become fixed. Misled by these statements, Dr. Brooks opened many oysters during the summer of 1878, and carefully examined the contents of the gills and mantle chambers, but found no young oysters. "I concluded," he says, "that the time during which the young are carried by the parent must be so short that I had missed it, and I entered upon the work this season with the determination to examine adult oysters every day, through the breeding-season, in search of young, and at the same time to try to raise the young for myself by artificially fertilizing the eggs after I had removed them from the body of the parent." The result of a diligent practice of the first of these resolutions surprised him. In the first place he proved anew the generally admitted doctrine, that oysters are not hermaphroditic; in other words, that each oyster is, at the breeding-season, either a male or a female. He writes:

During my investigations I submitted more than a thousand oysters to miscroscopic examination. My studies were carried on during the breeding-season, and I did not find a single hermaphrodite. The male cells are so small compared with the eggs, that it would be impossible to state that a mass of eggs taken from the ovary contained no spermatozoa, although they could not escape detection if they were at all abundant.

On the other hand, a single egg in the field of the microscope, in a drop of male fluid, would be very conspicuous, and could not escape detection; and the fact that not a single case of this kind occurred, is sufficient to establish the distinctness of the sexes at the breeding-season.

*Möbius' measurement, from 0.15 to 0.18 millimeters, is given (Austern und Austern-wirtschaft, 1877) as the diameter, not of the egg, but of the embryo, but his figures show that the European oyster, like the American, does not grow much during the early stages of development, but remains of about the same size as the egg.

Further than this, he discovered that although the American oyster seems well adapted to follow the European species, and various other marine and fresh-water Lamellibranchs, to draw into its mantle chamber, with the sea-water, the spermatozoa discharged from the mantle chambers of neighboring oysters, and thus to bring about the fertilization of the eggs inside the cavity of the shell, this does not seem to occur. He affirms this very positively, and scientific men generally have accepted the conclusions as facts. I quote the words of one paragraph relating to it:

I have carefully searched the gills and mantles of more than a thousand oysters, at a time when the reproductive organs were plainly seen to be discharging their ripe contents, and have not found a single fertilized egg or embryo in any part of the mantle chamber, in or on the gills, or anywhere else inside the shell. This negative evidence, together with the fact that the eggs can be hatched after they have been artificially removed from the ovaries, seems sufficient to prove, in the absence of all evidence to the contrary, that the eggs of the American oyster undergo development in the open ocean.*

That is to say, during all the period when the young of the European oyster is being safely nurtured inside the mantle-cavity of its parent, and protected from all harm by its strong shells, our infant oysters swim at large in open ocean—if lucky enough to get himself born at all from the egg which is sent abroad unfertilized, to meet a chance male cell and so become impregnated and start into life, if fortune favors.

EXPERIMENTS IN ARTIFICIAL FERTILIZATION.—As has been hinted, Dr. Brooks spent much of his time and efforts at the laboratory in experimenting upon the artificial fertilization of oysters, by mixing eggs extracted from a female with spermatozoa from a male. He found it an easy matter to secure their union, and made his embryological studies from eggs and embryos thus cultivated, in a watch crystal or in a glass beaker. He gives minute directions as to the proper method for repeating these experiments, which those having a microscope can easily undertake, but which may be omitted as not pertinent here.

DEVELOPMENT OF THE YOUNG OYSTER.—The next step, having got the eggs, or learned their nature, is to examine their fertilization and development. Dr. Brooks writes:

The body of the oyster, like that of all animals, except the very simplest, is made up of organs, such as the heart, digestive organs, gills, and reproductive organs, and these organs are at some period in the life of the oyster made up of microscopic cells. The eggs shown in Figures 49 and 53 will answer to illustrate the character of the cells which compose the body. Each of these consists of a layer of protoplasm around a central nucleus, which, in the egg, is a large, circular, transparent body known as the germinative vesicle. Each cell of the body is able to absorb food, to grow and to multiply by division, and thus to contribute to the growth of the organ of which it forms a part. The ovarian eggs are simply the cells of an organ of the body, the ovary, and they differ from the ordinary cells only in being much larger and more distinct from each other; and they have the power, when detached from the body, of growing and dividing up into cells, which shall shape themselves into a new organism like that from whose body the egg came. Most of the steps in this wonderful process may be watched under the microscope, and owing to the ease with which the eggs of the oyster may be obtained, this is a very good egg to study.

About fifteen minutes after the eggs are fertilized they will be found to be covered with male cells, as shown in Figure 51. In about an hour the egg will be found to have changed its shape and appearance. It is now nearly spherical, as shown in Figure 1, and the germinative vesicle is no longer visible. The male cells may or may not still be visible upon the outer surface. In a short time a little transparent point makes its appearance on the surface of the egg, and increases in size, and soon forms a little projecting transparent knob—the *polar globule*—which is shown in Figure 3 and in succeeding figures.

Recent investigations tend to show, that while these changes are taking place, one of the male cells penetrates the protoplasm of the egg and unites with the germinative vesicle, which does not disappear, but divides into two parts, one of which is pushed out of the egg and becomes the polar globule, while the other remains behind and becomes the nucleus of the developing egg, but changes its appearance so that it is no longer conspicuous. The egg now becomes pear-shaped, with the polar globule at the broad end of the pear, and this end soon divides into two parts, so that the egg (Figure 6) is now made of one large mass and two slightly smaller ones, with the polar globule between them.

The later history of the egg shows that at this early stage the egg is not perfectly homogeneous, but that the protoplasm which is to give rise to certain organs of the body has separated from that which is to give rise to others.

If the egg, at the stage shown in Figure 6, were split in the plane of the paper, we should have what is to become one half of the body in one part and the other half in the other. The single spherule at the small end of the pear is to give rise to the cells of the digestive tract of the adult, and to those organs which are to be derived from it, while the two spherules at the small end are to form the cells of the outer wall of the body and the organs which are derived from it, such as the gills, the lips, and the mantle, and they are also to give rise to the shell. The upper portion of the egg in this and succeeding figures is to become the ventral surface of the adult oyster, and the surface which is on the right side in Figure 6, is to become the anterior end of the body of the adult. The figure, therefore, shows the half of the egg which is to become the left half of the body. The upper portion of the egg soon divides up into smaller and smaller spherules until at the stage shown in Figures 24, 25, and 26 we have a layer of small cells wrapped around the greater part of the surface of a single large spherule, and the series of figures shows that the latter is the spherule which is below in Figure 6. This spherule now divides up into a layer of cells, and at the same time the egg, or rather the embryo, becomes flattened from above downward, and assumes the shape of a flat oval disk. Figures 29 and 30 are views of the upper and lower surface of the embryo at about this time. In a sectional view, Figure 31, it is seen to be made up of two layers of cells; an upper layer of small transparent cells, *ec*, which are to form the outer wall of the body, and which have been formed by the division of the spherules which occupy the upper end of the egg in Figure 25, and a lower layer of much larger, more opaque cells, *g*, which are to become the walls of the stomach, and which have been formed by the division of the large spherule, *a*, of Figure 25.

*Writing concerning his work in 1881, Mr. John A. Ryder remarks: "No evidence to show that our oyster is hermaphrodite was found during the entire season, nor were my searches for embryo or eggs in the mouth or in the gills, more successful than those carried on two years before by Professor Brooks. There is no doubt whatever that the oyster of Europe nurses its young on its mantle or gills for some time, nor can we well question the very high authority of Möbius, for saying that in most cases the sexes are separate, and that only one kind of products, viz, either eggs or spermatozoa, are at any time found in the generative organs. Lacaze Duthier's observations seem to confirm the conclusions of Möbius."—*Report of T. B. Ferguson, a commissioner of fisheries of Maryland, January,* 1881, p. 14.

This layer is seen in the section to be pushed in a little toward the upper layer, so that the lower surface of the disk-shaped embryo is not flat, but very slightly concave. This concavity is destined to grow deeper until its edges almost meet, and it is the rudimentary digestive cavity. A very short time after this stage has been reached, and usually within from two to four hours after the eggs were fertilized, the embryo undergoes a great change of shape, and assumes the form which is shown in three different views in Figures 32, 33, 34, and 35.

A circular tuft of long hairs, or cilia, has now made its appearance at what is thus marked as the anterior end of the body, and as soon as these hairs are formed they begin to swing backward and forward in such a way as to constitute a swimming organ, which rows the little animal up from the bottom to the surface of the water, where it swims around very actively by the aid of its cilia. This stage of development, Figure 32, which is of short duration, is of great importance in raising the young oysters, for it is the time when they can best be siphoned off into a separate vessel and freed from the danger of being killed by the decay of any eggs which may fail to develop. On one surface of the body at this stage, the dorsal surface, there is a well-marked groove, and when a specimen is found in a proper position for examination, the opening into the digestive tract is found at the bottom of this groove. Figure 33 is a sectional view of such an embryo. It is seen to consist of a central cavity, the digestive cavity, which opens externally on the dorsal surface of the body by a small orifice, the primitive mouth, and which is surrounded at all points, except at the mouth, by a wall which is distinct from the outer wall of the body. Around the primitive mouth these two layers are continuous with each other.

The way in which this cavity, with its wall and external opening, has been formed, will be understood by a comparison of Figure 33 with Figure 28. The layer which is below in Figure 28 has been pushed upward in such a way as to convert it into a long tube, and at the same time the outer layer has grown downward and inward around it, and has thus constricted the opening. The layer of cells which is below in Figure 28 thus becomes converted into the walls of the digestive tract, and the space which is outside and below the embryo, in Figure 28, becomes converted into an inclosed digestive cavity, which opens externally by the primitive mouth.

This stage of development, in which the embryo consists of two layers, an inner layer surrounding a cavity which opens externally by a mouth-like opening, and an outer layer, which is continuous with the inner around the margins of the opening, is of very frequent occurrence, and it has been found, with modifications, in the most widely separated groups of animals, such as the starfish, the oyster, and the frog, and some representatives of all the larger groups of animals, except the *Protozoa*, appear to pass during their development through a form which may be regarded as a more or less considerable modification of that presented by our oyster-embryo. This stage of development is known as the *gastrula* stage.

Certain full-grown animals, such as the fresh-water hydra and some sponges, are little more than modified gastrulas. The body is a simple vase, with an opening at one end communicating with a digestive cavity, the wall of which is formed by a layer of cells, which is continuous around the opening with a second layer, which forms the outer wall of the body. This fact, together with the fact that animals of the most widely separated groups pass through a gastrula stage of development, has led certain naturalists to a generalization, which is known as the "gastrula theory". This theory or hypothesis, is that all animals, except the *Protozoa*, are more or less direct descendants of one common but very remote ancestral form, whose body consisted of a simple two-walled vase, with a central digestive cavity opening externally at one end of the body.

The edges of the primitive mouth of the oyster continue to approach each other, and finally meet and unite, thus closing up the opening, as shown in Figure 36, and leaving the digestive tract without any communication with the outside of the body, and entirely surrounded by the outer layer. The embryo shown in Figures 32 and 36 are represented with the dorsal surface below, in order to facilitate comparison with the adult, but in Figure 37, and most of the following figures, the dorsal surface is uppermost, for more ready comparison with the adult. The furrow in which the primitive mouth was placed still persists, and soon a small irregular plate makes its appearance at each end of it. These little plates are the two valves of the shell, and in the oyster they are separated from each other from the first, and make their appearance independently.

Soon after they make their appearance, the embryos cease to crowd to the surface of the water, and sink to various depths, although they continue to swim actively in all directions, and may still be found occasionally close to the surface. The region of the body which carries the cilia now becomes sharply defined, as a circular projecting pad, the *velum*, and this is present and is the organ of locomotion at a much later stage of development. It is shown at the right side of the figure in Figure 37, and in Figure 45 it is seen in surface view, drawn in between the shells, and with its cilia folded down and at rest, as they are seen when the little oyster lies upon the bottom.

The two shells grow rapidly and soon become quite regular in outline, as shown in Figures 37 and 44, but for some time they are much smaller than the body, which projects from between their edges around their whole circumference, except along a short area, the area of the hinge, upon the dorsal surface, where the two valves are in contact.

The two shells continue to grow at their edges, and soon become large enough to cover up and project a little beyond the surface of the body, as shown in Figure 44, and at the same time muscular fibers make their appearance and are so arranged that they can draw the edge of the body and the velum in between the edges of the shell, in the manner shown in Figure 45. In this way that surface of the body which lines the shell becomes converted into the two lobes of the mantle, and between them a mantle cavity is formed, into which the velum can be drawn when the animal is at rest. While these changes have been going on over the outer surface of the body, other important internal modifications have taken place. We left the digestive tract at the stage shown in Figure 36, without any communication with the exterior.

Soon the outer wall of the body becomes pushed inward, to form the true mouth, at a point (Figure 37) which is upon the ventral surface, and almost directly opposite the point where the primitive mouth was situated at an earlier stage. The digestive cavity now becomes greatly enlarged, and cilia make their appearance upon its walls, the mouth becomes connected with the chamber which is thus formed, and which becomes the stomach, and minute particles of food are drawn in by the cilia, and can now be seen inside the stomach, where the vibration of the cilia keep them in constant motion. Up to this time the animal has developed without growing, and at the stage shown in Figure 36 it is scarcely larger than the unfertilized egg, but it now begins to increase in size. The stages shown in Figures 44 and 45 agree pretty closely with the figures which European embryologists give of the oyster-embryo at the time when it escapes from the mantle chamber of its parent. The American oyster reaches this stage in from twenty-four hours to six days after the egg is fertilized; the rate of development being determined mainly by the temperature of the water.

Soon after the mantle has become connected with the stomach, this becomes united to the body wall at another point a little behind the mantle, and a second opening, the *anus*, is formed. The tract which connects the anus with the stomach lengthens and forms the intestine, and, soon after, the sides of the stomach become folded off to form the two halves of the liver, as shown in Figure 44.

Various muscular fibers now make their appearance within the body, and the animal assumes the form shown in Figures 44 and 45.

All my attempts to get later stages than these failed, through my inability to find any way to change the water without losing the young oyster, and I am therefore unable to describe the manner in which the swimming-embryo becomes converted into the adult, but I hope that this gap will be filled, either by future observations of my own or by those of some other embryologist.

Such is the scientific history of the oyster-embryo. The practical utility of the knowledge, however, to the most of us, is that the American oyster lays a vast number of eggs, but that they are exposed to dangers so constant and innumerable, that under ordinary conditions few ever come to life, or at any rate succeed in living long enough to anchor themselves and take on the protection of shells. This is only another example of a fact well known to naturalists, and occurring widely among animals of low grade. The number of eggs laid, or even of individuals born, has very little to do with the abundance of a species, which is "determined, mainly, by the external conditions to which it is exposed".

LIFE OF THE YOUNG OYSTER.—The young American oyster leads a peculiarly precarious time, since it is first thrown out an unfertilized egg, and the chance that it will immediately meet with a male cell must be very slight; yet if it does not it will perish, for the sea-water destroys unimpregnated eggs within a few minutes after contact with it. Having by good chance become fertilized by meeting a male cell, the next period of great danger is the short time during which the embryos swarm to the surface of the water. They are so perfectly defenseless, and so crowded together close to the surface, that a small fish, swimming along with open mouth, might easily swallow, in a few mouthfuls, a number equal to a year's catch. They are also exposed to the weather, and Dr. Brooks found that a sudden cold wind or fall in temperature, as occurred several times during his experiments, killed every embryo in his care. The number which are destroyed by cold rains and winds must be very great indeed. As soon as they are safely past this stage and scatter and swim at various depths, their risks from accidents and enemies are greatly diminished. Up to this point, which is reached in from twenty-four hours to six days, there is no difficulty in rearing them in an aquarium, provided uniform warm temperature be preserved. "Möbius," according to Brooks, "has estimated the number of adults which spawn each year, and multiplying this number by the average number of eggs laid by each, and dividing by the number which grow up, he reaches the conclusion that each oyster which is born has $\frac{1}{1,145,000}$ of a chance of reaching maturity. In the case of the American oyster the number of eggs is very much greater and each one's chance of survival is accordingly very much less, and it is evident that the great fertility of the oyster will not protect a bed from destruction by excessive dredging."

In all these early stages, both as egg and as larva, the young swimming oyster is designated popularly as a "spat", "spawn", or "set". Perhaps *spawn* is the best of these terms to be used for our purpose, covering the time from the discharge of the egg until the oyster has attached himself and appears with shells, as a visible speck upon the shell or other anchorage which he has chosen. From this time until he distinctly shows the double *bivalvular* character of his shells and is an oyster, the infant is usually spoken of most expressively as a "blister".

DISTRIBUTIONS OF SPAWN BY WIND AND TIDE.—Regarding now only the vicissitudes of wind and weather, how far will the spawn drift from the parent, under favorable conditions, before it is destroyed, or else sink down and attach itself? This is one of the subjects in respect to which we have small accurate information, and about which there is necessarily much mystery. A few years ago it was accepted as true, that masses of spat were drifting back and forth with the tides and currents all around the coast, and it was only deemed needful to place something on the bottom for this spat to attach itself to, in order to catch a full "set" and obtain thousands of bushels of young oysters. In case of failure, the currents were blamed in an indefinite way for not bringing spawn to the beds. We have seen, though, how delicate and sensitive to harm Dr. Brooks ascertained the young oyster to be, and furthermore, that, even after the vivifying influence of fertilization, it would float only a few hours before becoming ready to attach itself to some support. Now, under ordinary circumstances, the summer drift of tidal currents does not exceed half a mile to a mile an hour, and there would, therefore, not be time for the spat to be carried a very long distance before its turn. If the aid of a strong wind is called in, it must be remembered that any harsh breeze would kill the spawn.

Observation has shown, moreover, in many cases, that a district contiguous to an existing bed of natural or transplanted oysters caught a set, while another area not far away did not, the opposite being never true. When a region—at least everywhere outside of Chesapeake bay—has become depleted of its natural growth of oysters, it is extremely rare that any spawn ever catches there, though on each side close by and in the line of direct currents, there may be productive tracts; by "close by", I mean within two or three miles. Such an instance is found in Warren river, Rhode Island, where there has not been a "set" for ten years. Men there will explain that it is only once in several years that "the right combination of temperature and degree of saltness in the water happens at the moment when the spawn comes in", but it is evident that formerly a growth of young oysters occurred regularly every season, and no "combination" was required. The simple truth is, that there are now no parent oysters native to Warren river, or acclimated in it, to furnish spawn, which does not now drift in from the outer bay. Practical men, therefore, in planning their work, put little trust in fickle currents and the feeble vitality of drifting spawn, while some deny wholly that it drifts at all. One of these latter theorists—and the view is too extreme, I have no doubt—who lives at Providence, Rhode Island, showed me at his wharf in the Seekonk river a float containing a hundred bushels of oysters. The tide was running beneath it and beside it with great force, as, evidently, it always does at that spot. On the 1st of August, 1877, he had that float filled, as now, with native oysters that he had brought from this bed. Suddenly he saw one shoot out a milky substance. "There's an oyster spawning," he cried out, and called his son to witness it. In an instant another exuded the spawn, shot it far out, and then, as though by concerted action, all began to throw out the spawn until all the float was white with it, hiding the bottom beneath a milky cloud. He continued to watch, and in fifteen or twenty minutes the cloud had disappeared, and the few inches of water in the float had resumed its former clearness.

In the autumn of 1878, about fourteen months after this occurrence, some men begged permission to rake beside the wharf, and found there a solid bank of oysters of small size. There could not be a shadow of doubt, that they were the direct growth of the spawn emitted by the oysters in the float the preceding year, which had sunk straight down, despite the swift current of the out-going tide, unless we are to believe it had floated out into the bay and been brought back again—the more difficult alternative of the two, I think. Three hundred bushels were taken of these young oysters under this old float, within a space 100 feet square.

PREPARING BEDS FOR THE RECEPTION OF SPAWN.—It has come to be the wise practice, therefore, in preparing beds of cultch for the catching of spawn and the rearing of oysters artificially, to place upon the bed of cultch a quantity of adult breeding-oysters called "spawners". These are sometimes placed in a group athwart the tidal current at that place, and sometimes are scattered about the bed promiscuously. The quantity varies, but it is considered that one bushel of spawners to ten bushels of shells or other "stool" is quite enough. Experiments in this practice are alluded to in the preceding chapters on Narraganset bay, on New Haven, and on the East river; and it is there shown, that even with these precautions, a planter cannot count on catching any mentionable quantity of spawn more than 20 rods away from his spawners, even in a swift tideway, so soon does it settle or perish. Within this limit, however, the catch of an abundance of infant oysters is almost certain. The elaborate processes of oyster-culture carried on in France and the channel-coast of England, are based upon the practice of placing mother-oysters under the most favorable conditions that can be devised for their health, and then closely surrounding them with objects and surfaces—such as tiles stacked loosely over each one—best calculated to offer immediate opportunity for attachment to the spat as soon as it is emitted. The difference in the nature of our mollusks precludes the following of these foreign methods, but it is certain that they may be imitated with profit, so far as the placing of spawners along with the cultch is concerned.

NATURE OF BEST BOTTOM FOR OYSTER-BEDS.—It has long been well understood that the infant oyster, swimming about in search of a resting-place or anchorage, never chooses a soft, muddy bottom, or a surface which is slimy and foul; or, if the volition implied makes the use of the word "chooses" objectionable (we do not know how much control the larva has over the matter), let me say, that whenever the little creatures settle upon such a soft or slimy surface, they do not attach themselves, or, unable to go farther, perish. Little better than the shifting, soft mud is a bottom of clay, with its soapy consistence. Gravel, on the other hand, offers advantages to the oyster whenever it is clean; therefore a hard gale or an unusually high tide, or any other marine disturbance calculated to scour the bottom of a piece of water tenanted by oysters, is greatly welcomed just before their breeding-time. About 1867 a terrible storm cleaned all the ground in the mouth of the Housatonic river, Connecticut, right in midsummer. The result was, that where there had rarely been profitable oystering before, was originated the present great "Stratford" seed-bed. The ridge-like character of most old oyster-reefs, breaking the slow and even flow of currents, and so tending to increase their force, no doubt causes them to be kept better cleaned than the adjacent lower bottom, and thus helps to make these reefs the best of all natural oyster-growing spots.

In fact, there is no doubt that the great secret for a successful spat is extreme cleanliness. Given this quality, there seems to be nothing to which infant oysters will not adhere—the shells of their neighbors and of other mollusks, living crabs, turtles, and terrapins, rocks and pebbles on the shore.

> "On shell or stone is drop'd the embryo seed,
> And quickly vegetates a vital breed."—*Crabbe.*

Equally well, also, on the piles supporting bridges and piers; on rafts, boat-bottoms, and floating timber; on buoys and stakes, and in enormous abundance on the leafless head of a tree fallen into the water, or on the roots and limbs of living trees (as notably in the case of the "mangrove oysters" of Florida); on sedges and eel-grass (whence in the south they drop off to make fine "cove" and "single" oysters, and in the north to be frost-bitten and perish in winter); and upon all sorts of odd objects, gravel (valuable in producing single, round stock), bricks, bottles, broken crockery, tinware, shoes, anything, and everything, the surface of which is free from that slippery coating, partly sediment, partly organic growth, which so rapidly accumulates under sea-water, especially in some localities.

ARTIFICIAL STOOLS.—It was long ago understood, therefore, that when artificial beds for the capture of spawn were proposed to be prepared, the substance of the cultch did not so greatly matter as its position and condition at the time of spawning. In Europe, rough stones set on edge or piled in loose stacks, crib-work of tiles or slate or strips of stone, suspended bundles of faggots, called "fascines", the bushy heads of dead trees, and various other "stools", were employed. In America it is customary to use nothing but oyster-shells, which sometimes have accumulated on the bed in sufficient numbers, and sometimes are expressly provided for the purpose, as has been described in the body of the present report.

The chief reason for this adherence to oyster-shells, is probably found in their cheapness and convenience.

DEVELOPMENT OF THE OYSTER.

Explanation of Plate XXXVII.

Figure 1. Eggs two hours and seven minutes after fertilization. It is now perfectly spherical, with an external membrane, and the germinative vesicle is not visible.

Figure 2. The same egg two minutes later. It is now elongated, one end is wider than the other, and a transparent area at the broad end marks the point where the polar globules are about to appear. At the opposite end the external membrane is wrinkled by waves which run from the nutritive toward the formative pole in rapid succession for about fifteen seconds.

Figure 3. The same egg two minutes later.

Figure 4. The same egg two minutes later. The yolk has become pear-shaped. The polar globule has appeared at the formative pole, in the middle of the broad end of the pear, and the nutritive end of the egg is now less granular than the formative end.

Figure 5. The same egg two minutes later. Three equidistant furrows have made their appearance, separating it into a single mass at the nutritive pole, and two at the formative pole. At this stage the three masses are about equal in size.

Figure 6. The same egg two minutes later. The first micromere, *c*, is now perfectly separated and smaller than the second, *b*, and each is smaller than the macromere, *a*.

Figure 7. The same egg one minute later. Both micromeres are separated and spherical, as is also the macromere. This stage ends the first period of activity.

Figure 8. The same egg forty-five seconds later. The two micromeres have begun to fuse with each other, and the second micromere, *b*, is also partially fused with the macromere, *a*.

Figure 9. The same egg one minute later. The first micromere, *c*, has also begun to unite with the macromere.

Figure 10. The same egg one minute later. The line between the second micromere and macromere has disappeared, and the first micromere, *c*, now projects from one end of the elongated mass formed by the union of the spherules *a* and *b*.

Figure 11. The same egg three minutes later. The fusion of *a* and *b* is now complete, and a large transparent vesicle is now visible in the first micromere, *c*, and another in the compound mass *a b*.

Figure 12. The same egg two minutes and thirty seconds later.

Figure 13. Another egg, about two minutes later. This is the true resting stage, at the end of the second period of rest. The two vesicles have become irregular. The remains of an external membrane adhere to one side of the egg.

Figure 14. The same egg seven minutes later than Figure 13. The compound mass *a b* is elongated; the first micromere, *c*, is well defined, and waves travel from the nutritive toward the formative ends of the two masses. Two segmentation nuclei occupy the positions of the large vesicles of earlier stages. This stage is the beginning of the second period of activity.

Figure 15. The same egg one minute later. The second micromere, *b*, is now well defined, as well as the first.

Figure 16. The same egg one minute later. This stage marks the end of the second period of activity. The formative end of the egg is now occupied by four micromeres, two of which seem to be the products of the division of the first micromere, *c*, and two of them the products of the second, *b*.

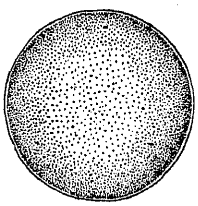


Fig. 1.

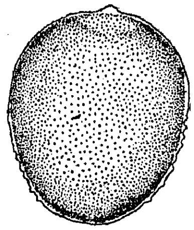


Fig. 2.

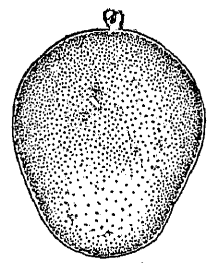
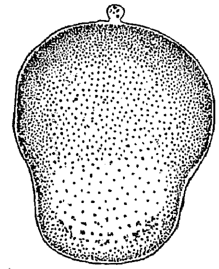


Fig. 3.



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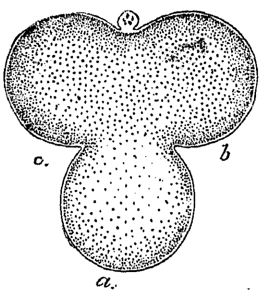


Fig. 5.

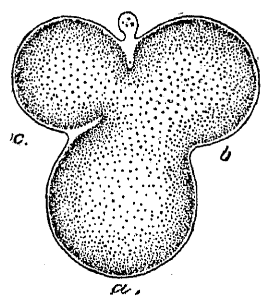
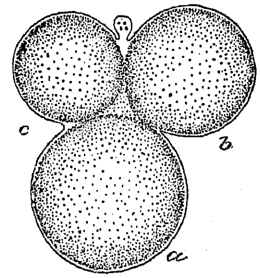


Fig. 6.



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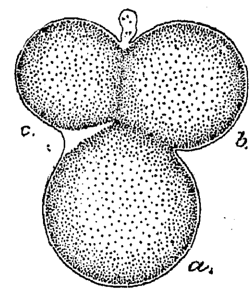

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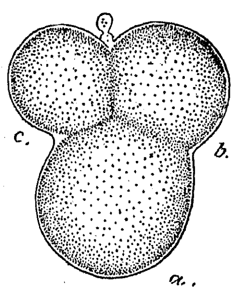


Fig. 9.

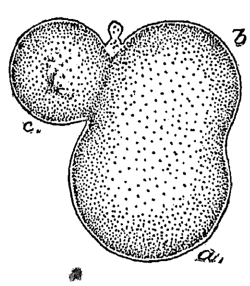
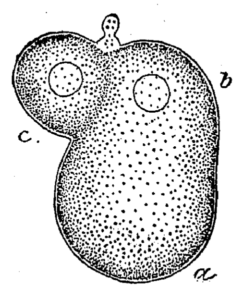


Fig. 10.



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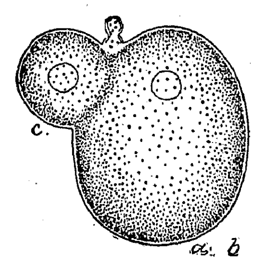

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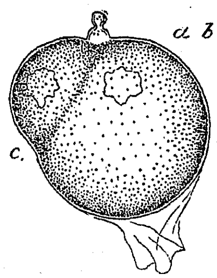


Fig. 13.

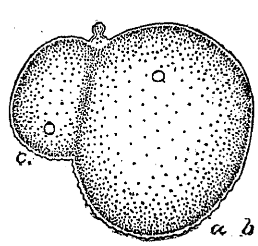


Fig. 14.

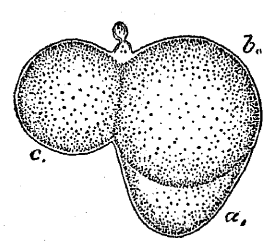


Fig. 15.

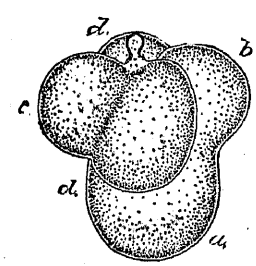


Fig. 16.

Figures of the egg of the oyster and the young oyster in progressive stages of growth, illustrating the studies of Dr. W. K. Brooks.

[From the report of T. B. Ferguson, commissioner of fisheries for Maryland.]

DEVELOPMENT OF THE OYSTER.

Explanation of Plate XXXVIII.

Figure 17. The same egg two minutes later, at the commencement of the third period of rest. The second micromere, *b*, has again oegun to fuse with the macromere, *a*.

Figure 18. The same egg three minutes and thirty seconds later. The second micromere is no longer separated from the macromere, and the mass *a b*, formed by their union, is nearly spherical.

Figure 19. The same egg two minutes and a half later, at the end of the third period of rest, viewed at right angles to Figure 18.

Figure 20. The same egg thirteen minutes later, and in the same position as Figure 18. The spherule, *c*, of Figure 19, has divided into two, and the second micromere, *b*, has become prominent, so that there are five micromeres at the formative pole.

Figure 21. The same egg one minute later, and in the same position as Figure 19.

Figure 22. The same egg in the position of Figure 20, fifteen minutes later than Figure 21, and in the fourth period of activity. There are now seven micromeres at the formative pole, six on one side of the polar globules and one, the second micromere, *b*, on the other.

Figure 23. The same egg twenty-one minutes later, viewed from the side opposite the second micromere. The cells, which have been formed by the division of the micromeres of the stage 19, now form a layer, the ectoderm, which rests, like a cap, on the macromere, *a*.

Figure 24. The same egg five hours and fifteen minutes later, in the same position as Figure 22, but not quite as much magnified. On one side the polar globule is still separated from the macromere, *a*, by a single spherule—the second micromere, *b*. Opposite this the growing edge, *g*, of the ectoderm is spreading still farther down over the macromere. At the point *g*, and at four other points, are pairs of small cells, which have evidently been formed by the division of the larger spherules.

Figure 25. Another egg at about the same stage.

Figure 26. The egg shown in Figure 24, fifty-five minutes later. The macromere, *a*, is almost covered by the ectoderm, and the second micromere, *b*, has divided into a number of spherules. At the growing edge, *g*, an ectoderm spherule is seen separating from the macromere.

Figure 27. A similar view of an egg twenty-seven hours after impregnation. The macromere is almost covered by the ectoderm, *e c*, and is not visible in a side-surface view. At *g* is an ectoderm spherule, which is separating from the macromere.

Figure 28. Optical section of the same egg; *e c*, ectoderm; *e n*, macromere, divided into two spherules. No segmentation cavity can be seen in a normal egg at this or any of the preceding stages.

Figure 29. View of the nutritive pole of an egg a few hours older.

Figure 30. View of the formative pole of a still older egg.

Figure 31. Optical vertical section of a somewhat older egg, figured with the polar globule above and the ectoderm to the right. The egg is now flattened from above downward, and is disc-shaped in a surface-view. The macromere has given rise to a layer of larger granular cells, which are pushed in so as to form a large cup-shaped depression. The more transparent ectoderm, *e c*, now carries a few short cilia scattered irregularly, and the two layers are separated from each other by a segmentation cavity. This figure is in Plate XXXIX.

Figure 32. Surface-view of the embryo at the first swimming stage.

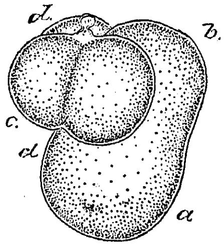


Fig. 17.

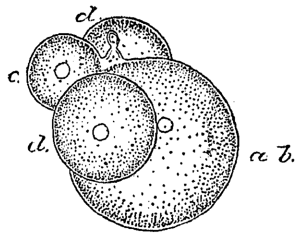


Fig. 18.

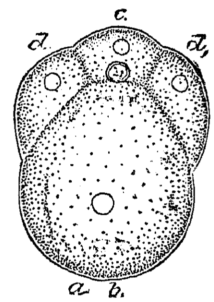


Fig. 19.

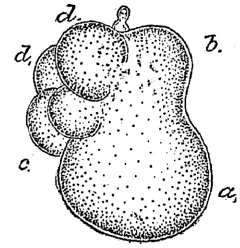


Fig. 20.

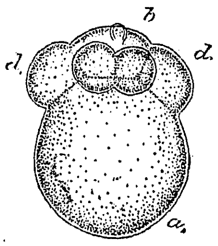


Fig. 21.

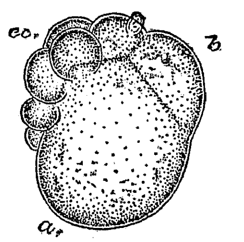
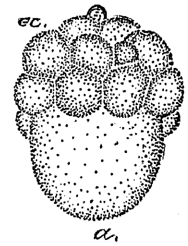


Fig. 22.



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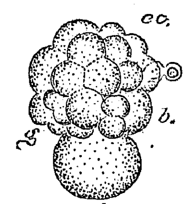
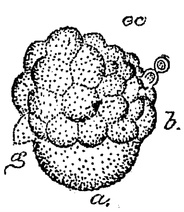


Fig. 24.



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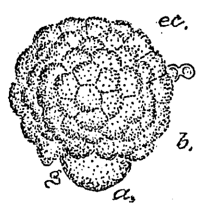


Fig. 26.

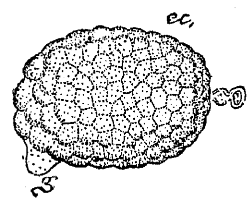
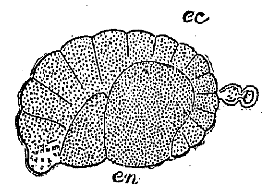


Fig. 27.



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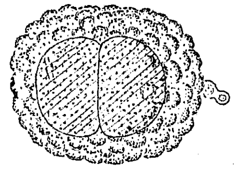
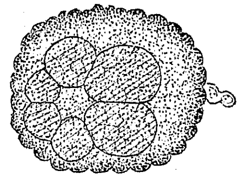


Fig. 29.



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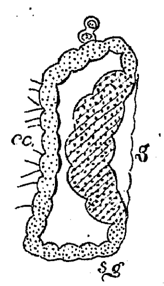

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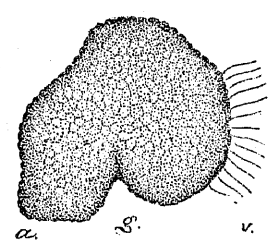


Fig. 32.

Figures of the egg of the oyster and the young oyster in progressive stages of growth, illustrating the studies of Dr. W. K. Brooks.

[From the report of T. B. Ferguson, commissioner of fisheries for Maryland.]

DEVELOPMENT OF THE OYSTER.

Explanation of Plate XXXIX.

Figure 33. Optical section of the embryo at the first swimming stage. The ectoderm has folded upon the endoderm, so as to form a primitive digestive cavity, with an external opening, *g*. The cilia of the velum have now made their appearance around the area occupied by the polar globule. This was not present in the egg from which the figure was drawn, but it was seen in other eggs, and is shown in a later stage of another embryo, Figure 36.

Figures 34 and 35. Two surface-views of the embryo shown in Figure 32.

Figure 36. An older embryo, in the same position as Figures 32 and 33. The external opening of the primitive digestive tract has closed up, and the two valves of the shell have appeared in the place which it had occupied. The endoderm has no connection with the exterior, and no central cavity could be seen.

Figure 37. A somewhat older embryo, figured with its dorsal surface above. There is a large, central, ciliated digestive cavity which opens externally by the mouth, *m*, which is almost directly opposite the primitive opening, the position of which is shown by the shell, *s*.

Figure 38. A similar view of a still older embryo. The shell, *s*, has increased in size, and the digestive tract has two openings, the mouth, *m*, and the anus, *a n*, which are very near each other on the ventral surface.

Figure 39. The opposite side of a still older embryo, in which the body-wall begins to fold under the shell, to form the mantle, *m*.

Figure 40. Dorsal view of an embryo at about the same stage.

Figure 41. Dorsal view of an embryo at the stage shown in Figure 38, with its valves extended; *r s*, right valve of shell; *l s*, left valve of shell; *a n*, anus; *a*, anal papilla; *m a*, mantle; *v*, velum; *b*, body-cavity; *s t*, stomach.

Figure 42. View of left side of a still older embryo; *i*, intestines. Other letters as in Figure 41.

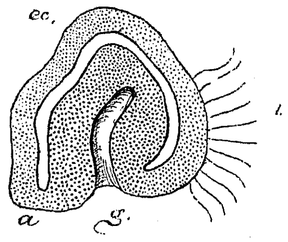


Fig. 33.

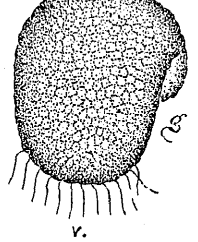
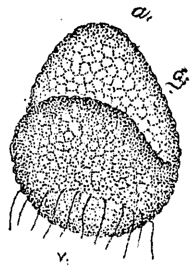


Fig. 34.



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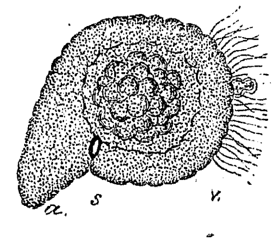
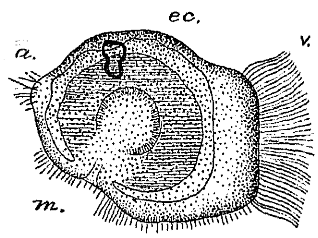


Fig. 36



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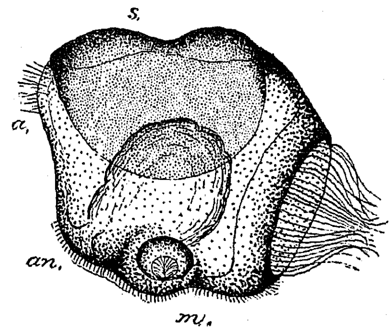

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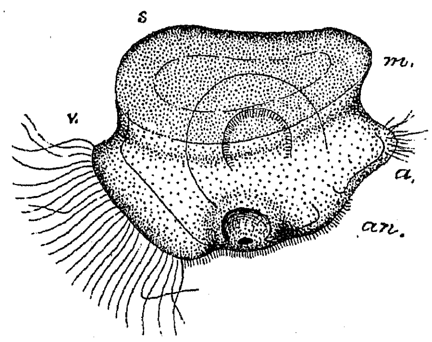

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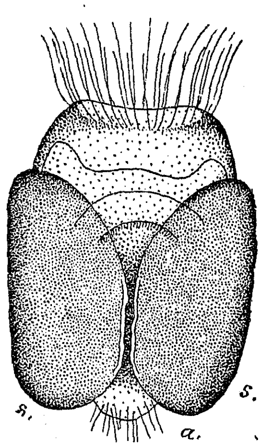

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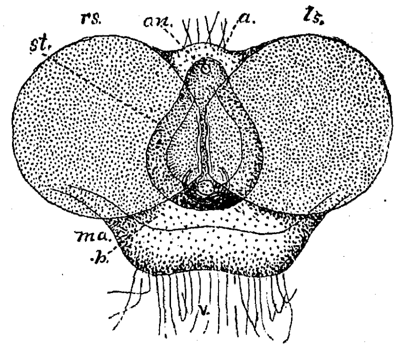


Fig. 41.

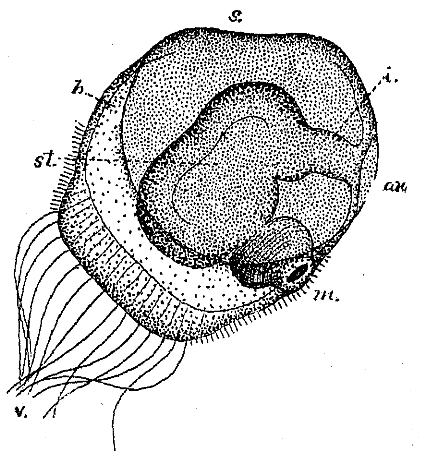


Fig. 42.

Figures of the egg of the oyster and the young oyster in progressive stages of growth, illustrating the studies of Dr. W. K. Brooks.

[From the report of T. B. Ferguson, commissioner of fisheries for Maryland.]

DEVELOPMENT OF THE OYSTER.

EXPLANATION OF PLATE XL.

Figure 43. Dorsal view of an embryo six days old, swimming by the cilia of its velum.

Figure 44. View of right side of another embryo at the same stage; *m u*, muscles; *l*, liver. Other letters as in Figure 41.

Figures 45 to 47. Views of embryo.

Figure 48. The seminal fluid of a ripe male oyster, mixed with water, and seen with a power of 80 diameters. *Zeiss*. a. 2.

Figure 49. Fluid from the ovary of a ripe female oyster, seen with the same magnifying power.

Figure 50. Seminal fluid of a ripe male oyster, magnified 500 diameters.

Figure 51. Egg a few minutes after mixture with the male fluid, magnified 500 diameters.

Figure 52. Egg about thirty minutes after fertilization, magnified 500 diameters.

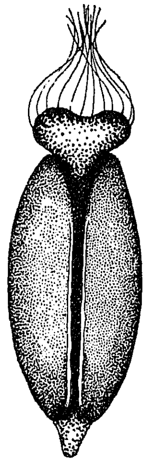
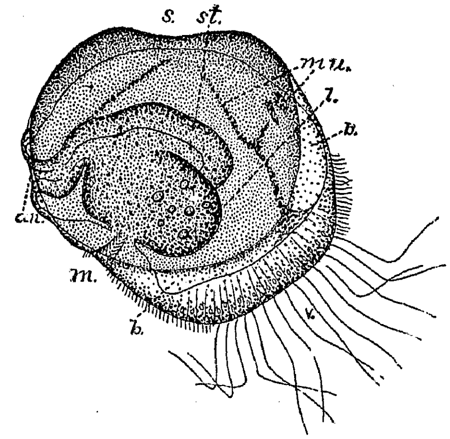


Fig. 43.

Fig. 47.



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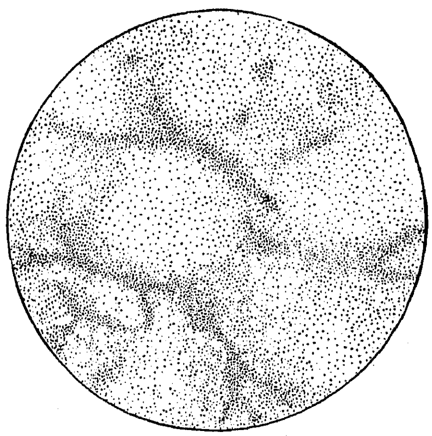


Fig. 48.

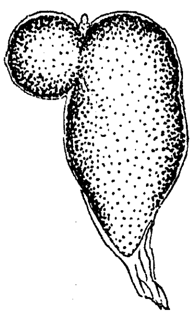
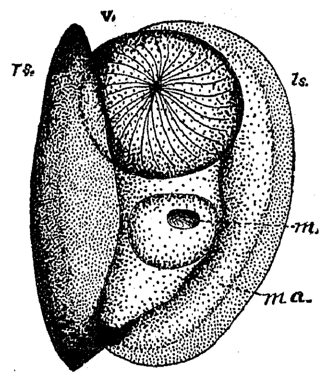


Fig. 46.



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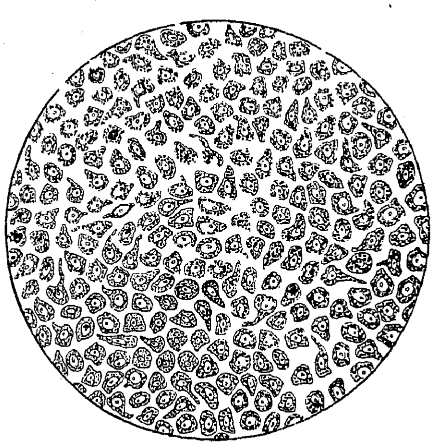
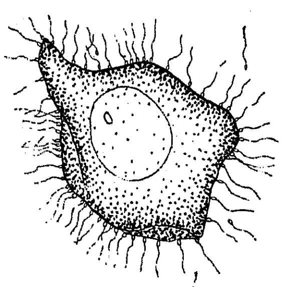


Fig. 49.



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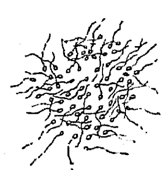

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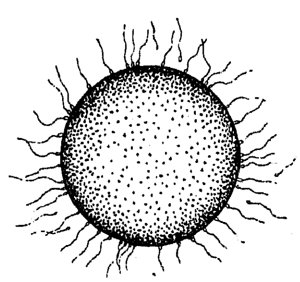


Fig. 52.

Figures of the egg of the oyster and the young oyster in progressive stages of growth, illustrating the studies of Dr. W. K. Brooks.
[From the report of T. B. Ferguson, commissioner of fisheries for Maryland.]

DEVELOPMENT OF THE OYSTER.

EXPLANATION OF PLATE XLI.

Figure 53. Section of a portion of the visceral mass of a female oyster, magnified 250 diameters; *a*, epithelium of the surface of the body; *b*, layer of connective tissue; *c*, layer of wrinkled cells, which are probably fat-cells, from which all the fat has been removed; *f*, sections of ten ovarian follicles; *e*, the ovarian eggs.

Figures 54 to 66. Abnormal or direct form of segmentation.

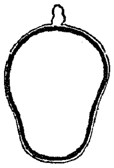
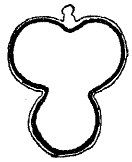


Fig. 54.



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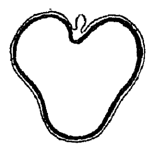

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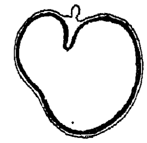

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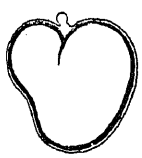

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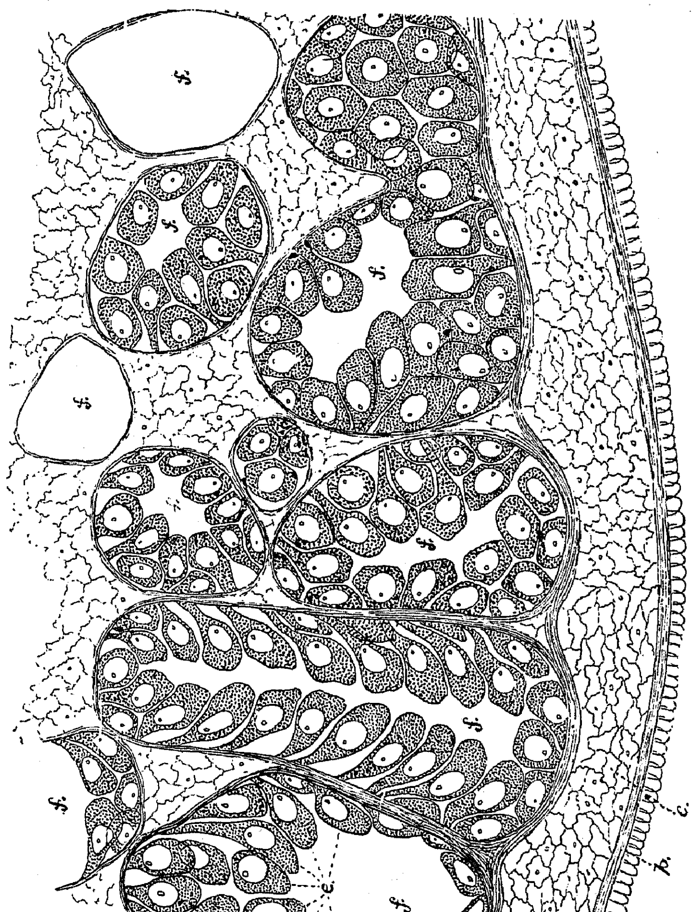


Fig. 53.

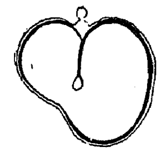


Fig. 59.

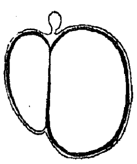


Fig. 60.

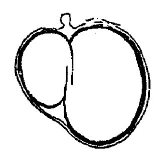


Fig. 61.

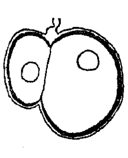


Fig. 62.

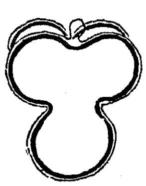
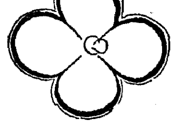


Fig. 63.



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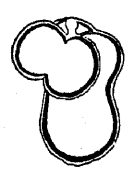

Fig. 65.

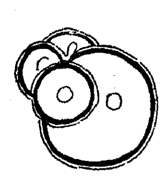

Fig. 66.

Figures of the egg of the oyster and the young oyster in progressive stages of growth, illustrating the studies of Dr. W. K. Brooks.

[From the report of T. B. Ferguson, commissioner of fisheries for Maryland.]

DEVELOPMENT OF THE OYSTER.

EXPLANATION OF PLATE XLII.

Figure 67. Section of a portion of the visceral mass of a male oyster magnified 250 diameters. The surface-epithelium of the body is shown at the lower end of the figure. Above this is a loose, thick layer of wrinkled cells, which have the appearance of adipose cells from which all the fat has been removed. Above this layer is a large duct, lined with epithelial cells, and filled with ripe spermatozoa, which have been poured into it from two follicles, which communicate with it on each side. Above this are sections of a number of the follicles of the testis, in three of which the contents are figured.

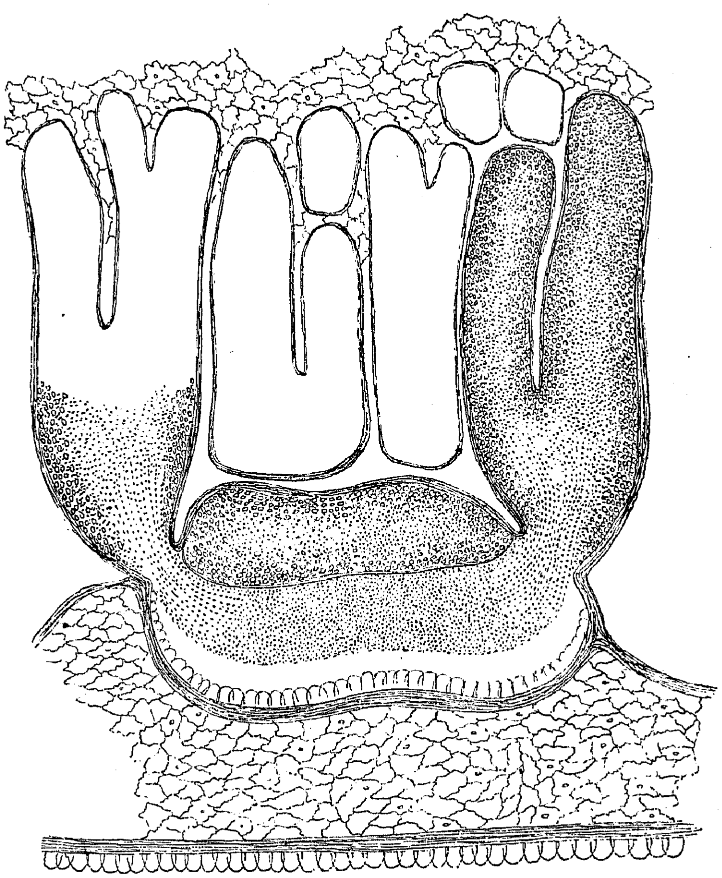

Fig. 67.

Figures of the egg of the oyster and the young oyster in progressive stages of growth, illustrating the studies of Dr. W. K. Brooks.

[From the report of T. B. Ferguson, commissioner of fisheries for Maryland.]

Some more fragile shell, such as a scallop or mussel or jingle (*Anomia*), is certainly better, because the growth of the attached oysters wrenches the shell to pieces, breaking up the cluster and permitting the singleness and full development to each oyster that is so desirable; or, if the old shell does not break of itself, the culling of the bunch it supports is far more easy than when the foundation is as thick and heavy as an oyster's or clam's shell. To aid this same end, tiles have been used as collectors of oyster-spat, which were covered with a certain composition which easily peels off, but which is firm enough to hold the young. When they have attained a size and age fit for removal, they can be stripped off without difficulty, removed to other quarters, or deposited in the localities used for growing or fattening, and the tiles can be re-covered with the composition and used again. (In the Chesapeake it is found that the under-side of the tiles catch the most spat.) Possibly, for a permanent bed, nothing is better than the natural shells, but, to catch the floating spawn, something of this sort might be tried to advantage, especially when it is desirable to move the young oysters, either to protect them from enemies or to grow them separately. The anchoring of an old seine at the bottom, the suspending of scallop, cockle, or other thin shells in the water, by stringing them from stake to stake a little way under the surface, or the copying of the French "fascines", would be other means to the same end. One of my correspondents in Long Island suggests inclosing small beds of oysters, just before spawning, by a high board fence, "with plenty of shells or scraps inside to catch the spawn, which thus could not float away". This idea is substantially followed in France, where stakes of wood are driven into the bottom in a circle around a pyramid of oysters placed on stones in the center; and on the Ile de Ré dikes are built of open stone work, so as to divide the bottom into beds, each of which is owned by a private proprietor; and other stone partitions or walls are run across, and upon these stones the spawn fastens. There are 4,000 of these beds or *parcs*.

The early experiments in making these artificial beds failed, through the error of placing the cultch in the water too soon. Before the oysters near them had spawned, the insidious but rapid deposit of the water had coated them with a greasy slime, which made them as unfit for the attachment of the larvæ as any part of the surrounding bottom. Thus it was learned that the cultch must be deposited as short a time before the emission of the spawn as possible.

TIME OF SPAWNING.—The time of spawning was found to be variable at different latitudes, in different depths of water, and according to diverse conditions of weather, etc. It seems to depend primarily upon temperature; hence, in the south, it begins as early as the heat of summer comes on, and follows it northward. In Chesapeake bay spawn has been collected from April until October. In the report of Master Francis Winslow, of the United States navy, concerning his surveys of Pocomoke and Tangier sounds, in the Palinurus in 1878, it is stated that there the spawning lasted from May to August, but occurred chiefly in June and July. "All opinions coincided that the oyster in shoal water spawned first, but differed as to whether, the depth being the same, all oysters on the same bed spawned at or about the same time, as many being for as against the theory." In regard to this point I will insert a statement from the *London Standard*, September, 1868, to the effect, that at the oyster parcs on the Ile de Ré, France, "every bed has its own time for spatting; thus, one division of the Ré beds may be spatting on a fine, warm day, when the sea is like glass, so that the spat cannot fail to fall, while on another portion of the island, the spat may fall on a windy day, be thus left to the tender mercy of a fiercely receding tide, and so be lost, or fall, mayhap, on inaccessible rocks a long way from shore". Mr. Winslow was also told that currents had no effect upon the spawning, yet that heavy freshets were very destructive to the "spat" in Pocomoke sound, driving it out into the bay, and large schools of fish, especially trout and taylors, devoured a good many every spring and summer. I have seen it asserted, in reference to the French and English coast, that the spatting of the oyster there does not depend on the weather at all, but it certainly does here, to a certain extent, a wet or warm spring hastening the beginning of the spawning-season, though it would not shorten its duration.

EFFECT OF TEMPERATURES UPON TIME OF SPAWNING.—The difference, too, in the time of spawning between the oysters in deep water and those in shoal, is probably due to temperature, the deep water being cold and so retarding the function. As showing how temperature affects this matter, let me say that experience on the northern coast shows, that when cold, windy days occur at spawning-time, there will probably be no emission at all; but when this weather changes and a night of warm rain is followed by a hot morning, thousands of oysters will be seen "shooting their spawn" at once. "The selection," says Winslow, "of the lower sides of the tiles and the interior of the 'boxes' may be an effort of nature to provide some protection for the young brood by, to a certain extent, inducing them to seek dark and secluded points for attachment, or the large number found in such places may be due to the inability of the various enemies of the spat to get at them when thus protected".

AGE OF SPAWNING OYSTERS.—It is pretty satisfactorily proved, that oysters begin to spawn when only one year old (or even much less, occasionally), though I found the popular impression in the northern states to be, that they must be three years of age before emitting spat. How long they continue to spawn, or whether there is any cessation before death, is not known. We are ignorant, indeed, of the age to which an oyster would live undisturbed; but old oystermen believe that it never exceeds twenty years, and that death is finally caused by a continued growth of shell, until its weight and thickness become too great for the venerable animal within to handle, whereupon he starves to death.

In Long Island sound it is considered that from the 5th to the 10th of July is the time when shells should be spread, with the design of immediately catching the spawn, which is not emitted to any extent before that date in those northern waters. The method of making these artificial beds is described in the chapters relating to that region.

SEASONAL VARIATIONS IN ABUNDANCE OF SPAWN.—But the most intelligent care is not always rewarded with a profitable catch, nor does every season bring a uniform addition of young to the natural growth on the native reefs. This variability is all the more marked in regions where oystering has been extensively pursued, and natural conditions and environment are disturbed. Nor are these variations widespread along a whole coast; they seem essentially local, confined, often, to very limited areas, indeed, and are marked by occasional seasons of extraordinary fertility, followed by total blanks or only a partial "set". Thus the last highly productive season in the Monument river, Massachusetts, was in 1874; at Pocasset, Massachusetts, 1876; in the Somerset, 1877; yet all these localities are close together. This failure may not always be a failure to spawn, but generally, perhaps, a waste and loss of all or nearly all the young, through rough weather or an unclean condition of the shores where they should have found resting places. Nevertheless, as Mr. Winslow observes, many persons of experience are of opinion, and I now concur with them in thinking, that not only the attachment of young may not be general nor occur each year, but that the emission of the products of generation may also be frequently confined to partial areas, and that by a combination of circumstances there can be a total failure of impregnation on all beds of any locality. Further, on this head, Mr. Winslow records some quotable observations, as follows, as resulting from his Chesapeake studies:

We have only been able to investigate the spatting of three seasons, and it may be found by subsequent observations, that two similar seasons of success, moderate success, or failure, will follow each other, but so far this has not been the case, and in the period of three years we have, comparatively to the other seasons, one at least of successful attachment.

I can see no reason for supposing that there is any regular recurrence of the spatting-seasons, but am inclined to believe that the success or failure is due to two causes—variations of temperature and variations of density. I have no means of ascertaining either the changes of temperature or density in the years preceding those in which I have been engaged upon this investigation, and in both seasons I arrived in the sounds too late for the temperatures or determinations of density obtained by the party to be of practical value.

Oysters will and do live in very dissimilar temperatures, and in waters of very different densities, as is shown by their existence in the waters of North America, from Nova Scotia to the Gulf, and on both the Atlantic and Pacific coasts. That the mature oyster is a hardy animal, readily adapting itself to new conditions and environment, is shown by the ease with which it is transplanted from the warm waters of the Chesapeake to the colder ones of New England; from the dense and salt waters of the ocean and bay to the brackish waters of the creeks and rivers, or *vice versa*, and from soft bottoms to hard or the reverse, but naturally this hardiness is not a quality of the immature oysters or the swimming embryos.

The influence of increased or diminished temperature upon the formation of the ova and spermatozoa, must be very serious and very considerable, and, judging by analogy, it would seem probable that the formation would be more rapid during a warm spring than during a cold one.

Whether the formation has been late or early, when once formed a sudden change of density or of temperature may so affect the oyster or the generative matter, that the latter would not be expelled, and only upon this hypothesis can be explained the retention of the products of generation noticed in so many oysters, and which is said to be so common, for none of the other conditions are subject to violent changes, such being peculiar to the density and temperature alone.

Probably the influence of changes of environment, especially of density and temperature of the water, is most severely felt by the embryos when in their free swimming state, and, in connection with the want of success of the spatting-seasons in the sounds, it is noticed that the temperature curves show a maximum change about the time when it is supposed that the young would attach in largest numbers, or about the period when they were swimming about in the water. It is also worthy of notice that Professor Brooks, about this time, met with the maximum amount of success in his efforts to artificially raise the embryos.

In consideration of the foregoing, I am of the opinion that the success or failure of any spatting-season is dependent upon the equability of the temperature, and that the higher the temperature during the spring months, the earlier the advent of the spawning-season, and that an increased temperature will also hasten the development of the spat, and of the young oysters after they have become attached. I also infer that sudden and extensive changes of density will likewise affect the advent, duration, and success of the spawning, though to a less extent.

Subsequent to the attachment of the animal, changes of the condition surrounding it are not of so much importance, though naturally such changes will more severely affect the delicate organism of the young oyster than that of the older and more hardened adult. During the first six months of its existence, the oyster is exposed to the greatest danger from the numerous enemies which surround it. The thin, delicate shells, from one-sixteenth of an inch to one inch in diameter, are readily bored by the drills or torn off by the crabs, and the immense numbers of both of these, leave no room to doubt their destructive effects. The inspection of the spat-collectors in the Big Annemessex river, shows that during the early months of their existence about 50 per cent. of the young oysters are destroyed, and future inspections of the hurdle will, I hope, give the rate of decrease in other periods of time.

Naturally, as the animal progresses, it becomes more hardy and better able to resist the attacks of enemies and changes of environment, and thus we find on the unworked beds, where the oysters are practically in a natural state, that the decrease in passing from young growth to mature oysters is about 30 per cent., or about one-third of a given number perish in passing from the first to the fourth year of their existence.

Here our information ceases, but enough has been gathered to indicate the proportion which nature has assigned as necessary between the young and the mature oysters. For every 1,000 of the latter there should be 1,500 of the former, if the number of brood-oysters necessary to maintain the fecundity of the beds is to be kept up, and though this proportion is based upon *data* which is not quite sufficient, yet, as I have said, it is all that has been afforded as yet, and may be accepted within certain limits. Certainly, whatever it should be, the number of the rising generation of the animals should never be less than that of the older, or there should always be as many young as mature on any bed. A greatly increased proportion of young to mature oysters would show either one of the two things—that the mortality in passing from youth to maturity was much greater than shown by the dredging results in the bay, or that a very large number of mature oysters had been removed by other than natural causes.

In considering these several beds, the question of food and other necessary supplies has not been considered, as it is evident that when an oyster-bed is formed and exists naturally, all the conditions for its successful life are probably present, and any failure of an important supply would be followed by a speedy extinction of all the oysters on the bed. Such determinations of the quality and quantity of the food, character of bottom and water, and other matters, are only of interest and desirable for the purpose of comparing one locality with another. Such was not the purpose of this investigation, and consequently the determination of those points has been but incidental to the work.

Probably the fecundity of a bed is increased to a certain extent by working upon it. The dredges or other implements used open the bed and spread it, thus giving more room for development, and allowing a greater amount of food to reach the animals. The mortality is great in all thickly-populated tracts and in any closely-united community, and it is evident that the removal of any of the brood-oysters could not be effected without destroying the fecundity of the bed, did not this very removal influence the mortality among the young, so as to allow a larger number to come to maturity. But this removal of brood-oysters may become so great that the most violent exertions of nature to supply others are unequal to the demand. It must also be evident, that as soon as the number of brood-oysters is thus diminished, even to the slightest extent, the fecundity of the bed is impaired.

This impairment constantly increases, influencing, as it does, both old and young. As the number of the latter decrease, so will the number of the former, and as that number is again and again diminished, the number of young produced by them must constantly diminish. Thus the cause for the destruction of the fecundity of the bed, and the gradual extinction of the animals upon it, can be readily understood and as easily comprehended, as the fact that the fecundity and preservation of the productive powers of a bed depends upon the number of mature, spawn-bearing oysters upon it. It is not meant by this, that none but the mature oysters are capable of reproduction, as such is not the case, oysters of even six or nine months' growth having been observed by me with ripe ova and spermatozoa in them, but the main dependence must be placed upon the adults in the community, as the spawn of the young growth is not considerable when compared with that of the other class.

Without a knowledge of the number of oysters on a bed, it is impossible to say what number should be removed, and as an attainment of the knowledge of the number on the bed is almost impossible, all that can be done is to keep the proportions between the young and the mature as nearly the same as on natural beds, and this should be the aim and result of all laws having the protection of the beds in view.

DEVELOPMENT OF THE OYSTER-SHELL.—The way in which the oyster's shell is developed in the embryo, has been shown by the quotations from Dr. W. K. Brooks' paper. It is increased with the growth of the oyster during the warm months of the year, but receives few additions in winter. These are supplied by the delicately-fringed mantle which, with the gills, forms the "beard" in popular phrase. From the ruffled edge of the mantle are deposited very fine particles of carbonate of lime, till at last they form a substance as thin as silver-paper, and exceedingly fragile. To these are added, more and more, until a satisfactory thickness and hardness is secured. When oysters are growing their shells they must be handled very carefully, as the new growth of the shell will cut like broken glass; it is said, also, that a wound on the finger from an oyster-shell is often very poisonous. If this be true, it is probably owing to the minute organisms adhering to the shell, which are left in the wound and produce a local fever. These shells are to the creatures they contain what his bones are to man. They support and protect the soft parts. Like the bones in the higher animals, they are composed of two substances, the one animal, the other earthy. The animal part resembles gelatine; the earthy part is principally carbonate of lime. They contain, however, small quantities of phosphate of lime, a little potash, and soda and acid. In one hundred parts of oyster-shells there will be found—

Water	17
Animal matter	2
Carbonate of lime	75
Phosphate of lime	3
Other salts	3
	100

MATERIALS FOR THE GROWTH OF THE SHELL.—The materials for its shell, like its food, are supplied by the sea-water; and where, by reason of there being a scarcity of these ingredients in the shores of the sea, the water at any one place lacks them, or is feebly supplied, oysters will not flourish, or will produce light and easily-broken shells. Such was the case on Nantucket. "If the shell is thin, or if it is formed very slowly, the danger from enemies and accidents is greatly increased; and those oysters which are able to construct their shells with the greatest rapidity, are the ones which survive and grow up. The amount of dissolved carbonate of lime which the ocean contains is unlimited, but the amount which can reach each oyster is not very great; and if all the oysters which attach themselves were to survive, there can be no doubt that they would exhaust the available supply of lime before they failed to obtain enough organic food." It is well known to conchologists that coral reefs and limestone islands are richest in all sorts of mollusks; and one reason, no doubt, why the young oysters thrive best on the natural oyster-bed is, that the old dead shells are soon corroded, and in a few years entirely dissolved, by the sea-water, affording an abundance of new shell-material for the survivors. The vast amount of dissolved lime poured into the Gulf of Mexico by the Mississippi and other rivers, doubtless largely accounts for the abundance of mollusks, marine worms, and radiates that throng in its waters. Varying conditions will cause much difference in the shells of oysters from various localities. Naturalists at first thought these differences amounted to specific distinction, and experienced dealers can pick out oysters from different regions not only, but from different beds in the same region. Mr. Winslow notes that, in the Chesapeake, oysters found upon beds that have been much worked differ materially, being single and broader, in comparison to their length, round and with blunt bills.

"They are usually dark in color, and have a considerable amount of mud and sand on the shells. The sponges do not appear to be as abundant, and the amount of dredging on any bed may always be known by the appearance of the oysters brought up. Upon an overdredged and almost exhausted bed the oysters will be large and single, blunt-billed, with dirty shells, and an almost entire absence of sponges, barnacles, and *Crepidula* will be noticed, but the shells will be covered with *Tubicola* and bored in many places by the *boring pholad*."

OYSTER PEARLS.—As in other mollusks, pearls are likely to be found in our common oyster, but, unfortunately, these are usually discovered in the mouth after the oyster has been cooked, and the value of the pearl thus destroyed. In the Peabody Museum at Yale College is a hollow, tear-shaped pearl taken from a common oyster at New Haven, which is a third of an inch in length. Mr. Henry C. Rowe, of the same city, showed me several large, round pearls, and told me he had had a hundred or so in the course of his life. As a rule, however, they have little market value.

OYSTER-BEDS.—Inasmuch as oysters can only exist under certain conditions, to be found only in restricted areas of sea-bottom, it is naturally to be expected that they will be found in colonies having a boundary defined with more or less exactitude. These restricted localities, because of their usual shape and appearance, are called "beds" and "banks" in the northern states, and "bars" or "rocks" in the southern, while in the Gulf of Mexico you hear only of "oyster-reefs". Although in waters so populous with this mollusk as Chesapeake bay, a floating plank or bush will be found covered with small oysters in almost any part of the bay, it would be far from the truth to conclude that even in that most favored region the bottom was paved with the bivalves. On the contrary, the beds there, as elsewhere, are so well marked that they can be laid down on a chart or staked out with buoys; and even in the best oyster-regions they occupy such an inconsiderable part of the bottom that any one ignorant of their position would have very little chance of finding oysters by promiscuous dredging. At the same time, it is not always apparent why an oyster-bank should occur where it is found, rather than at some other place; or why many areas, seemingly highly suitable, are not furnished with them. In the beginning, the character of the bottom has the greatest influence of all upon the location of a bed, undoubtedly, for a young oyster will not live except in certain suitable situations. Accident having fixed an oyster in a certain spot, however, and good fortune granted him safe growth, the growth of a bed there follows speedily, and with widening area augments in strength, until nearly beyond the reach of natural destructive agencies. The living and dead shells of the adult oysters furnish the best surfaces for the attachment of the young, and for this reason the points where oyster-beds are already established, are those where the young have the most favorable surroundings and the best chance for life, and the beds thus tend to remain permanent and of substantially the same size and shape. An idea of their extent, under favorable circumstances, may be had from the report to the Coast Survey, that in Tangier sound, Maryland, alone, there are 28 beds, whose united area is 17,976 square nautical miles, with twice as much additional bottom where oysters are occasionally caught.

EFFECT OF SEDIMENTARY DEPOSITS UPON THE BEDS.—The welfare of the beds is interfered with, seemingly, by few natural influences outside of living enemies. Mr. Winslow investigated the question of sedimentary deposits upon the beds of a portion of the Chesapeake, and reports in respect to Tangier sound as follows:

> Those beds lying in deep water are particularly free from an undue proportion of mud on the bottom, the shoalest beds having the thickest mud-covering. If there was a constant and increasing deposit upon the beds, they would long ago have disappeared, or at least have become of much smaller area, but the reverse is the case, the beds increasing in area constantly.
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> They are, however, exposed to one species of deposit which is very injurious. Heavy gales occurring in winter and summer frequently tear up the large quantities of grass, sea-weed, and sponge on the sand shoals about the sound and deposit it upon the beds. If this occurs in summer, when there are a smaller number of dredgers at work, the effect is very injurious, the "cultch" being covered, and the young, if spawned, smothered by the grass, weeds, sand, and mud which it collects. The California rock, Piney Island bar, and Manokin beds are those most subject to this evil. The gales also have the effect of covering the scattered oysters on the leeward sands, which process is called "sanding", and, from what I could learn, appears to be a very injurious one. The oysters are buried, and the bottom becomes smooth and hard. Where at least thirty bushels of oysters could be taken previous to a gale, not one oyster could be found subsequent to it. The winter gales have the greatest effect, owing probably to their greater severity and direction, which is from the northward and westward. The "sand" oysters are found in largest numbers on the eastern shores of the sound, and about Kedge's and Hooper's straits, consequently they would feel a northwesterly gale much more than one from the opposite direction. They are said not to recover from the "sanding" for several months, and upon their reappearance are noticeable on account of the whiteness of their shells.

In respect to Pocomoke sound, more harm was disclosed:

> The fact that on nearly all the beds, and especially those in the vicinity of the creeks and rivers and in the upper part of the sound, there is a light covering of mud more or less thick over the oysters, would lead to an inference that there must be a deposit of that character going on. On most of the beds the substratum of the bottom was hard, and the thickness of the surface covering gradually decreased as the entrance to the sound was approached. * * * The Pocomoke river, draining an extensive tract of the peninsula, would bring down a large amount of sediment, which the strong ebb-current would carry directly over the beds in the upper part of the sound. The amount in any given period of time would be difficult to ascertain, but the character will be shown to some extent by an examination of the specimens of bottom. Whether the amount of matter deposited is sufficient in quantity to seriously affect the beds is a matter of conjecture. I should judge that it was not, and my opinion coincides with that of all the oystermen I was able to interrogate.
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> That it must have some effect cannot be doubted, and the evident deterioration of the beds in Pocomoke sound may be accounted for, to some extent, by the supposition that the effect is injurious; but so many other and more direct causes exist for the deterioration, that it is difficult to eliminate their influence. The fact that the beds have existed and have been worked since the first settlement of the country, would lead to an inference that the effect, if prejudicial, was very slightly so.

The scattered oysters lying on the sands and those beds in the vicinity of sand-shoals and in shallow water, the Muddy marsh and Beach island rocks particularly, are exposed to damage by "sanding" in a manner similar to certain beds in Tangier sound, and which has already been described. The large amount of grass, sponge, and sea-weed growing on the sand-shoals, especially the one to the east of Herne island and south of the Guilford channel, is frequently torn up by the heavy gales and deposited on the beds with the same injurious effect that it had in Tangier sound. Heavy southerly gales will sometimes cover the beds above the Buoy spit and Shell rocks with mud for a short time, but not sufficiently long, it is said, to affect the oysters seriously.

EFFECTS OF ICE ON THE BEDS.—This account is typical of what might be said of oyster-beds in general along the whole coast. About the only other injurious agency is that of ice. In the Chesapeake heavy winter gales from the northward have the effect of diminishing the depth of water by piling up any floating ice upon the leeward shores and cutting away parts of the shores. Few beds are exposed, however, by the lowest of these tides, and it is rare that ice grounds, doing damage at these times only to a small extent, unless it remains for a long time in contact with the beds. In respect to this, Winslow has some interesting remarks:

If it [the ice] only touches in a few places, not much harm is done; indeed, it is supposed to protect the majority on the bed by covering them, but where there is a contact all over the "rock", the oysters are killed in a short space of time. * * *

The winter gales break up the ice-fields and pile them up in immense masses on the leeward shores and over the adjacent beds. The Shark's Fin bed suffers particularly in this respect. A good deal of damage is done to the shores by the ice, and the oysters feel the effect, showing it by becoming what is called "winter killed", or poor and weak, having a slimy, sickly appearance when opened. Many die on the beds from this cause, and after the disappearance of the ice, ten days or two weeks must elapse before they are fit for marketable purposes. Ordinary cold weather and a moderate amount of ice is said to improve the fishing, the oysters appearing to be drawn more to the surface of the bed and the shells to sink more toward the bottom. My informants said this effect was quite noticeable. No one that I was able to interrogate had ever seen an oyster frozen *in the water*, and the impression was, that so long as the oysters were covered they would recover from any ill effects of ice or ordinary cold weather.

In northern waters, such as Long Island sound and Narraganset bay, the oysters seem much more hardy in the endurance of cold than those of the Chesapeake. This would naturally be expected. Nevertheless, drifting ice often plows up the beds, both natural and artificial, to a ruinous extent in exposed situations, or, resting upon, freezes great areas of loose, single oysters into its under surface, and then, on a rising tide and before a brisk wind or strong current, moves off, bearing thousands of bushels away to scatter them over new ground, or hold them until they perish. This sort of action is an agency to be remembered in studying the geographical distribution of oyster-beds, since the mollusks will survive a long journey of this kind, and, finally, by the grounding or thawing of the floe, may be dropped all together in some favorable spot at a long distance from any other colony. The existence of such an isolated bed might easily be used as an argument, to show the great distance to which spawn travels, when, in fact, the colony owed its origin to nothing of the kind, but to having its progenitors carried there, as adults, by floating ice.

The question of the influence which ice has upon the existence of oysters as a race, in a certain region, becomes of great moment, when the locality is as nearly arctic as the gulf of St. Lawrence. I asked many questions on this point when at Prince Edward island, and also as to the effect of low temperature generally on the mollusks of that coast.

TEMPERATURE OBSERVATIONS.—The only observations on temperature that I could learn of having been made in the gulf of St. Lawrence were in 1872, by Prof. J. F. Whiteaves, of Montreal, who recorded them in an article in volume VI of the *Canadian Naturalist.** After describing the character of the bottom, this writer goes on to say:

Attempts were made to endeavor to ascertain the approximate temperature of the deep-sea mud. When the dredge was hauled up, its contents were emptied as quickly as possible into a large shallow tub, and this was covered with a tarpaulin and placed in the shade. An ordinary thermometer, with a metal case and perforated base, was then plunged into the mud, and the whole was kept carefully shaded for a time. With one exception the temperature of the mud was found to be from 37° to 38° Fahr., and this not alone in deep water; for sand brought up from 25 fathoms on the north shore of the St. Lawrence also made the mercury sink to 38° or 37° Fahr.

Again, the same author writes:

In the deepest parts of the river, on the south shore, between Anticosti and part of the Gaspé peninsula, the thermometer registered a few degrees higher. Sand dredged on the north shore in 25 fathoms also made the mercury sink to 38° or 37°.

Elsewhere he mentions that off Port Hood, Cape Breton, the temperature of the bottom ranged from 40° to 42° Fahr.; but adds, that not a trace of oysters are found living on that part of the coast. These are summer records.

Such notes were unsatisfactory, since they referred to an area outside of the oyster's range, and I therefore essayed to learn something of the temperature of the water upon the beds themselves—but I had no better means than an ordinary thermometer, which I believed to be not far from true—at various points where it was possible. It will be seen by the record of these observations below, that the temperature is higher than would naturally be suspected on a coast where the Gulf Stream is the other side of a polar current, that brings hosts of icebergs to the northern shores of Prince Edward and Cape Breton, and fills Northumberland sound with immense flows of dense,

* WHITEAVES, J. F. Notes on a deep-sea dredging expedition round the island of Anticosti, in the gulf of St. Lawrence. *Canadian Naturalist*, VI (new series), pp. 86–100.

blue arctic ice. The observations were made at various hours of the day, sometimes in sunshine, sometimes under a cloud, and at different stages of the tide. They are only to be taken as a mere indication of the general warmth of the water on the surface of the beds in that region, in the autumn. It is worth mention that the fishermen thought the water now about midway between its greatest cold and greatest warmth; but I can hardly believe this true.

Table of temperatures (Fahrenheit).

		Degrees.
September 18, 1879, Shediac:	Temperature of surface water; ebb tide	61
18	Temperature of air; ebb tide	58
19	Temperature of air (raining)	54
19	Temperature of shore water; low tide	55
19	Temperature of surface, ½ mile out in the bay	56
19	Temperature of bottom, on oyster bed, 12 observations	58
19, Point du Chêne wharf:	Bottom water, 2 fathoms	57
20, Summerside, Prince Edward island:	Bottom water, 2 fathoms, ebb tide, 10 a. m	52½
20	Bottom water, 2 fathoms, incoming tide, 10 a. m	55
20	Bottom water, 2 fathoms, high tide, 4 p. m	59
20	Bottom water, 2 fathoms, tide going out, 5 p. m., and deeper water	58
21	Bottom water, dead low tide, air chilly	56
22, Richmond bay:	Bottom water on bed, 4 p. m., ebbing tide	58

However, I had no opportunity to learn the minimum temperature which these oysters would survive. It would not be safe to say that the sole reason why oysters did not grow off Port Hood, for instance, was that the bottom water was as cold as 40° or 42° Fahr. There are probably various other reasons. I was told by fishermen on the island, and at Shediac, that they did not think the water could be too cold, short of actual freezing. They were united in the opinion, however, that ice had been the direct cause of the extinction of many of the beds. As I have said in my chapter descriptive of that district, however, I am sure that ice, or nature at large, has had less to do with this misfortune than the heedless greed of the oystermen themselves.

FOOD OF THE OYSTER.—The question of proper and sufficient food is also one of great importance, in considering the question of oyster-growth, whether in natural or artificial beds. The anatomical arrangement of the oyster's mouth and stomach, have already been explained, and the general character of his miscroscopic, floating food alluded to. Some further details in respect to this may be of importance. In a paper published in the report to the British government on oyster-culture in Ireland, in 1870, Prof. W. K. Sullivan, of Dublin, remarked, that independently of the mechanical constitution of the shore and littoral sea-bottom, *i. e.*, deposition of sediment, the currents, the temperature, etc., the nature of the soil produces a marked influence upon the food of the plants and sedentary animals that inhabit the locality, as well as upon the association of species. Especially is it the case with oysters, that the soil exerts so much influence on the shape, size, color, brittleness of shell, and flavor of the meat, that an experienced person can tell with great certainty where any particular specimen was grown. "Were we able to determine the specific qualities of the soil which produce those differences in the qualities of oysters, it would be an important step in their cultivation. Again, soils favorable for the reproduction of the oyster are not always equally favorable for their subsequent development; and, again, there are many places where oysters thrive but where they cannot breed. This problem of the specific influence of the soil is, however, a very difficult and complicated one. First, because it is almost impossible to separate the specific action of the soil from those of the other causes enumerated; and next, because, though much has been written on the subject of oysters, I do not know of any systematic series of experiments carried out upon different soils, and for a sufficient length of time, to enable accidental causes to be eliminated, which could afford a clue to the determination of the relative importance of the action of the several causes above enumerated, at the different stages of development of the oyster. * * * I believe the character and abundance of *Diatomacea* and *Rhizopoda*, and other microscopic animals, in oyster-grounds, is of primary importance in connection with oyster cultivation. The green color of the Colchester and Marennes oyster shows how much the quality may be affected by such organisms. It is probable that the action or influence of the soil of oyster-grounds upon the oyster, at the various stages of its growth, depends mainly upon the nature and comparative abundance of the *Diatomacea*, *Rhizopoda*, *Infusoria*, and other microscopical organisms which inhabit the ground. I have accordingly always noted where the mud appeared to be rich in *Diatomacea*, *Foraminifera*, and other microscopic organisms. A thorough study of a few differently-situated oyster-grounds, exhibiting well-marked differences in the character of the oyster from this point of view, by a competent microscopist, acquainted with the classes of plants and animals just mentioned, would be of great scientific interest and practical importance."

Of all the edible matter afloat in the water where the oyster lives, probably none is of greater importance to this and other mollusks than the *Diatoms*—microscopic forms of aquatic plants which, in almost infinite variety, swarm in both salt and fresh water, in the pond and ditch, in river and estuary, and throughout the open ocean. The distinguishing feature of the *Diatoms* is their indestructible skeleton of flint, in the shape of a pair of transparent glassy plates united at their edges. When the plant dies and the soft parts decay, this flinty skeleton falls to the bottom, but is not destroyed. Century after century they accumulate and form immense beds, contributing myriads of skeletons to the rocky mass.

THE GREEN OYSTERS OF EUROPE.—The *Diatoms* are brown, when they possess any color at all. It is not due to them, therefore, but to eating the chlorophyl-tinted spores or the whole plants of other species, that the "greening" of oysters, or the "green-gill", is due. This has frequently been ascribed to some metallic absorption, which rendered the oyster unfit to eat. I am, therefore, glad to be able to quote Professor Sullivan again on this point. He says:

As the green color of the mantle of oysters from certain localities just referred to is commonly attributed to copper, and as such oysters are consequently believed very generally to be poisonous, and their value therefore greatly depreciated, I made the most careful search for traces of that metal in the muds which I had received from grounds known to produce green-bearded oysters. Oysters and other mollusca placed in solutions containing copper and other metals absorb them, and retain them in their tissues. I have had two or three opportunities of examining oysters which had assimilated copper owing to mine-water containing it being allowed to flow into estuaries at places close to oyster-beds. In every case the copper was found in the body only of the oyster, which it colored bluish green, and not in the mantle or beard, *which was not green*. In the green-bearded oysters which I have had an opportunity of examining, the body was not green, and no trace of copper could be detected in any part of the animal. The color, too, was not the same as that of the true copper oysters, but rather that which would result from the deposition of chlorophyl or other similar chloroid vegetable body in the cells.

In the oysters at Arcachon, France, a violet tint has been observed, sometimes, which is due to a similar cause, although referred to the iodine and bromine of sea-water. Certain reddish algæ were found, when washed in fresh water, to impart to this a brilliant violet tint; and by careful observation it was ascertained that even the spores of these plants, which constitute a not inconsiderable portion of the nutriment, were similarly colored. In ordinary seasons, the dilution of the salt water by the rains in the Arcachon basin is sufficient to wash out the color of the spores of the algæ, but when the brine is strongly concentrated, there is no such appearance about the gills of the oyster as has been described.

RATE OF GROWTH IN OYSTERS.—It is, of course, largely upon their supply of food and of lime that their growth depends. This growth, however, is very variable, depending on the season, and in some years the increase is very slight. In general, transplanting young oysters in water similar to that in which they were born, causes them to grow more rapidly; but if they are carried into different temperature and other strange conditions, they will grow slowly. Thus in New York bay, the East river, and Newark bay "seed" far outgrows that brought from Virginia. In the Chesapeake, no doubt, the reverse would be true. But the conditions affecting growth may vary greatly within the same district. At Bird island, in Boston harbor, for instance, bedded oysters grow but very little, while those on the muddy shores of Winthrop, in fresher water, add a great length to their shells, but improve very little in flesh, making them very profitable to sell by the barrel, but not to open.

EFFECT OF WEATHER.—The weather affects their health somewhat. When heavy winds blow in from the sea, making high tides and cold, salt water, the oysters shut their shells and will not feed, but during off-shore winds they fill up well. Though a hard winter leaves oysters in a weak condition, the losses on the beds by death are greatest when the weather is changeable and high winds are frequent.

A Baltimore correspondent writes:

Thunder sours milk and kills oysters. You may load a vessel to its utmost capacity, start for market, and one good round clap of thunder will kill every oyster in the vessel immediately. Pounding with an ax upon the deck of a vessel, when oysters are thereon, or pounding upon the side of a vessel with a heavy weight, will kill every oyster that feels the jar.

I am not sure of the precise truth of this last assertion; but I know, that on the Massachusetts oyster-schooners no wood-chopping is allowed, and I have heard it argued that steamers could never be used in transporting Virginia oysters northward to the planting-beds, because of the jar of the machinery. How sensitive oysters are to feeling, appears from the fact, that they almost invariably close, the instant a boat comes near the bed. It has been said that they see the shadow; but to dispose of this, it is simply necessary to remind the reader that oysters have no eyes. It is by perceiving the jar in the water that they are apprised of the approach of some body, and, acting on instinctive presumption that it is an enemy, they drop their visors.

DESCRIPTION OF THE FLORIDA BAYS AND REEFS.—On the other hand, how oysters contribute to the advancement of the world of humanity, apart from the nourishment which men and various animals derive from their juicy bodies, is well illustrated on the western coast of Florida and elsewhere in the Gulf of Mexico. The extent to which organic, living agents are adding to the coast-line of this portion of the United States is remarkable, the more so as we hardly expect results so large and substantial from any means short of volcanic or geologic methods.

All along the western or gulf coast of Florida, particularly at its southern end, are great numbers of bars of oysters, worthless (in their natural growth) for civilized humanity, but beloved of the raccoons, which nightly come to eat them, and hence called "coon-oysters". Many of these reefs go bare at low tide, and you may walk about on them. They consist of nothing but masses of oysters so crowded and compact, that a solid and level surface (seamed by frequent shallow channels and spaces a few inches wide) covers over the whole reef, which may be several hundred yards long and forty or fifty yards in breadth. You may count up the number of individual oysters, when I tell you that a square foot will often contain a hundred.

When the reef has attained such a height that its crest is exposed to the air at low tide longer than it is visited by the water of the high tide, the oysters will cease to grow there, while still flourishing around the edges. The dead shells, growing brittle, are soon broken to pieces by the waves, and finally reduced to such small fragments, that they are like a shingle beach, or even like sand. Such a reef also, opposing the flow of the currents, furnishes lodgment to all sorts of drifting sea-wrack, receives a growth of the algæ and grasses which frequent such half-submerged levels, and is all the time built up at the top by the washing upon it of fragments broken from its edges. It is not long, therefore, before a sort of shelly soil is formed, and some floating mangrove stem or seed takes root there, and manages to get so firm a foothold that the storms do not tear it away.

THE OYSTER AS A REEF-BUILDER.—This done, the far-reaching and tangled roots of the bush form an eddy which deposits sand and floating stuff, until more mangroves have room to root themselves, and the bar ceases to be a "reef"; it has become a "mangrove key". Now, the mangrove (of which there are several kinds) is a very curious tree. It has a low, branching stem, and is thus pretty much all head; you cannot see anything as you approach but a compact mass of brightly green, thick, shining leaves, trailing to the ground. A nearer view discloses another very curious feature. From the main trunk, near the ground, extend out on all sides, and at varying height, some branches which do not go upward and bear leaves, but turn downward, enter the ground, and become roots. There are dozens of these stays surrounding every stem, and holding it, like so many cables, against the fury of the storms which sometimes hurl both wind and waves against the groves. But this is not all. Every low branch produces a considerable number of thick, leafless, straight twigs, which elongate straight downward through air and water, until they penetrate the soil and become rooted. The mangrove is not only braced upon a score of roots, therefore, but anchored from every one of its lower and larger arms. A perfect tangle and net-work of these roots and rooted stems thus surround each tree and every islet with an abatis often several rods in width.

Such a network speedily verifies its likeness to a basket by catching outside matter. Along the solid edges of the key itself, and everywhere in the neighborhood, are living oysters which annually send forth a cloud of young to seek new quarters. The mangrove stems afford capital resting-places, and speedily become encased in oysters which increase in size and number very rapidly. This suspended kind is known as the "mangrove oyster"; but I do not see that they are anything but progeny of the coon bars. Barnacles, too, in vast numbers, muscles, bryozoa, and many forms of minute water-animals cling to these half-submerged branches or flourish under their shelter, where the hard sand and the bare angles of oyster-rock are being buried under a coating of mud and decayed vegetation, which the basket-work of mangrove roots and salt-grass has caught and confined.

An especially noteworthy member of such a colony is a marine worm of small size, which forms about itself a tubular, twisted case of lime very like that of the *serpula*. Along certain portions of the coast, south of Tampa bay, these worms are extremely numerous; and they build up their cases so closely together that they join one another, and so cover the foundation upon which they grow with limy tubes somewhat larger than a darning-needle, the partially coiled bases of which are in unison, but the enpurpled mouths a fraction of an inch apart from one another, forming a solid mass of lime with a bristling (and, at high tide, very animated and beautiful) surface. Without being sure that I am right, I suspect that these worms survive only a single year, and then dying, leave their indestructible cases to serve as the foundation upon which their progeny may rear their tier of tubes. Thus, by the additions of successive generations (as in the case of the coral-growth, only through a different history), this worm-structure increases into an extensive mass of heavy rock. I have seen pieces many yards square and two feet or more thick. Growing irregularly, its crannies afford a haunt for many species of mollusks and crustaceans that like to hide away in holes; and its mass is further enlarged by the growth of bunches of oysters and the filling of all its interstices with sand and broken shells, which become solidified along with the worm-tubes by the production of a native cement. Thus millions of tons of solid limestone, most useful for building purposes, is every decade added to the Floridian coast by despised worms.

Attracted by the excellence of the hiding-places offered, and by the abundance of "small deer" lurking there, come to the mangrove roots many predatory sorts of aquatic animals in search of food—conchs, whelks, boring sea-snails, crabs of several species, and mollusk-eating fish, like the sheep's-head. Where there is teeming life, death is frequent, and thousands of empty shells and fleshless skeletons sink into the animated ooze, and rapidly fill it up, until the water no longer covers it, except at the highest tide, and then leaves an important toll of drift-wood, and the adventurous water-loving mangroves must push their roots farther and farther into the sea.

Meanwhile a similar process has been raising the center of the island. Decay of grass and salt weeds, and mangroves and drifted wood finally brings a surface permanently above the water. Huge flocks of water-birds daily alight upon it to rest and feed, and their droppings increase and enrich the soil. Various seeds are wafted or floated from the mainland and build up its stock of vegetation; various land animals, chiefly reptilian, make the new key their home. They die and are buried there. The simple mangrove swamp is succeeded by an intermixture of oak, pine, and palmetto, and their rotting logs gradually make a wide extent of solid ground. Discovering this, Indians get into the habit of landing there to open and feast upon oysters, clams, and conchs, and from the *debris* of these feasts accumulate mounds or ridges hundreds of yards long and perhaps forty feet high. When the white man comes along, he discovers the largest trees and most luxuriant undergrowth upon these mounds of shells. Recognizing the excellence of the soil, it is there he places his house and plants his farm. The old oyster bar is an island with a name on the maps.

Now, the formation of keys just in this way has long been going on, and clusters of them abound all the way from Apalachicola to Key West. A group of islands, near such a coast as Florida's, acts like the interlacing roots of a single mangrove key; the currents are stopped, tides slackened, shell-débris, drifted matter, and sand deposited, and great shoals, mud-flats, and sand-bars result. Given such an archipelagic condition, a straight sand-bar, or outer beach, is a natural result, and this, once it is formed, contributes still more to the shoaling of the channels inside, until they eventually become largely obliterated, and many of the islands join together and finally unite with the mainland.

But, as I have said, this is wholly the work of animal life. Not until the oysters and their neighbors have really formed a "key", do the mangroves, with their train of aids, take up the work; and not until this has long proceeded does the drifting of sediment down the rivers, or the washing up of bottom-sand by the outer waves, increase the bulk of the islands that soon add their well-prepared areas to the general coast.

V. FATALITIES TO WHICH THE OYSTER IS SUBJECT.

61. LIVING ENEMIES OF THE OYSTER.

THE STARFISH.—No creatures are so dangerous enemies of oysters, either in their wild state or when transplanted, as the members of the spiny-skinned tribe which naturalists term *Echinoderms*. This tribe contains many members, but the one that concerns us as oyster-growers is the starfish.

The starfish passes under various names among fishermen and oystermen. In England he is known most frequently as the "crossfish", "sun-star", and "sea-star". In this country the name most often heard, is "five-fingers" north of Cape Cod, and southward of there "starfish", "sea-star", or simply "star", to which it is abbreviated in the vicinity of New York.

None of these names, however, distinguish between the various species, except in the case of the "basket-fish" of Massachusetts bay, which is sufficiently different from the ordinary five-fingers to attract everybody's attention; and the smaller varieties are often mistaken for the young of a larger sort. While this is unfortunate ignorance, it practically does not matter to the oysterman, since all the different members of the family are alike enemies, to the full extent of their individual powers and opportunities.

The common name of the animal well describes its general form. "As there are stars in the sky so are there stars in the sea," remarked old John Henry Link, a century and more ago. From a central disk of small dimensions radiate five pointed arms, composed of a tough substance unlike anything else that I remember anywhere in the animal kingdom. "When it is warm in one's hand," wrote Josselyn, that quaintest of America's advertisers, in his *New England's Rarities*, 16, "you may perceive a stiff motion, turning down one point and thrusting up another." This was all right, but he adopted an error when he added : "It is taken to be poysonous."

Examining the starfish more closely, you perceive that it has an upper and a lower side, essentially different. The upper side, or back, presents a rough surface of a greenish, brownish, or reddish-green hue, which, when it is dried, turns to a yellowish-brown. This is the leathery membrane covering the skeleton of the animal, which consists of small limestone plates united together at their edges by a sort of cartilage, so that they can move in a slight degree. This forms the frame-work of the arm, and acts as a chain-armor to encircle and protect all the soft parts within. Underneath, on the lower side of the starfish, this frame-work terminates in two series of larger plates, which are braced against one another like rafters, and sustain the whole structure by a sort of arch. This armor is sufficiently flexible to allow the starfish to bend himself clumsily over or around anything he is likely to wish to climb upon or grasp.

Scattered everywhere upon the upper side are a large number of blunt, short spines, which seem to have no special arrangement, and are longest and thickest at the edges of the rays, and upon the plates bordering the lower side of each ray. Each one of these spines swells at its base, where are fixed, in a wreath, several curious little appendages called *pedicellariæ*, whose odd forms and movements can only be understood underneath a powerful microscope, on account of their diminutive size. They consist of a little pedicel which waves about, bearing upon its top a pair of (for it) huge toothed jaws, like the claw of a lobster, which waves about in a very threatening manner. Now and then it happens that some little particle of food or sea-weed will accidentally get caught by these valiant guardsmen of the spine, that towers up in their midst; but this to annoy rather than gratify them, and their functions are not yet explained. They occur in some form or other in all echinoderms, yet seem to contribute no service whatever to the animal. Outside of them, forming a second circle about each spine, is a set of water-tubes, whose functions will be explained presently. Near the center of the disk, on the back, notice the *madreporic body*, a small, smooth protuberance, filled with openings, like a sprinkler, and then turn the starfish over.

Though so tough and tuberculous above, on the under side it is soft and almost white in tint, except where the strong spines along the edges of each ray protect the soft parts between. In the very center of the disk is the opening of the mouth. It contains no teeth, but is surrounded by an elastic tube and guarded by the hard edges of the skeleton-plates which hem it in. From this center run five furrows, one down each of the arms.

Throughout all this branch of the *Radiates*, observes Professor Forbes, the reigning number is five. "Among the problems proposed by that true-spirited but eccentric philosopher, Sir Thomas Browne, is one, 'Why, among sea-stars, nature chiefly delighteth in five points'? and in his *Garden of Cyrus* he observes: 'By the same number (five) doth nature divide the circle of the sea-star, and in that order and number disposeth those elegant semicircles or dental sockets and eggs in the sea hedge-hog'. Among the lower and the typical orders we find this number regulating the number of parts. Every plate of the sea-urchin is built up of pentagonal particles. The skeletons of the digestive, the aquiferous, and tegumentary systems, equally present the quinary arrangement; and even the cartilaginous frame-work of the disk of every sucker is regulated by this mystic number."

But this is a digression. To return: Each furrow is filled, with the exception of a narrow path down the middle, with small fleshy tubes, terminating in a disk, which are so evidently its means of locomotion, that you at once call them *feet*. This is true enough so far as their function is concerned, for Five-fingered Jack certainly does walk by means of them; but entirely wrong anatomically. No *Radiate* has "feet" properly speaking. In order to see how the little beast makes use of these hundreds of walking appendages we must dissect him. Having done this, it appears, that through the seive-like surface of the madreporic body, on the back of the disk, enters a constant current of pure sea-water. This is received into a system of circular canals, which branch out, on each side of every ray, and send out through minute openings in the broad plates on the lower side of the arm's fibers, which, when swelled full of water, appear as the rows of feet-tubes already mentioned. These feet-tubes are called *ambulacræ*, the grooves along each side of the arm, where they spring and where they are supplied with water from the main canal underneath, the *ambulacral grooves*, while the plates themselves, and the whole concave under-surface between the spiny processes bordering the rays, form the *ambulacral tract*.

Now, the starfish's body is always full of water; beside the large stream flowing in through the madreporic body, a constant inflow seems to take place by absorption through the thousand minute water-tubes that wreath about each spine, notwithstanding no microscope has yet been able to detect any opening in them. This insures that the ambulacræ shall always be full of water; but the creature can control these, and when he wishes to take a step forward he places one, a dozen, or a score of these feet-tubes a little forward, and draws a slight amount of water from each, which causes a contraction of their sucker-disks, and gives them a firm hold. By a reverse process he lets go with his other feet, and by main strength drags his body up as far as he can. This operation frequently repeated would give a continuous movement to his body which is not ungraceful, as he dips down into a hollow or bends himself slowly over some obstacle. His movements are very deliberate, and he moves hardly as fast as the second-hand of a watch. It is to the fullness of this water-system that the animal owes its plump appearance. Take him out of the sea and the water will pour out all over him, in a fierce perspiration, which soon leaves him flat and thin on your palm. I may as well say here, that any one can handle them without fear; the old idea that they were poisonous was a worthless superstition.

In addition to this water-system, for locomotion, starfishes have a heart and system of blood-vessels. This consists of two circular vessels, one round the intestine, and one round the gullet, or heart, intervening between them. "There are no distinct respiratory organs, but the surfaces of the viscera are abundantly supplied with cilia, and doubtless subserve respiration; the sea-water being freely admitted into the general body-cavity by means of numerous contractile ciliated tubes, which project from the dorsal surface of the body." (Nicholson.) There is a nervous system, also, in this apparently immovable and insensible denizen of the deep. A gangliated cord surrounds the mouth and sends filaments out along the center of each arm, to the little red speck discernible at the tip, which is the eye. How much they can see with these eye-specks is doubtful; but there seems no doubt that they can perceive obstructions in their path, for they begin to get ready to mount them before actually striking against them.

The mouth, as I have said, is a mere circular opening, without teeth. The stomach is reached through a short gullet, and of itself is not large, so that it is difficult to understand how the tremendous gluttony for which this fellow is famous can be accommodated; until we have cut him open, and find that, as a part of the stomach, there extend loose yellow pouches far into each arm, which nearly fill up much of the interior of the rays. When no great meal is to be eaten these pouches or *cæca* are not brought into use, but when occasion arises they can contain a surprising quantity. On the floor of each arm, which we have cut open, is seen the ambulacral ridge, upon either side of which are the vesicles that supply the foot tentacles, which may be filled or emptied at the pleasure of their owner. Above these, occupying the most of the interior space toward the end of the ray, and also appressed between the cæca and the upper surface toward the center, are the berry-like clusters or racemose masses of the generative organs.

Few persons, probably, suspect that in so low a grade of beings the sexes are divided, yet this appears to be the case in the starfishes. According to Prof. Alexander Agassiz, the males and females of our common species of starfish can readily be distinguished by their difference in coloring; all those having a bluish tint being invariably females, while a reddish or reddish-brown color indicates a male. "When cut open, so as to expose the genital organs, the difference between the males and females is still more striking. The long grape-like clusters of reproductive organs, extending from the angle of the arms, on both sides of the ambulacral system, to the extremity of the rays, present very marked differences in the two sexes. The ovaries are bright orange, while the spermaries are of a dull cream color. At the time of spawning * * * the genital organs are distended to the utmost, filling completely the whole cavity of the ray; the abactinal system [*i. e.*, the sides and back of the rays] being greatly expanded by the extraordinary development of these organs."

The two species common on the New England coast are *Asterias arenicola* and *Asterias vulgaris*, and, though much alike otherwise, they have different times of spawning, the former (Massachusetts bay to Florida) throwing out its eggs a fortnight or more earlier in the summer than the latter, whose range is more northerly and hence in colder waters. Their period of spawning, also, is very short, comprising only three or four days. The eggs produced by the females, as well as the spermatozoa sent out by the males, find exit from the body through five very small holes in a series of large plates on the back at the angles of the arms. Such eggs as are fortunate enough to meet with spermatozoa in the water, before being overtaken by some form of destruction, are fertilized, and immediately begin a very curious series of changes in embryonic growth, which have been fully described by Alexander Agassiz. This embryolog is like that of no other group of animals, but may be roughly compared to the transformations of a butterfly in the chrysalis. The larva which hatches from the starfish's egg is entirely unlike its parent, in form or structure, being an oddly shaped, ragged, transparent little creature, permeated through and through by water-tubes. This larva, when perfected, is called a brachiolaria, and swims around for several days by means of vibrating cilia, which keep it whirling and bobbing about, not choosing its course, nevertheless, by an exertion of its will, but a prey to all the chance breezes and currents that can get it in their power.

These larvæ, says Mr. Agassiz, are to be found floating in large numbers at night, though never by day, near the surface among cast-off skins of barnacles, which furnish them with food during the time when they swim freely about, in company with multitudes of small crustacea, annelids and hydroids. At such a time they are fit food for shellfish, and no doubt many fall into those treacherous small currents that lead into an oyster's, clam's, or mussel's mouth. This helps to even up the account which the adult starfishes are making, in their daily onslaughts upon the mollusks.

The jaunty, free career of the brachiolaria, however, is soon over. Changes, begun before they were understood, now begin to alarm him. He is losing his shape and assuming a strangely symmetrical, five-armed form, covered with soft spines and tentacles. Before he knows it, and without the loss of a single portion, the bactolaria, by absorption, has lost himself in the body of a true young starfish, and finds himself slowly acquiring the stiff armor and dignified mien which marks his approach to an adult condition. He ceases his gay wanderings and sinks to the bottom, or crawls upon the frond of some floating sea weed. This occurs when he is about three weeks old. But now that he is no longer an embryo, but a real baby starfish, his growth is very slow. Mr. Agassiz says that by arranging the starfishes, big and little, found upon our rocks into series according to size, we may roughly estimate the number of years required by them to attain their full development; this he presumes to be about fourteen years. During the earlier years the growth is more rapid, of course, than later. One young specimen, kept in an aquarium at the Cambridge museum, doubled its diameter in five months. That they begin to spawn when six or seven years old, or hardly half-grown, is ascertained; but as to how long they may live after that, provided the dangers of the sea are escaped, we have no information that I am aware of.

The size to which they attain varies in different species. The rare British *Uraster glacialis*, Ag., has been seen 33 inches in diameter, and some even larger than this have been reported from near Eastport, Maine, where echinoderms abound in greater number, perhaps, than anywhere else on our coast. South of Cape Cod, however, it is rare to see one measuring more than ten inches across, and the great majority do not exceed six.

The destructiveness of these creatures has long been recognized by naturalists and fishermen alike. In Bishop Sprat's *History of the Royal Society* of London, we are told that many years ago the Admiralty Court of England laid penalties on those engaged in the oyster-fishery "who do not tread under their feet, or throw upon the shore, a fish which they call *five-finger*, resembling a spur-rowel, because that fish gets into the oysters when they gap and sucks them out". Numerous accounts might be given of instances when great damage had been done the shellfisheries, particularly along the Welsh and Cornish coasts, by starfishes, in a very short time. Oysters, not only, but clams and scallops of every sort, fall a prey to some of the many spiny raiders, whose size or habit of living in deep or shallow water, fits them to attack one or another sort of mollusk. Couch notes, in his *Cornish Fauna*, the large *Uraster rubens*, which is called clam or cramp in Cornwall, and occurs there in multitudes in spring, infests the fishermen's crab-pots, to steal the baits; and a Belfast man reports that he had had starfish frequently seize his lug-worm bait and be brought up on his hook while fishing. Mollusks, then, are not their only food. The carrion of the sea is eaten by them with voracity, and in this respect they are beneficial to us and the rest of animal life.

I do not propose to give a history of British starfishes, but before leaving them, must tell one or two superstitions attached to them by sea-faring men, who are so ready to invest with some supernatural quality every strange product of that mystery of mysteries, the sea, whose inscrutability and might impress him with supernal power, and excite his wonder more and more the longer he is acquainted with its majesty, its moods, and its inhabitants.

Forbes records that at Scarborough the fishermen call the big *Asterias aurantiaca*, a very destructive species, the "butt horn". "The first taken," he says, "is carefully made a prisoner, and placed on a seat at the stern of the boat. When they hook a 'but' (halibut) they immediately give the poor starfish its liberty, and commit it to its native element; but if their fishery is unsuccessful it is left to perish, and may eventually enrich the cabinet of some industrious collector."

In Ireland, it appears, the folk-lore of this subject is more grum. "The starfishes are called at Bangor (County Down) the *Devil's fingers*, and the *Devil's hands*, and the children have a superstitious dread of touching them. When drying some in the little garden behind my lodgings, I heard some of them on the other side of the hedge put the following queries: 'What's the gentleman doing with the bad man's hand? Is he ganging to eat the bad man's hand, do ye think?'"

Not a superstition, but an entire error was the belief, which I find still existing in the United States, that the starfish will poison painfully, if not fatally, the hand of any one touching it. Our oystermen know better; but I can tell them that the belief is very old. Pliny, who lived during the first century of the Christian era, asserted that starfishes "can burn all they touch". This proves he took hearsay evidence, which a naturalist is never safe to do, and did not handle them himself to see. Aldrovandus and Albertus, who wrote a few centuries later, followed his same love of the marvelous, in spite of common sense and easy proof to the contrary, and told their credulous readers concerning these creatures, that "their nature was so hot they cooked everything they meddled with". Possibly we may find here the origin of the stew, the roast, the take-home-a-fry-in-a-box, which otherwise remains very obscure. Finally, some outdoor students came along, picked up starfishes, found them harmless, and freed the foolish old tomes that called themselves "natural histories", but constantly set nature aside for the marvelous and absurd, from one more taint upon the name of observer.

The tale did not wholly lose its hold upon the minds of the ignorant, however; and even the learned sought until lately to prove that there was some sort of an acrid fluid discharged by the skin of the animal. This false idea arose, perhaps, from confounding the starfish with the various *Medusæ*, or jelly-fishes, which are also sometimes called "crossfishes"; or, possibly, it is merely an outgrowth of the attempt to account for the insidious destructiveness of the five-finger, which for a long time was misunderstood.

HOW A STARFISH KILLS AN OYSTER.—In Boston, last winter, one of the oldest oyster-dealers and planters there, gravely instructed me in the manner a starfish attacks his victim.

"Crawling round the bottom," he explained, "the star accidently gets afoul a bed of oysters. He don't know what they are, mebbe, but there they all lie with their shells a-gapin', after the nature of oysters. Poking round amongst 'em he accidently, as it were, gets the end of one of his arms into an open shell, and the oyster of course shuts down on him. Now, sir, he can't get away, but the oyster can't live but a little while with its shell open, and after a few hours he is dead. Then he lets up and the star makes a meal off him right there—takes him on the half-shell in his own gravy, as it were."

This is the first and last time I ever heard an American talk this nonsense, though many have expressed an ignorance of the whole matter, which was no credit to their eyesight; but in reading Prof. Edward Forbes' *British Starfishes* lately, where he mentions the cripples so frequently taken among starfishes, I find the following paragraph:

> The oystermen believe that it loses its rays in consequence of its oyster-hunting propensities, that it insinuates an arm into the incautious oyster's gape, with the intent of whipping out its prey, but that sometimes the apathetic mollusk proves more than a match for its radiate enemy, and closing on him holds him fast by the proffered finger; then the crossfish, preferring amputation and freedom to captivity and dying of an oyster, like some defeated warrior, finding
>
> "The struggle vain, he flings his arms away
> And safety seeks in flight."
>
> This story has long been believed. Link gives a vignette representing the mode of attack, with the motto "sic struit insidias".

Everybody who knows anything about it understands now, of course, that all this is absurd. The starfish goes about his foraging in a much more effective and sensible way. Indeed, he excels almost any other animal worth calling one, in economy of exertion in eating, since to secure, swallow, and digest his food is all one operation, when once he is inside the shell.

Having met with an oyster, scallop, or other thin-shelled mollusk—and young ones are preferred because their armor is weak—the starfish folds his five arms about it in a firm and deadly grasp. Then protruding the muscular ring at the entrance of his stomach through the circular opening in the center of the under-side of the disk, which I have described, he seizes the thin, newly grown, posterior edge of the shell, which oystermen call the "nib" or "bill", and little by little breaks it off. It has been surmised that the gastric juice decomposed the edge of the shell, until an opening was effected; or, entering, paralyzed the mollusk, until he relaxed the muscle which held the protecting valves together. But I do not think either of these suppositions supported by fact. The operation is proceeded with too rapidly to wait for the slow action of the stomach acids upon the carbonate of lime in the shell; and the vital parts of the mollusk are too far inward and sluggish to be promptly affected by any such acids. Moreover, it seems unnecessary, since the appearance of every shell attacked at once suggests a breaking down, chipping-off movement, which the starfish might easily produce, by seizing and suddenly pulling down with the suckers nearest the mouth, or by a contraction of the elastic opening of the stomach.

At any rate, the thin edge of the shell is broken away, until an entrance is made, which the occupant has no way of barricading. Then the burglar protrudes into this entrance the distensible mouth of his stomach, until it can seize upon the body of the mollusk. The consumption of this begins at once, and as fast as the poor oyster's or scallop's body is drawn within its folds, the capacious stomach is pushed farther and farther in, until at last, if the mollusk be a large one, the pouches that I have described as packed away in the cavities of the rays, are also drawn forth, and the starfish has substantially turned himself wrong side out. If he is dredged up at this stage, as many examples constantly happen to be, and dragged away from his half-eaten prey, his stomach will be found hanging out of the center of his body for a distance, perhaps, equal to half the length of one of the arms, and filled with the juices of the oyster he has devoured, and whose body, within the shell, will be found almost as squarely trimmed as could have been done by scissors. If put very gently into a bucket of salt water, and left in peace, the starfish will straighten himself out, and slowly retract his extruded abdomen, as he would have done after his meal was digested, had he been undisturbed; but if the least violence is used he will spurt out the liquid contained in the distended pouch, and quickly draw it back into his body. As a rule, however, the angry fisherman does not have patience for these experiments. This process is the one followed in the case of large sized mollusks. Very young oysters and other small prey are enveloped in the stomach, shell and all. The gastric juice then kills and dissolves out the soft parts, and the hard crust is thrown away by the eversion and withdrawal of the stomach.

Difficulty of destroying the starfish.—When oysters first were cultivated along the American coast, and this enemy first became known, the oystermen used to save all that they caught in their tongs and dredges, and pile them in a corner of their boats until evening. Then they would collect them into small packages and draw a cord around each lot tightly enough to cut through it. This done, the remnants were cast overboard and considered done for. But this was entirely a mistake, as was presently found out. Five out of six of these fragments not only retained life, but renewed the lost parts and became active again. Thus, instead of diminishing the pest these men were directly increasing it, since they were making two or three new starfishes out of each captive. It was a case of multiplication by division, which may be an invariable paradox in mathematics, but is by no means always one in zoölogy.

Starfishes often lose one or more of their rays, but reproduce them. Forbes figures one, where four out of the five arms had been broken off in some way, and had just begun to be replaced by the little stubs of new growth. This gave the animal, with one full-sized limb, the shape of a spike-headed bludgeon. Indeed, th re are certain members of the family, found in all seas, known as *Ophiurans*, or snake-armed sea-stars, which are liable to commit apparent suicide, hurl themselves all to pieces, the instant they are disturbed. This habit belongs, also, to a few larger forms, but, so far as I am aware, is never practiced by any of our familiar American starfishes, who seem to prefer to take their chances rather than voluntarily fling away their limbs. This fragility and spitefulness of certain of the starfishes is humorously described by Forbes, in his account of one large British seven-armed species, the "lingthorn", or *Luidia fragillissima.* Having been cheated out of a previous specimen by its breaking itself to pieces, Mr. Forbes took with him on his next collecting expedition, a bucket of cold fresh water, to which article starfishes have a great antipathy. "As I expected," he says, "a *Luidia* came up in the dredge—a most gorgeous specimen. As it does not generally break up before it is raised above the surface of the sea, cautiously and anxiously I sunk my bucket to a level with the dredge's mouth, and proceeded in the most gentle manner to introduce *Luidia* to the purer element. Whether the cold air was too much for him, or the sight of the bucket too terrific, I know not, but in a moment he proceeded to dissolve his corporation, and at every mesh of the dredge his fragments were seen escaping. In despair I grasped at the largest, and brought up the extremity of an arm with its terminating eye, the spinous eyelid of which opened and closed with something exceedingly like a wink of derision."

Now that I have spoken of the "brittle-stars," as the *Ophiurans* are well called, I may as well quote Mr. Forbes' account of the trouble they give on the French and English coasts, which entitles them to a place in this essay on an enemy of the shellfisheries. He remarks:

> The common brittle-star often congregates in great numbers on the edges of scallop-banks, and I have seen a large dredge come up completely filled with them; a most curious sight, for when the dredge was emptied, these little creatures, writhing with the strangest contortions, crept about in all directions, often flinging their arms in broken pieces around them, and their snake-like and threatening attitudes were by no means relished by the boatmen, who anxiously asked permission to shovel them overboard, superstitiously remarking "the things weren't altogether right". Rondletius * * * says they prey on little shells and crabs. They constitute a favorite article of diet in the codfish's bill of fare, and great numbers of them are often found in the stomach of that fish.

Starfishes are rarely found dwelling upon a muddy bottom, nor do they like clean sand very well. Upon the mud it is difficult for them to move about, and the open, smooth sand holds little food, and is likely to be shifted by a storm too quickly for them to escape being buried. Their home, then, is chosen on rocky coasts, where submerged reefs afford plenty of craggy points for them to cling to, and whose crannies at once serve as homes for the animals they feed upon, and safe hiding-places for themselves. Beds of jingles, *Anomia*, deckheads, *Patella*, limpets, and other rock-loving mollusks are strongholds of starfish life.

EXTENT OF DAMAGE WROUGHT BY THE STARFISH.—The amount of damage done to the oyster-fisheries of the American coast by sea-stars, was one of the objects of constant inquiry in my work north of Staten Island. To the southward of Sandy Hook, at the utmost, no harm is reported, since the starfishes are extremely few, and almost wholly confined to the mussel-beds in the inlets.

In Prince Edward island they did not reckon this enemy as of much consequence, and had no losses of any consequence to report.

Crossing the Maritime provinces to the harbor of Eastport, Maine, I learned that all attempts to bed down northern stock or to transplant and raise any northern seed-oysters, had been completely frustrated by hordes of giant starfish, which ate up the mollusks almost as fast as they could be put down. Here, then, the sea stars are responsible for an entire disuse of otherwise available privileges for oyster-culture.

The same condition of affairs exists to a great extent on the rest of the coast of Maine, and I am not sure but the mysterious extinction, at about the date of the advent of Europeans, of the once extensive living beds of oysters between the mouths of the Kennebec and the Merrimac, was largely due to the attacks of this five-fingered foe. At Portland, however, where many southern oysters are laid down every year, I heard little complaint. This immunity is probably due to the fact, that no young oysters are planted here, or grow naturally; and also to the fact, that the beds are made upon muddy flats, in shallower water than starfishes enjoy. The same is true of the whole of Massachusetts bay, except Wellfleet, where the planters count sea-stars among the enemies, but secondary to the three or four species of mollusks that prey upon the planted beds.

South of Cape Cod, however, where oysters spawn and grow naturally, and beds of cultivated oysters are raised from eggs and infancy, starfishes are plentiful. All of the shores of Buzzard's bay are infested with them, and from there to the western extremity of Long Island sound they do enormous damage annually to the oyster interests—a damage probably not overestimated at $200,000 a year. The south shore of Long Island and the bay of New York are less afflicted. Their attacks are not uniform and continuous, it appears, but vary with years, the time of the year, and other circumstances. A steady increase, however, has been observed in their numbers, wherever oyster-cultivation has been carried on for any considerable length of time. The planters at Providence, New Haven, and Norwalk, whose memories go back for twenty-five years or more, relate that in their early days this plague was not regarded as of any consequence, and that the starfishes are steadily increasing. Such a report is no more than we should expect, in view of the enormous increase of the food afforded them by oyster-culture.

STARFISH INVASIONS.—There have occurred times in the past, nevertheless, as now happens at intervals of a few years, when an excessive crowd of starfishes invaded the beds. Such a disastrous visitation was witnessed in the Providence river, Rhode Island, about 1858. The starfishes came in "sudden droves", as my informant expresses it, "which burnt up everything". The planting-grounds were mainly on Great Bed, about three miles below the city of Providence, and of all this extensive tract only two acres escaped, owing their safety to the fact, that just before that they had been partially buried under a layer of sunken sea-weed and drifted matter. Another of the planters had his heaviest bed between Field's point and Starvegoat island (which probably were not long ago connected), where the low tide left them so nearly bare that his men could pick up the starfishes, while his rivals had no means of combating them in the deeper water. In the general scarcity that ensued, he made large profits from this rescued bed, and got a start to which he owes a large part of his present eminence in the New England trade. So complete was the destruction caused by this visit, that the state revoked the leases of all that ground, and the planters left it wholly for a new tract at Diamond reef, where the water was so fresh that starfishes could not live. This single inroad upon Providence river probably cost the planters there $150,000. It occurred late in the summer, and the marauders staid there picking up the fragments of the feast that remained until winter. Then a heavy fall of snow and rain, in conjunction with an unusually low tide, chilled and so completely freshened the water as to kill them all off. So it is related; and it is said to have been some years before that tract was reoccupied by planters.

Similar traditions exist elsewhere along this "sound" coast; and the planters stand in constant fear that the army of the enemy, which they daily fight, may at any time be suddenly re-enforced from some invisible quarter to an extent which shall make any contest useless. In 1878, for example, after some rough and gloomy weather in the latter part of October, a planter at Pocasset, Massachusetts, went out in his boat to look at his oysters which lay in three to five feet of water. He at once noticed that the starfishes had made a raid upon him under cover of the storm. Taking an eel-spear as a weapon, he forked up 2,500 by actual count within the next two days, and later gathered 500 more. In spite of this they ate up about 300 bushels from his beds alone. Adding what his neighbors suffered, he considers the single week's loss at that point to have been about 1,000 bushels, worth $1,200.

At Warren, Rhode Island, I saw a pile of dead starfishes, said to amount to 1,000 bushels, which had been dredged off the beds in the river there. A bushel of living sea-stars contains from 100 to 200, according to size; say, 150 on the average. In drying, however, the bulk of a bushel is reduced three-fourths. Therefore this decaying heap, ready to be turned into manure, represented something like 1,000 by 150 by 4 = 600,000 starfishes. Suppose them to be the only starfishes caught in Warren river, and to have eaten only one oyster each before their capture, and we have 600,000 mollusks, or about 3,000 bushels, destroyed. But the oystermen say not one in twenty-five fingers gets caught, and that 50,000 bushels would come nearer to each season's loss of young and old oysters.

It is in the latter part of the summer and in the autumn that the starfish pest occurs in its greatest violence along the Rhode Island and Connecticut coasts. Then they, themselves, are done with their spawning and have renewed their vigor, and the young of all sorts of mollusks, crabs, and other prey abound upon the shores and invite the five-fingers to an easy repast. It is at this season that the sudden appearance of great bodies of starfishes make the heart of the planter sink within him; for he knows that if they once attack a bed of his, they march straight through it, and leave as dead a path as if it had been swept by a fire. It is utterly useless to struggle against them, except by putting on a large force of men and taking up all the oysters on the bed. On more than one occasion steamers have been employed, in order to hasten the work of dredging, at a large expense.

I was told all along the coast, in order to account for the sudden unforeseen appearance of these bodies of starfishes in the midst of an oyster-bed, that they came rolling in from the deep sea in a compact ball, all clinging tightly together. This ball might be a foot in diameter, or as big as a barrel, and was rolled along on the bottom by the tide. When it struck the feeding-ground it went to pieces, and the individual members at once began to devour the oyster next to them, beginning with the tenderest. I discredit the truth of this statement, since I never could find an actual witness of such a phenomenon. The nearest I came to it was this: Captain Eaton, an old oysterman, whom I saw at New Haven, told me that several years ago, when he was with his brother at Norwalk, they raked up one end of a cylindrical roll of starfishes clinging tightly together, which they hauled into their boat until it would contain no more, when they had to break the roll or "string", as he called it, which was a foot or more in diameter. He did not mention anything inside of this cylindrical body, which was solid starfishes and nothing else.

There is no reference in books, that I know of, to anything of this nature, except that Forbes quotes a French writer, Deslonchamps, of 1825, who says that on the French coast, when the tide was out, and while two or three inches of water remained on the sand, "he saw balls of *Asterias rubens*, five or six in a ball, their arms interlacing, rolling out. In the centers of the balls were *Mactræ stultorum* [a kind of large clam] in various states of destruction, but always unable to close the valves, and apparently dead." How much faith is to be put in this account, repeated by many fishermen, and how much of it is pure fable, is hard to say from present data. In general it is known that the starfishes live and breed among the rocks, begin to feed in summer, but do not move about much when once they strike a feeding-ground, and either perish or retreat to deep water when the cold of winter approaches. Mussels are preferred to oysters or clams, though I have heard it asserted that they will even make their way into a quahaug, if hard pressed. The smaller, thin-shelled bivalves fall an easy prey to them. One of these (*Arcavirgata?*) is called the "blood-quahaug" by the rivermen, and when it is present the starfish will take nothing else. One of the tracks saved from the attack which ruined the Great Bed in Providence river, is said to have owed its safety to the abundance of "blood-quahaugs" upon it, which satisfied the starfishes.

The only offsetting value in this plague, that I am aware of, is its usefulness as a manure, for which purpose those taken by the oystermen are saved. They are especially recommended for grape-vines. Large quantities are thus made use of in Great Britain and France.

"Anciently," as I have read, "the *Urasters* were used in medicine. They were given internally as a decoction with wine, in hysterical diseases and against epilepsy. The physicians of old times, members of a profession never very remarkable for logical acumen, applied them externally in hernia, from some fanciful analogy between their pouting stomach and the appearance of the rupture. Any medical man who would wish to revive the practice will find the prescriptions carefully gathered together in Link, who, however, does not appear to have put much faith either in the medical or gastronomical virtues of starfishes; yet, conceiving it necessary to find some use for them, according to the manner of his times, he tells us they are of use to man, not because they serve as food to him themselves, but because they feed the fishes, and the fishes feed him, adding, 'miror hinc et in providentia divina sapientiam.'"

In spite of his belief, however, I do not know any fishes that feed upon the sea-stars, except the cod.

PREVENTION OF STARFISH RAVAGES.—The question following a knowledge of the facts which have been given above, is: What can be done to prevent, or at any rate lessen, the ravages committed by the starfishes upon oyster-cultivation? This is a very hard question to answer. The boundless tracts of the outer sea harbor them beyond any hope of extermination by us, and all operations must apparently be confined to the small localities occupied by the oysters. Here, again, the expense involved in ridding one's property of the pests, makes it a question whether it were not more profitable to let them alone. Possibly this might be the case in individual instances; and probably it has been found so and acted upon almost universally up to the present. The result is a colonization and increase of starfishes which forsake the single localities to which they were once confined and devastate a whole neighborhood. Every man now suffers through his neighbor's neglect as well as his own.

At Norwalk, Connecticut, the starfishes are probably now more injurious than at any other place on the coast, and I paid much attention to the matter there. The result of my inquiries seemed to show, that one man, in a sloop, devoting his whole time to it, could keep ten acres of oyster-ground clean of starfishes by dredging them off.

He would continually sail back and forth, round and round over the ground, and catch the ugly visitors as fast as they came. There are in Norwalk harbor about 700 acres of cultivated bottom. This would need the persistent services of 70 men, therefore, at a total annual expense of not less than $50,000. In lieu of this, the oystermen who own contiguous beds, should combine during the summer to dredge the starfishes all off a certain district, and divide the expense or labor equally among them all. Such combined and persistent work, when the plague first appears, will certainly clear them off; and when once they are got rid of, they will not be again troublesome until the following season, and then in less numbers. There is no more reason why the starfishes cannot be so reduced in Long Island sound, that they shall not be harmful to the oyster-beds, than there is why the Canada thistle cannot be kept down in the three shore counties of Connecticut. It is merely a question of steady labor. But this labor must be unselfish. I heard it whispered, that certain oystermen would keep very quiet so long as no sea-stars were on their own acre or two, rejoicing slyly in the losses their rivals in business were sustaining. So short-sighted and unmanly a policy as this must be abandoned.

It was also suggested to me, and I advised with many planters in Connecticut and New York on the matter, that a bounty might profitably be paid for the destruction of starfishes. The question was: Who shall pay this bounty?

It was thought by many that the general government should do it, but I consider this obviously a mistake. Another opinion was, that the state should do so; but only a portion of the state is interested, and much opposition would no doubt be manifested by the inhabitants inland. The same would, perhaps, be true of the shore counties if they attempted the scheme, though to a less extent. It seems, then, that the proper source to look to for appropriations for such an object, are the townships along the shore in whose waters the oystermen rent their ground and plant. This confines the expense to the district benefited, and, by making one officer in each town an inspector of the claims and the only authorized paymaster, restricts the possibilities of fraud.

The next question is: How much shall the bounty be? This ought to vary somewhat in different localities, according to scarcity, value of interests risked, etc. In general it was thought that the claim ought to be based upon count rather than measure, and that in western Connecticut from 5 to 10 cents a hundred would be large enough to encourage constant effort to collect them, and not too large to prove a profitable investment in the amount saved. I suppose that the town authorities could redeem a considerable percentage of their outlay, by selling the starfishes collected to farmers for manure, or to factories to be made into fertilizers.

I am not aware that any steps have been taken by any of the towns to set a bounty upon the capture of this plague; but if combined action were taken, I feel sure it would be wise, and the results conspicuously beneficial to the whole oyster-interest. If the towns will do nothing of the sort, an association of oystermen, at such crowded producing-points as City Island, Stamford, Rowayton, South Norwalk, New Haven, and Providence would no doubt find it profitable.

Some years ago a trial was made in Narraganset bay of a trawl, made after the pattern introduced about 1872 by the United States Fish Commission. The Fish Commissioners of Rhode Island, in company with a firm of oyster-planters at Providence, went down the bay, and swept one of the oyster-beds with the improved trawl, hauled by a steam-tug. "On hauling it up, in a few minutes they counted nearly two hundred starfish, large and small, which were snared and caught at this first haul. A second haul brought up still more." If this report is correct, it is strange that so effective an instrument was abandoned. A still more useful appliance is the "tangles", made of rope-yarn and shaped like a mop or a deck-swab. This being drawn over the bottom, the starfish are entangled in its film. The "tangles" are constantly used in the natural history work of the United States Fish Commission. Tens of thousands of starfish are sometimes brought up at one haul.

THE DRILL.—A small but numerous and persistent enemy of the oyster, is the "drill" or "borer". Under this name is included, however, a numerous class of univalve mollusks, which are carnivorous in their tastes, and armed with a tongue-ribbon, so shaped and so well supplied with flinty teeth, that by means of it they can file a round hole through an oyster's shell. The mode in which it is done has been clearly described by the Rev. Samuel Lockwood, as follows:

> The tongue is set with three rows of teeth like a file; it is, in fact, a tongue-file, or dental band, and is called by conchologists the lingual ribbon. * * * Having with the utmost care witnessed a number of times the creature in the burglarious act, I give the following as my view of the case: With its fleshy disk, called the foot, it secures by adhesion a firm hold on the upper part of the oyster's shell. The dental ribbon is next brought to a curve, and one point of this curve, on its convex side, is brought to bear directly on the desired spot. At this point the teeth are set perpendicularly, and the curve, resting at this point as on a drill, is made to rotate one circle, or nearly so, when the rotation is reversed; and so the movements are alternated, until, after long and patient labor, a perforation is accomplished. This alternating movement, I think, must act favorably on the teeth, tending to keep them sharp. To understand the precise movement, let the reader crook his forefinger, and, inserting the knuckle in the palm of the opposite hand, give to it, by the action of the wrist, the sort of rotation described. The hole thus effected by the drill is hardly so much as a line in diameter. It is very neatly countersunk. The hole finished, the little burglar inserts its siphon or sucking-tube, and thus feeds upon the occupant of the house into which it has effected a forced entrance. To a mechanic's eye there is something positively beautiful in the symmetry of the bore thus effected—it is so "true"; he could not do it better himself, even with his superior tools and intelligence.

These small "snails", "drills", "borers", and "snail-bores", as they are variously called, belong to several species of *Natica*, *Purpura*, *Anachis*, *Astyris*, *Tritia*, *Ilyanassa*, etc.; but the master and most destructive, as well as most abundant of them all, is the *Urosalpinx cinerea* of Stimpson. It is this which is the common "drill" of the oyster-beds; and it is its eggs, laid in small vase-shaped capsules, which are often found attached in groups to the under surfaces of stones. Several of the small mollusks mentioned above lay eggs in this way, but the drill's capsules have very short stalks, or are almost sessile, and are compressed with an ovate outline, while angular ridges pass down their sides. The natural home of the drill is the tide-pools and weedy borders of rocky shallows, where barnacles, hydroids, anemones, rock-loving limpets, and other associated forms that find shelter among the algæ, afford it abundant food. Though this is precisely where the mussels grow till the rocks are almost black with them, it is said that they are never attacked by the drills.

The *Urosalpinx* sometimes stray to the oyster-beds, but is usually carried there with the seed-supplies, and finding plenty of nourishment live and increase. Though its multiplication is not very rapid, it is fast enough to make it a very serious obstacle to success, in the course of a few years. In nearly every case, I was told that formerly there were no drills, but now the oyster-beds were overrun. This was reported in particular of the Great South bay of Long Island and at Keyport, New Jersey. I heard less of its ravages in New Jersey, except in the Delaware; but in Chesapeake bay nearly every dredge-haul in any part of Maryland or Virginia waters, brings up; the Potomac seems to be the district least infested. Of course, in such natural haunts as the rocky shores of Buzzard's bay and Connecticut, would be present if there were no oysters, and are all the harder to dislodge.

Once having attacked an oyster-bed, they work with rapidity; and seem to make sudden and combined attacks at considerable intervals. Their disappearance from certain restricted localities, too, for a long time, is unexplained.

What is the best way to combat them, or whether there is any hope of ridding the beds of them, are questions often discussed by oyster-culturists. It is certain that a great deal of trouble might be avoided, if care were exercised in culling seed, to throw out—not into the water, but on the ground or deck—all the drills, instead of carrying them to one's beds, deliberately planting them, and then grumbling at destruction which previous care would have avoided. It would cost less, in point of mere labor, no doubt, to prevent this plague than to cure it when it becomes no longer endurable. Some planters clean up pieces of bottom very thoroughly before planting, in order to get all this sort of vermin out of their way, as well as to stir up the mud and fit it for the reception of spat. It is on hard bottom that drills are especially troublesome, and here some planters go over the ground with a fine-meshed dredge in order to get them up, but they fail to catch all. This is done at Norwalk, Connnecticut, I know, and the men who have steamers, find in the celerity with which they are able to accomplish this sort of work, a great argument against any restriction to exclusively sailing-rig.

The drill can be exterminated to a great extent, also, by diligently destroying its eggs. Small boys might well be paid to search for them and destroy them, among the weedy rocks by the shore, at low tide. A gentleman at Sayville, Long Island, assured me that in those years when large eels were plentiful, the drills were kept down because the eels fed on their eggs. This gentleman said, that in the Great South bay the drills were nearly conquering the planters; and he advised the removal of all shells from the bottom of the bay, in order that the drills might have nothing left on which to place their eggs. This might do there, where there are no rocks along the shore and the drill is not native; but I doubt whether so sweeping a measure of protection could ever be carried out.

On the Pacific coast *Gastrochæna*, and various pholadiform mollusks are a great bane to the oyster-beds, but they penetrate by digging burrows wherein their whole shell is lodged. Large numbers of these, with the help of boring-worms and sponges, may so riddle a reef as to cause its entire disintegration.

THE WINKLE.—Destructive pests on the oyster-beds are, also, found in the two large, spiral mollusks, *Sycotypus canaliculatus* and *Fulgur carica*, which along the coast are confounded under the names "periwinkle", "winkle", "wrinkle" (New England), and "conch" (southern), with occasionally a distinguishing prefix. Various other large shells also come under these generally applied names; and in the Gulf of Mexico we have, additionally, the "king conch", "queen conch", and "horse conch", all of which are edible.

The *Sycotypus* is more common north of New York—though it does not exist at all beyond Cape Cod—while along the coast of New Jersey and southward it is the *Fulgur* which is chargeable with nearly all mischief perpetrated, since the other species is rarely seen. Occasionally, as Verrill mentions, specimens of both may be found crawling on sandy flats or in the tide-pools, especially during the spawning-season, but they do not ordinarily live in such situations, but in deeper water and on harder bottoms off shore. It is needless to say that they do not burrow at all, though they are able to insert the posterior part of the foot into the sand sufficiently to afford them a strong anchorage against currents. A very soft or a very rocky bottom they equally avoid.

The curious egg-cases of these mollusks, to which the names "sea-ruffle" and "sea-necklace" are often given by fishermen, always attract the attention of visitors to the seaside, who find them cast upon the beaches; and we can well echo the pious exclamation of the old historian of Martha's Vineyard, "the Author of nature makes a wonderful and copious provision for the propagation of this worm".

As shown in the figure, the eggs are discharged in a series of disk-shaped, subcircular, or reniform, yellowish capsules, parchment-like in texture, united by one edge to a stout stem of the same kind of material, often a foot and a half or two feet in length. "The largest capsules, about an inch in diameter, are in the middle, the size decreasing toward each end. On the outer border is a small circular or oval spot, of thinner material, which the young ones break through when they are ready to leave the capsules, each of which, when perfect, contains twenty to thirty or more eggs or young shells, according to the season." Verrill adds interesting particulars as follows:

Dr. Elliott Coues, who has observed *Fulgur carica* forming its cases at Fort Macon, North Carolina, states that the females bury themselves a few inches below the surface of the sand on the flats that are uncovered at low-water, and remain stationary during the process. The string of capsules is gradually thrust upward as fast as formed, and finally protrudes from the surface of the sand, and, when completed, lies exposed on its surface. The string begins as a simple shred, two or three inches long, without well-formed cases; the first cases are small and imperfect in shape, but they rapidly increase in size and soon become perfect, the largest being in the middle; the series ends more abruptly than it begun, with a few smaller and less perfect capsules. The number of capsules varies considerably, but there are usually seventy-five to one hundred or more. At Fort Macon Dr. Coues observed this species spawning in May, but at New Haven they spawn as early as March and April. It is probable that the period of spawning extends over several months. Mr. Sanderson Smith thinks that they also spawn in autumn on Long Island. It is not known how long a time each female requires for the formation of her string of capsules. There are two forms of these capsules, about equally abundant in this region. In one the sides of the capsules are nearly smooth, but the edge is thick or truncate along most of the circumference, and crossed by numerous sharp transverse ridges or partitions, dividing it into facets. Dr. Coues states that these belong to *Fulgur carica*. An examination of the young shells, ready to leave the capsules, confirms this. The other kind has larger and thinner capsules, with a thin, sharp outer edge, while the sides have radiating ridges or raised lines. Sometimes the sides are unlike, one being smooth and more or less concave, the other convex and crossed by ten or twelve radiating, elevated ridges, extending to the edge. This kind was attributed to *Fulgur carica* by Dr. G. H. Perkins, and formerly by Mr. Sanderson Smith, but a more careful examination of the young shells, within the capsules, shows that they belong to *Sycotypus canaliculata*.

Eggs so exposed are subject to numberless accidents, being drifted ashore, ground to pieces by storms, and no doubt eaten by bottom-feeding fishes, so that only a few eggs out of the hundreds in each "necklace" are ever born, or, accomplishing that, are able to survive the perils of unprotected youth and grow to adult age and strength. Having once done so, however, this mollusk probably lives to a very great age.

An examination of the plate, or, better, of a specimen, will show that in both species the muscular part is large and strong and the mouth powerful. The food of the conch being mainly the flesh of other mollusks, its method of killing them is one of brute strength, since it is unprovided with the silicious, file-like tongue, by means of which the small "drills" set at naught the shelly armor of their victims. The conch is a greater savage than this. Seizing upon the unfortunate oyster, unable to run away, he envelops his shell in the concave under-surface of his foot, and, by just such a muscular action as you would employ in grasping an object in the palm of your fist, crushes the shell into fragments and feasts at leisure on the flesh thus exposed. Where oysters or other prey are abundant, this operation is quickly repeated and vastly destructive. One planter in the upper part of Buzzard's bay, where this pest is very troublesome, told me that one winkle was capable of killing a bushel of oysters in a single hour. They do not confine themselves to oysters altogether, of course; any mollusks or other marine animal, sluggish and weak enough to be caught and broken up, suffering from their predacity. I was told in New Jersey, by an intelligent man, that the conch would even draw the razor-shell out of his burrow and devour it. If this be true, no doubt the soft clam also falls a victim to the same marauder. The quahaug is generally safe in his massive shells.

The oyster-beds most subject to attack and harm by the winkles and conchs, are those planted in water which is quite salt, as is the practice in New England and Long Island sound. The beds of the Great South bay, Staten Island, and the southern Jersey coast, are well protected by the outer beaches from the sea, and to these barriers owe their immunity from the *Fulgur*, while the *Sycotypus*, though present inside the beaches, seems to do small damage. Oystermen will tell you, also, that beds which are disturbed from time to time by the planter, will suffer more harm than neglected beds, especially in summer. Of course, the report is to be expected, that where planting has gone on for many years, there these predatory mollusks have visibly increased in numbers.

In regard to ridding our beds of this pest, I can only advise, as heretofore, that every effort be made to destroy every specimen taken and every "necklace" of eggs which can be got hold of. The trawl, tangles, etc., recommended for the suppression of starfishes, would take up these eggs at the same time, and thus increase their efficiency. Persistent fighting is the only resource against this enemy.

Some points of minor interest may be mentioned before leaving this subject. Both of these shells were used by the Indians of the coast ceremonially, and as material for the making of white wampum, their money of inferior value, which consisted of bead-shaped sections of the central column of the shell. From them, also, were fashioned sundry articles of service and ornament, such as trowels, spoons, and dippers; they are sometimes even yet called "ladle shells". The Indians ate the animals, too, when hard-pressed for food, and have been followed in this practice by the whites, to some extent. De Voe says they used sometimes to be sent into Catherine market, New York, from Long Island, and found sale; "but," he adds, "they are not generally relished, being somewhat strong flavored. They are mostly used by the poor who live near the coast." Several foreign mollusks, not greatly different, are eaten—generally being boiled—and perhaps proper cooking would make these conchs more palatable than they have hitherto proved.

THE DRUM.—Perhaps as destructive an agent as the conchs and winkles, is the fish known as the drumfish, (*Pogonias cromis*, Linn.); for, although this plague is not steadily present, when it does occur the devastation is enormous. "Let us make a visit," says that brightest of American writers on animals and out-of-door matters, "to one of these orderly communities in Oysterdom known as a 'planting-ground'. We are seated in a boat, and, gliding through the phosphorescent sheen, soon near the oyster-bed. It is a moonlight night, about the close of summer. Hark! what singular sound is that? Boom! boom! boom! Almost sepulchral, and, strange to say, it comes up from beneath the waters. One would think they were Nereids' groans. The oystermen, whose capital lies invested there, hear it with sad forebodings of loss, which they cannot well sustain. It is one of a school of visitors who come with marauding purpose. The fishermen call it the big drum. This drumfish is known among naturalists by the name *Pogonias chromis.* The acknowledged beat of this scamp is the Gulf Stream, from Cape Cod to Florida; and a terrible fellow is this Pogonias, for he is recorded as having attained the great weight of eighty pounds. One of twenty-five pounds would be but an ordinary affair. Their mouths are furnished with pavements of hard teeth, a little rounding on the top, and set together exactly as are the cobble-stones of the old city highways. The function of these dental pavements is to crunch the young oysters, which, after being crushed, are thus swallowed, shells and all."

The great schools in which these fish go are illustrated by the following records:

On Monday last John Earle and sons caught, with a seine, at one draught, in Bristol ferry, 719 drumfish, weighing upward of 50 pounds each. Niles' *Weekly Register*, July, 1833, also says: "Some days ago a haul was made in Great Egg Harbor bay, near Bearsley's point, cape May, at which 218 drumfish were caught, their entire weight being from 8,000 to 9,000 pounds. This is said to be the largest haul of that description of fish ever made in that bay."

Another still larger, noticed as a great haul of drumfish: "On Wednesday, June 5, 1804," says the postmaster of Oyster Ponds, Long Island, "one seine drew on shore at this place at a single haul 12,250 fish, the average weight of which was found to be 33 pounds, making in the aggregate 202 tons, 250 pounds. This undoubtedly is the greatest haul of this kind ever known in this country. A hundred witnesses are ready to attest the truth of the above statement. They are used for manure."

Knowing the carnivorous propensity of the fish, one can easily imagine how an inroad of such a host must affect an oyster-ground. They do not seem to make any trouble, however, north of New York city, and rarely along the south side of Long Island. At Staten Island and Keyport they come in every few years and devastate thousands of dollars' worth of property. Such a memorable visitation happened about 1850, in July. The following summer the planters in Prince's bay, fearing a repetition of the onslaught, anchored shingles and pieces of waste tin on their beds, scattering them at short intervals, in the hope that their dancing, glittering surfaces might act as "scare-crows" to frighten the fish away. Whether as an effect of this, or because of a general absence, no more drums appeared. In New York bay, off Caven point, where the old "Black Tom reef" is now converted into an island, one planter of Keyport lost his whole summer's work—material and labor—in a single September week, through an attack by drums. A City Island planter reported to me a loss of $10,000 in one season a few years ago; but the East river is about the northern limit of the drums, at least as a nuisance to oyster-culture, so far as I can learn. The vexation of it is, too, that the drum does not seem to eat half of what he destroys; but, on the contrary, a great school of them will go over a bed, wantonly crushing hundreds of oysters and dropping them untasted, but in fragments, on the bottom.

In return, the drum is himself an edible fish, but of rather poor quality, and only seen in market between July and October. There is a tradition that there were only ten species of fish known to the Dutch when they discovered America. When they caught the shad they named it *elft* (eleventh); the bass *twalft* (twelfth); and the drum, *dertienen* (thirteenth). Our name, however, owes its origin to the strange, hollow, roaring noise the fish makes in the water, like the roll of a muffled drum.

When drums are absent, various other carnivorous fishes prey upon oysters, such as the tautog, sheepshead, toad-fish, members of the cod family (if any of them ever get near a bed, which is rarely at present), and the skates or rays. Of all these the sting-ray or "stingaree" of the fishermen (including several sorts of *Dybastes*) is the chief. He is always present and steadily at work along the whole coast. Lying flat on the bottom, he works his triangular flippers until he has washed away the sand from about the oyster he wishes to seize, if it is at all concealed, and then crushes it between his powerful jaws. Even clams do not escape his sagacity in capture and strength of mastication, but are devoured in great numbers. A dredge can hardly be hauled from New Jersey to Cape Cod, without bringing one or more of these enemies of the hard-working oysterman.

MINOR ENEMIES.—Beside these foes, many minor "vermin" must be contended with. The oyster-catcher, and other birds, steal not a few at low tide. Barnacles, annelids, and masses of hydroid-growth sometimes form about the shells, and intercept the nutriment of the mollusk, until he is nearly or quite starved; this is particularly true in southern waters. At Staten Island the planters are always apprehensive of trouble from the colonization of mussels on their oyster-beds. The mussels having established themselves grow rapidly, knit the oysters together by their tough threads, making culling very difficult, and take much of the food which otherwise would help fatten the more valuable shellfish. In the Delaware bay the spawn of squids, in the shape of clusters of egg-cases, appropriately called "sea-grapes", often grows on the oysters so thickly, during the inaction of summer, that when the fall winds come, or the beds are disturbed by a dredge, great quantities of oysters rise to the surface, buoyed up by the light parasitic "grapes", and are floated away. This is a very curious danger. Lastly, certain crabs are to be feared—chiefly the *Callinectes hastatus*, our common "soft crab", and the *Cancer irroratus*. Probably the latter is the more hurtful of the two. I have heard more complaint on this score at the western end of the Great South bay, Long Island, than anywhere else. Mr. Edward Udall told me that the crab was the greatest of all enemies to oysters on the Oak Island beds. They eat the small oysters, up to the size of a quarter dollar, chewing them all to bits. These are on the artificial beds, for they do not seem to trouble the natural growth. But attracted by broken oysters, when the planter is working, they come in crowds to that point. Mr. Udall stated that once he put down 500 bushels of seed brought from Brookhaven, and that it was utterly destroyed by these crabs within a week, and while he was still planting. He could see the crabs, and they numbered one to every fifty oysters. It is well known that in Europe the crabs are very destructive to planted beds, and it is quite possible that many mysterious losses may be charged to these rapacious and insidious robbers. By the way, Aldrovandus, and other of the naturalists of the Middle Ages, entertained a singular notion relative to the crab and the oyster. They state that the crab, in order to obtain the animal of the oyster, without danger to their own claws, watch their opportunity when the shell is open to advance without noise and cast a pebble between their shells, to prevent their closing, and then extract the animal in safety. "What craft!" exclaims the credulous author, "in animals that are destitute of reason and voice."

THE OYSTER-CRABS.—In respect to the little crab, which becomes red in the cooked oyster, but is greenish-brown in life, opinion is divided as to whether its presence is of any harm to the oyster whose shells give it shelter; but the probability is that it is not. Its scientific name is *Pinnotheres ostreum*, and its history briefly as follows, so far as concerns the present inquiry:

The little red oyster-crab seems to be a parasite. He slips in and out of the oyster almost at pleasure, and enjoys a portion of all the good things the oyster feeds upon. We are told that a careful examination shows that they are almost invariably females and full of eggs. The males are so exceedingly rare that it is a matter of astonishment how the propagation of the species is effected and maintained. These crabs were regarded as luxuries by George Washington.

THE OYSTER-CRAB AS MESSMATE AND PURVEYOR.—It is many years, writes Mr. John A. Ryder, since Mr. Say named the little oyster-crab of our coasts *Pinnotheres ostreum*, and its habits in relation to the oyster seem to have excited but little interest, especially in foreign waters. Professor Verrill, in his report to the United States Fish Commission, observes that it is the female which lives in the oyster, and that the male, which is smaller and quite unlike the female, is rarely if ever seen to occur, but that it has been seen by him swimming at the surface of the water in the middle of Vineyard Sound. His statement that it occurs wherever oysters occur, I cannot agree with, since out of many hundreds of St. Jerome oysters which I saw opened, I never saw a specimen of *Pinnotheres;* they may occur, but rarely. This little crab has quite a number of allies which inhabit various living mollusks, holothurians, etc., of which admirable accounts are given by Van Beneden, in his work on animal parasites and messmates.

There can be no doubt that the oyster-crab is a true messmate, and it is highly probable that the presence of these animals in the oyster is rather to be regarded as advantageous than otherwise. The animal lives in the gill cavity of the oyster, and, as will be seen from the following observations, may be the means of indirectly supplying its host with a part of its food. During a reconnoitering trip down the Chesapeake on the yacht Lookout, in the first week of July last, in dredging, some oysters were hauled up which contained *Pinnotheres.* In the case which I am about to describe, the included crab was a female, with the curiously expanded abdomen folded forward under the thorax and partially covering a huge mass of brownish eggs. Upon examining these eggs, what was my astonishment to find that they afforded attachment to a great number of compound colonies of the singular bell animalcule, *Zoöthamnium arbusculum.* Upon further examination, it was found that the legs and back of the animal also afforded points of attachment for similar colonies, and that here and there, where some of the individuals of a colony of *Zoöthamnium* had been separated from their stalks, numerous minute rod-like vibriones had affixed themselves by one end. In this way it happens that there is a quadruple commensalism established, since we have the vibriones fixed and probably nourished from the stalks of the *Zoöthamnium*, while the latter is benefited by the stream of water drawn in by the cilia of the oyster, and the last feeds itself and its protégé, the crab, from the same food-bearing current. Possibly the crab inside the shell catches and swallows food which, in its entire state, could not be taken by the oyster, but in any event the small crumbs which would fall from the mouth and claws of the crab would be carried to the mouth of the oyster, so that nothing is wasted. We must consider the crab, with its forest of bell animalcules, in still another light. Since the animalcules are well fed in their strange position, it is but natural to suppose that they would propagate rapidly. They multiply in two ways, viz, by dividing both lengthwise and crosswise, one-half of the product being set free, and known swarmers. These cast-off germs of the animalcule colonies are no doubt hurried along in the vortex created by the cilia of the gills and palps, carried to the mouth and swallowed as part of the daily allowance of the food of the oyster. We are accordingly obliged to look upon the *Pinnotheres* in this case as a veritable nursery, upon whose body animalcules are continually propagated and set free as part of the food-supply of the oyster, acting as host to the crab. I do not suppose, however, that such a condition will always be found to obtain, and it must also be remembered that myriads of *Zoöthamnium* colonies were dredged up on algæ from the bottom in the immediate vicinity. Such an abundance of germs in the water would favor their being readily transplanted or fixed to the body of the oyster-crab.*

*Report of T. B. Ferguson, a fish commissioner of Maryland, for 1881, pp. 24, 25

62. FATALITIES TO WHICH OYSTERS ARE SUBJECT.

SEDIMENT.—In addition to the active, animate enemies of the oyster, the beds suffer seriously, at certain times, from the elements, as has been pointed out frequently in the preceding pages. Great storms will sweep the oysters all off the beds, bury them under shifting sand or mud, or heap upon them the drifting wrack torn from the shores. Beds which lie at the mouths of rivers are liable to be injured by floods also, which keep the water wholly fresh, or bring down enormous quantities of silt and floating matter, which settles on the beds and smothers the oysters.

A few years ago a large tract of peat was drained at Grangemouth, Scotland. The loose mud and moss was carried down the drains upon an oyster-bed in the estuary; the consequence was that the oysters were covered over with mud, and entirely destroyed. Nothing is so fatal to oysters as a mud storm, except it be a sand storm. The mud and the sand accumulate in the oyster's delicate breathing organs, and suffocate him.

Mr. John A. Ryder, already quoted in the previous paragraphs, writes as follows about mud, as injurious to oysters:

"The origin of the black ooze at the bottom can be traced directly to the sediment held in suspension in the water, which slowly ebbs and flows in and out of the inclosure, carrying with it in its going and coming a great deal of light organic and inorganic *débris*, the former part of which is mainly derived from the comminuted fragments of plants growing in the creek. This seemed to be the true history indicated by what was noticed in studying the box-collector. The same opinion is held as to the origin of this mud by both Coste and Fraiche in their works on oyster-culture.

"There is probably no worse enemy of the oyster-culturist than this very mud or sediment. It accumulates on the bottom of the oyster-grounds, where, in course of time, it may become deep enough to cause serious trouble. Especially is this true of ponds from which the sea ebbs, and to which it flows through a narrow channel. The falling leaves from neighboring trees in autumn also contribute to this pollution, as well as heavy rains which wash deleterious materials into it.

"Adult oysters which are immersed in part in this mud struggle hard to shut it out from their shells. If one will notice the inside of the shells of oysters which have grown in a muddy bottom, it will often be seen that there are blister-like cavities around the edges of the valves filled with mud, or a black material of a similar character. There is not the slightest doubt in my mind, that in these cases the animal, in order to keep out the intruding mud has had recourse to the only available means at its command. A great many of the oysters in the pond are affected in this manner, but it is extremely uncommon to find shells of this kind in opening oysters coming from a hard bottom. It is easy to understand that such efforts at keeping out the mud from the shell will not only waste the life-forces of the animal, but also tend to greatly interfere with its growth. The importance, therefore, of artificial preparation is apparent, where it is desirable to establish ponds for the successful culture of this mollusk.

"Only in one case have I observed that the mud tended to impair the flavor and color of the oyster. In this instance the animal was thoroughly saturated with the black ooze, the very tissues seeming to be impregnated with the color, the stomach and intestine loaded to engorgement with the mud, the animal manifesting every sign of being in a decidedly sickened condition. The cause of this was probably that the shell, with its tenant, had sunken too deeply into the mud when the ingestion of the black ooze commenced, giving rise to the remarkable changes which I have recorded. No doubt had this condition of things for any length of time, the animal would have been smothered by the mud." *

MUD AND THE YOUNG FRY.—"The accumulation of the slightest quantity of sediment around a young oyster would tend to impede its respiration, and in that way destroy it, yet in the natural beds there are so few naturally clean places which remain so, that it is really surprising that so many young oysters pass safely through the critical periods of their lives without succumbing to the smothering effects of mud and sediment. When it is borne in mind, that at the time the infant oyster settles down and fixes itself once and for all time to one place, from which it has no power to move itself, it measures at the utmost one-eightieth of an inch, it will not be hard to understand how easily the little creature can be smothered, even by a very small pinch of dirt. The animal, small as it is, must already begin to breathe just in the same way as its parents did before it. Like them its gills soon grow as little filaments covered with cilia, which cause a tiny current of water to pass in and out of the shell. The reader's imagination may be here allowed to estimate the feeble strength of that little current, which is of such vital importance to the tiny oyster, and the ease with which it may be stopped by a very slight accumulation of dirt. Möbius estimates that each oyster which is born has $\frac{1}{1,145,000}$ of a chance to survive and reach adult age. So numerous and effective are the adverse conditions which surround the millions of eggs matured by a single female, that only the most trifling fraction ever develop, as illustrated by the above circulation. The egg of the oyster being exceedingly small and heavier than water, immediately falls to the bottom upon being set free by the parent. Should the bottom be oozy or composed of sediment, its chances of development are meager indeed. Irrecoverably buried, the eggs do not, in all probability, have the chance to begin to develop at all. The chances of impregnation are also reduced, because the male and

* John A. Ryder in report of T. B. Ferguson, a fish commissioner of Maryland, for 1881, pp. 48, 49.

female oysters empty their generative products directly into the surrounding water, whereby the likelihood of the eggs meeting with the male cells becomes diminished. What with falling into the mud and what with a lessened chance of becoming impregnated, it is not unlikely that Möbius' estimate is very nearly correct; but the American oyster, whose yield of eggs is much greater, not only on account of its larger size, but also because the eggs are smaller than those of the European, has probably still fewer chances of survival.* The vigorous growth of small organisms on surfaces fitted for the attachment of young oysters also tends to cause sediment to gather in such places in the interstices of the little organic forest, where the eggs of the oyster no doubt often become entombed or smothered by the crowded growth surrounding them."†

INTERFERENCE OF OTHER ANIMAL LIFE.—"We have called attention," continues Mr. Ryder, "to the probable interference of small organic growths to the fixation of the young fry; in practice it is found that the larger organic growths which establish themselves on the collectors also become injurious. The two most conspicuous types are the sessile ascidians or tunicates and the barnacles. I have frequently found fully one-half of the surface of a slate covered with a dense colony of ascidians; in this condition a great percentage of available surface is lost which ought to serve for the attachment of spat. The surfaces so occupied would also be comparatively clean were it not for these organisms, which actually become a serious annoyance. They, like the oyster, affix themselves to the slates while still in the free swimming larval stage, since the surfaces designed for the oyster are equally well adapted to them. The barnacles, which also affix themselves in great numbers, become a nuisance for the same reason. The larval barnacle is an extremely active little creature, and dashes about in the water with great rapidity. As soon as it has completed this stage of its growth, it betakes itself to some object, to the surface of which it attaches itself by the head end, when a singular change takes place, at the end of which it is found that it has begun the construction of the curious conical shell which it inhabits. They grow very rapidly, so that in a couple of months the shell will already measure over half an inch in diameter. In this way farther inroads are made upon the room which should be taken up by oysters.

"Of course the larger types are not alone in taking up space, since infusoria, bryozoa, polyps, etc., are also culpable, as well as algæ, such as diatoms and the higher forms. The only remedy for this accumulation of animal growths on the surfaces of the slates and other collecting apparatus, will be to have the frames which hold the slate in position so arranged that each tile, shingle, or slate can be removed, in order that it may be readily overhauled and these organisms removed from the surfaces which it is desired shall remain clean This work would have to be done at intervals of every two or three weeks, and should be conducted with great care, so as not to remove the oysters which have affixed themselves along with the other things which it is the intention to destroy. The removal of the smaller forms from the surfaces of the slate would be more difficult, and attended with danger to the fry already attached. With this object in view, I would suggest the use of wooden racks or frames lying horizontally, which would receive the slates into deep notches made with a saw, so as to hold them vertically or edgewise, rendering their removal, for the purposes of cleansing, and their replacement, an easy matter. Other devices would no doubt answer the same purpose, and be more convenient even than the last. If posts were securely fixed in the bottom eight or ten feet apart, so as to project a foot or so above the water at the highest tide, a single board six inches wide, nailed against the tops of the posts edgewise, and extending from one to the other, would provide a simple arrangement from which to hang the slates singly, by means of galvanized wire fastened or hooked to nails partly driven into the board. By the help of this plan one man with a boat could overhaul many hundreds of slates in a single day, and effectually care for them for a whole season. This last contrivance would not answer well, perhaps, where there was a swift current, but would be a most admirable arrangement in still ponds or "claires". In such places the whole area might be provided with posts grouped or placed in rows, so that when the attendant was at work he could pass in order from one row to the other in a narrow boat, or two attendants in one boat could take care of two rows, the ones on either hand, at the same time."‡

FOOD OF THE OYSTER.—"The food of this mollusk, as is well known, consists entirely of microscopic beings and fragments of organic matter, which are carried by currents from the palps and gills, which have been already described, to the large mouth of the animal at the hinge-end of the shell. The inside of the gullet and stomach, like some other parts of the body, are covered with cilia, so that food once fairly in the mouth will be carried by their action down to the cavity of the stomach, where it is carried into the folds and deep pouches in its walls, and even into the openings of the bile ducts, to undergo digestion or solution, so as to be fitted in its passage through the intestine, to be taken into the circulation, and finally disposed of in building up the structures of the body.

"Along with the food which is taken, a very large amount of indigestible dirt, or inorganic matter, is carried in, which in a great measure fills up the intestine, together with the refuse or waste from the body. This material, when examined, reveals the fact that the oyster subsists largely on diatoms, a low type of moving plants which swim about in the water, incased in minute sandstone cases, or boxes, of the most delicate beauty of workmanship.

* According to estimates which I have made, based on the figures of the eggs of *Ostrea edulis*, given by M. Davaine, they are $\frac{1}{130}$ of an inch in diameter. Estimates based on the figures of Lacaze Duthiers give $\frac{1}{270}$ of an inch, while Möbius estimates the size of the young fry at $\frac{1}{150}$ of an inch.

† Op. cit., pp. 49-50.

‡ Op. cit., pp. 50, 51, 52.

These, when found in the intestine, have usually had their living contents dissolved out by the action of the digestive juices of the stomach. I have found in our own species of oyster, the shells of three different genera of diatoms, viz, *Campylodiscus*, *Coscinodiscus*, *and Navicula*. The first is a singularly bent form; the second is discoidal; and the last boat-shaped, and all are beautifully marked. Of these three types, I saw a number of species, especially of the latter, but as I was not an authority upon the systematic history of any of them, I had to neglect the determination of the species. No doubt many more forms are taken as food by the oyster, since I saw other forms in which the living matter inside the silicious cases was brown, the same as in most of the preceding forms, which I have indicated. Some of these brown forms were so plentiful as to color a considerable surface whereon they grew of the same tint as themselves. But in no instance have I found any indications of the animal of the oyster becoming colored by feeding on these diatoms, as it is said the European oyster does when feeding on *Navicula ostrearia*, which is green, imparting its own green color to the fluids, and thus to the tissues of such oysters as may be so situated as to readily feed upon it. A recent writer* gives an account of some experiments made by M. Puysegur, of sissable in artificially producing this green color, from which I quote: "In each plate [filled with water charged with green diatoms], according to its size, we put three to six perfectly white oysters which had never been in the 'clears', and the shells of which had been previously washed and brushed clean. In similar plates, like numbers of the same oysters were laid in ordinary sea-water. Twenty-six hours after the commencement of the experiment the oysters in the water charged with diatoms had all acquired a marked greenish hue; the other oysters remained unaltered. * * * After the oyster had turned green it was laid in ordinary sea-water for a few days, when the greenness disappeared altogether. It reappeared when the oyster was replaced in fresh water containing *Navicula ostrearia*." M. Decaisne, of the *Jardin des Plantes*, Paris, repeated the experiments with the same results.

"Beside the diatoms, the spores of algæ, the larvæ or young of many animals, such as sponges, bryozoa, hydroids, worms, mollusks, many of which are small enough to be taken in by the oyster, though their bodies in most cases being soft and without a skeleton, it is impossible to find any traces, either in the stomach or intestine, of their remains, to indicate that they have formed a part of the bill of fare of the animal. What, however, demonstrates that such small larval organisms do help to feed the oyster, is the fact that at the heads of the small inlets or creeks along the Chesapeake, where the water is but little affected by the tides and is somewhat brackish and inclined to be stagnant, there always appears to be a relatively greater development of a somewhat characteristic surface or shallow water fauna of minute forms.

"In St. Jerome creek the microscopic fauna of its headwaters is entirely different from that of the body of the creek; two minute forms inhabit in vast numbers the former, while I sought in vain for them in the more open and changeable waters of the main body of the inlet, which are brought into active movement twice a day by the action of the tides. One of these forms, an infusorian,† one-twenty-fifth of an inch in length, was found covering every available surface of attachment, so that countless multitudes of the naked young would be swimming about in the water previous to building the curious spiral tubes which they inhabit—admirably fitted in this state as food for the oyster. Beside the type referred to, there were a number of other infusorians, which in their so-called swarming stages of development, the young would become available as oyster-food. Of such types I noticed four different species, either belonging or very nearly related to the genus *Cothurnia;* all of the forms built tubes for themselves. I also noticed several forms of bell animalcules, the swarmers of which would become available as food for the oysters lying in the vicinity.

"The diatoms did not seem to me to be more abundant in the headwaters than in the open creek. There was one moss animal of remarkable character, which I found in the headwaters only. This creature was very abundant, and no doubt its embryos, like those of the infusoria referred to, were available as food.

"Of free-swimming infusorians, I noticed a number of genera; one especially attracted my attention from its snake-like appearance and singularly rapid contortions; it had a tuft of vibrating hairs or cilia at the head end in close relation with the mouth. Another more abundant type was the curious genus *Euplotes*, with a thick shell inclosing the soft protoplasm of the body; the latter was of an oval form, flat beneath and rounded on the back, so that the resemblance, when the large foot-like cilia were in motion, carrying the animal about, was strikingly like a very minute tortoise, the resemblance being heightened when the animal was viewed from the side.

"Rod-like algæ, of minute size, the larvea of crustacæ, especially the vast numbers of extremely small larval copepoda, must enter as a perceptible factor into the food-supply of the oyster.

"There is no doubt but that the comparatively quiescent condition of the headwaters of these inlets and creeks, available as oyster-planting grounds, are more favorable to the propagation of minute life than the open bay or creeks, where the temperature is lower and less constant. Practically, this is found to be true, for oystermen seem to be generally agreed that oysters "fatten" more rapidly, that is, feed more liberally in the headwaters—blind extremities of the creeks—than elsewhere. This notion of the oystermen is in agreement with my own observations during the past year. Oystermen also assert that oysters "fatten" more rapidly in shallow waters than in deep ones, a point upon which I made but few observations; but such as I did make tended to confirm such an opinion.

*The Green Color of Oysters, H. M. C. *In Nature*, vol. xxii, pp. 549–50, 1880. Translated from the Revue Maritime et Coloniale, February, 1880.

†On the occurrence of *Freia producta* (Wright), in the Chesapeake bay.—*American Naturalist,* 1880, pp. 810, 811.

In illustration, I may contrast the condition of the oysters in the pond leased by the commission at St. Jerome and those dredged off Point Lookout, in twenty or thirty feet of water, on the 3d day of October, 1880. The oysters in the pond, by the middle or end of September, were in good condition as to flesh, and marketable, while those from deeper water off Point Lookout, and but little later in the season, were still extremely poor, thin and watery, and utterly unfit for market. These differences in condition, it seems to me, are to be attributed in a great measure to differences of temperature and the abundance of food, but mainly to the latter.*

GROUND-ICE.—North of Long Island an enemy is found, which does not exist in the milder south, in the shape of "ground-ice" or "anchor-frost". It is little understood, though often experienced, and I was able to collect only vague data in regard to it. It appears that in hard winters the bottom of the bays freezes solid in great patches, even at a depth of 15 or 20 feet. The mud freezes so hard that rakes cannot be pressed into it; and if a stronger implement, like a ship's anchor, is able to penetrate it, the crust comes up in great chunks. These frozen patches are sometimes 40 feet square and continue unthawed for long periods. When such "anchor-frost" takes place at an oyster-bed, of course the mollusks are frozen solidly into the mass, and few of them ever survive the treatment. To the Cape Cod planters this is a serious obstacle to success.

* Op. cit., pp. 19–23.