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# NATURAL HISTORY OF ECONOMIC MOLLUSKS

OF THE

# UNITED STATES.

BY

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# CUTTLES, SNAILS, BIVALVES, ETC.

By Ernest Ingersoll.

## 205. THE CUTTLES—CEPHALOPODA.

The mollusks called "Cuttles" or "Cuttle-fishes" bear a very important relation to the fisheries and consequently to the food supply of the United States. It has recently been ascertained that some of these Cuttle-fishes attain huge bulk and corresponding abilities for destruction. The two species of *Architeuthis* (*A. princeps* and *A. Harveyi*), roaming through the North Atlantic and now and then stranded upon the beaches of Newfoundland, have each a total length of from thirty to fifty feet, and a weight of solid flesh amounting to thousands of pounds.

"The Cuttles," says Dr. Philip Carpenter, "have very acute senses. They have an approach to a brain, inclosed in a cartilaginous skull. They can hear sounds, and evidently enjoy the taste of their food. They have a large, fleshy tongue, armed with recurved prickles, like that of the lion. They either crawl on their head tail upwards, or swim, tail foremost, by striking with their arms, or squirt themselves backwards by forcing water forward through their breathing funnels.

"They are ferocious creatures, the tyrants of the lower orders, and do not scruple to attack and devour even fishes. The larger kinds are deservedly dreaded by man. Their weapons consist in their powerful arms, which are abundantly furnished with rows of cup-like suckers, each of which fastens on its prey or its foe like a limpet to the rock. Often these are accompanied with sharp-curved teeth, strong enough to be preserved even in fossil species."

The giant Cuttle-fishes of the north (*Architeuthis*) and the commoner Squids and Calamaries of our Atlantic coast belong to the ten-armed division of the order termed Decapods. The three smaller species ordinarily met with are *Loligo Pealei*, *Loligo Pealei* var. *pallida*, and *Ommastrephes illecebrosus*. On the extreme southern coast they are replaced by an Octopod (*Octopus granulatus*).

Of these four, *Loligo Pealei* is the common Squid of Long Island Sound and southward, and when full grown it is more than a foot in length. The color when living is very changeable, owing to the alternate contractions of the color-vesicles or spots, but red and brown predominate, so as to give a general purplish-brown color. An allied variety or subspecies, named *pallida*, is a "pale, translucent, gelatinous-looking" creature, with few spots on the back and nearly white beneath. Commonly five or six inches long, exclusive of the arms, it frequently grows much larger, and is of broader and stouter proportions than the type-form, from which it is further distinguished by its broader caudal fin and the larger size of its suckers. It belongs especially to the western end of Long Island Sound, "where it is abundant with the schools of menhaden, on which it feeds."

"This species," writes Verrill,[1] "is found along the whole coast from South Carolina to Massachusetts Bay.

"It is the *Common Squid* from Cape Hatteras to Cape Cod. In Long Island Sound and Vineyard Sound it is very abundant, and is taken in large numbers in the fish-pounds and seines, and used to a large extent for bait. It is comparatively scarce, though not rare, north of Cape Cod. The young were trawled by us in many localities in Massachusetts Bay in 1878. Large specimens were taken in the pounds at Provincetown, Massachusetts, August, 1879. It was taken in considerable

[1] Report U. S. Fish Commission, part vii, 1882, p. 355.

quantities, in breeding condition, in the fish-pounds at Cape Ann, near Gloucester, Massachusetts, May, 1880 (var. *borealis*). It has not been observed north of Cape Ann. Its southern limit is not known to me, but it appears to have been found on the coast of South Carolina.

"In depth, it has occurred from low-water mark to fifty fathoms. The eggs[1] have often been taken by us in the trawl, in great abundance, at many localities along the southern shores of New England, in five to twenty-five fathoms.

"It is known to be a very important element in the food supply of the bluefish, tautog, sea-bass, striped bass, weakfish, king-fish, and many other of our larger market fishes.

"In the Gulf of Mexico this species appears to be replaced by another species (*Loligo Gahi* D'Orbigny). Of this we have several specimens, collected on the west coast of Florida, at Egmont Key, near Tampa Bay, by Col. E. Jewett and Mr. W. T. Coons. This species is closely allied to *L. Pealei*, but has a more slender form, with the caudal fin shorter and narrower in proportion to the length of the mantle. The pen has a shorter and broader shaft, and a narrower and more oblong blade, which has parallel, thickened, and darker-colored portions between the midrib and margins. The tentacular suckers have their horny rings more coarsely and equally toothed, there being only a partial alternation of larger and smaller teeth.

"Along our southern coast, from Delaware Bay to Florida, a much shorter and relatively stouter species (*Loligo brevis* Blainv.) occurs, which might be mistaken by a careless observer for the present species. In addition to its shorter body, it has very different large, tentacular suckers, with the teeth on the horny rim coarser and all of similar form and size. Its pen is also shorter and relatively broader, and different in structure."

"I am not aware," he says elsewhere,[2] "that any definite information has hitherto been published as to the rate of growth or length of life of any of our cephalopods. By some writers it has been stated that the Squids are all annual, but this seems to be a mere assumption, without any evidence for its basis. Therefore I have for several years past preserved large numbers of specimens of the young of *Loligo Pealei*, collected at different seasons and localities, in order to ascertain, if possible, the rate of growth and the size acquired during the first season, at least. One of the following tables (I) shows some of the data thus obtained.[3]

"There is considerable difficulty in ascertaining the age of these Squids, owing to the fact that the spawning season extends through the whole summer, so that the young ones hatched early in June are as large by September as those that hatch in September are in the following spring. Owing to the same cause, most of the large lots of young Squids taken in midsummer include various sizes, from those just hatched up to those that are two or three inches long. They are often mixed with some of those of the previous year, considerably larger than the rest. Earlier in the season (in May and the first part of June), before the first-laid eggs begin to hatch, the youngest specimens taken ($60^{mm}$ to $100^{mm}$ long) are presumed to belong to the later broods of the previous autumn, while those somewhat larger are believed to be from earlier broods of the previous summer, and to represent the growth of one year very nearly.

"Taking these principles as a guide, I have arrived at the following conclusions from the data collected:

"1. The young Squids begin to hatch at least as early as the second week in June, on the

[1] In early summer this Squid resorts to gravelly and weedy bottoms to lay its eggs. They are contained in bunches or clusters, sometimes six or eight inches in diameter, consisting of hundreds of gelatinous capsules each holding numerous eggs. These clusters are attached to some fixed object, and the oysters upon planted beds offer conveniences which the Squid is very likely to adopt. This occurrence seems to be a source of decided harm in Delaware Bay, for the oystermen there assert that the larger "sea-grapes" (as they call the egg-bunches) lift many oysters from the bottom by their buoyancy and float them off in stormy weather.—E. I.

[2] Report U. S. Fish Commission, part vii, 1882, pp. 353–355.

[3] See the original article.

southern coast of New England, and continue to hatch till the middle of September, and perhaps later.

"2. By the second week in July, the first hatched of the June Squids have grown to the size in which the body (or mantle) is $30^{mm}$ to $48^{mm}$ long; but these are associated with others that are younger, of all sizes down to those just hatched. They begin to show a disposition to go in 'schools' composed of individuals of somewhat similar sizes.

"3. By the second week in August, the largest June Squids have become $50^{mm}$ to $68^{mm}$ in length of body, and the later broods are $5^{mm}$ to $30^{mm}$ long. As before, with these sizes occur others of all ages down to those just hatched. It should be observed, however, that in those of our tabulated lots taken by the trawl the very small sizes are absent, because they pass freely through the coarse meshes of the net.

"4. By the second week in September, the June Squids have the mantle $60^{mm}$ to $82^{mm}$ long. All the grades of smaller ones still abound. A few larger specimens, taken the last of August and in September, $84^{mm}$ to $110^{mm}$ long, may belong to the June brood, but they may belong to those of the previous autumn.

"5. In the first week of November, the larger young Squids taken had acquired a mantle-length of $79^{mm}$ to $85^{mm}$, but these are probably not the largest that might be found. Younger ones, probably hatched in September and October, $8^{mm}$ to $20^{mm}$ in length of body, occurred in vast numbers November 1, 1874. The specimens taken November 16, off Chesapeake Bay, having the mantle $40^{mm}$ to $70^{mm}$ long, probably belong to the schools hatched in the previous summer.

"6. In May and June the smallest Squids taken, and believed to be those hatched in the previous September or October, have the mantle $62^{mm}$ to $100^{mm}$ long. With these there are others of larger sizes, up to $152^{mm}$ to $188^{mm}$, and connected with the smaller ones by intermediate sizes. All these are believed to belong to the various broods of the previous season. In these the sexual organs begin to increase in size and the external sexual characters begin to appear. The males are of somewhat greater length than the females of the same age.

"7. In July, mingled with the young of the season, in some lots, but more often in separate schools, we take young Squids having the mantle $75^{mm}$ to $100^{mm}$ long. These we can connect by intermediate sizes with those of the previous year taken in June. I regard these as somewhat less than a year old.

"8. Beyond the first year it becomes very difficult to determine the age with certainty, for those of the first season begin, even in the autumn, to overlap in their sizes those of the previous year.

"9. It is probable that those specimens which are taken in large quantities, while in breeding condition, during the latter part of May and in June, having the mantle $175^{mm}$ to $225^{mm}$ long in the females and $200^{mm}$ to $275^{mm}$ long in the males, are two years old.

"10. It is probable that the largest individuals taken, with the mantle $300^{mm}$ to $425^{mm}$ long, are at least three years, and perhaps in some cases four years old. The very large specimens generally occur only in small schools and are mostly males. The females that occur with these very large males are often of much smaller size, and may be a year younger than their mates.

"11. When Squids of very different sizes occur together in a school, it generally happens that the larger ones are engaged in devouring the smaller ones, as the contents of their stomachs clearly show. Therefore, it is probable that those of a similar age keep together in schools for mutual safety.

"12. Among the adult specimens of var. *pallida* taken November 16 and December 7, at Astoria, there are several young ones, from $75^{mm}$ to $120^{mm}$ in length, with rudimentary reproductive organs. These may, perhaps, be the young of the year, hatched in June."

Young Squids in inconceivable numbers, and even the adults, are greedily devoured by bluefish, black bass, striped bass, weakfish, mackerel, cod, and many other marine animals. Thus they are really of great importance as food for our most valuable market fishes.

North of Cape Cod the Squid is represented by the Sea-arrow or Flying Calamary, *Ommastrephes illecebrosus*, sometimes called "short-finned" in contrast to the long "fins" characteristic of the Loligos, which they resemble in size and color.

Professor Verrill has given the following graphic account of this species:

"When living, this is a very beautiful creature, owing to the brilliancy of its eyes and its bright and quickly-changing colors. It is also very quick and graceful in its movements. This is the most common 'Squid' north of Cape Cod, and extends as far south as Newport, Rhode Island, and in deep water to the region off Cape Hatteras. It is very abundant in Massachusetts Bay, the Bay of Fundy, and northward to Newfoundland. It is taken on the coast of Newfoundland in immense numbers, and used as bait for codfish. It occurs in vast schools when it visits the coast, but whether it seeks those shores for the purpose of spawning or in search of food is not known. I have been unable to learn anything personally in regard to its breeding habits, nor have I been able to ascertain that any one has any information in regard either to the time, manner, or place of spawning. At Eastport, Maine, I have several times observed them in large numbers in midsummer. But at that time they seemed to be wholly engaged in the pursuit of food, following the schools of herring, which were then in pursuit of shrimp (*Thysanopoda norvegica*), which occur in the Bay of Fundy, at times, in great quantities, swimming at the surface. The stomachs of the Squids taken on these occasions were distended with fragments of *Thysanopoda*, or with the flesh of the herring, or with a mixture of the two, but their reproductive organs were not in an active condition. The same is true of all the specimens that I have taken at other localities in summer. From the fact that the oviducts are small and simple, and the nidamental glands little developed, I believe that it will eventually prove that this species discharges its eggs free in the ocean, and that they will be found floating at the surface, either singly or in gelatinous masses or bands, not having any complicated capsules to inclose them. Nothing is known as to the length of time required by this species to attain its full size. It probably lives several years.

"This Squid is an exceedingly active creature, darting with great velocity backward, or in any other direction, by means of the reaction of the jet of water which is ejected with great force from the siphon, and which may be directed forward or backward, or to the right or left, by bending the siphon. Even when confined in a limited space, as in a fish-pond, it is not an easy matter to capture them with a dip-net, so quick will they dart away to the right and left. When darting rapidly the lobes of the caudal fin are closely wrapped around the body and the arms are held tightly together, forming an acute bundle in front, so that the animal, in this condition, is sharp at both ends, and passes through the water with the least possible resistance. Its caudal fin is used as an accessory organ of locomotion when it slowly swims about or balances itself for some time nearly in one position in the water.

"The best observations of the modes of capturing its prey are by Messrs. S. I. Smith and Oscar Harger, who observed it at Provincetown, Massachusetts, among the wharves, in large numbers, July 28, 1872, engaged in capturing and devouring the young mackerel, which were swimming about in 'schools,' and at that time were about four or five inches long. In attacking the mackerel they would suddenly dart backward among the fish with the velocity of an arrow, and as suddenly turn obliquely to the right or left and seize a fish, which was almost instantly killed by a bite in the back of the neck with their sharp beaks. The bite was always made in the same place, cutting out a triangular piece of flesh, and was deep enough to penetrate to the spinal cord. The attacks

were not always successful, and were sometimes repeated a dozen times before one of these active and wary fishes could be caught. Sometimes, after making several unsuccessful attempts, one of the Squids would suddenly drop to the bottom, and, resting upon the sand, would change its color to that of the sand so perfectly as to be almost invisible. In this position it would wait until the fishes came back, and when they were swimming close to or over the ambuscade, the Squid, by a sudden dart, would be pretty sure to secure a fish. Ordinarily, when swimming, they were thickly spotted with red and brown, but when darting among the mackerel they appeared translucent and pale. The mackerel, however, seemed to have learned that the shallow water was the safest for them, and would hug the shore as closely as possible, so that in pursuing them many of the Squids became stranded and perished by the hundreds, for when they once touch the shore they begin to pump water from their siphons with great energy, and this usually forces them farther and farther up the beach. At such times they often discharge their ink in large quantities. The attacks on the young mackerel were observed mostly at or near high water, for at other times the mackerel were seldom seen, though the Squids were seen swimming about at all hours, and these attacks were observed both in the day and evening.

"It is probable, from various observations, that this and other species of Squids are mainly nocturnal in their habits, or at least are much more active in the night than in the day. Those that are caught in the pounds and weirs mostly enter in the night, evidently while swimming along the shores in 'schools.' They often get aground on the sand-flats at Provincetown, Massachusetts, in the night. On the islands in the Bay of Fundy, even where there are no flats, I have often found them in the morning stranded on the beaches in immense numbers, especially when there is a full moon, and it is thought by many of the fishermen that this is because, like many other nocturnal animals, they have the habit of turning toward and gazing at a bright light, and since they swim backwards, they get ashore on the beaches opposite the position of the moon. This habit is also sometimes taken advantage of by the fishermen, who capture them for bait for codfish. They go out in dark nights with torches in their boats, and by advancing slowly toward a beach drive them ashore. They are taken in large quantities in nets and pounds, and also by means of 'jigs' or groups of hooks, which are moved up and down in the water, and to which the Squids cling, and are then quickly pulled out of the water. They are also sometimes caught by fish-hooks, or adhering to the bait used for fishes.

"Their habit of discharging an inky fluid through the siphon, when irritated or alarmed, is well known. The ink is said to have caustic and irritating properties.

"This Squid, like the *Loligo*, is eagerly pursued by the cod and many other voracious fishes, even when adult. Among its enemies while young are the full-grown mackerel, who thus retaliate for the massacre of their own young by the Squids. The specimens observed catching young mackerel were mostly eight to ten inches long, and some of them were still larger.

"This species, like the common *Loligo*, has the instincts and habits of a cannibal, for small Squids of its own species form one of the most common articles of its diet. From an adult female of ordinary size (G, of our tables), caught at Eastport, Maine, I took a great mass of fragments of small Squids, with which the stomach was greatly distended. These fragments completely filled a vial having a capacity of four fluid ounces.

"From the rapidity with which the Squids devour the fish that they capture it is evident that the jaws are the principal organs used, and that the odontophore plays only a subordinate part in feeding. This is confirmed by the condition of the food ordinarily found in the stomach, for both the fishes and the shrimp are usually in fragments and shreds of some size, and smaller creatures, like amphipods, are often found entire, or nearly so; even the vertebræ and other

bones of herring are often present. On the other hand, in some specimens, the contents of the stomach are finely divided, as if the odontophore had been used for that purpose."[1]

The loss which the fisheries sustain through their voracity, however, is probably equalized by the food which Cuttle-fishes furnish the carnivorous fishes and various other denizens of the deep. For example, the sperm whale seems to rely largely upon a diet of big Squids, sinking to the bottom where they are groping about, to drag them up, or nipping off their large arms as they swim about near the surface. Dolphins and porpoises also prey upon the Cuttles, and all the flesh-eating fishes pursue and devour them at every opportunity, particularly the cod and bluefish.

Knowledge of this fact long ago led to the Squid being taken by fishermen as an attractive bait. More than half of all the Bank fishing is said to be with such bait. When the shoals of this mollusk [*Loligo* Squid] approach the coast hundreds of vessels are ready to capture them, forming an extensive cuttle fishery, engaging five hundred sail of French, English, and American ships. Their habit of moon-gazing, also, is sometimes taken advantage of on the coast of Maine by the fishermen, who capture them for bait for codfish; they go out in dark nights with torches in their boats and by advancing slowly toward a beach drive them ashore. Violent storms heap great windrows of dead Squids on the beach, where they are gathered up, and they are also sometimes taken on lines adhering to the bait set for fishes. These "drives" and accidents happen in the spring, when Cuttles are flocking into shallow water to lay their eggs.

Since this solidly-fleshed animal is so extensively eaten by other animals it is not surprising to find that men also should number it among the edible products of the sea. "The flesh of the large cephalopodous animals," says Simmonds,[2] "was esteemed as a delicacy by the ancients. Most of the Eastern nations, and those of the Polynesian Islands, partake of it and relish it as food. They are exposed for sale dried in the bazaars or markets throughout India, and . . . dried Cuttle-fish may be seen among the articles of Chinese, Japanese, and Siamese food. In Chili the flesh is also considered a delicacy, and in Barbados the bastard Cuttle-fish or 'Calmar' (*Loligo sagittata* Lam.) is used as an article of food by the lower classes."

In the Mediterranean also, particularly near Tunis, and along the Portugal coast, the catch and consumption of Cuttles is large, amounting to nearly a million pounds a year, most of which is sold in Greece, after being salted and dried or pickled. These are Octopods. The same sort of Cuttle-fish (*Octopus punctatus*) serves the double purpose on the Pacific coast, from California to Alaska, of bait for the fisheries and food for the Indians. For the latter purpose it is chiefly sought in Puget Sound, where the coast tribes hunt and kill Octopods often large enough to be dangerous foes in a quarrel, by going to their haunts in canoes and spearing them. To some small tribes the Octopus affords the chief supply of animal food. There is no reason why squid-flesh from the northern Atlantic Ocean should not become available as food, and prove desirable—to those who like it. It would be both wholesome and cheap; and a single *Architeuthis* would furnish a meal for a frigate's crew. In Bermuda the *Octopus granulatus* regularly forms a portion of the fare of the fisher families. As the Bermudan fish and methods of capture prevail across among the Florida reefs, no doubt this habit prevails there also. In New York City there is a considerable sale of fresh Squids to foreign residents, and the trade is increasing. There seems no reason why on some coasts this flesh should not be far more thoroughly utilized than it is at present.

In addition to its value as a bait, or as a source of oil (our *Ommastrephes* has been thus utilized somewhat), and as possible food, the cephalopods contribute two or three useful articles

[1] Report U. S. Fish Commission, part vii, 1882, pp. 305–308.
[2] Commercial Products of the Sea, p. 116.

to commerce. A large portion of them carry under the skin of the back a long, flat, calcareous "bone" or plate, which serves as a stay or support to the frame in lieu of a skeleton. In some species it is long and slender like a quill-pen. This bone, reduced to powder, forms a useful pounce, "used in rewriting over erasures to prevent blotting, and in medicine as an antacid." It is also combined into a dentifrice. The principal use for it, nevertheless, is for feeding to caged birds requiring lime for their health. For this purpose several hundred-weight of "cuttle-bone" are brought into the United States annually. It is furnished chiefly from Chinese waters, but is also collected floating in the Mediterranean. None of our American species afford a useful cuttle-bone, however; so that this import can scarcely be diminished. The name "Calamary" is often applied to a Cuttle-fish, and arises from the fact that each of them carries in an internal gland a supply of blue-black, ink-like liquid, which upon the slightest alarm he discharges into the water, making a dense cloud under cover of which he rapidly retreats.[1] This ink, removed and dried into little cakes, with a greater or less adulteration, forms the sepia of painters and the India ink of draughtsmen. Now it is brought almost wholly from Oriental ports, via London, but it might probably be saved on our coast as well. Provided with pen and ink on all occasions, these mollusks seem truly to stand at the head of the class of animals they represent—not wholly because of their superior size and loftier brain and organization, but also on the score of literary accomplishments.

## 206. THE SEA-SNAILS—GASTEROPODA.

The Gasteropod mollusks, bearing a shell in a single piece and usually spirally whorled, are not of much direct utility to man, as a rule, on this side of the world, north of the tropics; but there are a few species which deserve mention. Their principal claim to notice in this connection lies in the fact that they figure upon the habitual bill of fare of various fishes. No doubt the list appended might be greatly enlarged if we were better informed, particularly in respect to the southern coast. Thus far the chief knowledge possessed in respect to the molluscan food of American fishes is derived from Gould's "Report upon the Invertebrates of Massachusetts," and Prof. A. E. Verrill's report to the United States Fish Commission. From this and other sources is compiled the succeeding catalogue of species of Gasteropod mollusks that are fed upon by fishes; these, it must be observed, are confined to the Atlantic coast, and, to a great extent, to the waters of New England, through lack of information in respect to the similar food of the fishes of the southern and the western coast. The list includes about fifty species, and reads:

*Bela turricula*, *Bela harpularia*, *Bela pyramidalis*, *Bela decussata*, *Admeté Couthouyé*, *Neptunea despecta*, *Buccinum undatum*, *Buccinum ciliatum*, *Tritia trivittata*, *Ilyanassa obsoleta*, *Trophon clathratus*, *Trophon clathratus* var. *scalariformis*, *Purpura lapillus*, *Astyris rosacea*, *Astyris lunata*, *Natica clausa*, *Lunatia heros*, *Lunatia grœnlandica*, *Lunatia immaculata*, *Amauropsis islandica*, *Velutina zonata*, *Velutina lævigata*, *Lamellaria perspicua*, *Littorina*—several species, *Triforis nigrocinctus*, *Bittium nigrum*, *Turritella erosa*, *Trichotropis borealis*, *Crepidula fornicata*, *Crepidula plana*, *Aporrhais occidentalis*, *Scalaria grœnlandica*, *Scalaria Novangliæ*, *Margarita cinerea*, *Margarita grœnlandica*, *Margarita argentata*, *Machæroplax obscura*, *Puncturella noachina*, *Tonicella marmora*, *Trachydermon albus*, *Trachydermon ruber*, *Chiton*—various species, *Auricula restita* var. *Emersonii*,

[1] There are frightful tales abroad of the ferocity with which the larger of these creatures will attack man, and they are greatly dreaded by the shell-divers of the South Seas; but the truth is the Cuttle-fish is timid, and will hide or run away whenever he can from anything so large and strange as a man; that is, any Cuttles smaller than the giants of Newfoundland. A diver who touched a large Octopus would instinctively be seized, of course, since the creature would know no different course of action; but voluntary attack is not credited by those who know most about the habits of the animal.

*Odostomia striatula*, *Philine lineolata*, *Amphisphyra hiemalis*, *Amphisphyra debilis*, *Diaphana Gouldii*, and *Cylichna alba* among salt-water forms; with many species of *Melampus*, *Paludina*, *Planorbis*, *Limnea*, *Physa*, and other fresh-water genera.

But many of these species, and several not mentioned here, have additional claims to our notice. For example, *Buccinum undatum*, the Cape Ann "Periwinkle," might well serve as food, since in Europe it has long been thus utilized. In all the coast towns of England and Scotland this shell is peddled for food, under the name "Whelk" or "Wilk," and it may be bought at all the street-corners in the poorer quarters of London, where it is esteemed a great luxury. Our Whelk might equally well be eaten, and is very common northward from Cape Cod to the arctic regions, living chiefly on rocky shores, but also inhabiting muddy bottoms. It is thus accessible to castaways upon bleak arctic coasts where no other edible shell fish of consequence occurs, and ought not to be forgotten by those who take the risk of shipwreck in Labrador or Greenland.

Next demanding attention are two of the largest mollusks on the Atlantic coast north of the tropics—*Fulgur carica* and *Sycotypus canaliculata*. North of New Jersey these two are confused under the general names of "Periwinkle," "Winkle," and "Wrinkle." The former of these species extends "northward only to Cape Cod," and is uncommon beyond Long Island, while the second is of more frequent occurrence in Vineyard Sound and along the Connecticut shore than southward. Both are carnivorous, and find in the Oysters a quiet, easy prey; they consequently do great damage to the beds, and are properly destroyed by fishermen whenever a chance occurs. I believe this is especially true of the *Sycotypus*. On the coast of New Jersey and southward, where the *Fulgur* reaches an immense size, and is known as the "Conch," the oystermen complain very little of it.

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, on hard 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 sea side, 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!" 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 single 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 began, 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*."[1]

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 a specimen of either of these species will show that in both 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 that. Seizing upon the unfortunate Oyster, unable to run away, he envelops its 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 these pests are very troublesome, thought 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, suffers 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

[1] Report U. S. Fish Commission, part i, 1873, pp. 355, 356.

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 it is to be expected, as reported, 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 star-fishes, in my Report to the Census Bureau upon the Oyster Industries, would take up these eggs at the same time, and thus do double service. Persistent fighting is the only resource against this enemy, however, as in the case of others.

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 be sent into Catharine 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.

Under the name of "Drill" is included 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 enemy's shell,—a habit which renders them of much account in the fisheries, where the victim they attack is the valuable Oyster, as they are sadly prone to do. The mode in which the entrance is made has been clearly described by 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 strays to the oyster-beds, but is usually carried there with the seed supplies, and, finding plenty of nourishment, lives and increases. 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 them 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 they 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 became 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, Connecticut, 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 eels were plentiful the Drills were kept down because the eels fed on their eggs. This gentleman said 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. Where large numbers of these are present, with the help of boring-worms and sponges, they may so riddle a reef as to cause its entire disintegration under the first gale. A fourth borer is *Purpura lapillus*, which is of interest in another direction. The famous Tyrian purple of ancient days—the regal dye that was deemed too splendid a color to be worn by any but kings and nobles—was produced from a sea-snail, and conchologists have busied themselves to discover which particular one.

In the works of Pliny and Aristotle, the earliest sources of knowledge on the subject, the information is too vague to be relied upon. Dr. Roth, of Munich, in a paper read before the Jerusalem Literary Society, says that several years ago (previous to 1857) he found at Jaffa the *Purpura patula*, sought as food by the Christians during fast days: "On puncturing this animal there issued a greenish liquid, which, when exposed to the sunshine, changed to purple. This purple increased in brilliancy when it was washed." Comparing this with the accounts left by the ancients, Dr. Roth thinks the color he produced is evidently their blue color, for they had a blue-purple, a deep purple, and a red-purple. "Between Soor and Saida," according to the same author, "the *Murex truncatus*, or *trunculus*, is found in abundance, and its color is more brilliant than that of the *Purpura*. One of these *Murex* is sufficient to dye a square inch of cloth, which would require five individuals of *Purpura patula*. Wool takes the dye better than any other substance; silk takes it with difficulty."[1]

Linton, in his work "On Ancient and Modern Colours," as quoted by Simmonds ("Commercial Products of the Sea," p. 304), states that the *Purpuræ* of the best description were chiefly found on the rocks of Tyre, on the coast of Asia. They were also collected at Mininge, on the Grætulan shore in Africa, and on the coast of Laconia in Europe. The colors varied according to the locality in which they were taken, and also according to the animal's haunt, as has since been proved by zoologists. Thus, when it lived among sea-weeds or mud the juice it contained was comparatively worthless; when among pebbles its quality was improved; and the dye was best when the food and surroundings were varied. Researches carried still further proved that to produce the richest and most costly dye which art could exhibit, the liquid must be used in conjunction with that procured from other shell-fish. Just what the species were that were used it is now impossible to tell, but they were allied to *Murex* and *Buccinum*. Niter, urine, water, salt, and certain sea-weeds were also mixed with the *Purpura* liquor in compounding certain tints. "In the reign of Augustus," says Simmonds, "one pound of wool dyed with the Tyrian purple sold for about £36 sterling [about $175]. We need not wonder at this enormous price when the tedious nature of the process is considered, and the small quantity of dye obtained from each mollusk. For fifty pounds of wool the ancients used no less than two hundred pounds of the liquor of the *Murex* and one hundred pounds of that of the *Purpura*, being six pounds of liquor to one of wool; consequently the rich Tyrian purple fabrics vied in value even with gold."

The liquor was procured by placing the small shells in a mortar and crushing them. Animals extracted from the larger shells were added, and also urine, pure water, or water in which purple Snails had been allowed to putrefy. In this mixture the cloth was soaked and afterwards exposed to the light, sometimes under the influence of warmth to accelerate the process.

It is said that the dyeing property is a transformation of uric acid into purpurate of ammonia, called murexide. This is a splendid substance when pure, presenting in one direction beautiful metallic green reflections, and in others brown and purple tints. Some chemists assert that it is

[1] PHIPSON: Utilization of Minute Life. London Groombridge & Sons, 1864, p. 144.

to this substance that the iridescent plumes of humming-birds, pheasants, and peacocks owe their wonderful brilliancy. Murexide is now obtained not only from mollusks, but from guano, etc.

Dyes from mollusks have been obtained in all ages and almost all quarters of the world, and not only our *Purpura lapillus*, but also another species which we share with Great Britain, the Whelk (*Buccinum undatum*), have been the subject of successful experiments of this sort. "If the shell of *Purpura lapillus* is broken, there is seen on the back of the animal, under the skin, a slender, longitudinal, whitish vein, containing a yellowish liquor. When this juice is applied to linen, by means of a small brush, and exposed to the sun, it becomes green, blue, and purple, and at last settles into a fine unchangeable crimson." The housewives of New England therefore have growing abundantly on their sea-side rocks little living bottles of indelible ink which cannot be excelled by any manufactured product for either beauty or durability, since neither acid nor alkali will affect its color.

On the Pacific coast occur shells of the genus *Olivella*, so called because they resemble small olives. There are three species, *Olivella biplicata*, *O. gracilis*, *and O. dama*. The first named of these shells certainly, and possibly the other two, now and then were made into money by many Californian tribes of Indians, which money circulated widely on the Pacific slope. The common Indian name for this *Olivella* money was "colcol." It was made by grinding off the apex or spire of the shells in such a way that they could be strung. They are still used by some tribes in the form of double necklaces as ornaments, but are regarded as of small value. Sometimes the shell was broken crosswise and ground into little disks which passed as coins. This money was very ancient and widespread through aboriginal traffic in connection with other forms of shell-money to be mentioned hereafter, and which the present writer has fully discussed in a paper on "Wampum" contained in the American Naturalist,[1] to which the reader is referred.

Cameos are articles of ornament made by carving portions of various shells in such a way that a raised figure of one color shall be relieved against a ground of another tint constituting the under layer of the shell. These colors may vary—white on an orange ground, or on dark claret; pale salmon-color on orange; yellow on pink, etc. Anciently cameos were cut upon gems with immense labor, but latterly this easier imitation in shell has almost entirely superseded the intaglios in onyx, agate, and jasper. The cameo artists live mostly in London and Paris, and use several species of large shells that combine a white crust with a nacreous understratum of a different tint. Two only of these shells come from American waters, and these only touch our coast in tropical Florida—*Cassis madagascariensis* and *Strombus gigas*—the "Helmet-shell" and the "Conch."

Of the Helmet-shell several sorts are used in cameo-cutting. Our American example (which got its name, *madagascariensis*, through an error in regard to the locality of the type-specimen) has a blackish inner coat, called an "onyx" ground, and shows up white on a dark claret-color. It is known to the trade as the Black Helmet, and is highly esteemed by cameo-cutters.

The Conch or Queen Conch (*Strombus gigas*) is of less account in cameo-making, because it affords a less quantity of surface suitable for the work—a portion of its broad, rose-tinted lip. Various other ornaments are often made from this and other large shells by turning and sawing with special machinery, and thus a large demand is created, which is satisfied chiefly through brokers in London and Liverpool. Just how many shells are sent to England annually it is impossible to tell; but the amount reaches some tens of thousands. There is also a large commerce in them both to Europe and to the United States to be used as ornaments alone, and to be given away by grocers and tea-dealers to promote their custom. In the West Indies, and on

[1] American Naturalist, xvii, May, 1883, pp. 467–479.

many plantations in the Gulf States, the Conch is perforated at the apex of the spire, and forms a horn, used to call workmen in from the fields and at dinner. From fragments of this great mollusk, also, the Indians of Florida and the Antilles made their most esteemed beads and pendants. Cabeza de Vaca says that the columella of large Conchs were chiefly available for this purpose. "These beads are more or less cylindrical or globular, and always drilled lengthwise. Some are tapering at both ends, resembling a cigar in shape, and were two and one-half inches in length. The aborigines also made . . . peculiar pin-shaped articles consisting of a more or less massive stem which terminates in a round knob."

The *Strombus* enters, when ground, into the manufacture of porcelain: is extensively burned for lime; and is carefully calcined for medicinal purposes. There is also derived from it a secondary product of great value—the conch-pearl. When perfect, this pearl is described as either round or egg-shaped and somewhat larger than a pea, of a beautiful rose color, and watered, that is, presenting, when held to the light, the sheeny, wavy appearance of watered silk. It is however, very rare to find a pearl which possesses all the requirements that constitute a perfect gem, and such proves an exceedingly valuable prize. Although many of these pearls are annually obtained by the fishermen in the Bahamas, not more than one in twenty proves to be a really good gem. Pink is the most common and only desirable color, although white, yellow, and brown pearls are occasionally found. Even among the pink ones there is usually some defect which mars their beauty and materially injures them; some are very irregular in shape and covered apparently with knobs or protuberances; others are too small, while many lack the watering which gives them their great value and chief beauty. Most of the conch-pearls have been sent to London, and the demand for them is increasing; a few come to New York.

*Lunatia heros* is very conspicuous along our coast, from the Gulf of Saint Lawrence to Cape Hatteras or beyond, wherever sandy shores and pure waters are to be found, and it is abundant and of very large size on the outer beaches of the coast of New Jersey. "When in motion the white soft parts are protruded from the shell to a remarkable extent and spread out broadly on all sides, so as nearly to conceal the shell; the foot is large, flat, and broadly expanded, with thin edges, and by means of it the animal is able to burrow, like a mole, beneath the surface of the sand." This Snail, like many others of its tribe, drills round holes through the sides of various bivalve shells by means of the small flinty teeth on its ribbon-like tongue, which acts like a rasp, and having thus made an opening it inserts its proboscis and sucks out the contents. All sorts of burrowing bivalves in this way fall victims to this and its close ally, the *Neverita duplicata*. "Nor do they confine themselves to bivalves, but will drill any unfortunate Gasteropods they may happen to meet, not even sparing their own young." Their usual haunts are away from the oyster-beds, however, so that, although they are a familiar sight in the dredge, the harm they do to this industry is of small account.

Following this in the list come various small shells, such as those of the genera *Littorina*, *Rissoa*, *Melampus*, and *Bittium*, of which it can only be said that they serve a very useful purpose as scavengers, swarming upon the mud exposed at low tide and greedily devouring carrion of fishes, etc., which would otherwise decay and pollute both air and water. The same good service is done by the small mollusks previously noticed as "Borers," and many following.

This brings us to the beautiful family of Abalones, Ormer-shells, or Sea-ears, in which there is a very large trade on the Pacific coast, under the industry of the Chinese there, to which will be given a special chapter.

In the Limpets (*Crepidula* and *Acmea*) the oystermen consider they have a friend, since when they see these clustering upon their planted beds they look forward to a profitable harvest the

coming autumn. A Californian species (*Fissurella aculeata*) was used as money by some of the native red men of the coast.

In respect to the odd pill-bug-like shells of the several species of *Chiton* of our eastern shore I can say nothing; but in Bermuda a larger Chiton is gathered for soup, and the broth is said to be very good. The Bermudans also make use of that Chiton as a bait with which to take the large lobsters of the island, themselves intended to act as bait for fishes.

The sea surrounding Bermuda is of great transparency, and the fishermen can readily discern the long horns of the lobster protruding from his hiding place among the rocks, at a considerable depth. The only plan by which they can get him, however, is to entice him out of his refuge. To do this they mat together a quantity of Chitons until they have formed a ball several inches in diameter. To this they attach a string, and—having previously baited the bottom in front of the lobster's den and left him to enjoy it until his confidence was captured—let the ball dangle before his nose. Thinking this only a larger tidbit, he seizes it, and, to his amazement, is swiftly drawn up to daylight and torn to pieces to form a lure for equally unwary fishes.

"These shells have been called by different names, all, however, indicative of their form, such as 'Wood-louse,' 'Sea-boat,' 'Rattle-snake's Tail,' 'Lobster's Tail,' 'Sea-bug,' and 'Sea-caterpillar.' The French say that the animal may be eaten, and we are told that the Iceland fishers swallow it raw to quench thirst, and pretend that it is good, also, against sea-sickness." The American Indians of the Northwest coast, South Sea Islanders, and other savages find the Chiton acceptable as food.

In *Melamprus bidentatus* we have a small shell which swarms upon the mud and among the eel-grass, affording food to many fishes and acting as a scavenger of the marshes. In addition to this, it has a place in these remarks because it belongs to the division of air-breathing mollusks, and introduces not only the fresh-water shells *Limnea*, *Physa*, *Planorbis*, etc., that feed the inland fishes, but also the edible land Snails. To these latter interesting mollusks I lately devoted a chapter in my "Friends Worth Knowing,"[1] from which I quote whatever applies to the present purpose:

"Snails, being great eaters, meet their just reward in being eaten. The paludine forms are sought after by all sorts of water birds, particularly ducks and rails; while the thrushes and other birds crush the shells of the land Snails and extract their juicy bodies. The woodland birds, however, will not eat the naked-bodied Slugs: the slime sticks to their beaks and soils their feathers; but the ducks seem to have no such dainty prejudices. Some mammals, like the raccoons and wood-rats, also eat them; insects suck their juices, and the carnivorous Slugs prey upon one another. Lastly, man, the greatest enemy of the brute creation, employs several species of Snails for culinary purposes. By the Romans they were esteemed a great luxury, and portions of plantations were set apart for the cultivation of the large, edible *Helix pomatia*, where they were fattened by the thousand upon bran sodden in wine. From Italy this taste spread throughout the Old World, and colonies of this exotic species, survivors of classical 'preserves,' are yet found in Great Britain where the Roman encampments were. They are still regarded as a delicacy in Italy and France, the favorite method of preparation being to boil in milk, with plenteous seasoning. Frank Buckland says that several of the larger English species are excellent food for hungry people, and recommends them either boiled in milk, or, in winter, raw, after soaking for an hour in salt and water. Some of the French restaurants in London have them placed regularly upon their bills of fare. Thousands are collected annually and sent to London as food for cage-birds. Dr. Edward Gray stated, a few years ago, that immense quantities were shipped

[1] Harper and Brothers, New York, 1880.

alive to the United States 'as delicacies'; but I am inclined to consider this an exaggeration growing out of the fact that, among our fancy groceries, 'a few jars of pickled Snails, imported from Italy,' figure as a curiosity, rather than something needed for the table. The same author records that the glassmen at Newcastle once a year have a snail feast, collecting the animals in the fields and hedges on the Sunday before.

"Mr. W. G. Binney, for whom a sirup of Snails was prescribed by two regular physicians in Paris in 1863, points out how old is the belief that land mollusks possess valuable medicinal qualities. In the Middle Ages the rudimentary shell of the Slug acquired a high rank among the numerous bezoars and amulets which were supposed to protect the body from evil influences, and to impart health and activity. The accounts of these virtues, copied from one author to another, have perpetuated the early superstitions until it is difficult to overcome them by the light of the present day, when, even in England, Snails are supposed to possess a useful power in cases of lung trouble. A full relation of all the absurdities which gained credence would form a curious and marvelous page in the history of credulity. They have, also, from very early times, been used in the preparation of cosmetics; and no longer than two or three centuries ago the water procured from them by distillation was much celebrated, and employed by ladies to impart whiteness and freshness to the complexion. Finally, I hear that there is celebrated in Rome, even now, a midsummer festival, upon which occasion all family feuds may be made up, or any differences between friends easily adjusted, since that is the spirit of the day; and a sign or token of this renewed friendship and good-will is the present of a Snail from one party to the other, or an exchange of mollusks between them. The symbolism and virtue reside in the alleged amicable influence of the head and 'horns'—why, perhaps comparative mythologists may be able to tell us.

"In this country no such fanciful notions have ever gained credence. The Snails are too habitually hidden to attract the attention of any but a few; and even when their existence is known, they are unfortunately regarded with such a disgust as would preclude any acceptance of them, either for food or medicine."

In Thomas De Voe's "Market Assistant," p. 312, is the following information, which refers to about the year 1860: "From the French journals we learn that there are fifty restaurants and more than twelve hundred private tables in Paris where Snails are accepted as a delicacy by from eight to ten thousand consumers. The market price of the great vineyard Snails is from 2 francs 50 centimes to 3 francs 50 centimes (47 to 66 cents) per hundred, while those of the hedges, woods, and forest bring only from 2 francs to 2 francs 25 centimes (38 to 43 cents). Snails are, and have been for several years, imported [into New York] from Europe, but are principally used by foreigners. They are generally stewed after having been scalded out of their shells."

The custom-house counts this import among "fancy groceries," so that no separate record is obtainable of the amount consumed. In the case of several of the large Southern species, such as the Apple-snail (*Ampularia*), the *Bulimi*, and the large pond Snails, their remains in the shell-heaps show that in prehistoric time they formed a regular part of the food of the red men. The Seminoles, of Florida, and various native races west of the Rocky Mountains, eat them yet.

## 207. THE WING-SHELLS—PTEROPODA.

The Pteropods, or wing-footed mollusks, are a small group which swim freely throughout the broad ocean. Their shells are of small size, fragile, and semi-transparent. They form, therefore, available food for a large number of surface-feeding fishes, and particularly of the cetacea; the right whale, indeed, is said to live almost wholly upon certain species of them which abound in

arctic seas and swarm near the surface at night, so that he need only drop his jaw and engulf them by the hundred in his capacious mouth as he swims along with his head half out of water. Probably the same thing is true of the other balænoids.

### 208. THE TUSK-SHELLS—SOLENOCONCHA.

The class denominated in Professor Verrill's Check List *Solenoconcha* includes only one mollusk that may concern us at present—*Dentalium*. This mollusk (chiefly *D. pretiosum*) occurs all along the northern Pacific coast of America, and is known to Americans as the "Tusk-shell," to Russians as "Sookli," and to the Alaskan Indians as "Hya-qua." From Northern California all the way to the arctic regions the coast tribes collected this shell, polished it, and arranged it on strings as money—a circulating medium of trade, similar to the wampum of the eastern coast. There were certain rules as to fineness, arrangement, size, and measurement, which decided the value of the shells before and after stringing; and so useful was this *allocochick*, as the California Indians called it, that the Hudson's Bay Company and other traders adopted it as current coin in their buying and selling of peltries and provisions.

The strings of *Dentalia* were also worn as necklaces by the women, or twined in the hair of both sexes; as trimming for garments, and ornaments for horse-trappings and the equipments of war and the chase. Among other methods of employing them to enhance personal charm was to insert two of them, point to point, from opposite sides, through a perforation in the partition which separates the nostrils, which decoration was further increased by sticking a bright feather in the large end of each of the hollow shells. This money is going out of use now, and only the old Indians, conservators of ancient customs, attempt to hoard it up. A full account of it may be found in the article upon "Wampum" already alluded to, printed in "The American Naturalist" for May, 1883.

### 209. THE BIVALVES—LAMELLIBRANCHIATA.

It is in the class of plate-gilled or lamellibranchiate mollusks, more popularly known as "bivalves," that we find the most examples of direct utilization by man, or immediate contribution to the fisheries. Bivalves are widespread and well-known. They afford luxuries as well as solid nourishment for our tables, enter largely into manufactured products, serve as ornaments, and are so beloved by food-fishes generally that they are useful as bait.

The partial list of bivalved mollusks that are ascertained to enter into the diet of American food-fishes includes the following, mainly from the northern Atlantic coast as in the case of the gasteropods, and is instructive as showing how extensively fishes depend upon molluscan food:

*Ensatella americana*, *Crytodaria siliqua*, *Mya arenaria*, *Spisula ovalis*, *Macoma sabulosa*, *Angulus tener*, *Petricola pholadiformis*, *Venus mercenaria*, *Cyprina islandica*, *Cardium pinnulatum*, *Cardium islandicum*, *Cryptodon Gouldii*, *Venericardia borealis*, *Astarte quadrans*, *Nucula proxima*, *Nucula tennis*, *Yoldia limatula*, *Yoldia sapotilla*, *Yoldia myalis*, *Yoldia thraciformis*, *Leda tenuisulcata*, *Argina pexata*, *Mytilus edulis*, *Modiola modiolus*, *Modiolaria discors*, *Crenella glandula*, *Pecten tenuicostatus*, *Pecten islandicus*, *Pecten irradians*, and *Ostrea virginica;* to which must be added *Unio*, *Anodonta*, and other fresh-water bivalves, and the brachiopods *Rhynconella psittacus* and *Terebratulina septentrionalis.*

In this list many species are of importance otherwise, and some worth notice, although not fed upon by fishes, are not mentioned; the first to be named in this latter class is the dreaded Ship-worm (*Teredo*), of which there are seven species in the United States:

*Teredo navalis*, Linné. Cape Cod to Florida; Sweden to Sicily.
*Teredo norvegica*, Spengler. Cape Cod northward.
*Teredo megotara*, Hanley. Massachusetts Bay to South Carolina.
*Teredo dilatata*, Stimpson. Massachusetts to South Carolina.
*Teredo Thompsoni*, Tryon. Cape Cod, Massachusetts.
*Xylophaga dorsalis*, Forbes and Hanley. North Atlantic.
*Xylotrya fimbriata*, Jeffreys. Long Island Sound to Florida; British Columbia; Europe.

The most commonly observed of these is the *Teredo navalis*. This is the same species that has attracted so much attention in Europe, during nearly two centuries, on account of the great damage that it has done, especially on the coast of Holland. Its history has been reviewed at length by Professor Verrill in his "Invertebrates of Vineyard Sound," from which the present account is principally derived.

"Although popularly known as the 'Ship-worm,' these creatures are not at all related to the worms, but are true mollusks, quite nearly allied, in many respects, to the common 'Long Clam' (*Mya*) and to the *Pholas*. Like those shells, the Teredo excavates its holes or burrows merely for its own protection, and not for food; but the Teredo selects wood in which to form its holes, and when these have been excavated it lines them with a tube of shelly material. The holes are very small at the surface of the wood, where they were formed by the young Toredos, but they gradually grow larger as they go deeper and deeper into the wood, until they sometimes become ten inches or more in length and a quarter of an inch in diameter; but the size is generally not more than half these dimensions. The holes penetrate the wood at first perpendicularly or obliquely, but if they enter the side of the timbers or planks across the grain the burrows generally turn horizontally in the direction of the grain a short distance beneath the surface, unless prevented by some obstruction, or by the presence of other toredo tubes, for they never cross the tubes of their companions or interfere with each other in any way, and there is always a thin layer or partition of wood left between the adjacent tubes. It is, however, not necessary that they should follow the grain of the wood, for they can and do penetrate it in every direction, and sometimes not more than half the tubes run in the direction of the grain, and they are often very crooked or even tortuous. They rapidly form their burrows in all kinds of our native woods, from the softest pine to the hardest oak, and although they usually turn aside and go around hard knots, they are also able to penetrate through even the hardest knots in oak and other hard woods. The Teredos grow very rapidly, apparently attaining maturity in one season, and therefore, when abundant, they may greatly damage or completely destroy small timber in the course of four or five months, and even the largest piles may be destroyed by them in the course of two orthree years.

"When removed from its tube the animal is found to have a very long, slender, smooth, soft, whitish body, tapering somewhat toward the outer or posterior end, which has a muscular, circularly wrinkled collar, by which the animal is, when living, attached to the inside of the shelly lining of its tube. To the inside of this collar two shelly plates, known as the 'pallets,' are attached by their slender basal prolongations; their outer portions are broad and flat, and more or less emarginate or two-horned at the end. These are so connected with the muscles that when the animal withdraws its tubes into its hole the free ends of these pallets are made to fold together and close the opening, thus serving as an operculum to protect the soft tubes against enemies of all kinds. Between the bases of the pallets arise the siphonal tubes, which are soft and retractile, united together for half their length or more, but separate and divergent beyond; they are nearly equal, but the ventral or branchial tube is perhaps a little larger than the other, and is fringed with a few small papillæ at the end. The tubes are white or yellowish, sometimes speckled with

reddish-brown. At the anterior end of the body, and farthest from the external opening of the hole, is seen the small but elegantly sculptured white bivalve shell. The shell covers the mouth and palpi, liver, foot, and other important organs. The foot is a short, stout, muscular organ, broadly truncate or rounded at the end, and appears to be the organ by means of which the excavation of the burrow is effected. The shell is covered by a delicate epidermis, and probably does not assist in rasping off the wood, as many have supposed. The gills are long and narrow, inclosed mostly in the naked part of the body, and are reddish-brown in color.

"The Teredos obtain their microscopic food in the same manner as other bivalve mollusks, viz, by means of a current of water constantly drawn into the branchial tube by the action of vibrating cilia within; the infusoria and other minute organisms are thus carried along to the mouth at the other end, while the gills are supplied with oxygen by the same current; the return current passing out of the dorsal tube removes the waste water from the gills, together with the fæces and excretions of the animal, and also the particles of wood which have been removed by the excavating process.

"As the animal grows larger the burrows are deepened, the lining of shelly matter increases in length and thickness, the shell itself and the pallets increase in size, and the terminal tubes grow longer. But as the orifices of the terminal tubes must necessarily be kept at the external opening of the burrow, the muscular collar at the base of the tubes constantly recedes from the entrance, and with it the pallets; at the same time imbricated layers of shelly matter are usually deposited in the upper end of the shelly tube, which are supposed to aid the pallets in closing the aperture when the tubes are withdrawn. When the animal has completed its growth, or when it has encountered the tubes of its companions and cannot pass them, or when it approaches the exterior of a thin piece of wood and cannot turn aside, it forms a rounded or cup-shaped layer of shelly matter, continuous with the lining of the tubes and closing up the burrow in front of its shell. Sometimes it retreats and forms a second partition of the same kind.

"This species produces its young in May and probably through the greater part or all of the summer. The eggs are exceedingly numerous, probably amounting to millions, and they are retained in the gill-cavity, where they are fertilized and undergo the first stages of their development. The embryos pass through several curious phases during their growth. In one of the early stages they are covered with fine vibrating cilia, by means of which they can swim like ciliated infusoria; later they lose these cilia and develop a rudimentary bivalve shell, which is at first heart-shaped, and the mantle begins to appear and larger retractile cilia develop upon its edge, which serve as organs for swimming; but at this period the shell is large enough to cover the whole body when contracted. In this stage they swim actively about in the water; later the cilia become larger, a long, narrow, ligulate foot is developed, by means of which they can creep about and attach themselves temporarily to solid objects; the shells become rounder, a pair of eyes and organs of hearing are developed. After this the little animal begins to elongate, the locomotive cilia are lost, the eyes disappear, and the mature form is gradually assumed. These young Teredos, when they finally locate upon the surface of wood-work and begin to make their burrows, are not larger than the head of a pin, and consequently their holes are at first very minute, but owing to their rapid growth the holes quickly become larger and deeper."[1]

This species is very abundant along the southern coast of New England, from New York to Cape Cod, wherever submerged wood-work, sunken wrecks, timber buoys, or floating pieces of drift-wood occur. It also infests the bottoms of vessels not protected by sheathing. At Provincetown, Cape Cod, about forty feet of the end of the steamboat wharf was so weakened by its

[1] Report, U. S. Fish Commission, part i, 1873, pp. 384–386.

borings that it completely gave way under a ship-load of merchandise stored upon it. This pest is not confined to pure sea-water, but occurs in the piles and timbers of wharves in harbors that are not only brackish, but also muddy and contaminated with sewage. Capt. B. J. Edwards told me that formerly when the cedar channel-buoys in Buzzard's Bay, Massachusetts, were not taken up they would last not more than two years, owing chiefly to the attacks of this Teredo: but under the present system there are two sets of buoys, which are alternately taken up and put down every six months. After a set has been allowed to dry thoroughly they are scraped to remove the barnacles, etc., and then receive a thorough coat of verdigris paint each time before they are put down. With this treatment they will last ten or twelve years, but they are more or less perforated and injured every year, until finally they become worthless. This statement does not apply to the spar-buoys, which are taken up only once a year, in April and May. Captain Edwards says that the Teredos would destroy an unpainted spar-buoy in one year, but when painted with verdigris they will only work where the paint becomes rubbed off. They first attack buoys or piles just below the water's edge, but eventually will destroy the entire submerged wooden portion. Commenting upon this information, Professor Verrill says:

"Inasmuch as the Teredos produce their young all through the summer, and they develope to a very large size in one season, it is evident that the best time to take up the buoys would be in midsummer, before the early crop of young have grown large, and leaving too little time for the later crop to become large, in the buoys thus put down, before winter, when most of them would probably be killed by the cold weather. In this way the damage might be materially diminished, if not inconsistent with the other duties of the officers of the vessels employed in this service. There are, as yet, no means of estimating the extent of the damage done to our wharves, shipping, etc., by this and the various other species of Teredo found on our coast, but, judging from their abundance along the whole coast, it is much greater than is generally supposed.

"The *Teredo navalis* is also abundant on the coast of Europe, from the Mediterranean and Black seas to Christiania and the coasts of Great Britain. Its habits have been quite thoroughly investigated by several Dutch naturalists, owing to the great damage that it has done on their coast, at times even threatening a general inundation of the country by destroying the wood-work of the dikes. This Teredo occupies a zone of considerable breadth, for it often lives considerably above low-water mark, and extends several feet below it, even to the depth of fourteen feet, according to some writers.

"The best remedies in common use to resist or prevent its attacks are copper sheathing, used chiefly on vessels; broad-headed nails, closely driven, used for piles and timbers; creosote and coal-tar, frequently applied. The various poisonous substances that have been applied to timber for this purpose, however useful they may be in other respects, have little or no effect on the Teredo, for it does not depend upon the wood for its food, and even protects its body externally with a layer of shell, lining its holes. The only remedies that are likely to succeed are those calculated to prevent the lodgment and entrance of the young ones beneath the surface. Even creosote, thoroughly applied under pressure at the rate of ten pounds per square foot, has been found insufficient to prevent their attacks, for piles thus treated at Christiania were found by Mr. Jeffreys to be filled with the Teredo within two years after they were put down.

"Several other species of Teredo also occur on this coast. The *Teredo megotara* has been found in floating pine wood at Newport, Rhode Island, and in cedar buoys, etc., at New Bedford, Massachusetts; as well as in Massachusetts Bay, at Provincetown, and other places; it is also found as far south as South Carolina at least. This species sometimes grows to a large size, forming tubes at least eighteen inches long. It sometimes occurs, also, in the piles of wharves in this region

[Vineyard Sound, Massachusetts]. The *Teredo Thomsoni* has been found in great numbers in the marine railway and also in cedar buoys at New Bedford. It has also been found at Provincetown in a whaling-ship that had cruised in the West Indies.

"The *Xylotrya fimbriata* is very similar to the common *Teredo*, except that it has long, oar-shaped pallets, with slender stalks; the blade is flattened on the inside and convex externally, and consists of ten to twelve or more funnel-shaped segments which set one into another; their margins project at the sides, making the edges of the blade appear serrated. This species appears to be indigenous on this coast. It has been found living in a sunken wreck in Long Island Sound, near New Haven, and I have also taken it from the oak timbers of a vessel, the "Peterhoff," employed in the blockading service, during the late war, on the coast of the Southern States. It grows to a rather large size, often forming holes a foot or more in length and a quarter of an inch in diameter, though usually smaller. The pallets are sometimes half an inch long."

Less likely to be mistaken for worms, but equally clever at boring, is a group of shells called Pholads, from the Greek word φωλέω, lurking. They perforate all substances that are softer than their own valves, and some that seem to be harder. Woodward says: "It is to be remarked that the condition of the Pholades is always related to the nature of the material in which they are found burrowing; in soft sea-beds they attain the largest size and greatest perfection, whilst in hard and especially gritty rock they are dwarfed in size and all prominent points and ridges appear worn by friction." The Pholads have white shells, generally very thin but hard and strong, and adorned with rasp-like sculpture. It was supposed formerly that the excavation was made by twisting and moving this rough shell in the burrow; but the muscular, club-shaped foot is no doubt the instrument of abrasion.

We have upon the east coast three species, but none of them are of practical importance. They might become available for food, however, since the same mollusks are eaten in the southern counties of England, where they are called "Piddocks," and some cousins (*Zirphæa crispata*, *Platydon cancellatus*, etc.) are esteemed delicacies on the coast of California under the name of "Date-fish." Other west-coast species (*Navea*, *Gastrochæna*, etc.) are enemies of the Oyster, Abalone, and other mollusks which themselves have a commercial importance, since they burrow into their shells and so ruin them for service to man. There is, nevertheless, an attendant advantage in this, since in a state of nature the Pholads thus break to pieces and tend to level reefs that would prove obstructive to navigation, particularly in the case of coral banks. When the object leveled is an expensive dike or breakwater, however, the result is exactly reversed, as it is very likely to be where man's arts attempt to change the natural arrangement of things.

Our Razor-shell (*Ensatella americana*) is frequently used for food in Europe and in New England, and its valves have occasionally been applied to artistic service. It passes under the various names of "Razor-fish," "Razor-clam," "Knife-handle," etc., and is enticed from its sandy burrow by sprinkling salt upon the sand under which it lies, or is rooted out with a spade. John Josselyn, Gent., records that its "shell, calcin'd and pulveriz'd, is excellent to take off a pin and web, or any kind of filme growing over the eye." The Californian Razor-fish (*Siliqua patula*) is also edible.

Next upon the list comes the "Soft Clam," "Long Clam," or "Nanninose" (*Mya arenaria*), dear to New Englanders and only less numerous than the Hard Clam in the markets of New York and Philadelphia. This Clam lives just beneath the surface of the sand and mud above low-water mark, and is easily dug out with a hand-shovel. A very large class of persons all along the shore from Maine to Delaware derive their living wholly or in part by digging it and shipping to city markets. This is chiefly the case north of New York, however. On the northern coasts of New

England immense quantities of this bivalve are collected and salted to be used as bait in the cod fishery. Statistics and a full discussion of the habits and artificial culture of this Clam will be found in the special chapter devoted to the Clams.

Washed up by storms from the deep sands—down at least to ten fathoms below the low-water line—and hence known as the "Beach," "Sea," or "Surf" Clam, the huge *Spisula solidissima* furnishes occasional repasts to the dwellers along the whole Atlantic shore. It is chiefly eaten in Massachusetts, however, and its flesh is tough and by some persons considered unwholesome. It is often cast up in such great quantities as to become available for manure, mixed with various other marine animals of all sorts and sizes and much sea-weed. The large, smooth, white valves are collected in considerable quantities to be decorated inside with pictures in oil or India ink, which are again sold in the picture stores, often for a good price. This Clam is also preserved as bait. On the Pacific coast an allied species (*Spisula falcata*) serves the various purposes to which the eastern one is applied.

Following this comes the Quahaug (*Venus mercenaria*), which is known in the markets as "Hard Clam," "Round Clam," or, in New York, simply "Clam." From Cape Cod to Florida it is very abundant, but must be gathered by raking, since it does not burrow in the shore-sands like the Soft Clam. A commerce still larger than in the case of the Soft Clam is carried on with this species as bait, and also for food, in which respect it ranks next to the Oyster in the United States.

On the Pacific coast—where eastern shell-fish are constantly sent for transplantation and for immediate consumption—there are various bivalves used as food, such as *Semele decisa*, the "Flat Clam"; *Macoma nasuta*, the "Tellens," of San Francisco; *Schizothærus Nuttalli*, the "Gaper"; *Chione succincta*, and allied species, which replace eastern "Little Necks"; and *Saxidomus aratus*, to relish which was learned from the Indians.

In regard to this latter mollusk (*Saxidomus aratus*) it is interesting to note that its shell was broken into pieces by the Indians of the California coast and worked into flat, circular disks by rubbing upon stone. Eighty of these disks strung upon sinews were in recent use by the Indians of Lake County, California, as a medium of exchange in trade, and were valued at one dollar. In Sonoma County *Saxidomus gracilis* seems to have served the same purpose.

Another form of aboriginal money was made from the valves of the ponderous Hen Clam of southern California (*Pachydesma crassatelloides*), already mentioned. This money was called "*hawok*," and took the shape of perforated disks which could be strung as beads. The larger pieces, according to Stearns, were worth twenty-five cents, and were cut from the thicker parts of the shell; while the thinner portions supplied beads worth only four cents each. Further information will be found upon this in my magazine article above referred to.

The *Pachydesma* and its neighbor, the *Cardium Nuttalli*, are considered edible by the west coast people; but on the Atlantic shore, where occur several large species of "Cockle" (as the members of the genera *Cardium*, *Astarte*, *Venericardia*, and the like, are called), they are rarely or never used as food. This neglect seems curious, since this mollusk is eaten in great abundance in England, and may be bought everywhere in London during summer. "Prodigious quantities of this shell-fish are also consumed in Holland, where their cheapness recommends them to the common people as a principal article of food during the winter." In New England *Cyprina islandica* is eaten now and then, but bears a poor reputation in comparison with the Quahaug. In the Southern States the large "Painted Clam" (*Callista gigantea*) is equally available as food, and the *Gnathodon cuneatus* of the Gulf of Mexico is already an article of diet, as well as useful in road-making, to which utility many other mollusks contribute in all sea-shore towns.

These thick-shelled bivalves disposed of, a large group of thin-shelled mollusks deserve notice. Foremost among these are the Mussels, which are of several kinds. In Europe the *Mytilus edulis* (which is not different from our common Black Mussel of both the east and west coasts) holds an important place among sea-foods. In 1873 the mussel fishery of France alone was worth over 800,000 francs ($160,000). In that country they are regularly bred in inclosures of sea-water, upon frames and hanging ropes constructed for the purpose, and many persons are employed. In England, Scotland, Ireland, along the Mediterranean, in the West Indies, and along the whole circumference of South America, edible species of one name or another grow. Our *Mytilus edulis* is circumpolar in its distribution, and is excessively numerous at all rocky points suitable for its growth. In New York it is pickled in large quantities and shipped throughout the interior of the country. Its shells are extensively used by oyster-planters as a cultch upon which to catch young Oysters, and when polished are made into paint-holders for artists and various articles of bijouterie and personal ornament. The American Indians and the native New Zealanders used them as tweezers in pulling out their beards.

Mussels of a different sort are the *Modiola plicatula*, the *Modiola modiolus*, the *Modiola hamatus*, and *Modiola capax;* the first two are of the northern Atlantic, the third is more southern, and the fourth a native of California. These are sometimes eaten, but are not considered so good as the *M. edulis*. On the coasts of New Jersey and Long Island, however, incredible quantities are gathered from the banks at the inlets through the outer beaches where they grow, and are spread upon sea-shore farms as manure. In gathering this fertilizer a large number of vessels and men find irregular employment at times when they would otherwise be idle.

Another important bivalve in a commercial way is the Scallop, fisheries for which flourish in Long Island Sound, Narragansett Bay, and elsewhere. Large fleets of vessels are engaged in summer in dredging for these shell-fish. The powerful central muscle by which the animal opens and closes its shells forms the edible portion, the rest being discarded. These white fragments are to be seen piled upon platters or strung in strings as a constant delicacy in all our markets. The common Scallop of commerce is the *Pecten irradians*. Years ago the very large species, *Pecten islandicus*, an inhabitant of Eastern Maine and the Bay of Fundy, used to be obtained, and was highly prized for its flavor, but it has long been too rare to serve any purpose other than as a curiosity to conchologists. A more common and useful species, north of Cape Cod, is *Pecten tenuicostatus*, which supplied the Indians with a culinary instrument, and is good food.

"Scallop shells were formerly worn by pilgrims on their hat or the cape of their coat, as a mark of their having crossed the sea for the purpose of paying their devotions at the holy shrine in Palestine; in commemoration of which they are still preserved in the armorial bearings of many families of distinction whose ancestors had performed that ceremony. From its use by cooks now, this shell has given the name to 'scalloped' Oysters. In early times, when plates and drinking-vessels were not so plentiful as they are now, the concave or hollow valve of the Scallop served as a cup, and the flat valve for a plate. The idea has even been carried out by our pottery manufacturers, and plates and dishes have been molded after the forms of bivalve shells. Reticules, needle-books, pincushions, and other articles are made by shell-dealers with the scallop shell."

Of both the Scallop and the Mussel a special account will be given in another place, considering the value of each commercially.

The fresh-water bivalves belonging to the large family of the *Unionidæ* ought not to be omitted in this review. To the raccoon, otter, muskrat, and many other mammals and birds, as well as to the fishes, they are a steady source of food. Observing this, the Indians adopted them from the earliest prehistoric times as edible, and enormous heaps of shells upon the banks of many

of our interior rivers, especially in Pennsylvania, the Ohio Valley, and the Southern States, show how extensively and constantly they were sought. White men occasionally eat them, and in case of extreme hunger would perhaps pronounce a roasted *Unio* or *Anodonta* good. Some years ago a great furore was created by the discovery of a fine pearl in one of the Unios of North Carolina—a thing likely to happen in the case of any of them, since they have an interior which is often as finely nacreous as that of the Mother-of-pearl Oyster of the Gulf of California. Hundreds of persons immediately began searching the rivers all over that region, and total extirpation of the poor Mussels was prevented only by the discouragement of finding few pearls and these of insignificant size. It is probable that from the heavier species, in captivity, good pearls might be obtained artificially by following the plan pursued by the Chinese with their sea Pearl-oyster The experiment is worth trying.

Shells of fresh-water Mussels are frequently worked up into pocket-books and other fancy articles, as in the case of the *Mytilus*. When the brown epidermis is removed a beautiful iridescent polish is obtainable. There are almost innumerable varieties of these fresh-water Mussels, and full cabinets have a considerable value.

The manufacture of jewelry and shell-flowers consumes large quantities of small shells and and the polished opercula of large ones, chiefly derived from Florida. It is said that in London about a million of the commoner sorts are sold to street-sellers and country peddlers, who retail them to be made into fancy work and as objects of curiosity. The same thing is frequently seen in the United States, though more commonly in the shape of the traveling dealer who brings a large and varied stock to a country town, hires a shop for several weeks, and sells his shells mainly by auction.

The spread of commerce and improved facilities for dredging have made species once rare now common; but astonishing prices, reaching hundreds of dollars for a single specimen, in some cases were paid by owners of conchological cabinets for rare species half a century ago. This stimulated research and distributed much money among sea-side collectors. Even now dealers in objects of of natural history derive a large profit by importing shells whose only value is their scientific importance; while the institutions devoted to their study and the books to which an interest in conchology have given rise are entitled to a money estimation not to be despised.

# A CONTRIBUTION TO THE LIFE-HISTORY OF THE OYSTER.

(*Ostrea virginica*, Gmelin, and *O. edulis*, Linn.)

By John A. Ryder.

## 210. OUTLINE SKETCH OF THE COARSER ANATOMY OF THE OYSTER.

"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 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."[1]

The dark-purple scars near the centers of both valves are simply the areas covered by the attachments of the adductor, which is composed of a vast number of extremely fine muscular fibers, which collectively pass straight across the space between the inside of the valves, being firmly fixed at either end of the latter. The tendency to separate the valves at their free borders, inherent in the ligament, is balanced or counteracted by the muscle. The head end of the animal lies close against the hinge, the point where, as previously described, the two valves are firmly fixed to each other by a dark-brown, crescent-shaped body, the ligament, which, while it serves to attach, also tends, by reason of its elastic properties, to cause the valves to separate at their free borders in order to allow the passage of the water inward to the gills, and of food to the mouth, while it also allows the water which has passed through the gills to escape by way of the cavity above the gills which is prolonged into the cloaca, carrying along with it, in its outward passage, the fæces from the vent. The foregoing lines fairly describe the mechanism of the shell and in part the physiological significance of the same.

The structure of the shell is laminar, or, in other words, it is composed of numerous layers of a material identical in composition with chalk, deposited one on the other by the mantle, the organ which builds the whole shell in this way, the chalky substance being derived from the fluids of the animal, which in turn derives it from its food. These layers, deposited as they are internally, in a horny organic matrix, as growth proceeds project in succession past each other at the free edges of the valves and external surface of the shell, so that the successive deposits may readily be distinguished on its external surface, giving rise to a very rough imbricated appearance of the edges of the layers on the outside. Attempts which I have made to determine the age of Oysters from a supposed periodic deposition of the shelly material, corresponding to the years of its age, I find to be impracticable.

The structure in the layers of the shell of the chalk or calcic carbonate is minutely prismatic. Nathusius-Königsborn has found that certain portions of the shell of the European Oyster contain very minute air spaces. Both native and foreign species are found to have hollow cavities in the valves, usually containing water.

[1] W. K. Brooks: Development of the American Oyster. Studies from the Biological Laboratory of Johns Hopkins University, No. IV, 1880, pp. 5–7.

"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 cavity above them, and so out of the shell again. As the stream of water passes through the gills the blood is aërated 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.

"There are no accessory organs of reproduction, and the position, form, and general appear-

ance 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 [against] the bends and folds of the digestive tract."[1]

(The last of the foregoing statements as to the impossibility of discriminating the sexes without the aid of the microscope is no longer true, though it was true at the time the above was written. The method of discriminating the sexes discovered by the writer is discussed in another portion of this sketch of the history of the Oyster.)

The stomach is pretty definitely marked off from the other portions of the digestive tract. It may be said to be that portion of the latter which is surrounded by the liver. The portion of the intestine immediately following the short widened region which we regarded as the stomach is the most spacious portion of the gut, and in it is lodged a very singular organ which has been called the "crystalline style." This is an opalescent rod of a glass-like transparency and gelatinous consistence which measures, according to the size of the Oyster, from half an inch up to one and a half inches in length. Its anterior end is the largest, and in a large specimen measures nearly an eighth of an inch in diameter, but at its posterior end is scarcely half as thick; both ends are bluntly rounded. I fell into an error in supposing that this style was lodged in a special pouch or sac as described in my report to the Maryland commissioner in 1880. The "crystalline style" really lies in the first portion of the intestine and extends from the pyloric end of the stomach to the first bend of the intestine, where there is a marked constriction of the alimentary canal. It appears therefore to be a sort of loose valve in the cavity of the gut; its function may be to prevent coarse particles of food from passing, or it may in some way assist digestion. In specimens hardened in acid or alcohol this rod is destroyed, or at least disappears, so that I have been unable to find it. The greater portion of its substance is apparently made up of water.

The peculiar double induplication of the wall of the intestine is described in another place. The fæcal matters are extruded in the form of a demi-cylinder, with one side excavated in a groove-like manner. This shape of the fæcal matters is due to the presence of the double fold. The fæces themselves are composed of extremely fine particles of quartz or sand grains, the tests of diatoms, organic matters, humus, cellulose, fragments of the chitinous coverings of some of the minute worms and articulates, etc., which have been swallowed and digested by the animal. The anus is situated on the dorsal side of the great adductor muscle where the intestine ends.

The organs of sensation of the Oyster, though not very highly developed, are of sufficient importance to merit attention. The auditory sense, although I have never been able to dissect out the auditory vesicles, I am satisfied exists, because one cannot noisily approach an Oyster bank where the Oysters are feeding without their hearing so that instantly every shell is closed. The tentacles of the mantle are often extended until their tips reach beyond the edges of the valves. If the animal in this condition is exposed to a strong light the shadow of the hand passing over it is a sufficient stimulus to cause it to retract the mantle and tentacles and to close its parted valves. The mantle incloses, like a curtain, the internal organs of the creature on either side, and lies next the shell, and, as already stated, secretes and deposits the layers of calcic carbonate composing the latter. The free edges of the mantle, which are purplish, are garnished with small, highly sensitive tentacles of the same color. These tentacles are ciliated and serve as organs of touch, and also appear to be to some extent sensitive to light.

[1] W. K. Brooks: *Op. cit.*, pp. 8–10.

The nervous system of the Oyster is very simple, and, as elsewhere stated, is to some extent degenerate in character. It is composed of a pair of ganglia or knots of nervous matter, which lie just over the gullet, and from these a pair of nervous cords pass backward, one on each side, to join the hinder pair which lie just beneath the adductor muscle. The mantle receives nerve branches from the hindmost ganglia or knots of nervous matter; these, as their centers, control the contraction and elongation of the radiating bundles of muscular fibers, as well as those which lie lengthwise along the margin; the former contract and withdraw the edges of the mantle from the margin of the shell, while the latter in contracting tend to crimp or fold its edges. The tentacles are mainly innervated by fibers emanating from the hindmost ganglia, while the internal organs are innervated from the head or cephalic ganglia. The hind ganglia also preside over the contractions of the great adductor muscle. The nerve threads which radiate outward from it to the tentacles dispatch the warnings when intruders are at hand that it must contract and close the shells.

## 211. THE MINUTE ANATOMY OF THE OYSTER.

There is a spacious segmentation cavity developed in the embryo which becomes the subdivided body-cavity—schizocœl of later stages. Between the ectoderm and endoderm the mesoblastic tissue is developed apparently by proliferation, so that the segmentation or body cavity becomes in part obliterated. The mesoblast of the embryo formed as above stated is the tissue from which the mesenchyme or connective tissue of the adult is developed. The blood channels or canals are developed in the mesenchyme of the adult—mesoblast of the embryo. The large, coarse vesicular connective tissue cells form a sort of trabecular network of pillars and transverse supports between and around which the sanguineous fluids circulate. The blood channels or canals are developed directly from the spaces between the columns and their conjoining masses of connective tissue cells; an exception to this is found only in the structure of the anterior and posterior aortæ, the heart, and branchiocardiac vessels, which have proper walls lined with endothelial cells. Throughout the greater part of its extent the mesenchymal or connective tissue is spongy, its cells being built around complex anastomosing spaces for the blood. There is, therefore, a true schizocœl developed in the Oyster; it has been formed as the mesoblastic tissue has grown into the segmentation cavity and subdivided the latter into hæmal canals and spaces. The blood cells originate in all probability in the same way. These are amœboid, colorless, and measure about one three-thousandth of an inch in diameter. The vascular channels have no specialized endothelial walls in the mesenchymal parts of the body.

The adductor muscle of the shell and the radiating muscular bundles running from the insertion of the former to the edge of the mantle are derived from the mesoblastic cells of the embryo, the observations of Dr. Horst on this point having, I think, completely set at rest what was formerly a matter of theory. The radiating muscular bundles—pallial muscles—of the adult lie just beneath the epiblast or epithelium on the outer sides of the mantle leaves. These pallial muscles in the embryo are represented by two sets of dorsal and ventral muscular bundles, the functions of which are to retract the velum into which they are inserted. The muscular fibers of the walls of the heart are not striated and decussate in every direction. The inner walls of the heart are crossed in various directions by muscular bands or trabeculæ, and a more or less complete muscular septum divides the ventricle in the median line; the heart is, therefore, approximately four-chambered.

The mesenchymal or mesoblastic tissues comprise the great bulk of the body of the animal, and extend out into and form the greatest proportion of the thickness of the mantle, and also

down into the branchial sacs between their epiblastic or epithelial, ciliated, external walls. It also forms the principal bulk of the thick vertical, transverse septa which subdivide the branchial pouches internally, and forms likewise the bulk of the branchial filaments themselves. These latter are numerous and give the surface of the gills their furrowed or plaited appearance. The individual plaits or ridges seen in section are found to be quite complex and to be themselves compoundly ribbed and to have chitinous rods embedded in their substance just beneath the external epithelium. These rods run lengthwise through the substance of the branchial riblets. The branchial capillaries are excavated in the mesenchymal or connective tissue of the branchial filaments or tentacles, between which there are numerous openings or ostia for the passage of the water from the inferior portion of the pallial chamber into the gill cavities in order to effect respiration. It is difficult, however, to make this arrangement understood without the aid of figures.

The mesenchyme also gives support to all of the visceral structures, the ultimate secretory follicles or saccules of the liver being imbedded and supported by it. The same is true of the generative structures and the intestine. No portion of the walls of the stomach, œsophagus, or hepatic ducts can be found the walls of which do not lie directly in contact with this mesenchymal or mesoblastic tissue. It also extends out into and forms the greater proportion of the substance of the palps or lips of the Oyster, and is very spongy and highly vascular in this region. The internal or oral surface only of the palps or lips are closely plaited with numerous folds of ciliated epithelium. These folds may number from one hundred and twenty-five or more. The surface of the palps in the immediate vicinity of the mouth is not plaited or folded.

The mesenchymal cells are much larger than either the epithelial or endothelial cells, and will average one five-hundredth of an inch in diameter. They inclose in all cases, both in winter and summer, a large, irregular nucleus from which a complex network of intracellular granular fibrils radiate in all directions through the enveloping cellular substance. At one side of the nucleus there are always one or more accessory bodies, perfectly globular, which complicate the character of the nucleus in a singular manner. These vesicular, very hygroscopic, mesenchymal or connective tissue elements are not fat-cells, as has been erroneously supposed by Brooks. Their nuclei are invariably central and not parietal in position, as in fat-cells. These cells are probably very hygroscopic, as would appear judging from their singular appearance under the microscope. They appear to be widely distributed in the molluscous invertebrates; they were originally named "vesicular connective tissue cells" by the histologist Schaefer. An Oyster may in the summer season absorb water and swell up so as to fill up almost the whole cavity of the shell, and when opened it may lose so much blood and water in the course of half an hour that it will have shrunk to one-tenth of its original bulk. This is a common occurrence, and is explained by the probable hygroscopic character of the connective tissue cells and the spongy nature of the whole mesenchyme which consists of these elements. This also explains why it is that Oysters may be much swollen in a short time by osmotic action, when immersed in water of a less specific gravity than the sea-water from which they were first taken. The process has nothing in common with what might be called fattening, as we shall see hereafter.

There is an apparent atrophy or wasting away of the mesenchyme of the body-mass and mantle during the spawning season, with a great concomitant development of the reproductive follicles or tubules. In winter the reproductive follicles atrophy, when the mesenchyme again increases in bulk in the body-mass and mantle. It also undergoes another remarkable series of changes corresponding to summer and winter. In summer it acquires an almost glass-like transparency, so that the mantle, palps, and superficial portions overlying the viscera become

translucent. In this condition, if the reproductive glands are undeveloped, the dark mass of the liver may be seen through the body walls. Towards the autumn, on the other hand, the connective tissue cells acquire a milky opacity and great solidity as compared with their watery, transparent condition in summer. This last condition, which involves the whole mantle, the palps and superficial portions of the visceral mass, indicates to the oysterman the condition of fatness. The Oysters in this state are plump; do not so readily diminish in bulk when removed from the shell as in summer; but that this change is due to storage of fatty matters I have not yet seen any evidence of any sort which would amount to proof. There is some oily matter in the Oyster, but not enough to account for the changes which we have described.

The atrophy of the connective tissue during the summer season would appear to indicate that the material for the genesis of the reproductive elements was derived from the mesenchyme, by a direct transformation of its substance in which the generative follicles are imbedded. It is, in fact, the great development of the mesenchymal substance in the autumn and winter, when the reproductive function is in abeyance, that constitutes the condition of the animal known to oystermen as fatness. These relations illustrate very beautifully a well-known physiological principle, viz, that nutritive processes are very intimately related to the reproductive; they are in fact interdependent.

In summer, when the reproductive organs are gorged with their products, their follicles are crowded together into contact; in winter, in their atrophied condition, they lie imbedded in the superficial portion of the mesenchyme of the body-mass, the same as in summer, but are much less developed, so as to appear in sections like a very open network of strands of very small, nucleated, incipient embryo cells, the connection of which may be traced into the now collapsed and internally ciliated branches of the oviducts. All the parts of the reproductive apparatus are therefore present in winter, but in an undeveloped condition. The oviducts branch and spread over each side of the body-mass just outside of the stratum of reproductive follicles and immediately beneath the mantle. They do not ramify through the substance of the reproductive organ, but traverse its surface, the follicles emptying their contents into the ducts by way of openings upon the inner faces of the latter. The main openings of the oviducts of either side open into the upper branchial cavity on either side of the hinder and ventral portion of the body-mass just below the muscle. There is but one opening on either side, notwithstanding the various statements to the contrary.

Embryologically considered, the liver is an endodermal structure, a diverticulum of the stomach. The great bile ducts pass outward from the cavity of the stomach and subdivide again and again and end blindly in spacious ovoidal hepatic follicles, the simple plicated walls of which consist of hepatic cells. The function of the liver is in all probability both excretory and secretory, and takes an all-important share in the processes of digestion. That the function of the liver is partially excretory is rendered all the more probable from the fact that there is little or no evidence of the existence of a renal apparatus or organ of Bojanus in the Oyster such as is found in other mollusks. Dr. Horst looked in vain for a rudiment of this last structure in the embryos of *Ostrea edulis*. Transverse sections through those portions of the body where it would most likely be found, made from both native and foreign examples, exhibit no structure in the least degree resembling what is regarded as the organ of Bojanus in *Unio* and *Anodonta*.

The wall of the intestine, like that of the stomach, is ciliated throughout, and is also of endodermal or hypoblastic origin. Its wall is folded inward along one side in a peculiar way, so that its lumen is more or less crescentic in cross-section. This arrangement, together with the very minute minor folds on its inner surface composed of long, columnar, ciliated epithelial cells, increases the

amount of absorbing surface very materially. The internal surface of the stomach is also very much plicated; but here the folds are both large and conspicuous, with small folds often intervening. There are neither annular nor longitudinal muscular fibers in the wall of the intestine; the sole motive force used in the propulsion of the ingested food appears to be exerted by the ciliary covering which everywhere clothes the internal surface of the alimentary tract from the mouth to the anus.

It would appear that the intestine makes two complete bends upon itself at a very early stage of embryonic life, according to the observations of Horst, long before it measures a ninetieth of an inch in diameter. The development of the liver seems to be at first lateral and somewhat ventral; an arrangement traces of which may still be noticed in cross-sections of the adult.

The course of the intestine in the adult may be described as follows:

The mouth is a wide opening between the upper median angles of the palpi; so wide, indeed, that the animal can scarcely be said to have an œsophagus; immediately follows the stomach, which is seen to have very pronounced folds internally, with a generally transverse direction, but two of these, which lie in a somewhat ventral position, are a pair of inward projecting folds which are themselves plicated. The intestine then follows an oblique course, downward and backward, when it makes a sharp bend returning beneath the floor of the pericardial space, passing obliquely upward and forward, somewhat to the right and dorsal of the stomach, when it crosses exactly over the mouth or very short gullet, passing downward to the left side of the animal, alongside and a little to the lower side of the stomach, when it again turns upward and passes over the pericardial space to end in the rectum just over the middle of the adductor muscle. The clusters of hepatic lobules or follicles dip down into the folds of the walls of the stomach, but the liver does not follow the course of the intestine proper, which is provided internally with a curious pair of longitudinal and parallel folds, which project into the intestinal cavity and extend from the pyloric end to very near the anus. The presence of these folds gives to the fæcal matters their singular appearance, which are not in the form of a cylinder as they leave the vent, but in the form of a tube with a part of one side removed. Tracing the course of the intestine by sections is not the proper way; they can be very easily dissected out for their entire length by means of the scissors and forceps.

The systemic heart of the Oyster is that organ which serves to propel and redistribute the colorless blood of the animal through the body for its nourishment, and through the gills that the blood itself may discharge into the water the poisonous gases with which it is loaded in passing through the body, and receive a fresh supply of oxygen as fresh supplies of water pass through the gills. The heart consists of three principal chambers; the upper, largest, whitish and partially divided by a median septum or partition, is the *ventricle*, and the two lowermost and smaller, brownish paired chambers are known as the *auricles*. These three chambers which comprise the heart of the Oyster lie in a crescent-shaped space, the pericardial space, just forward of the adductor muscle. The ventricle is almost globular; its walls are made up of a delicate meshwork of unstriped muscular fibers, which are so interlaced as to be altogether untraceable. From the ventricle a great posterior and an anterior aortic vessel arises. These two vessels distribute the blood to the posterior and anterior portions of the body of the animal, but soon divide into paired vessels which traverse the mantle on either side both anteriorly and posteriorly, while one great median branch passes forward over the stomach. The blood is really distributed soon after leaving the main vessels, especially in the body through the spongy connective tissue spaces, as already described, and is collected into a great ventral canal from which a large part of it passes into the gills. From the four gills or branchial pouches the blood flows back to the ventricles

through six great branchiocardiac vessels, three of which are arranged on each side; two pairs of these are anterior in position and one pair posterior.

The circulation of the Oyster is quite different in character from that observed in a vertebrated animal. In the latter the heart pumps the purified blood *to* and through the gills before it passes to all parts of the body; in the Oyster, on the other hand, the fresh, pure blood is pumped by the heart *from* the gills before it passes to all parts of the body.

A curious and interesting point which I think it desirable to mention, because I have not noticed that attention has hitherto been especially called to it, is the metamorphosis of the larval Oyster into the adult. A. de Quatrefages[1] has alluded to it, but not in explicit terms. I have shown in my sketch on the growth of the animal that the larval shell was quite different from that of the adult, in fact, more like a very diminutive *pisidium* than anything else. The metamorphosis of the larval shell, or rather its passage into that of the spat, is abrupt. Not so with the soft parts; the oldest larvæ yet studied by any competent biologist show that the mouth of the larva is placed on the ventral side of the embryo, and that the hinge is situated on almost exactly the dorsal or opposite side. The ventral position of the mouth of the larvæ and its anterior or cephalic position in the adult show that a very important series of changes in the position of the viscera must take place between the time when the larva loses its principal embryonic features and acquires the adult arrangement and relations of its hard and soft parts. In other words, we are made aware, after instituting the foregoing comparison, that the Oyster actually undergoes a metamorphosis.

If an Oyster be carefully opened it will be found that the animal adheres to the shell at four points, or at two points on either valve. The principal points of attachment are of course the insertions of the great compound adductor muscle, made up of two portions which may be distinguished by the color of the cut ends of the component fibers. The great shield-shaped purple areas on either valve mark the points of insertion of the great adductor in the American Oyster, and also in the Portuguese form, which resembles it considerably. In *Ostrea edulis*, or the European species, the insertion of the adductor muscle is very rarely colored, so rarely indeed that we may regard this feature as one of the specific marks of this form. But in both the American and the European species there is a second muscular attachment, as implied above, which appears to have been very generally overlooked. It is situated nearer to the hinge than to the great adductor, and is sometimes marked by a slight depression not over an eighth of an inch in its greatest transverse diameter. It gives attachment to a feeble muscular bundle which springs out of the mantle on either side of the visceral mass, and when the animal is torn loose a slight whitish scar on the soft part marks its position on the surface of the mantle. I have been informed that Mr. W. H. Dall, who has investigated the matter, has identified this muscle with the pedal muscle of some other acephalous mollusks.

## 212. SEX, SEXUAL PRODUCTS, AND DIFFERENCE OF THE SEXUAL HABITS OF THE AMERICAN AND EUROPEAN OYSTERS.

"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 × 500=250,000 eggs. Nearly all the eggs of a perfectly

[1] Metamorphoses of Man and the Lower Animals. Translated by H. Lawson, M. D., pp. 104–109. London, 1864.

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 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 correct.[1] 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.[2]

"During my investigations I submitted more than a thousand Oysters to microscopic examination. My studies were carried on during the breeding season, and I did not find a single

[1] Möbius' measurement, from .15 to .18 millimeter, is given (Austern und Austernwirthschaft, 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.

[2] W. K. Brooks: *op. cit.*, pp. 13–15.

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."[1]

Writing about this matter in 1880, I said: "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 mantle 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 in 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."

In reference to the structure of the cells which make up the body of the Oyster, as well as regarding the eggs, Dr. Brooks, on page 19 of his essay, writes as follows:

"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."

Brooks has represented the freshly laid ova of the Oyster with a spherical nucleus and nucleolus; the former is large and clear, and is imbedded near the center of the egg, and inside of it the nucleolus is lodged somewhat to one side. I do not find the latter spherical, as described, but formed as if composed of a larger and smaller highly refringent pair of spheres, partly fused with each other, or of the same form as the nucleoli of the eggs of *Anodonta* as described by Flemming.

Some investigations conducted under the auspices of the Dutch Government indicate that the structure of the generative organs of the European Oyster is not, as has been supposed, strictly follicular, but that they may rather be regarded as a mass of anastomosing tubes of irregular caliber. The complete proof of this has been developed by the writer in the course of investigations carried out upon our native Oysters, in which the generative organs were very immature during the winter season. Both Brooks and myself have spoken of the generative follicles as though they had been clearly made out; it now appears that we will be compelled to modify our terminology somewhat, in the face of the fact that I have sections of the immature generative organ which exhibit it as a network of germinal cells, as well as sections of the mature organs which show a more or less distinct tubular structure opening toward the surface into the superficial or surface outgoing canals. At the same time the tubes show more or less extensive junction or anastomosis with each other at certain points along their length, with a general tendency to be disposed vertically to the surface of the visceral mass. This arrangement reminds one somewhat of the

[1] W. K. Brooks: *op. cit.*, p. 35.

more or less parallel disposition of the seminal tubules of the testicles or milt of fishes and higher animals.

In microscopical cross-sections of the adult Oyster, whether it be male or female, the reproductive glands are found to be composed of a great number of minute pouches or follicles. In the gross arrangement of the follicles no difference between the sexes is discernible when thin sections are scrutinized with the microscope. Upon making an examination of the contents of the follicles with the microscope a great difference at once becomes manifest; in the male the spermatic particles in the follicles appear very finely granular, and if mature the tails or flagella of the spermatic particles tend to be directed toward the outlet of the follicle; in the female, sections of the follicles show the eggs in various stages of development attached by their narrow extremity to the walls of the reproductive saccules. The egg is pyriform in shape while still in the ovary, but the stalk is not as long as in the eggs of *Scrobicularia*, as described by von Jhering. As elsewhere stated, the oyster-egg is not globular when first extruded. It will be readily understood that the sexes may be very readily distinguished by these and other marks observed in sections. The immature ova are vastly larger than the spermatozoa, which measure under the ten-thousandth of an inch at their largest end. The head of the spermatozoön of both the American and European Oyster is globular; that of the spermatozoön of the Soft Clam (*Mya*) is ovoidal in form. The tail or flagellum of the spermatic particle is the locomotive organ which lashes back and forth very rapidly and propels it through the water and finally brings it into contact with the egg.

## 213. NEW METHODS OF DISTINGUISHING THE SEXES AND OF TAKING THE EGGS OF THE OYSTER.[1]

Discrimination of the sexes.—One of the first requisites of a practical system of artificial fertilization of the eggs of the Oyster is a means which, in the hands of unskilled persons, will enable them, without the aid of a microscope, to infallibly distinguish the sexes apart. Such a means we now propose to describe. Having tested it practically, and found it possible to instruct persons of ordinary intelligence in a few minutes, we have no hesitation in offering an account of the method so as to make it more generally available in the hands of those who may be interested in this subject.

It is premised that the spawn is squeezed from the reproductive glands by the method to be described further on. As soon as the spawn is emitted from the generative opening in consequence of the pressure exerted upon the gland and the ramifications of its ducts, it is drawn up by means of a small pipette or medicine dropper, provided with a small collapsible bulb at the upper end which is held between the thumb and forefinger. Pressing the bulb between the fingers, then immersing the open end of the pipette into the extruded spawn, and then allowing the bulb to expand by its own elasticity, it will draw or suck up the spawn which has been pressed out very neatly; and if one is careful, absolutely nothing but the spawn is picked up. One soon becomes very expert in the use of the pipette.

The next requisite is a shallow glass dish, or even a plain tumbler will answer, into which say a half gill of clean sea-water has been poured. Taking up the extruded spawn from the opening of the duct it is dropped from the pipette into the clear water. This last simple operation enables us to tell without fail to which sex the products belong. If the creamy white mass consists of eggs which have been pressed from the generative openings and is dropped into the water, it will at once break up into a granular cloud as the spawn strikes the latter, the granules themselves

[1] The observations and experiments discussed in this article were conducted at Saint Jerome's Creek during the months of July and August, 1882.

being very distinctly visible, especially if the glass vessel be resting upon a dark ground so as to bring the whitish granules into relief. The granules are nothing more than the ova or eggs of the Oyster, and at once indicate that the individual from which they were obtained is a female. In case the products are male, they break up as they mingle with the water into a milky white cloud in which no granules are visible to the naked eye. It is also very important to observe that as the milt is stirred in the water it breaks up at first into long, fleecy white clouds which resemble very strikingly in miniature what are known to meteorologists as cirrus clouds, or, vulgarly, "mare's tails," reminding one of these in the way in which the fine particles of milt give rise to streaks, wisps, and fibers as it breaks up in the water, without giving rise to any visible granular appearance as occurs in the case of the female products, but to an opalescent or milky aspect. These distinctions, once learned, are so palpable that the novice may as infallibly discriminate the sexes of the Oyster apart by their aid as can be done by the most skilled biologist with a powerful microscope.

THE IMPREGNATION OF THE EGGS.—The method formerly used was to first learn the sex of a number of adult Oysters with the microscope, then cut out the generative glands with their products and chop up those of different sexes separately in small dishes with sea-water. This system we may now say is barbarous, because it is crude; large numbers of eggs are destroyed by crushing, or are injured by the rough usage to which they are subjected, and, besides, there is no assurance that the eggs or milt operated with are quite mature. It is also troublesome to free the generative gland from fragments of the liver which help to pollute the water in the incubating vessels with putrescible organic matter, and thus interfere greatly with the life and healthy development of the embryos.

By our method the objectionable features of the old plan, as stated above, are overcome. If possible, select good-sized Oysters; open them with the greatest possible care so as not to mutilate the mantle and soft parts. Carefully insert an oyster-knife between the edges of the valves and cut the great adductor muscle as close as possible to the valve which you intend to remove, leaving the animal attached to the other valve, which, if possible, should be the left or deepest one. The soft parts being firmly fixed or held fast by the great adductor muscle to the left valve prevents the animal from slipping under the end of the pipette, held flatwise, as it is gently and firmly stroked over the generative gland and ducts to force out the generative products.

To prepare the animals to take the spawn from them, after opening, the following precautions are to be observed: Note that the reproductive gland in great part envelopes the visceral mass, and extends from the heart space, just in front of the great adductor, to within a half inch or so of the head or mouth end of the animal, which lies next to the hinge. Note also that both sides of the visceral mass which incloses the stomach, liver, and intestine are enveloped on either side by a membrane which also lies just next the shell and is garnished by a fringe of purplish; sensitive tentacles along its entire border except at the head end where the mantle of the left side passes into and is continuous with that of the right side of the animal. The ventral or lowermost side of the animal, anatomically speaking, is marked by the four closely corrugated gill plates or pouches, which are preceded in front by the four palps or lips, but both the gills and palps depend downward between the lower borders of the mantle of the right and left sides. Note, too, that if the mantle is carefully cut and thrown back on the exposed side of the animal between the upper edges of the gills and the lower edge of the cut or exposed end of the great adductor muscle, the lower and hinder blunted end of the visceral mass will be exposed to view. It is on either side of this blunted end of the visceral mass between the upper edge of the gills and lower side of the great muscle that the reproductive glands open almost exactly below the great adductor.

From these openings we will afterwards find, if the animal is sexually mature and the operation is properly conducted, that the spawn will be forced out in a vermicular, creamy white stream. But in order to fully expose the reproductive organ we should carefully continue to sever the mantle of one side with a sharp penknife or small scissors, some distance forward of the great muscle towards the head, cutting through the mantle just above the upper borders of the gills and following a cavity which lies between the latter and the lower border of the visceral mass. A little experience will teach one how far it is necessary to carry this incision of the mantle. For some distance in front of the heart space the mantle is free or detached from the visceral mass and reproductive organ which lies immediately beneath, and this enables one, if the last described incision has been properly made, to almost completely expose the one side of the visceral mass and the richly tinted, yellowish-white reproductive gland which constitutes its superficial portion. The opening of the gland and its superficial ramifying ducts being laid bare on the exposed side of the animal we are ready to press out the spawn on that side. Before beginning this, however, it is important to observe that the principal duct passes down just along the edge of the visceral mass where the latter bounds the heart space, in which the heart may be observed to slowly pulsate, and that this great duct ends somewhere on the surface of the ventral blunted end of the visceral mass. To expose the great or main generative duct it may be necessary to cut through or remove the pericardial membrane which incloses or covers the heart space on the exposed side. If the Oyster is sexually mature, the main duct will be observed to be distended with spawn, and that, originating from it and branching out over almost the entire surface of the visceral mass, there are minor ducts given off, which again and again subdivide. If these are noted, and it is observed that they are engorged, giving them the appearance of a simple series of much branched great veins filled with creamy white contents, it may be certainly presumed that your specimen is mature and that spawn may be readily pressed from it.

The operation of pressing the spawn out of the ducts requires care. The side of the end of the pipette may be used, being careful not to crush or break open the ducts as you gently and firmly stroke the pipette flatwise over the side of the visceral mass backward from the hinge towards the heart space and over the great duct at the border of the latter diagonally downward and backward to the opening of the reproductive organ. If this has been properly done it will be found that the generative products are being pushed forward by the pipette through the ducts, as the pressure will be seen to distend the latter, the contents of the branches flowing into the larger and larger trunks until they are forced outward through the main duct and opening below the great adductor, where they will pour out in a stream one-sixteenth of an inch or more in diameter if the products are perfectly ripe. The sexes may be discriminated as described at the outset, and it is well to first find a male by the method already given and proceed to express the milt as described above into say a gill of sea-water, adding pipetteful after pipetteful until it acquires a milky or opalescent white color. As the milt or eggs are pressed out of the opening of the ducts they are to be sucked up by the pipette and dropped into the water, the mixture of milt being first prepared, to which the eggs may be added as they are expressed from the females. The judgment of the operator is to be used in mixing the liquids; in practice I find that one male will supply enough milt to fertilize the eggs obtained from three or four females, and it does not matter if the operation takes from twenty to thirty minutes' time, as the male fluid, which it is best to prepare first, will retain its vitality for that period.

It is always desirable to be as careful as possible not to get fragments of other tissues mixed with the eggs and milt, and the admixture of dirt of any kind is to be avoided. To separate

any such fragments nicely, I find a small strainer of coarse bolting or cheese cloth to be very convenient.

In the foregoing description we have described the method of obtaining the spawn only from the side of the animal exposed in opening the shell. A little experience will enable one to lift up the head end of the animal and throw it back over the great adductor muscle, expose the opening of the reproductive organ on the left side, or whatever the case may be, and also express the spawn from that side, thus as effectually obtaining all of the ripe eggs or milt as is possible in the process of taking the same from fishes.

It is remarkable to note the success attending this method, since almost every egg is perfect and uninjured, the percentage of ova which are impregnated is much larger than by the old method, reaching, I should say, quite ninety per cent. of all that are taken when the products are perfectly ripe. It is also found that the products are not so readily removed by my process if they are not perfectly mature, which is also to a certain extent a safeguard against getting poor or immature spawn. In the course of an hour after the products of the two sexes have been mingled together it will be found that nearly every egg has assumed a globular form, has extruded a polar cell, lost the distinct germinative vesicle and spot in the center, and begun to develop.

It is noteworthy that our practice as herein described has completely vindicated the statement made by the distinguished French anatomist and embryologist, M. Lacaze-Duthiers, that there is but a single generative opening on each side of the visceral mass of the Oyster, and that, as we have stated, it is found to open just below the great adductor muscle.

We have also discovered, since the foregoing was written, that the use of an excessive amount of milt is of no advantage. The water in which the eggs are to be impregnated only requires to be rendered slightly milky; a very few drops of good milt is sufficient to make the impregnation a success. Too much milt causes the eggs to be covered by too large a number of spermatozoa; thousands more than are required if too much is used. These superfluous spermatozoa simply become the cause of a putrescent action which is injurious to the healthy development of the eggs. A drop of milt to twenty drops of eggs is quite sufficient.

Immediately after the ova have been fertilized it is best to put them into clean sea-water at once, using water of the same density as that in which the adults grew. If the attempt is made to impregnate the eggs in water much denser than that in which the adults lived, it is probable that the milt will be killed at once. This singular fact, which was accidentally discovered by Colonel McDonald and myself, shows how very careful we should be to take into consideration every variation in the conditions affecting a biological experiment. If sufficient water is used no trouble will be experienced from the pollution of the water by dangerous micro-organisms which are able to destroy the oyster embryos. From fifty to two hundred volumes of fresh, clean water may be added to the volume in which the eggs were first fertilized. This may be added gradually during the first twenty-four hours, so as to assist aëration and prevent the suffocation of the embryos.

## 214. RATE OF GROWTH OF OSTREA VIRGINICA.

Size of the egg.—The egg of the American Oyster, according to Brooks, is approximately $\frac{1}{500}$ inch, being very nearly perfectly spherical after the extrusion of the polar or direction cells (*Richtungsbläschen* of the German embryologists). This accords with what the writer has observed in our species, and in the Portuguese Oyster, probably *O. angulata* Lam., the size of the egg appears to be about the same, judging from specimens of the latter examined by me in March last. Judging from the figures and the stated amplifications given in the papers of M. Davaine,

the egg of *Ostrea edulis* is $\frac{1}{150}$ inch in diameter. Estimates based on the figures of M. Lacaze-Duthiers give dimensions of $\frac{1}{240}$ inch. These discrepancies I think are probably too great, and may be due to imperfect micrometric methods. If they are real it would indicate a specific difference of some importance between *O. edulis* and *O. virginica*.

The actual volume of the egg of the American Oyster would accordingly be a little more than $\frac{1}{25000000}$ cubic inch, a solid so minute that we are unable to frame any adequate conception of its diminutiveness. Under the best conditions, as seen against a dark back-ground, it is visible as a grayish-white speck; almost an optical point. It is from this diminutive spherical mass of living matter that the young Oyster is developed. The development of the embryo proceeds, as far as I can make out, according to the accounts given by Davaine, Brooks, Horst, and others, similarly to that of other lamellibranchs. To Hatschek[1] we are indebted for the most secure foundation for our future embryological investigations upon this difficult group of mollusks; and we must not forget to mention the very important researches of Ray Lankester (Phil. Trans., 1875), principally upon *Pisidium*. I have not been able to observe the development of the larval Oyster beyond the size attained by it after the complete segmentation of the egg, the development of the shell, the velum, and alimentary tract. In fact, no embryos which I have attempted to rear from artificially impregnated eggs have ever lived long after the time when they began to take food, which is immediately after they acquire the velum, permanent mouth, and vent, and are almost or altogether covered on either side by the very symmetrical larval shells, which consist of carbonate of lime laid down in a matrix of conchioline. The isolation of the conchioline is readily effected by the use of acetic acid, the acid dissolving out the lime entirely. I find that Brooks and Dr. Horst[2] have tried a similar experiment with similar results. The latter writer has also been able to watch the development of the naturally impregnated ova of *Ostrea edulis* until a pretty advanced stage was reached. He disagrees with Brooks in his interpretation of the gastrula stage, and thinks that the invagination regarded by the American investigator as the blastopore must be considered to represent simply the first rudiment of the shell-gland. In assuming this position, from what I have been able to gather in the course of my own investigation of the development of the American species, I think we are bound to accept Dr. Horst's determination of the homology of the shell-gland of the Oyster with that of other lamellibranchiate and cephalophorous mollusks.

Early stages of development.—The oral invagination, according to Dr. Horst, originates on the opposite or ventral side of the embryo and has no connection with the dorsal pallial invagination or shell-gland. The early stages of the American and European species, like the later ones, appear to present no marked differences, except that the latter appears, on the evidence of Dr. Horst, Möbius, and others, to carry the ova and embryo in the mantle cavity, from which the first-named author obtained his material for study, by breaking a hole through the shell near the margin, so as to enable him to introduce a pipette into the pallial chamber. This method of getting embryos is impossible in our native species, which has wholly different breeding habits, as is proved by the investigations of Brooks, Winslow, Rice, and myself. How much further than heretofore Messrs. Brooks and Winslow have been enabled to carry the development of our native Oyster during the past season at Beaufort, North Carolina, I have not been able to learn, nor do I know anything more definitely as to how much success has been attained in the artificial production of *Ostrea edulis* from artificially-impregnated eggs at the hands of Mr. Littlewood, of England,

[1] Ueber Entwickelungsgeschichte von Teredo. Arbeiten aus dem Zool. Inst. Wien., Bd. iii.

[2] Bijdrage tot de Kennis van de Ontwikkelingsgeschiedenis van de Oester (*Ostrea edulis* L.), door Dr. R. Horst. Tijdschr. d. Ned Dierk. Vereen, Deel, vi, 1882.

who has claimed that he had succeeded in rearing them to the age of five months, specimens of which it is said were shown at the Fishery Exhibition recently held in Edinburgh.

EXPERIMENTS AT SAINT JEROME'S CREEK.—Our experiments made at Saint Jerome's Creek during the past summer gave the most contradictory results, and the interval of development between that of our oldest embryo with its diminutive Pisidium-like valves measuring about $\frac{1}{600}$ inch in diameter, and that of the embryo when its valves first begin to lose their embryonic form, still remains unbridged. The dimensions of the embryo or "fry," as we may more properly call it when it becomes fixed, are between $\frac{1}{80}$ and $\frac{1}{90}$ inch according as the measurement is made longitudinally or transversely. The difference in magnitude between the oldest artificially incubated fry seen by me and that of the youngest fixed embryos which I collected is very small, amounting only to $\frac{41}{4500}$ inch, or a little more than $\frac{1}{109}$ inch. To determine the relative volumes of these stages, and consequently the amount of food which has been taken in and converted into the structure of the more advanced stage in addition to the original bulk of the egg, we need only take the cubes of their respective diameters and compare them. Taking the diameter of the egg, or $\frac{1}{500}$ inch, as the diameter of the most advanced embryo seen by me, which we will consider unity, and comparing it with $\frac{1}{90}$ inch, or the transverse diameter of the newly fixed fry, we find, after having reduced the last quantity to its simplest form as compared with 1, or the diameter of the egg, that we have 5.1+. The diameters then of the first and last embryonic or truly larval stages are to each other as 1 is to 5.1+, and consequently their volumes will be to each other as the cubes of these numbers, or as 1 is to 132.651+. The difference between these two quantities, or 131.651+ times 1, will give us approximately the amount of food material which has been taken up by the embryo in passing from the condition when it was first able to feed until it fixed itself, showing that the process of growth has been going on vigorously in order to augment the volume of the young creature at the enormous rate indicated by our figures. We have, however, been dealing not with absolute but with relative or compared volumes only; if the egg contains $\frac{1}{250000000}$ cubic inch of protoplasmic matter approximately, the newly-fixed fry, which we will assume to be globular, and contains, as shown above, over 132 times as much material, the absolute bulk of the latter will be $\frac{1}{250000000}$ cubic inch multiplied by 132, or $\frac{132}{250000000}$ cubic inch, which, in its simplest form, is therefore $\frac{1}{1923076}$ cubic inch, or the absolute volume of the newly fixed fry. Ninety cubed, or 729,000 young Oysters could therefore be contained in a cubic inch of space, if taken at the stage at which they begin to be transformed into spat. This large number is, of course, small when compared with 125,000,000, the number of eggs which might be contained by the same extent of space.

THE LARVAL CHARACTER OF THE YOUNG OYSTER.—The proof of the larval character of the youngest fixed stage of the Oyster rests upon the three following well-ascertained facts: 1st. The perfect symmetry and great convexity of the valves; 2d. The entirely different shape of the shell as compared with those of the spat and adult; 3d. Its wholly different microscopic structure when compared with the later and full-grown stages. The form of the shell, at the time the animal is about to begin to develop the spat shell, is suborbicular, very thin, ventricose, resembling in many respects the shell of *Cyclas* or *Pisidium*, having the symmetry of those genera, with umbones of about the same form and prominence. These features mark the larval shell of the Oyster so unmistakably that its valves may always be very readily recognized at the tips of the valves of spat under a year old. The larval valves lie on the tips of the valves of the spat like small hemispherical caps, but can usually not be found after the young Oyster enters upon its second year, as its umbones, together with the larval shells which surmount them,

have been eroded by the action of the carbonic dioxide in solution in the sea-water. The presence of the larval shells in an unimpaired condition on the umbones of the valves of Oysters is therefore an indication that such specimens are young, probably under a year old.

The third character, alluded to above, which distinguishes the larval shell of the Oyster is the perfect homogeneity of the calcareous matter. Unlike the valves of the spat or translucid flakes from the shell of the adult, they exhibit no prismatic arrangement of the calcic carbonate in a matrix of conchioline. In the valves of the adult and spat, on the other hand, the calcic carbonate tends to assume a prismatic arrangement vertical or at right angles to the plane of the length and breadth of the shell. This distinction is so marked that in very young individuals which have only lately become fixed one may very readily determine with the aid of the microscope the line of demarkation along which the formation of the larval shell ceased and where the prismatic calcareous structure of the valves of the spat began to be developed.

Characters of the larval shell.—The only characters of structure which the larval shell has in common with that of the spat and adult are the lines of growth visible in all three. This shows that the valves grow in extent at all stages by the addition of lime to the edges of the valves, each layer of mineral matter and organic matrix extending over successively greater and greater areas, as in the growth of the shells of mollusks in general, the umbones being the points from which the valves grow in an eccentric manner in consequence of the gradually increasing extent of the mantle—the shell-secreting organ—as the growth of the animal proceeds. Having clearly defined the nature of the larval shell of the Oyster, up to the time when it is ready to begin to build or secrete the shell of the spat, we may next discuss the character of the transition from the one to the other.

The transition is apparently an abrupt one. The excessive convexity of the valves of the fry contrast strongly with the almost flat lower valve and feebly convex upper one of the spat. At the free edges of the larval shells where they pass directly into the structure of the valves of the spat there is a marked offset or angle marking very distinctly the difference of convexity between the two stages of shell development.

Food of the young Oyster.—As already remarked, I have seen food in the intestine of the young Oyster on the second day of development, but how long it may take before the young embryo of this stage of growth shall have taken and appropriated one hundred and thirty-two times its own volume of food material, I am not able to say. This it must do before it can have attained to the size of the larva which is transformed into spat. The food is propelled through the alimentary canal by the action of innumerable vibratory filaments which clothe the inside of the throat, stomach, and intestine as in the adult; the intestine, stomach, and liver are not, however, as complex as in the full-grown animal.

Of the method of fixation I have as yet learned nothing of value. That this is accomplished by some sort of byssus I have no doubt. The fact that it is the left valve which is always the lowermost and attached one would indicate that the method of fixation was not capricious or haphazard in its nature.

I would infer from what we learn from the study of other animals that it may require quite a week before an embryo reaches the dimensions of one-eightieth of an inch, but we have no data upon which to base any conclusions of value. Of the later stage of development we know something definitely. The main fact which we have so far decided is the size of the larval shell.

Rate of growth.—After fixation the growth of spat is very rapid, as may be inferred from the fact that I have found spat upon collectors which had not been placed in position

more than a week to ten days, upon which I detected spat one-fourth of an inch across. In other cases the following were the observed dimensions: On a collector which had been placed near a bed of spawning Oysters for twenty days I obtained a specimen of spat seven-sixteenths of an inch across; from another collector immersed for forty-four days I obtained specimens thirteen-sixteenths of an inch in diameter; from another out forty-eight days a specimen measuring about one inch. Another set of collectors which had been out for seventy-nine days had spat attached which measured one and three-fourths inches across. Some still larger spat collected by me was not over eighty-two days old, and measured nearly two inches in length from the hinge to the distal margin of the valves. Still larger specimens have been observed by the writer, which bore every evidence of having affixed themselves during the same season.

If we contrast the above measurements with those given by Möbius of the spat of *O. edulis* of known age, I conclude that the American Oyster grows three or four times as rapidly as the former. For instance, Möbius figures a European Oyster twelve to fifteen months old, which measures only one and one-fourth inches in diameter. Contrasting this with the size of the American at seventy-nine to eighty-two days old, and measuring from one and three-fourths to nearly two inches in diameter, we see how greatly our species surpasses that of Europe in vigor and rapidity of growth.

Of the rate of growth beyond the ages given above I have only a few data, based on the spat which was caught on collectors put out in Saint Jerome's Creek in July and August, 1880. In the following autumn the collectors which had been put out into the creek were taken up and the spat removed from them. This was then put into a box, through which the water could circulate freely, and put back into the creek, in order that we might be enabled to learn how much growth these young Oysters would make during the winter and next season. I did not have an opportunity to examine them, however, until the 10th of July, 1882. From the time of their fixation in July and August, 1880, to the time when I made my last examination of these specimens, a period of about twenty-three months had accordingly elapsed. One of the largest specimens examined by me measured three and three-eighths inches in length and two and five-eighths inches in width. Another smaller specimen measured two and a half inches long and two and a quarter inches in width. They were about the size of Oysters available for planting, and I have no doubt that in the course of two or three years more, if placed under favorable conditions, they would reach a marketable size. The inference, therefore, is that it takes at least four to five years for an Oyster to grow large enough, starting from the egg, to be available for market.

In order that an Oyster may grow to attain the great size of certain single individuals which I have seen, it may take even ten years. I should think it would take at least that length of time for an Oyster to grow until its valves would measure nine inches in length, a few of which I have seen of this enormous size. These, it must be remembered, were not "Raccoon Oysters" or "Cat's-tongues," as the narrow, elongate individuals are called which grow so densely crowded together upon the banks as to be abnormally lengthened. Under favorable conditions, I do not think it improbable that an Oyster may live to the age of twenty years, attaining corresponding dimensions.

## 215. THE FOOD OF THE OYSTER.

Observations at Saint Jerome's Creek.—The following extracts, taken mainly from my report for 1880 to the Fish Commissioner of Maryland, will give some idea of the kinds of organisms usually encountered on oyster banks and beds. These observations were made at

Saint Jerome's Creek, a few miles north of the mouth of the Potomac, during the months of July, August, September, and October:

"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. 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 siliceous 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.

"Besides the diatoms and the spores of algæ, the larvæ or young of many animals, such as sponges, *bryozoa*, hydroids, worms, mollusks, are small enough to be taken in as aliment 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 Saint Jerome's 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,[1] 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. Besides the type referred to, there were a number of other infusorians, which in their so-called swarming stages of development would become available as Oyster food. Of such types I noticed four different species, either belonging or very nearly

[1] On the occurrence of *Freia producta*, Wright, in the Chesapeake Bay. *Am. Naturalist*, 1880, pp. 810, 811.

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 larvæ of crustacea, 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. In illustration I may contrast the condition of the Oysters in the pond leased by the commission at Saint Jerome's 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."

These observations give us some hints regarding the advantages arising from the cultivation of Oysters in more or less stagnant water, in which, as in the French parks or *claires*, an abundance of microscopic life would be generated in consequence of a nearly uniform temperature, higher in the early autumn months at least than the waters of the open sea, where cold currents also would tend to make it still less uniform and thus interfere with the generation of the minute food of the Oyster. In other words, it would appear that the effect of the French method is to furnish the best conditions for the rapid and constant propagation of an immense amount of microscopic food well adapted to nourish the Oyster. That unlike Oysters exposed to a rapid flow of water on a bottom barren of life they grow and quickly come into a salable condition.

SITUATIONS BEST ADAPTED FOR OYSTER CULTURE.—In this country narrow coves and inlets with comparatively shallow water appear to furnish the best conditions for the nutrition and growth of Oysters; and according to my own experience these are the places where we actually find minute animal and vegetable life in the greatest abundance, and, as might have been expected, the Oysters planted in such situations appear to be in good condition early in the autumn, long before those which are found in deeper and more active water, where their

food has less chance to multiply. If the French mode applies successfully to an inferior species, ours, which grows so much more rapidly, ought to derive a proportionally greater benefit from being treated in the same manner. However, before we are ready to deal with the material on which the Oyster feeds, we desire a more perfect acquaintance with the microscopic life which grows upon oyster-beds and swims about in the adjacent waters. From the fact that the lower forms of life in fresh water often appear in great abundance one year, while in the next, from some unexplained cause, none of the same species will be found in the same situation, we may conclude that similar seasonal variations occur in the phases of the microscopic life of a given oyster-bed and its vicinity.

INFLUENCES OF ENVIRONMENT.—Such yearly variations in the abundance of microscopic life are probably the causes of the variable condition of the Oysters taken from the same beds during the same season of different years. Violent or sudden changes of temperature are probably often the cause of the destruction of a great amount of the minute life upon which the Oyster feeds. Backward and stormy seasons doubtless also affect the abundance of the microscopic life of the sea. All of these questions have, however, as yet been scarcely touched, and, judging from the disposition of many of our students of zoology to be content merely with a description of new species and the compilation of lists, instead of also entering into investigations of the life-histories, the relative abundance of individuals, and the influence of surrounding conditions upon the forms they study, it will take some time yet before we get the information so much desired. When we arrive at this knowledge we will know why it is that Oysters taken from a certain bed are in good condition for a season or two and then for one or more years are found to be watery and of poor quality, as well as why it is that the Oysters of certain beds, which for years have had a high reputation for their fine qualities, are suddenly found to be more or less green in the beard, as I have been informed is now the case with the Oysters of Lynn Haven Bay, Virginia.

As to the influence of brackish water in improving the condition of Oysters, let me observe here that those who hold to that opinion appear to forget to bear in mind that brackish-water beds are often in the case just described; that lying in shallow, relatively quiet water, an abundance of food is generated which is rapidly consumed by the animals, quickly bringing the latter into condition, the brackish state of the water getting the credit of the result.

"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.[1] . . . 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 that 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 experi-

[1] E. INGERSOLL: Report on Oyster Industry, Tenth Census.

ments 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 a 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."

PROTOZOANS OF SAINT JEROME'S CREEK.—The Protozoan fauna of Saint Jerome's Creek presents considerable variety; several species of test-building *Cothurniæ* were noticed, one *Vaginicola*, three species of *Vorticella* or bell-animalcules, free-swimming *Euplotes*, *Nassula*; of the latter type an exceedingly elongate form was noticed, with a body almost as slender as a thread-worm. Monads were noted sometimes in profusion, though some of these may have been the spores of algæ. Amœboid forms were very few, and the only one which was frequently noticed was a form so nearly like *Actinophrys sol* that I would pronounce it the same.

The *Freia producta* Wright was most common; this creature is related to the fresh-water trumpet animalcules, and is one of the most beautiful Protozoans I have ever seen. I reproduce here, with some changes, my description of the Chesapeake form from the "American Naturalist" for November, 1880:

"The tubes in which the animalcule resides are formed of a narrow transparent ribbon of horny consistency, wound into a spiral and terminating in a trumpet shaped extremity, from which the odd peristome of the inhabitant protrudes. The basal or attached end is usually bent at an angle to the tube and bears a striking resemblance to the foot end of a stocking resting upon the sole. This portion is not composed, like the tube, of a spiral ribbon, but is simply a thin-walled sac, from the open end of which the ribbon takes its rise, but it is composed of the same kind of material. Many of the tubes show a trumpet-like rim projecting from the sides of the former, a little above the middle, and of the same form as the terminal rim, showing that this, like the form described by Mr. Wright from British waters, may stop building its tube for a time and then recommence.

"The adult animal, tube and all, when fully extended, will measure one twenty-fifth of an inch in length. It is of the same color as *Stentor cæruleus*, or bottle-green, but has the power of elongating and twisting itself as greatly as *S.ræseli*. The peristome is quite unlike that of *Freia ampulla* and bears a strong likeness to the blades of a pair of obstetrical forceps. The blades are deeply grooved, forming a deep ciliated demi-canal with parallel sides, and at the junction of their bases lies the spacious, twisted, and spirally ciliated pharynx, which is bounded dorsally and ventrally by the prominent folds which unite on either side with the long, curved lobes of the peristome. There is a small basal disc as in *Stentor*, and the ectosarc is traversed as in that genus by parallel granular bands, regarded as muscular fibers by some writers. The usual food-balls and vacuoles are present, and I was enabled to define sharply the endosarc from the ectosarc,

and clearly see the nucleus. The tube or ribbon-secreting organ described by Wright I was unable to discover.

"When fully extended the basal portion of the animal becomes attenuated to a thin bluish filament, which widens towards the peristome, where the body is over half as thick as the inside diameter of the tube. When fully retracted and resting, the animal resembles in its oblong shape a retracted and resting *Stentor*, and measures about $\frac{1}{10}$ as long as when fully extended. The ribbon which forms the tube makes from four to twenty-four turns in specimens of different ages."

This organism I since find to be an inhabitant of the bay also, but is not so abundant as in the creek. Small mica collectors fixed to floating corks in the hatching jars and aquaria used during the past season were found to afford a nidus for *Freia* as well as *Zoöthamnium*, the latter multiplying at a most astonishing rate in a very few days. Under similar conditions, amœbæ, apparently *A. proteus*, multiplied at a suprising rate; this was the case, too, with a small brown diatom which would coat in three or four days the sides of the glass vessels with a thin brownish film composed of countless myriads of individuals of the one species. The temperature of the bay-water used in the aquaria at this time would range from 76° F. to 89° F. The *Vorticellidæ* also soon attach themselves, and next to the hypotrichous infusorians found in the locality are the most important animalcular forms found in the Chesapeake. At the mouth of the Cherrystone River I last year found *Lienophora cohnii* in great abundance ectoparasitic upon an unidentified hydroid. The heliozoön, *Actinophrys sol*, is found in the bay and Saint Jerome's Creek, and I think it capable of swallowing dead or enfeebled Oyster eggs and embryos.

MUTUAL RELATIONS BETWEEN THE OYSTER AND ITS PREY.—Möbius calls an Oyster-bank a *Biocœnosis* or interdependent community of life. The many species of animals found on the banks and beds are no doubt more or less mutually dependent upon each other for subsistence, but this is perhaps not any more true of Oyster-banks than it is of terrestrial faunæ. There are no doubt vast numbers of floating embryos of Oysters eaten by other animals growing on the beds which bring their food supply to themselves by means of currents produced by ciliary motion. On the other hand, there are no doubt vast numbers of the minute swimming embryos of these, drawn in and swallowed by the Oyster, which may, indeed, for aught we know, in this way swallow many of its own young, for the current produced by the Oyster by means of the cilia clothing its gills is by no means a feeble one, though it is exceeded in power by the current flowing into and out of the siphons of *Mya*. In the latter I have frequently, upon opening the animal, found several *Copepoda* plainly visible to the naked eye swimming about in the water in the inferior mantle cavity, which had evidently been drawn in by the inward current. It is plain in this case that very mild means may become effective as prehensile and destructive agents, so as to bring remotely related types into intimate vital relations.

Though an animal may be apparently invulnerable on account of the effectiveness of its covering, it cannot emancipate itself from the abiding struggle it has to make to obtain food, no matter how passively it may appear to conduct itself. The Oyster has such a character, yet it has been apparent from what has been observed before, that it is entirely dependent for a vigorous existence upon the favorableness of surrounding conditions. The beds and banks in a true sense are interdependent communities, whose vigor may no doubt be impaired by the removal of a single one of its members. Suppose we should take away the algæ, diatoms, Oyster-crabs, vibriones, bacteria, infusoria, in fact all the minute life; we should greatly impair if not destroy the vitality of the beds. While it is true that many of even the smallest forms may destroy food which should properly be consumed by the Oyster, that were it not for the presence of these same small forms some destructive element might attain such a development as to be more injurious still.

There is therefore no doubt but that a delicate balance of power is maintained by these rivals which is best for the health of the community. The stability of permanent oyster-beds, it must be remembered, furnishes the right conditions for the survival of many types. It is a place where they find both a home and plenty of food. It is the very favorableness offered by these places which tends to induce them to congregate and multiply, and it becomes a serious question whether the artificial establishment of banks will not in time cause the proper types to congregate and multiply so as to afford the needed food supply for the Oysters. That destructive members of the community may also be attracted is admitted, but if the beds are established in shallow waters, as I have previously suggested, the destruction of such unwelcome intruders may be very readily effected. "Drills" and boring-sponges are naturally to be thought of as types which should be destroyed, while diatoms, infusoria, small polyps, bryozoa, minute algæ, etc., are to be favored in every way. Those forms again which the oyster-culturist knows are only there for the purpose of getting a good living with little trouble to themselves ought to be destroyed.

It might be an advantage to introduce certain desirable forms onto a bank, which might be supposed to be useful as a food supply. Infusoria and diatoms not previously existing might be introduced in this way; this, I think, would be especially easy in the case of the former where the type was one which is fixed during its adult life.

## 216. ON THE CAUSE OF THE GREEN COLOR OF THE OYSTER.

Experiments at Washington and Philadelphia.—I have frequently read accounts of Oysters which had become green-fleshed in certain localities, and it has also been asserted that competent chemists had discovered poisonous green substances of metallic origin in such specimens. Tests made at the Smithsonian Institution by Professor Endlich in 1879 failed to disclose anything poisonous in some green Oysters which had excited the suspicion of the Board of Health of the city of Washington. This investigator, it is desirable to state, resorted to every test known to him in order to discover if anything poisonous was present, and failing to discover any harmful substance concluded that the color must be due to some inert material. In order to see if the color was due to the presence of some green compound of copper, Prof. H. C. Lewis, of the Academy of Natural Sciences of Philadelphia, kindly made some delicate tests for me, using small dried fragments of an Oyster very deeply tinged with green in various regions, especially in the liver, connective tissue, and mantle. The fragments were burned in a bead of microcosmic salt and chloride of sodium on a clean platinum wire in a gas flame; this test did not give the characteristic sky-blue flame which should have been developed had there been the minutest trace of copper present.

It is therefore clear that the substance, whatever it may be, is not a corrosive metallic poison derived from copper, which if present would almost undoubtedly be detected by a peculiar acrid metallic taste, which would be experienced when one ate such Oysters. In making some practical tests as to the relative qualities of such Oysters as compared with white-fleshed ones, opportunities for which were kindly furnished me by Mr. J. M. Carley, of Fulton Market, I failed to detect the slightest difference of flavor. Such also is Professor Leidy's verdict, who informs me that he made a similar experiment, and a restaurateur, with whom I discussed the matter, declared that he was in the habit of selecting them for his own eating, preferring their flavor to that of the white Oysters.

Variations in color.—If it be objected that the green color indicates an unhealthful condition of the animal, it may be stated that other color variations of the flesh have fallen

under my observation recently. What is now alluded to is the yellowish, verging toward a reddish cast, which is sometimes noticed in the gills and mantle of both the American and European species. This, in all probability, like the green color, is due to the reddish-brown matter which is contained in much of the diatomaceous food of the animal.

Mr. J. M. Carley has also called my attention to these variations, and was inclined to attribute them to the soil in the vicinity of the beds. But if the classical writers are to be trusted, to the green, yellow, and white fleshed sorts we must add red, tawny, and black fleshed ones. Pliny tells us of red Oysters found in Spain, of others of a tawny hue in Illyricum, and of black ones at Circeii, the latter being, he says, black both in meat and shell. Horace and other writers awarded these the palm of excellence.—(O'Shaughnessy.) However, the black appearance may only have been due to an abundance of the natural purple pigment in the mantles of the animal, which varies very much in different forms; some, judging from the dark purple color of the whole inside of the shell, must have the whole of the mantle of the same tint. The amount of color in the mantle, especially at its border, varies in local varieties of both the American and European species, as may often be noticed.

Sometimes almost the whole of the outside surface of the mantle is charged with dark purple pigment cells. That copper is not usually the cause of the green color of Oysters I also have the additional testimony of Prof. W. K. Sullivan, of Dublin, who 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."

The American consumer, however, need not be alarmed about the presence of copper in our species, as there are no beds on our eastern coast into which the washings from mines ever flow, as we have no workable deposits of copper near any of our beds, as in Cornwall, England. Besides, I am inclined to doubt the statement of Professor Sullivan that Oysters or other mollusks can absorb copper salts until their tissues are "colored bluish-green." Every competent histologist knows how very readily organisms are killed by the action of inorganic acids and salts, several of which are constantly used by biologists in fixing histological characters. Liebig, in his "Animal Chemistry," long ago pointed out that the oxides and metallic compounds of antimony, arsenic, copper, and lead had a very remarkable affinity for protoplasm, producing its immediate death. In consequence, he suggested a very high chemical equivalency for living matter. This has since been confirmed by the studies of Loew and Pokorny, who found that silver nitrate would produce a reaction with protoplasm if diluted to the extent of one part to a million of water.

Probable cause of the green color.—It is highly probable that the green color of the Oyster is due to the absorption from its food of a harmless vegetable pigment. In this country green-bearded Oysters occur at Lynn Haven Bay, Hongers and York Rivers, Virginia, on the

coast of New Jersey, in New York Bay, and Long Island Sound. I have seen specimens from a number of these localities, and also tasted them both raw and cooked without being able to detect any disagreeable or apparently harmful flavor.

Diatoms and green algæ occur in great abundance in the stomach of the Oyster, especially the former. The intestine is sometimes packed with countless numbers of the empty frustules or tests of diatoms, mixed with dark, muddy ooze or sediment and very fine particles of sand or quartz. It has been objected that the green color could not be derived from diatoms, because these organisms are, as a rule, apparently brown rather than green. This objection I find to be based upon a misapprehension of the structure of the *Diatomaceæ*, as may be gathered from the following general statement taken from Sachs' "Text Book of Botany," one of the latest and highest authorities. On page 222 he says: "The diatoms are the only algæ except the *Conjugatæ* in which the chlorophyl occurs in the form of disks and bands, but in some forms it is also found in grains, and the green coloring matter is concealed, like the chlorophyl grains in *Fucaceæ*, by a buff colored substance, diatomine or phycoxanthine." It appears, then, according to the foregoing quotation, that it is not impossible for diatoms to be the cause of the green tint in Oysters, which, let me remark, is very nearly that of some pale green forms of those organisms which I have observed in water from oyster coves where I have conducted microscopic studies. Both green and brown diatoms may frequently be found in the stomach, and in making examinations to discover them I find it best to thrust the nozzle of a pipette directly into the stomach through the mouth and œsophagus. The pipette should have a compressible bulb, so as to enable one to draw up the contents of the gastric cavity into the tube without injuring the animal or taking up any fragments of it to vitiate the experiment.

Observations of Gaillon and Johnston.—Speaking of the abundance of the *Navicula ostrearia* of Kützing, M. Benjamin Gaillon, in 1820, said that they inhabit the water of the tanks or "parks" in which the Oysters are grown in such immense abundance, at certain seasons of the year, that they can only be compared to the grains of dust which rise in clouds and obscure the air in dusty weather. Dr. Johnston, speaking of the French Oysters, says that in order to communicate to them a green color, which, as with us (in England), enhances their value in the market and in the estimation of the epicure, they are placed for a time in tanks or "parks," formed in particular places near high-water mark, and into which the sea can be admitted at pleasure by means of sluices; the water being kept shallow and left at rest is favorable to the growth of the green *Confervæ* and *Ulvæ;* and with these there are generated at the same time innumerable crustaceous animalcules which serve the Oysters for food and tincture their flesh with the desirable hue.

This last remark of Dr Johnston's at first struck me as improbable, but I have met with great numbers of small crustaceans, *Copepoda* mainly, in the branchial cavity of the common Clam (*Mya arenaria*). Certain peculiar species have also been described by Allman from the branchial cavities of ascidians. More recently, while investigating the contents of the stomach of the Oyster, by the method already described, I find that it also swallows crustaceans, which are digested and absorbed as food. The tests of nauplii or very minute larval crustaceans with the contents digested out were frequently met with. Doubtless many very small *Copepoda* are also swallowed and digested, but these are not green. Besides the foregoing, I sometimes met with the very young shells of larval gasteropods and lamellibranchs; indeed, it is not improbable that the adult Oyster may consume its own larvæ. The remains of bryozoa were also observed, such as *Pedicellina americana.* The test of a peculiar elongate rhizopod and the cephalula stage of several worms were also noticed. Of the smaller organisms usually associated with more or less clearly marked

putrefactive changes, one which I find almost uniformly present is a filiform or thread-like organism allied to *Spirillum*. It, however, was always found in the stomach in great abundance, and especially in the pyloric portion of the intestine in which the crystalline style is lodged. This organism is probably harmless; a similar one is frequently found in both fresh and salt water, and has at times been developed in prodigious numbers in the reservoirs from which the supplies of water were drawn for a large city, without any evidence of its having produced a harmful effect upon those who drank of the water.

Views of Leidy, Puysegur, and Decaisne.—Professor Leidy, at a recent meeting of the Academy of Natural Sciences of Philadelphia, stated it as his belief that Oysters feed at times on the zoospores of certain algæ, as those of *Ulva latissima* (sea cabbage), which he knew from personal observation to be green, and which he thought might possibly be the cause of the green coloration of the soft parts of the animal as sometimes observed in certain localities. Very possibly this may be the case, but judging from what I have seen and heard from oystermen, as well as from what I have read in various publications relating to this matter, I am not inclined to regard this as the only source of the unusual green tint of the flesh of the Oyster. I hope to be able to show that it is probably of vegetable origin, and therefore quite harmless. That it is not copper we may be equally certain, as Professor Lewis' tests have shown, for any such quantity of a copper salt as would produce the green gills, heart, and cysts in the mantle, such as are often observed, would, without doubt, be as fatally poisonous to the Oyster as to a human being. The source of the green has recently been investigated by two French savants, MM. Puysegur and Decaisne, who found that when perfectly white fleshed Oysters were supplied with water containing an abundance of a green microscopic plant, the *Navicula ostrearia* of Kützing, their flesh acquired a corresponding green tint. These investigators also found that if the Oysters which they had caused to become imbued with this vegetable green were placed in sea-water deprived of the microscopic vegetable food the characteristic color would also disappear. Whether this will finally be found to be the explanation in all cases remains to be seen, as some recent investigations appear to indicate that it is possible that a green coloration of animal organisms may be due to one of three other causes besides the one described above as the source of the green color of the Oyster.

Geddes upon chlorophyl-containing animals.—Patrick Geddes, in a recent number of "Nature," has pointed out that the "list of supposed chlorophyl-containing animals . . . breaks up into three categories: first, those which do not contain chlorophyl at all, but green pigments of unknown function (*Bonellia*, *Idotea*, etc.); secondly, those vegetating by their own intrinsic chlorophyl (*Convoluta*, *Spongilla*, *Hydra*); thirdly, those vegetating by proxy, if one may so speak, rearing copious algæ in their own tissues, and profiting in every way by the vital activities of these." This latter is one of the most interesting and important of modern biological discoveries, that living animal bodies may actually afford a nidus for the propagation of green microscopic plants and not be injured but rather be benefited thereby. The oxygen thrown off by the parasitic vegetable organism appears to be absorbed by the tissues of the animal host, while the carbonic-acid gas thrown off by the latter is absorbed by the vegetable parasite, thus affording each other mutual help in the processes of nutrition and excretion. This singular association and interdependence of the animal host and vegetable guest has received the somewhat cumbrous name of *Symbiosis*, which may be translated pretty nearly by the phrase "associated existence." This is not the place for the discussion of the purely scientific aspect of this question as already ably dealt with by Dr. Brandt, Patrick Geddes, Geza Entz, and others, and

we will therefore only notice their researches in so far as they appear to have a bearing upon the origin of the green color of the Oyster.

ENTZ' DISCOVERIES.—Entz has discovered that he could cause colorless infusoria to become green by feeding with green palmellaceous cells, which, moreover, did not die after the death of their hosts, but continued to live, growing and developing within the latter until their total evolution proved them to be forms of very simple microscopic green algæ, such as *Palmella*, *Glaucystis*, etc. My own observations on some green-colored infusorial animals have been of so interesting a character that I will here describe what I observed in a green bell animalcule (*Vorticella chlorostigma*). Upon investigating their structure, I found that next the cuticle or skin in the outer soft layer of their bodies, known as the "ectosare," at all stages there was a single stratum of green corpuscles very evenly or uniformly imbedded. In another form (*Stentor*), as already noticed by Stein, the same superficial layer of green corpuscles was observed, reminding one very forcibly of the superficial layer of chlorophyl grains observed in the cells of some plants, as, for instance, *Anacharis*. Now, it is well known that certain animalcules are at times quite colorless and at others quite green; this appears to be the case with *Ophrydium*. In this last case I have a suspicion that vegetable parasites may be the cause of the green variety, but as for the others, *Stentor* and *Vorticella*, I am not so sure that their green forms are so caused. In them the superficial positions of the green corpuscles and their behavior toward reagents lead me to think that they must be regarded as integral parts of the creatures in which they are found.

NATURE OF THE GREEN MATTER IN ANIMALS.—A grass-green planarian worm (*Convoluta Schultzii*), found at Roscoff by Mr. Geddes, was observed by him to evolve oxygen in large amounts, like a plant, and "both chemical and histological observations showed the abundant presence of starch in the green cells; and thus these planarians, and presumably, also, *Hydra*, *Spongilla*, etc., were proved to be truly vegetating animals." While some organisms, like the foregoing, appear to have true chlorophyl grains imbedded superficially in their own substance, others, like the radiolarians, some siphonophores, sea anemones, and jelly-fishes, harbor true vegetable parasites, or, preferably, vegetable guests.

That the green observed in a number of animal organisms is of the nature of chlorophyl, or leaf green, has been proved by Lankester by means of the spectroscope. A. W. Bennett, in alluding to Lankester's observations, says: "In all cases the chlorophylloid substance agrees in having a strong absorption band in the red—a little to the right or left—and, except in *Idotea*, in being soluble in alcohol, and in having strong red fluorescence, and in finally losing its color when dissolved."

The vegetable organisms which have been found to inhabit the lower forms of life alluded to in the foregoing paper have been regarded as belonging to two genera, which Dr. Brandt has named *Zoöchlorella* and *Zoöxanthella*, and which are probably in part synonymous with the genus *Philozoön*, afterwards proposed by Mr. Geddes. The latter gentleman, however, claims to have first demonstrated the truth of the view that the yellow cells of radiolarians and polyps are algæ; secondly, the foundation of the hypothesis of the lichenoid nature of the alliance between algæ and animal into a theory of mutual dependence; and, thirdly, the transference of that view from the region of probable speculation into that of experimental science.

Hitherto no one has apparently noticed the occurrence of green vegetable parasites in bivalve mollusks except Professor Leidy, who has very kindly permitted me to use the facts observed by him relating to *Anodon*, one of our common fresh-water Mussels. In this animal he some years ago observed what must be considered to be algous parasites. He found them in great numbers infesting the tissues of the Mussel and of a larger size than the nuclei of the cells of the host in which they were imbedded. They were also provided with a nucleus, and were, there-

fore, not a part of the animal but a distinct vegetable organism. These facts, observed a long time since, render it very probable that Professor Leidy was one of the first to notice the intracellular parasitism of a plant in an animal.

The green color of the Oyster, as far as my experience goes, is not intense, as in many green animals, such as we observe in *Stentor*, *Spongilla*, *Hydra*, etc., but is a pale pea-green tint. This has been found to be the color of affected natives as well as of foreign ones, the gills and mantle being usually most distinctly tinged. Exceptionally the heart is affected, its color sometimes being quite intense.

Experiments upon European Oysters.—In studying some Oysters which were obtained from England through the kind offices of Messrs. Shaffer and Blackford, in response to a request coming from Professor Baird, certain ones were found which were decidedly green. Of these the French specimens of *Ostrea edulis*, and a very singular form, labeled "Anglo-Portuguese," had the gills affected, and in some of the latter the liver, heart, and mantle were very deeply tinged in certain parts, so much so that I decided to make as critical an examination as my resources could command.

Spectroscopic investigations gave only negative results, as it was found impossible to discern any positive evidence of chlorophyl from the spectrum of light passed through thin preparations made from specimens of green-tinted Oyster, some of which, like those made from the heart, are decidedly green to the naked eye. There was no absorption noticed at the red and blue ends of the spectrum, such as is observed when the light which enters the slit of the spectroscope first passes through an alcoholic solution of leaf green or chlorophyl; indeed, the spectrum did not appear to be sensibly affected by the green substance which causes the coloration of the Oyster. No attempt was made to test the matter with the use of alcoholic green solutions obtained from affected Oysters, as the former are not easy to get with a sufficient depth of color, because of the relatively small amount of coloring matter present in the animals. Unstained fresh preparations were used in all of these experiments.

Colors in different parts.—I find the liver to be normally of a brownish-red color in both the American and European Oyster, sometimes verging toward green. When the flesh or gills of the animal is green, the liver almost invariably partakes of this color, but in an intensified degree. The green stain or tincture appears in some cases to have affected the internal ends of the cells which line the follicles or ultimate saccules of the liver. This color is able to survive prolonged immersion in chromic acid and alcohol, and does not allow carmine to replace it in sections which have been stained with an ammoniacal solution of that color, the effect of which is to produce a result similar to double staining in green and red. The singular green elements scattered through the connective tissue remain equally well defined, and do not take the carmine dye. I at first believed these to be parasitic vegetable organisms, and I also supposed I saw starch granules in them, which physical tests with an iodine solution failed to confirm. These large and small green granular bodies in the connective tissue, and those close to the intestinal wall, as well as those in the heart I, find present in fewer numbers in white-fleshed Oysters, but simply with this difference, that they are devoid of the green color. It is evident, therefore, that they cannot be of the nature of parasites, though the color is limited to them, only the surrounding tissue, except in the region of the heart, appearing of the normal tint. This condition of the specimens observed by me does not, however, disprove the possibility of the occurrence of vegetable parasites in the Oyster, where there is as much, or perhaps more likelihood of their occurring than in some much more highly organized animals.

It is a fact, however, that the Oyster is singularly free from true parasites of all kinds; the

oyster-crab being perhaps the only creature which is ever frequently found within its valves, and then only as a harmless messmate. More recently it has been my good fortune to be able to study a second lot of European Oysters, in two varieties of which the green color was unusually developed, especially in the heart. In a specimen of Falmouth Oyster I found a large cyst or sac in the mantle near the edge filled with green cells, which, like those in the heart, when opened readily separated from one another, being quite as independent of each other as the ordinary discoidal corpuscles in the serum of red blood. The hearts of affected specimens were found to have the wall of the ventricle abnormally thick, and covered inside with the readily detachable green cells in a thick layer and measuring one three-thousandth of an inch in diameter. An application of the test for starch with iodine gave a negative result. If iodine was first applied to these cells in strong solution, and they were then treated with sulphuric acid, the characteristic blue reaction was not developed, showing that there was no cellulose wall covering them, and that they were most positively not parasitic, algous vegetable organisms. In potassic hydrate solution they were completely dissolved, a further proof of the absence of cellulose.

Their dimensions, one three-thousandth of an inch, is the same as that of the blood-cell of the Oyster. They are nucleated, with the nucleus in an eccentric position as in the blood-cell of the animal. Their occurrence in the heart and gills so as to tinge those organs of their own color is almost positive proof of their true origin and character. Furthermore, I find in sections that they sometimes occlude the blood-channels. In the cysts in the mantle, as in the heart, they are free, and in the normal untinged heart they are not abundant. All of the foregoing facts indicate that these green bodies are in reality blood-cells which belong to the animal. How they become green is not easy to determine. The fact remains that no evidence of the presence of green *Micrococci* or *Microbia*, as independent existences, could be made out. The fact that I found instances in green Oysters where an unusual greenish material was found in the follicles of the liver, the living cells of which were also affected, would indicate that the color was probably absorbed from the food of the animal, which, as we know, consists largely of living vegetable matter. It is not improbable that the tinged nutritive juices transuded through the walls of the alimentary canal acquired the color of the food which had been dissolved by the digestive juices.

How to account for the accumulation of the green cells in the heart and in cysts in the mantle is not, however, an easy matter, unless one be permitted to suppose that the acquisition of the green color by the blood-cells is in reality a more or less decidedly diseased condition, for which we have no ground in fact, since the green Oysters are in apparently as good health as the white ones. They were found 'fat' or 'poor,' just as it may have happened that their food was abundant or the reverse. They are also found in all stages of the 'greened' condition. Sometimes they have only a very faint tinge of the gills, or they may be so deeply tinged as to appear unpalatable, with the heart of a deep green, or with green cysts developed in the mantle, or with clouds of this color shading the latter organ in certain places. A vastly greater proportion of green Oysters are eaten in this country, at all events, than is generally supposed, especially of those just faintly tinged in the gills.

The most important glandular appendage of the alimentary tract of the Oyster is the liver. It communicates by means of a number of wide ducts with a very irregularly formed cavity, which we may designate as the stomach proper, in which the food of the animal comes into contact with the digestive juices poured out by the ultimate follicles of the liver, to undergo solution preparatory to its absorption during its passage through the singularly formed intestine.

If thin slices of the animal are examined under the microscope we find the walls of the stomach continuous with the walls of the great ducts of the liver. These great ducts divide and

subdivide until they break up into a great number of blind ovoidal sacs, into which the biliary secretion is poured from the cells of their walls. A thick stratum of these follicles surrounds the stomach, except at its back or dorsal side. It is not correct to speak of the liver of the Oyster as we speak of the liver of a higher animal. Its function in the Oyster is the same as that of three different glands in us, viz. the gastric follicles, the pancreas, and the liver, to which we may add the salivary, making a total of four in the higher animals which is represented by a single organ in the Oyster. In fact, experiment has shown that the secretion of the liver of mollusks combines characters of at least two, if not three, of the glandular appendages of the intestine of vertebrated animals. There are absolutely no triturating organs in the Oyster for the comminution of its food: it is simply macerated in the glandular secretion of the liver and swept along through the intestine by the combined vibratory action of innumerable fine filaments with which the walls of the stomach, hepatic ducts, and intestine are clothed.

In this way the nutritive matters of the food are acted upon in two ways: first, a peculiar organic ferment derived from the liver reduces them to a condition in which they may be absorbed; secondly, in order that the latter process may be favored it is propelled through an intestinal canal which is peculiarly constructed so as to present as large an amount of absorbent surface as possible. This is accomplished by a double induplication or fold which extends for the whole length of the intestine, the cavity of which in consequence appears almost crescent-shaped when cut straight across. On the concave side the intestinal wall is thrown into numerous very narrow longitudinal folds, which further serve to increase the absorbing surface. Such minor folds are also noticed in the stomach, and some of these may even have a special glandular function. There are no muscular fibers in the wall of the intestine as in vertebrates, and the sole motive force which propels the indigestible as well as digestible portions of the food through the alimentary canal is exerted by the innumerable vibratory cilia with which its inner surface is clothed. The intestinal wall is wholly made up of columnar cells which are in direct contact externally with the connective tissue which is traversed by numerous large and small bloodvessels devoid of specialized walls.

This apparatus is admirably suited to render the microscopic life found in the vicinity of the animal available as a food supply. The vortices created by the innumerable vibratory filaments which cover the mantle, gills, and palps of the Oyster enables it to draw its food toward itself, and at the same time the microscopic host is hurled into the capacious throat of the animal to undergo conversion into its substance as described above. The mode in which the tissues may become tinged by the consumption of green spores, diatoms, or desmids it is easy to infer from the foregoing description of the digestive apparatus of the animal; and the colorless blood-cells, moving in a thin, watery *liquor sanguinis*, would, judging from their amœbiform character, readily absorb any tinge acquired by the latter from the intestinal juices.

## 217. LOCAL VARIATIONS IN THE FORM AND HABITS OF THE OYSTER.

Mr. Darwin ("Variation of Animals and Plants," vol. ii, 2d ed., p. 270) writes: "With respect to the common Oyster, Mr. F. Buckland informs me that he can generally distinguish the shells from different districts; young Oysters brought from Wales and laid down in beds where '*natives*' are indigenous, in the short space of two months begin to assume the 'native' character. M. Costa[1] has recorded a much more remarkable case of the same nature, namely, that young

[1] Bull. de la Soc. Imp. d'Acclimat., viii, p. 351.

shells taken from the shores of England and placed in the Mediterranean at once altered their manner of growth and formed prominent diverging rays, like those on the shells of the proper Mediterranean Oyster. The same individual shell, showing both forms of growth, was exhibited before a society in Paris."

VARIATIONS IN THE SHELL.—The statement by Mr. Buckland in regard to the local forms of *Ostrea edulis* is undoubtedly true, as I know from personal observation of specimens obtained for me from various parts of Europe through the efforts of Professor Baird. In some cases the local differences between the shells from different places were so marked that had a person mixed certain lots together indiscriminately without my knowledge I could afterwards certainly have sorted out the more marked varieties. Local influences also very largely determine the "greening" of Oysters, as I can assert from personal observation of both the American and European species. Practical oystermen affirm that they can readily discriminate the local varieties of Oysters grown in various noted localities along the eastern coast of the United States. From what I have seen it is very probable that this may be the case, as one may often observe well-marked differences of form as well as color.

Local adaptation undoubtedly takes place, for how else are we to account for the fact that a change in the specific gravity of the water to which the adult has been accustomed will kill the milt? This point has an important practical bearing in relation to the effect of heavy rains in diluting the water when the animals are spawning. Might not a marked change in the specific gravity of the water at the time of spawning kill all the spermatozoa which are set free, and thus also prevent the impregnation of whatever mature ova were being thrown out at that time by the adults?

INFLUENCE OF TEMPERATURE.—Certain it is that temperature has an influence upon the time of spawning. A lot of Oysters marked "Anglo-Portuguese," which had been transplanted from Portuguese to English waters, and which I received in the month of March and others in January last, had the reproductive organs remarkably advanced in development as compared with specimens of *O. edulis* from different parts of England, Wales, Scotland, Holland, and France. So great was this difference that, although planted for some time in the colder waters of England, the reproductive organs of the Portuguese form had not apparently had their disposition to become functionally active at this early season influenced to any great extent. In fact, I obtained living mature eggs and milt from a number of specimens of this variety, while I looked in vain for ripe spawn in any of the others of the true *O. edulis*. This would indicate that the influence of temperature, though not altogether hereditary in this case, was persistent, and had so impressed itself that the reproductive organs of these Oysters, coming from a warmer latitude, had begun to mature their sexual products even after transplanting into more northerly and colder waters much sooner than the natives of those same latitudes.

Like this persistent influence of a climate to which certain forms of Oysters have been long accustomed, the influence of the specific gravity of the water of a certain locality may also be persistent. The Oysters of Saint Jerome's Creek seem to be adapted to the specific gravity of the water of the vicinity, so that if artificial sea-water is prepared, differing much in this regard from the native water, we find that the spermatozoa are immediately killed if put into it. From this it follows that if the specific gravity to which the adults become accustomed is normal to their sexual products, may it not be well to look into the effect of such changes upon the health of the adults?

I have met with spawning Oysters in December, such at least in which the spawn was nearly mature, but this was an exceptional case. I find them in April and May in considerable abun-

dance; the months of May, June, and July may, however, be regarded as their principal spawning months. Ripe spawn may be sparingly obtained in the latter part of August, and even up to the first of October, but the three months mentioned are the periods during which the experimentalist ought to be in the field prepared for work in this, the latitude of Washington. What amount of variation from this period may be made manifest as we go north or south along the eastern coast of the United States I am unable to state; and what amount of local variation may also be due to causes of a purely local character I am also unable to say, not having examined the Oysters at a sufficient number of localities to make such facts as I may possess of any value.

## 218. THE OYSTER-CRAB AS A MESSMATE AND PURVEYOR.

It is many years since Mr. Say named the little Oyster-crab *Pinnotheres ostreum*, and its habits since that time seem to have excited but little interest. Professor Verrill, in his observations published in the "Report of the United States Fish Commissioner for 1871–'72," records the fact that it is the female which lives in the Oyster, and that the male, which is smaller and unlike the female, especially in the form of the abdominal segments of the body, is rarely if ever seen to occur as a messmate of the Oyster, but that he has seen it swimming at the surface of the water in the middle of Vineyard Sound. He also says that they occur wherever Oysters are found. This singular 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," and also by Semper in his treatise entitled "Animal Life."

QUADRUPLE COMMENSALISM.—The Oyster-crab is a true messmate, and it is in the highest degree probable that the presence of these animals in the mantle cavity of the Oyster is to be regarded as advantageous rather than otherwise. The animal usually lives between the ventral lobes of the mantle of its host, into which the four lobes of the gills and palps also depend, and, as will be seen from the following observations, may be the means of indirectly supplying its passive protector with a portion of food. During a trip down the Chesapeake in July, 1880, while I was with the Fish Commission vessel, some Oysters were dredged up by the crew which contained some Oyster-crabs. In the case I am about to describe the included crab was a female with the curiously expanded, bowl-like abdomen folded forward under the thorax, 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 arbuscculum*. 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 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 bell animalcule, 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 *protegé*, the crab, from the same food-laden current. Possibly the crab inside the shell of its host 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 would be 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, and that the branches of the curious tree-like colonies would also increase in numbers. The individuals of the colonies multiply in about three ways: first, by branching; secondly, by splitting lengthwise; thirdly, certain much enlarged and overfed zoöids divide crosswise. By the two last modes one-half of the product is often set free, the free animalcules so originated being known as "swarmers." These cast-off or free zoöids which drop from the colonies are no doubt carried along by the vortex created by the cilia of the gill and palps, and hurled into the mouth and swallowed as part of the daily allowance of the food of the Oyster. We may therefore regard *Pinnotheres*, in such instances, as a veritable nursery, upon the body and legs of which 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 attached to the fronds of the handsome *Grinnelia*, a red alga commonly found in certain parts of Chesapeake Bay. Where this plant grows in abundance on the bottom I have estimated that one might find upwards of a hundred animalcules attached to a square inch of frond surface, which would indicate an animalcular population of upwards of four millions of individuals to the square rod, a number as great as that of the human inhabitants of the city of London.

Development of the Oyster-crab.—The Oyster-crab undergoes a development and metamorphosis similar to that of our edible crab, *Callinectes*, but the body in the Zoœa stage is blotched with dark, branched pigment cells. The eyes also are vastly more developed than in the adult, where they are partly suppressed from disuse. There is no dorsal spine, nor are the antennary and rostral appendages so well developed as in the Zoœa of *Callinectes*. After the young are hatched they probably leave the abdominal covering of the parent, swim out of the Oyster for a season, and, if female, seek a permanent abode in some Oyster near by, behaving somewhat like the species described by Semper as inhabiting the water-lungs of certain holothurians. After undergoing further development, the young *Pinnotheres* reaches the megalops stage of its development, when it is probable that the choice of its home takes place. After it has entered the mantle cavity of its host as a diminutive larva, and has grown to be adult, when it measures a half inch or more in diameter, it is probably ever after a prisoner within the shell of its molluscan protector. It undergoes a retrogressive metamorphosis as it grows adult, its eyes become relatively less conspicuous than in youth, and it never has a thick, hard shell like its allies which live in the open water, but the external skeleton remains almost entirely soft and chitinous, or in the state in which we commonly find the outer covering of an edible crab which has just molted. This arises apparently from the conditions by which the animal is surrounded; the protection afforded it by its host does away with the need of a thick, hard covering such as we find inclosing the bodies of its free-swimming allies. Unlike the latter, too, the limbs of the Oyster-crab are to some extent degenerate and weakened; its chelæ or claws are feeble, and, when removed from its home, seems a very sluggish, helpless sort of creature, without a particle of the pugnacity of its allies, and if placed on its back will sometimes remain in that position helplessly beating the air with its weak limbs. This is a remarkable instance, which also serves very admirably to illustrate the principle of degeneration in organic evolution, so ably dealt with by Prof. E. Ray Lankester.

The Oyster itself is also an example of the effect of disuse in producing retrograde development, and even shows signs of gradual adaptation when removed from one locality to another. Unlike most other bivalves, the Oyster has no soft muscular foot which it may protrude outward from between the edges of its valves. No visible rudiment of such a prominence can be found

in the adult, though something of the sort, it is asserted by embryologists, appears to be developed in the larvæ. As the Oyster lost its power of locomotion from the non-development of the foot, due doubtless to a gradually acquired sedentary habit which has become permanent, the pedal structures have been almost entirely aborted, leaving nothing excepting the poorly developed pedal muscles described by Dall. There is accordingly little or no evidence of the existence of a pedal or foot ganglion in the Oyster, because there is no need for one, as in other forms; it, too, has disappeared with the structure which required its presence.

Returning to the consideration of the Oyster-crab, it is well known that it is much relished by many persons. The animal may be eaten alive, and has a peculiar, agreeable sweetish taste. Recently an enterprising New York party has taken to canning them, the supplies for this purpose being obtained from some of the large oyster-canning establishments. The economic value of the animal as food, although not great, is sufficiently important to demand a passing notice.

## 219. PHYSICAL AND VITAL AGENCIES DESTRUCTIVE TO OYSTERS.

Most of the observations which follow were made at Saint Jerome's Creek, Maryland, but inasmuch as the physical and vital enemies of Oysters appear to be similar the world over, I have no hesitation in reproducing what I have previously published elsewhere. And of physically injurious agents the black ooze or mud found in the vicinity or on the bottom of many of our most valuable beds and planting grounds is probably the most to be dreaded if it accumulates in too great quantity.

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 persisted for long 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 $\frac{1}{1145000}$ 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 calculation. The egg of the Oyster, being exceedingly small and heavier than water, immediately falls to the bottom on 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 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.

"In addition to the active, animate enemies of the Oyster, the beds suffer seriously, at certain times, from the elements. . . . 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.

"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 fifteen or twenty 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 forty 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."[1]

Interference of other animal life.—We have called attention 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 further 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 infusorians, bryozoans, 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

[1] E. Ingersoll, Report on Oyster Industry, Tenth Census.

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.

Star-fishes are notorious for the havoc they are capable of making among Oysters. They have the power apparently of everting their saccular stomachs and extracting the soft parts of their prey from the shell. Whole beds have been seriously injured by the inroads of these creatures. They do not seem to be dreaded much in the Chesapeake Bay, however, and appear to annoy the oyster-planters of New England most seriously.

"The oyster-catcher, and some 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 poor 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 shell-fish. 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 the artificial beds, for they do not seem to trouble the natural growth. But tolled by broken Oysters, when the planter is working, they come in crowds to that point. Mr. Udall stated that once he put down five hundred 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.'"[1]

In a specimen of the common *Ostrea virginica*, recently handed me for examination by my friend, Mr. John Ford, the substance of the shell was thoroughly cavernated so as to render it extremely brittle and readily crushed; in fact, the inner table of the shell left standing showed a great number of elevations within, which indicated points where the intruding parasite had been kept out by the Oyster, which had deposited new layers of calcareous matter at these places so

[1] E. INGERSOLL: Report on the Oyster Industry, Tenth Census.

as to give rise to the elevations spoken of. Besides this, the inner table had become so weakened at the insertion of the adductor muscles that the animal in closing had torn a part of it loose, which had been repaired by the deposition of a brown, horny substance. Evidence of the presence of the boring sponge may very frequently be noticed in shells of Oysters brought to the markets, though it often appears as if the parasite had left its work incomplete, being killed on its host. I find that Schmidt has also noted this, and that the boring operations of the sponge usually seem to stop in the case of living mollusks at the nacreous layer.

Upon examining some Scotch Oysters, obtained for me for study by Professor Baird, I was struck with the fact that every one was infested with this organism. The effect of the parasitism was that all of the specimens had abnormally thick shells, due evidently to the effort made by the Oyster to deposit more and more calcareous matter in order to exclude its persistent tormentor. Internally the shell showed irregularities due to the intrusion of the sponge. It is highly probable that in this case the growth of the Oysters had been impeded by the parasite, in consequence of the effort made by the animals to exclude their enemy by increasing the thickness of their shells. This same tendency to increase the thickness of the valves I have noticed in specimens of our native Oyster, the shells of which were infested with this parasite. It is very remarkable that the Oyster should make an effort to exclude its enemy by such a means; and it is not less remarkable to observe that the lime carbonate secreting function of the mantle is often stimulated to extra exertion long before the parasite has actually intruded into the cavity of the shell.

Dr. Leidy gives a lucid account of the living sponge as found in *Ostrea virginiana* and *Venus mercenaria.* He says: "This boring sponge forms an extensive system of galleries between the outer and inner layers of the shells, protrudes through the perforations of the latter tubular processes, from one to two lines long and one-half to three-fourths of a line wide. The tubes are of two kinds, the most numerous being cylindrical and expanded at the orifice in a corolla form, with their margin thin, translucent, entire, veined with more opaque lines, and with the throat bristling with siliceous spiculæ. The second kind of tubes are comparatively few, about as one is to thirty of the other, and are shorter, wider, not expanded at the orifice, and the throat unobstructed with spiculæ. Some of the second variety of tubes are constituted of a confluent pair, the throat of which bifurcates at bottom. Both kinds of the tubes are very slightly contractile, and under irritation may gradually assume the appearance of superficial, wart like eminences within the perforations of the shell occupied by the sponge. Water obtains access to the interior of the latter through the more numerous tubes, and is expelled in quite active currents from the wider tubes."

The boring process seems to be effected by the action of the living soft material of the sponge, according to observations which have recently been made by a Russian naturalist, according to whom it appears that the calcareous matter is dissolved away by the parasite. I am told by a practical oysterman that a bed once planted with Oysters which are badly infested by the boring sponge is apt to remain so for some time, and that the beds adjoining become infested, for the reason that the embryo sponges, which are thrown off in large numbers from the infested "plants," swim about in the water, attach themselves to other Oysters, to begin their injurious growth and excavations in sound shells.

## 220. NATURAL AND ARTIFICIAL OYSTER-BANKS.

Characteristics of natural oyster-banks.—I have examined a number of oyster-banks, which were readily accessible in shallow water, with gratifying results as to the habits of the animal under virtually undisturbed conditions. These banks, like those formed by the

European Oyster, always appear to be much longer than wide, but many of them are almost entirely exposed to the air during low tide, a rare occurrence, according to Möbius, with the banks on the Schleswig-Holstein coast of the North Sea. I learned from the owners of some of these banks that, although a considerable proportion of the Oysters on them were at times frozen to death during the severe winters, the fecundity of those which remained was such, combined with the naturally favorable conditions found on the banks for the growth of old and young, as to restore the beds to their wonted productiveness in one or two seasons. Whether this description of the fecundity of the beds found in shallow water is overdrawn or not matters little, since there was the plainest evidence that we had here before our eyes the best natural conditions for the propagation and feeding of the individuals. The beds are, in a word, natural spat-collecting grounds; places where such conditions obtain as will allow a large proportion of the swarming brood of the spawning season to affix itself securely and survive in positions where an abundance of food may be got. The tide ebbing and flowing over the beds not only carries with it in suspension the microscopic food best adapted for the nourishment of the Oysters, but also tends, owing to the peculiar arrangement of the shells on the banks, to keep the surface of the latter clean, so as to be well adapted as favorable points of attachment for the young.

In all of the natural banks which I have had the pleasure of examining in the Chesapeake, the individual Oysters assume an approximately vertical position. The assumption of this position seems perfectly natural; with the hinge end downwards and the free edges of the valves directed upward the animals are in an excellent position to feed, while the outside vertical surfaces of the valves are well adapted to afford places of attachment for the spat. The latter, however, appears to attach itself in the greatest abundance to the old Oysters at the surface of the bank. The result is that when one removes the Oysters from the bed they are found to adhere together in clusters, generation after generation being piled one on top of the other in succession. As many as four generations may be made out in most cases; the oldest being buried in the mud and sand below and is often found to be smothered by those which have followed. Even below the last stratum of living Oysters, if one keeps digging, it is discovered that the shells of numerous still more remote ancestors of the living ones now occupying the bed are disposed vertically in the sand and earth beneath. Attached to the upper edges of these dead shells follows, we will say, the first living generation and so on to the fourth, composed mainly of young individuals or spat only a few days or months old. Whether it is proper to regard the superimposed series of individuals as generations may be questioned, but as no more expressive word occurs to me, I wish to be understood as using it here with qualifications.

Positions of the spat.—The spat does not fix itself in any constant position; the young may have the hinge of the shell directed downward, upward, or to the right or left hand. Singularly enough the shells do not grow in the directions which the free edges of the valves are made to assume in the young. Should the young happen to be fixed hinge downward the free edges of the valves grow in length directly upward; in case the hinge is directed either to the right or to the left, the layers of calcic carbonate will be deposited in such a way upon one side as to cause the free edges of the valves to be eventually directed upwards, causing the umbonal portion of the valves to describe an arc of 90°. In case the hinge is at first directed upward, the layers of carbonate of lime will be deposited in such a way by the mantle as to bring the mouth of the shell upward. The attempt to get into a vertical position will, however, not always be successful in cases like the last; the arc of 180°, which it is necessary for the animal to traverse from its starting point in order to build its shell with the free edges opening upward, seem to be a feat a little too difficult of accomplishment, in spite of the wonderful persistence of effort manifested by the inhabitant.

The habit of growing in the erect position, where the banks are prolific and undisturbed, causes the individuals to be very much crowded together, so that they do not have a chance to expand and grow into their normal shape. From this cause, overcrowding, the shells of the individual Oysters become very narrow and greatly elongated; the peculiar forms which result are known to oystermen as "Raccoon Oysters," or "Cat's-tongues," the latter name being probably derived from a suggestive resemblance to the tongue of a cat. Fossil Oysters appear to have had the same habit. In some banks their crowded condition may be inferred from the fact that I counted as many as forty Oysters in an area included by a quadrangle of wire including exactly one square foot; thirty individuals to the square foot was a fair average on one bank examined.

All of the observant writers upon the Oyster agree that it is essential that the bottom upon which oyster-banks are to be permanent should not be liable to shift or be covered by mud or sediment. The experience of the writer strongly enforces such a conclusion. The permanent banks, owing to the great number of dead shells scattered through the bottom soil upon which they have been established, acquire a peculiar solidity or fixedness which the currents of tide water cannot sensibly affect. When these banks are once covered by the clusters of Oysters more or less securely held together by the lower portions becoming imbedded in the soil below, and mutually wedged and fitted together by the any msurfaces of contiguous clusters which have become neatly adapted to each other by pressure, it is a very hard matter for the tides to smother the bank unless sufficient soil in suspension is carried by the waters to completely cover the animals.

Establishment of artificial beds.—The inferences to be drawn from the foregoing observations are very important. They naturally lead to the inquiry whether artificial Oyster-beds cannot at least be established in shallow water, where the difficulties in altering the character of the bottom so as to adapt it to the wants of the Oyster are not practically insurmountable. I believe that the establishment of artificial beds, which would in time become similar in every respect to the natural ones, is possible in a moderately rapid tideway. The localities, I apprehend, are abundant along the shores of the Chesapeake, and I certainly know of few places where the existing natural conditions for such a project are any better than those found in Saint Jerome's Creek. The bottom would, of course, have to undergo such preparation as would insure to it solidity, and it might be well to imitate the flat, ridge-like character of the natural banks in constructing artificial ones. The long axis of the beds should probably lie transversely to the direction in which the tide ebbs and flows in and out of the creeks, as appears to be the case with many banks examined. The next thing to do would be to colonize these artificial banks with Oysters stuck thickly into the bottom, hinge downward, imitating the position of the animals in the natural banks. The cost of such an experimental bank would be comparatively insignificant.

Since the publication of the substance of the foregoing suggestion I have seen the idea practically realized in the Cherrystone River, Virginia. A heap of Oyster-shells had been scattered so as to form a low, solid elevation, which was submerged twice a day by the tide. Upon this spat had caught and grown until the whole in two years was as completely and solidly covered by living natural-growth Oysters as any good natural bank. The desirability of using the poorly grown stock from natural and artificial banks as "seed" for planting appears reasonable, and could no doubt be made profitable where banks of a sufficient extent could be established, from which a supply of seed could be obtained.

I have been informed by an old oysterman that pine bushes stuck securely into the sea bottom so as to be submerged in shallow areas have been found very effectual as collectors. In fact, he told me that in one case which had fallen under his observation an oyster-planter who followed this plan had the satisfaction of seeing his submerged bushes load with spat, much of which afterwards grew to marketable size. Afterwards a productive ridge or bank was the result where the brush palisade had originally acted as a collector. Thick palisades of brush might be stuck into the bottom near permanent oyster-banks with good results. Doubtless it would be possible to establish banks by this method if, in addition, oyster-shells or stones were strewn on the bottom along either side of the brush palisade, in order to afford a foundation for the fixation of the first generations of oysters.

SPAT-COLLECTORS.—Lieutenant Winslow, in 1879, used hurdles or nests of half-round tiles, eight to sixteen in number; the results from one placed in the Big Annemessex were very flattering. After it had been immersed twenty-four days 1,506 Oysters had attached themselves. After forty-five days had elapsed 1,334 still remained, and after ninety-three days were past the number still adherent was 539. I have had no such success, but in other parts of the bay, as at Tangier Sound for instance, spat falls in great abundance. I have seen the inner face of one valve of a dead Oyster furnish attachment for over forty spat from one-eighth to three eighths of an inch in diameter. Sponges, pieces of wreck, old shoes, pebbles, iron ore, leather, the external surface of the shell of *Modiolaria*, branches of trees and logs which have fallen into the water act as collectors. Oysters are sometimes found inside of bottles which have been thrown upon the bottom, the fry having wandered through the neck and attached itself to the inner surface, growing to the size of two inches in diameter and over. The spat is shaped much like the scallop or *Pecten*, a form which it often retains until it measures more than two inches in diameter. The primary requisite in collectors is that they shall present clean surfaces while the spawning season is in progress. Small inequalities are probably an advantage, as the very youngest spat is often found in chinks and angles on the shells of the adults. No other organisms should be allowed to grow and cover up or smother the oyster spat. Barnacles, infusoria, moss animals, polyps, and many other organisms are liable to accumulate on the surface of the collectors to the detriment of the young Oysters which have established themselves. Many of these animals, polyps especially, eat the young fry in the free-swimming stage, as shown by Dr. Horst.

The use of the methods employed abroad for collecting spat has not been tested in the United States upon a scale large enough to enable us to arrive as yet at any very important conclusions. Roofing slate coated with mortar promises good results; the valves of oyster shells strung upon wire, pine cones, and brush have been used, but in unfavorable places, so as to vitiate to some extent the results which were expected. A coating of cement will not answer; it gets too hard, so that the spat when it is to be removed from the collectors cannot be loosened without injuring its delicate, thin valves. The coating of lime and sand should be thick enough so as to make a layer of at least an eighth of an inch over the surface of the collector. It should also be allowed to thoroughly "set," as a stone mason would say, after it has been applied so as not to wash off readily. A strong mortar should be mixed for the coating, composed of sharp sand and good lime, in the proportions of about equal parts, and thin enough to dip the slates or tiles into the mixture bodily. If the first coat is not found to be thick enough a second and third may be applied. The tiles or slates after coating should be allowed to dry for two or three days so as to allow the coating to "set" firmly.

Various ways of supporting the tiles and slates have been devised, cheap forms of which are described in the treatises of Coste and Fraiche. The primary requisite in putting down collectors is that they shall be so placed as not to be covered by mud, especially where the bottom is overlaid with ooze. In such cases they must be supported so as to prevent their falling into the mud, the effect of which would be to make them useless. In practice, I suspect, that it would be well to look after the collectors occasionally and to brush off the mud, because in some places I have noticed that thick deposits of sediment soon collect upon the upper surfaces. This accounts for the fact that several observers have noticed that the spat is disposed to attach itself and survive on the lower surface of the collectors.

I am informed by Mr. C. P. Hull that the practice of strewing oyster-shells as spat-collectors on hard sea-bottom two or three fathoms deep is becoming quite common on the Connecticut shores of Long Island Sound. Here, the practice is to scatter two hundred and fifty to three hundred bushels of shells over an acre of bottom. The method there has also been so successful and profitable as a means of increasing the area of the oyster fishery that the price of the dead shells has increased and is likely to continue to do so, since the demand is greater than the supply. Mr. Hull, himself a practical oyster-culturist, proposes to introduce this system into practice on his projected plantations on the Chesapeake, where a beginning has already been made by this method under the direction of Captain Hine, at Cherrystone, the superintendent of the firm of Maltby & Co., of Norfolk, now largely interested as planters in the Cherrystone River. This method is the same as that extensively practiced in Europe.

How an oyster takes on flesh.—Among oystermen the business of fattening or feeding the Oyster is one of the most important, from the fact that upon the condition of the marketable product largely depends its value. Fatness, so called, in the Oyster is a condition wholly different in nature from the state known under that name in stall-fed domestic animals. The turgidity of the reproductive organs is not usually indicative of fatness, as it appears some authors have supposed, Möbius being the only one who has apprehended its true nature. The word "fat," as applied to indicate the condition of the Oyster when in flesh, is a misnomer, since it is not fat at all which is the immediate cause of the condition of plumpness which betokens a fitness for market, but a very extensive deposit of protoplasmic matter which has been assimilated and laid down mainly in the substance of the mantle. It is this relatively large amount of delicate, easily-digested protoplasm, stored up in the palps and mantle, which renders the Oyster so wholesome and nutritious.

The deposition of this protoplasmic material in the mantle, palps, and body stands in intimate relation to the activity of the reproductive organs. During the spawning season Oysters are said to be "poor," that is to say poor in condition, for at this time the mantle, especially where it lies next the body on each side, is very thin and quite transparent; the radiating pallial muscles along the border of the mantle, as well as its vessels and nerves, may now be readily studied under the microscope, owing to its transparency and the absence of opaque granular protoplasm. If we examine the reproductive organs at this time, as a rule, we will find them greatly developed and pouring out their products through two large ducts, the combined caliber of which is not far short of that of the intestine. It will be evident to any thinking mind that if the major part of the food material elaborated by the digestive and nutritive systems goes to the ovaries or testes to be transformed into sex products, which are continually thrown off during the breeding season, little of such material can be stored up in the tissues of the body. We have described exactly what happens. In the month of September, when the Oysters in this latitude are for the most part done spawning, the drain of elaborated material having ceased to flow from the openings of the

reproductive organs, it is diverted in another direction, but is retained in the system and has to be deposited somewhere in the body. The most extensive deposits of this elaborated living matter occur in the mantle, body, and palps, the color of which rapidly changes from the watery, transparent condition prevalent during the spawning season to a creamy white. The whole animal also acquires a solidity which it did not possess before; it loses its watery, impoverished appearance, together with its disposition to shrink to a fraction of its original bulk from an extensive loss of fluids when opened. The mantle and palps become opaque and thicker than before, and their substance is softer and more easily lacerated. The change here described undoubtedly affects the connective tissue principally, as elsewhere stated. The material of the latter has the milky appearance of the reproductive organ when mutilated, and may readily be mistaken for the latter by the inexperienced. It appears that the generative and nutritive functions are opposed to each other in the Oyster as in other animals; all of which indicates, too, the amount of energy which must be expended during the breeding season in the production of germs. Whatever surplus nutriment is stored up in the winter appears to be immediately devoted to the formation of germs upon the arrival of the warm months, when food is also probably most plentiful and when the external conditions are right for the development of the embryos. The effort which the Oyster makes, at the expense of so much material, to reproduce its kind ought to be respected. In the protection of the Oyster during the close season we are simply following the dictates of experience and common sense.

The account which we have given above of the physiology and interdependence of the fattening and reproductive processes of the Oyster, it seems to me, affords an opportunity to point out how little philosophy there is in the doctrine that Oysters may be fattened by putting them for a day or two in water less salt than that from which they were first taken, in order that they may be water-swollen by the action of osmose, so as to give to them a plump appearance. It is surprising how little dependence is to be placed upon the statements of oystermen and fishermen in regard to the habits of the objects with which they are supposed to be most familiar. And this statement, like many others of a similar kind, has no basis of fact and experimental evidence to rest upon. I may sum up the utter absurdity of the widespread belief in the possibility of fattening Oysters by removing them from salt to less salt water for a few days, by saying that it amounts to the same thing as to assert that water is a fatty or oleaginous substance!

The results of my most recent investigations upon the minute anatomy of *Ostrea virginica* may be fitly described in this place, since they have an important bearing upon the process of fattening. The subject of this investigation was one of the most impoverished-looking Oysters which it has ever been my fortune to find. It was collected on the 20th of July this present year (1882) and placed in a chromic acid solution of one per cent. for forty-eight hours, when it was washed and finally transferred to alcohol, to be cut into sections when convenient. This I have recently done. When the specimen in question was fresh it was characterized by the almost perfect transparency of the mantle, and, as it afterwards turned out, the total atrophy of the generative organ. Before the hardening process had been undergone, the mantle was greatly distended by watery fluid, so much so that, after hardening, it had shrunken to about one-tenth of its bulk while in the fresh and living state. The hardened specimen was cut into thin sections after imbedding in paraffine, by means of a modification of the Taylor freezing microtome; the sections for thinness left nothing to be desired, and revealed a condition of things different from any previously observed by the writer in sections of either native or foreign Oysters. A careful microscopic scrutiny showed that nowhere in the section was there a trace of even a rudiment of the generative network described as the atrophied condition in a previous portion of this paper. Not even

a trace of the connective tissue in which the rudiments of the latter are usually imbedded remained, but the hepatic follicles or ultimate saccules of the liver were lying in immediate contact with the mantle, with no tissue whatever intervening. I have hitherto found the liver surrounded by a thick stratum of connective tissue in all of the specimens examined. The statements in a previous portion of this essay in regard to the existence of vessels which traverse this connective tissue mass will therefore have to be modified so far as to say that not only does the connective tissue of the body mass completely disappear, but also the vessels themselves which are excavated through its substance.

Turning now to the condition of the mantle, I find this in a no less remarkable state than the parts already described. The "vesicular connective tissue cells," as they have appeared to me hitherto, have given place to an entirely different structure, apparently much less solid and substantial. Instead of the clearly defined coarsely cellular structure usually noticed in sections made from less impoverished individuals, the tissue has now become very coarsely areolar, all trace of the peculiar nuclear bodies having vanished, together with the internal protoplasmic network which they so clearly exhibit. The areolæ inclosed by the fibers of the connective tissue of the mantle are very coarse and may measure as much as half a millimeter across in sections of the hardened and shrunken specimen. When the mantle was gorged in life, with blood probably, some idea of the coarseness of these meshes may be formed. The meshes may then have measured four or five millimeters in diameter, the resulting cavernous state of this highly elastic tissue enabling the mantle to become gorged or swollen by endosmosis to a remarkable degree, so much so as to cause the animal to be apparently bulky, yet in reality distended with sanious fluids merely. The question now arises, What has become of this connective tissue which has so completely disappeared? The only interpretation which I can offer is that the connective tissue substance has been transformed into sexual products which have been poured out by way of the efferent sexual ducts, and that our specimen represents the extreme of exhaustion consequent upon the completed exercise of the reproductive function for the season. The animal, in other words, has now exhausted its germ-producing resources, and must begin to feed and store up material for the next season's generative products. It therefore becomes highly probable that the reproductive organs develop anew each season. My reason for thinking so is, that in this specimen the atrophy or wasting away of the reproductive organ has gone so far that no trace even of the efferent ducts of that body remains. The specimen, taken as it was in July, also shows that the spawning season may be completed before the end of summer.

The connective tissue of the Oyster is, therefore, in reality transformed into ova and spermatozoa, depending simply upon the sex of the individual whether it shall be the former or the latter. This also raises the question whether the same individual may not be of a different sex during different seasons, since it appears that the whole reproductive organ disappears and develops anew every year. This it is however to be noted is arguing from a very different basis from that of some foreign writers who have been absurdly illogical enough to say that the Oyster was of a different sex in different years, apparently forgetting that it would be impossible to open the same individual twice in succession; since opening it kills the animal and puts the second examination totally out of the question.

The function of the mesenchymal or connective tissue in the Oyster is, therefore, of the nature of a store of reserved material—protoplasm laid up for the purpose of conversion into germs as the reproductive organ develops anew. It is then in the highest degree improbable that it is of the nature of an oily or fatty substance, out of which it would be impossible to form such highly vitalized bodies as the ova and spermatozoa of the Oyster. While it is true that we find the mesenchyme

developed to the greatest extent during the winter when it may be said the Oyster is in the best condition as regards flesh, it does not follow that this plumpness is due to fatty matters, but rather to a larger amount of protoplasm filling up the mantle, palps, and body mass.

Our sections of the specimen described above show some other singular features which cannot be passed over in silence. The principal of these is the presence of thick-walled vessels in the ventral lobes of the mantle. In life we find branching vessels visible in the transparent mantle in very impoverished specimens, such as the one under discussion. These vessels may be followed to what are apparently their ultimate ramifications and seem to end abruptly. It is these vessels which become obscured when the animal acquires flesh; they are, in fact, hidden in the thick deposit of connective tissue laid down in the mantle. They are grayish or whitish in color as they shimmer through the transparent external epithelial and connective tissue layers of the mantle organ. They are also different in character from other vessels excavated in the connective tissue of the mantle, and which disappear with the atrophy of the latter's substance, just as we noticed was the case with the vessels of the body mass. In a specimen as greatly impoverished as the one under discussion, the thick-walled pallial vessels become very conspicuous in transverse sections. They may not have the same function as the bloodvessels of the ordinary wall-less form found in the connective tissue, from which type they may be at once distinguished by their thick, finely cellular walls.

The almost total atrophy of the mesenchyme or mesoblast during the spawning season is a very remarkable fact, no less so than its regeneration. It appears, however, as far as I have been able to learn from transverse sections of very small spat, one-eighth to one-sixteenth of an inch in diameter, that the absence of a well-developed connective tissue deposit also characterizes the soft parts of the young animal. Indeed, the liver follicles here are relatively few in number, whereas they are very numerous in the adult. The follicles in the young also lie in immediate contact with the mantle, resembling in this respect the spawn-spent adults. This, for embryological reasons, ought to be so. We find, in fact, according to the unanimous testimony of observers, that the mesoblast in the Oyster develops by the proliferation of cells from the outer and inner layers into the segmentation or body cavity. Why, then, should it not be absorbed and regenerated in the same way in the adult? There seems to be no valid reason assignable why this should not be so, if we look upon the mesenchyme with its vessels and areolar tissue and cavernous spaces as having been primarily derived from the embryonic body cavity.

The arrangement of the intestine as shown in sections of spat as small as that described above is essentially the same as in the adult. The second bend of the intestine crosses the gullet in the same way, but the double lateral longitudinal fold or induplication is not so well marked as in the intestine of the adult. The stomach is more nearly cylindrical and not so irregular as in the adult. The contents of both the stomach and intestine show that diatoms have formed a large proportion of the food of the young animal, in the sections of which, these contents, in a number of my preparations, have been kept *in situ*.

The sections of the soft parts may be very readily double stained so as to bring out the tissues of the reproductive organs very distinctly. To effect this, I throw the section into a solution of methyl green for a few minutes, then into magenta, when it will be found that the green will dye only the reproductive tissues, leaving the others scarcely tinged, while the red will stain the mantle, liver, and connective tissues, mapping out these parts so distinctly as to make a really useful as well as beautiful preparation.

Considerable care must be exercised in the preparation of the color solutions, so as not to have them too intense. The sections should also be at once and quickly dehydrated or else the

alcohol will abstract the green and spoil in part the effect of the double stain. In making sections, the best ones which I have ever made have been prepared from portions of whole Oysters which had been imbedded in paraffine, the latter substance having in the molten state interpenetrated all the cavities and spaces in the hardened specimen, which had been previously dehydrated and saturated with oil of turpentine.

*Note on the organ of Bojanus of the Oyster.*—In the first part of this paper it is stated that the organ of Bojanus is rudimentary or wanting in the Oyster. This statement must now be modified. Within the past year, M. Hoek, of Leyden, has demonstrated the existence of the organ of Bojanus in *Ostrea edulis*, and the writer has shown it to be present in the American species as a crescent-shaped glandular or canaliculated structure lying just below the adductor and close against it, as a paired organ which also extends slightly into the substance of the mantle on either side. M. Hoek has shown that, as in other acephalous mollusks, this organ communicates with the pericardiac cavity and the genital openings. Its function is excretory.

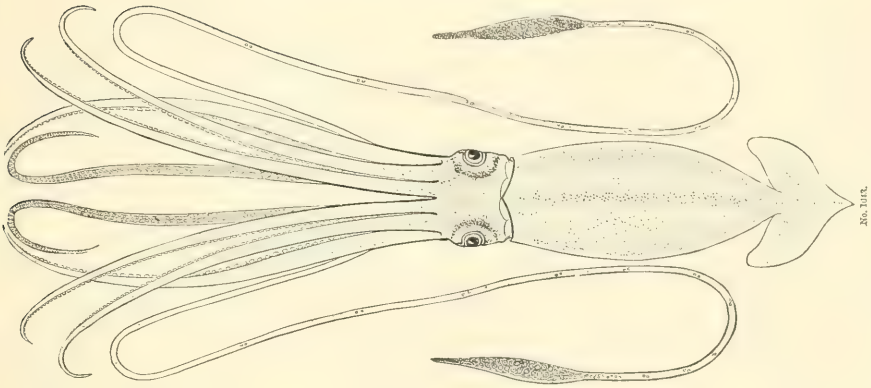
*Valves of the heart.*—A pair of very distinct valvular folds separates each of the auricles of the heart of the Oyster from the ventricle, opening upward into the latter. They prevent the blood from regurgitating into the auricles, and cause the blood-current to assume one constant direction, viz, from the auricles to the ventricles, and from the latter through the anterior and posterior aortic vessels to the various parts of the body.

*Fixation of the spat.*—Recent studies have led me to the conclusion that the existence of a byssus in the fry of the Oyster is very doubtful, and that fixation is accomplished at a very early stage, possibly twenty-four hours after the embryos commence to swim, by the border of the mantle, as I have endeavored to show in my paper "On the Fixation of the Fry of the Oyster," illustrated with figures, and recently prepared for the Bulletin of the United States Fish Commission, where I also show that the beaks of the larval valves are constantly directed one way, and that the hinge end of the larval shell is inclined upward, the free margin of the left larval valve being brought into close contact with the surface to which attachment occurs through the instrumentality of the margin of the mantle. The attachment itself is a very firm one, and consists of the horny matrix of the calcareous material which serves as a cement to glue the free margin of the lower valve of the fry and spat to the surface which has been chosen as a permanent abode.

THE COMMON SQUID.

Loligo Pealei (Le S.).

Drawing of female from Vineyard Sound, Massachusetts.



No. 1172.

THE GIANT SQUID.

Architeuthis princeps, Verrill.

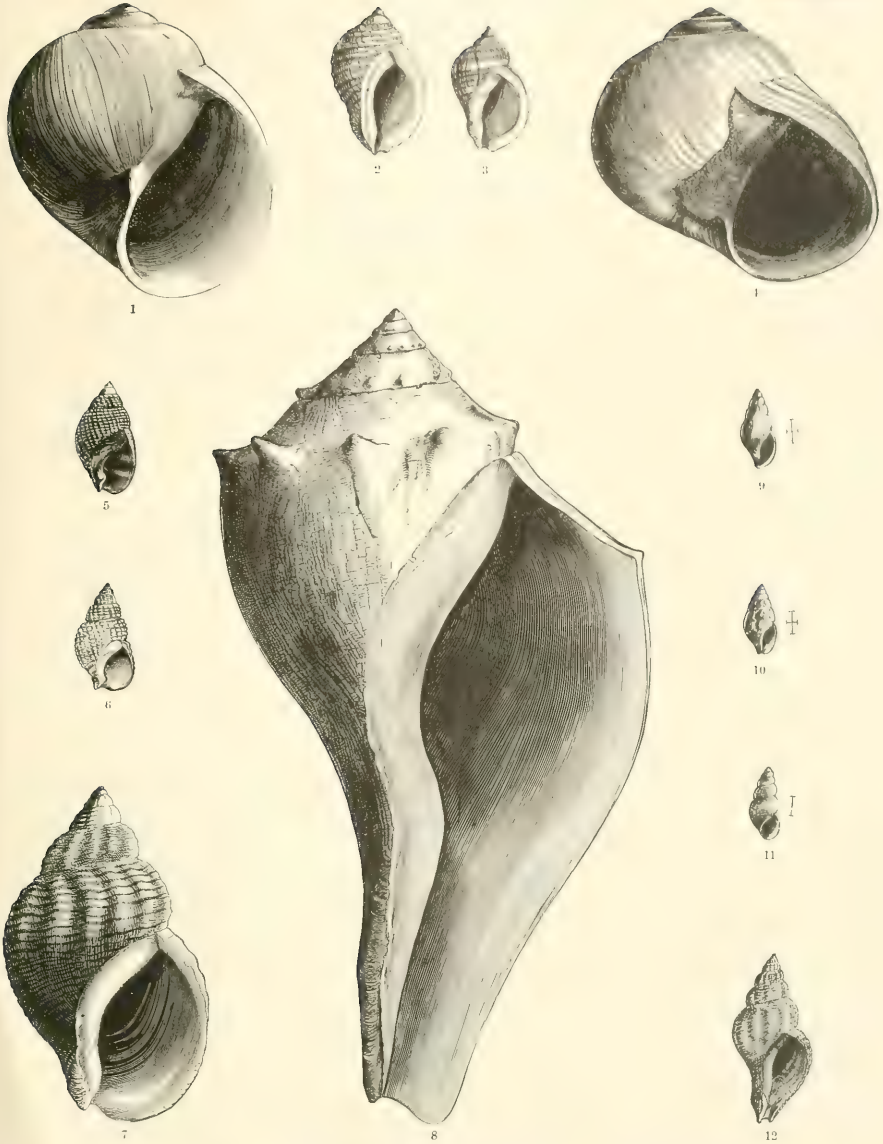
Drawing by Prof. A. E. Verrill, from specimen obtained at Fortune Bay, Newfoundland, December, 1874.

No. 1369

THE SHORT-FINNED SQUID.

Ommastrephes illecebrosus (Le S.), Verrill.

Drawing of young male from Provincetown, Mass.




## SEA SNAILS, PERIWINKLES, DRILLS, AND BORERS.

FIG. 1. *Lunatia heros*, p. 700.
FIG. 2. *Purpura lapillus*, p. 698.
FIG. 3. *Purpura lapillus*, banded variety.
FIG. 4. *Neverita duplicata*, p. 700.
FIG. 5. *Ilyanassa obsoleta*, p. 696.
FIG. 6. *Tritia trivittata*.
FIG. 7. The Whelk, *Buccinum undatum*, p. 699.
FIG. 8. The Periwinkle, *Fulgur carica*, p. 694.
FIG. 9. *Astyris zonalis*.
FIG. 10. *Astyris lunata*.
FIG. 11. *Rissoa aculeus*.
FIG. 12. The Drill or Borer, *Urosalpinx cinerea*, p. 697.

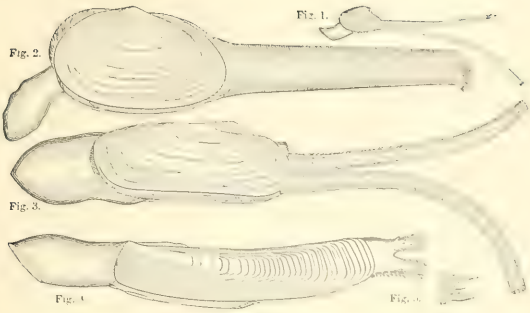



Fig. 6.

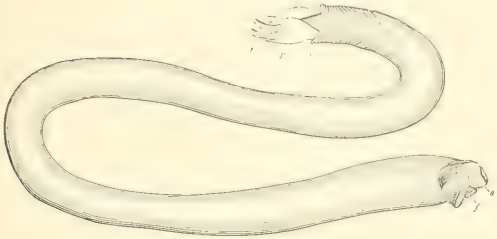


Fig. 7.

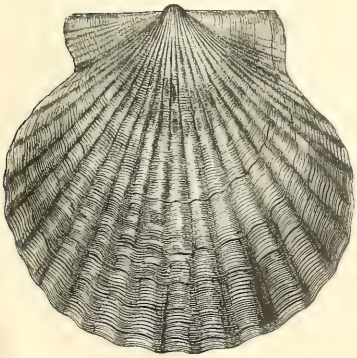


Fig. 8.

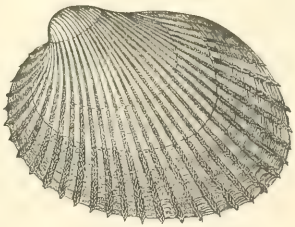


Fig. 9.

FIG. 1. *Angulus tener.*
See Report U. S. Fish Commission. Part I, p. 677. Animal reduced one-half.

FIG. 2. The long clam, soft clam, or Nanninose, *Mya arenaria.*
With animal in extension, reduced to one-half the natural size.

FIG. 3. *Tagelus gibbus.*
See Report U. S. Fish Commission. Part I, p. 675, with animal. The siphon not fully extended. One-half natural size.

FIG. 4. The Razor Clam, *Ensatella americana*, p. 707.
With animal extended. One-half natural size.

FIG. 5. The Razor Clam with some of the terminal papillæ enlarged.

FIG. 6. The Razor Clam, *Ensatella americana.*
Shell natural size.

FIG. 7. The Ship Worm, *Teredo navalis.*
Enlarged two diameters.

FIG. 8. The Scallop, *Pecten irradians*, p. 709.
Natural size.

FIG. 9. The Bloody Clam, *Argina pexata.*
Natural size.

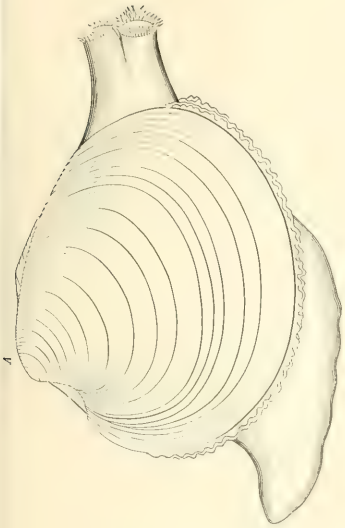


Fig. 1.

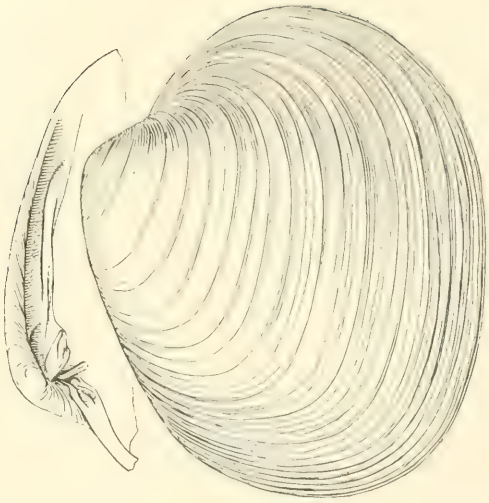


Fig. 2.

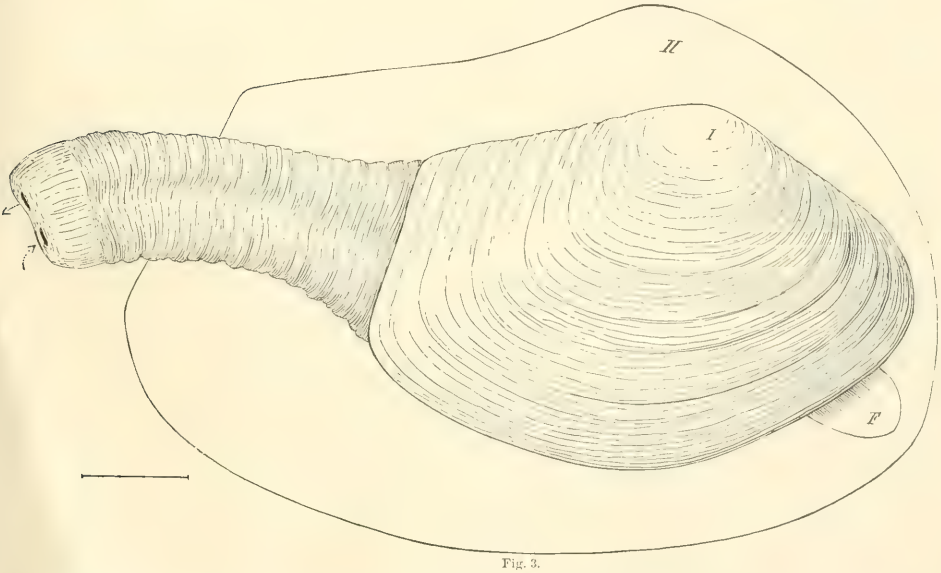



Fig. 3.

FIG. 1. The Quahaug or Little-necked Clam, *Venus mercenaria*. Natural size.

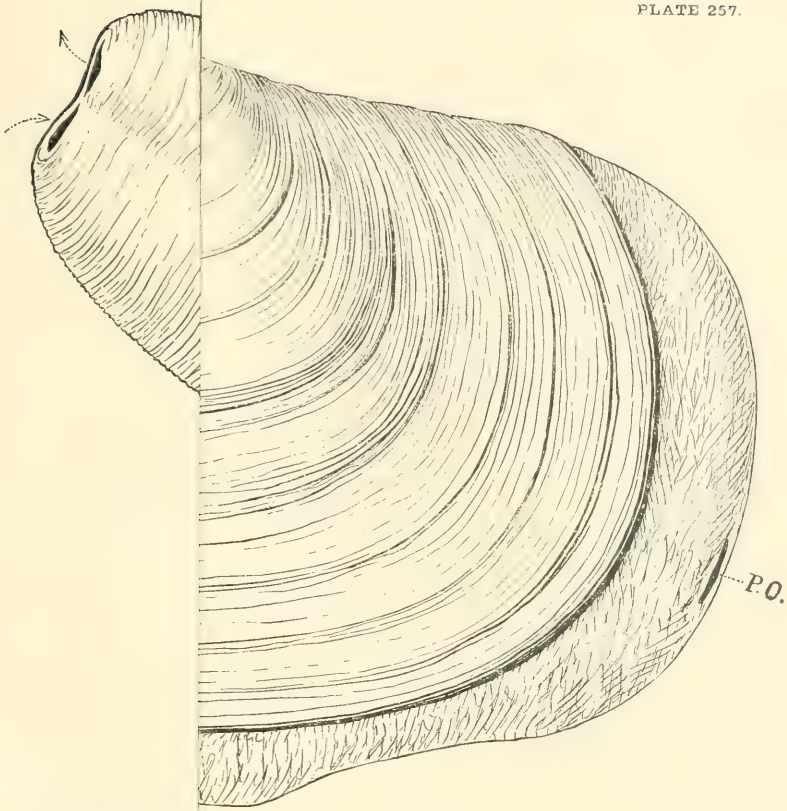
FIG. 2. The Quahaug of Puget Sound, *Saxidomus nuttalli*. Natural size of large specimen. Drawn by J. H. Emerton.

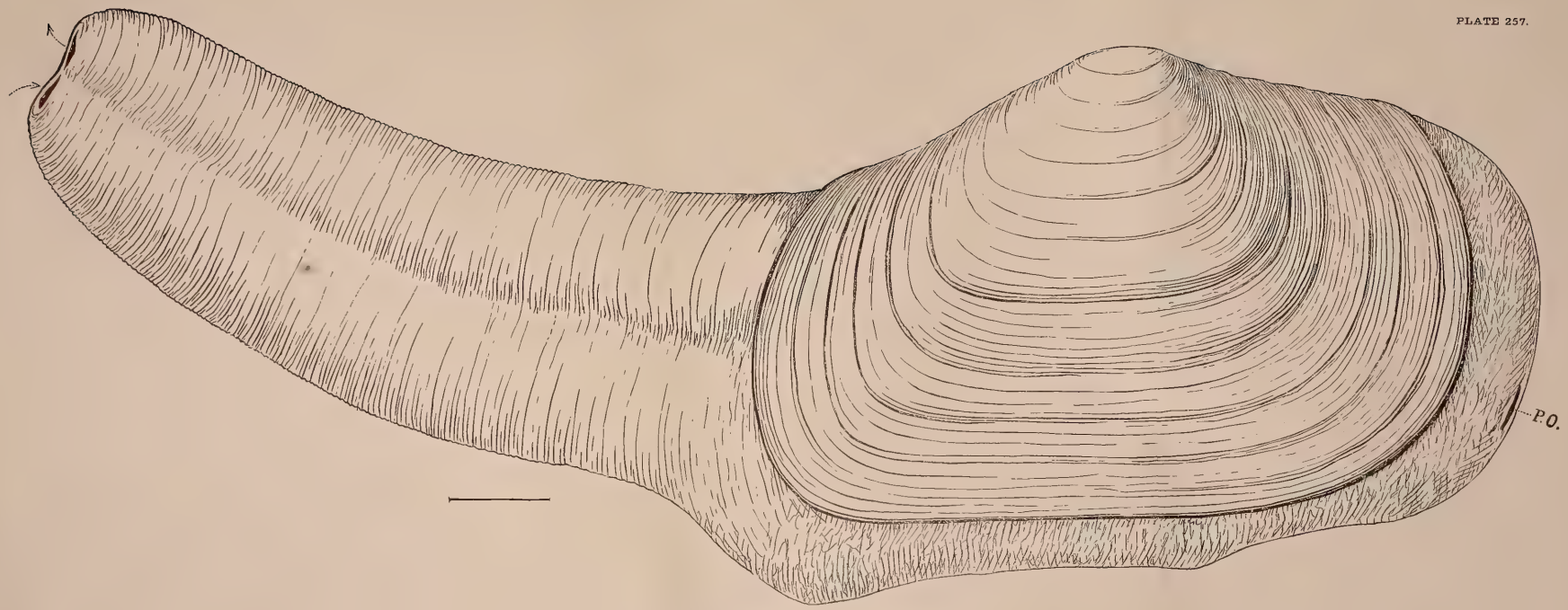
FIG. 3. The Gaper Clam of the West Coast, *Schizothærus nuttalli* (Conrad).

(I.) Specimen of ordinary size, reduced about one-fourth in length. The siphons are somewhat contracted; the foot (F) expands about as usual.

(II.) Outline of the left valve of a larger specimen, reduced to the same extent. Drawn from nature by R. E. C. Stearns.

PLATE 257.






THE GEODUCK, OR GIANT CLAM OF THE PACIFIC.

Glycimeris generosa.

Natural size; specimens with siphons partly contracted; weight when alive 6½ pounds. Drawn by R. F. C. Stearns.

Fig. 1

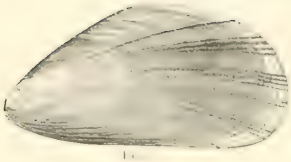


Fig. 3

Fig. 4

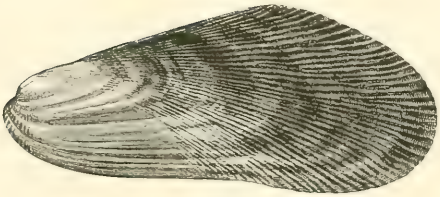


Fig. 5.

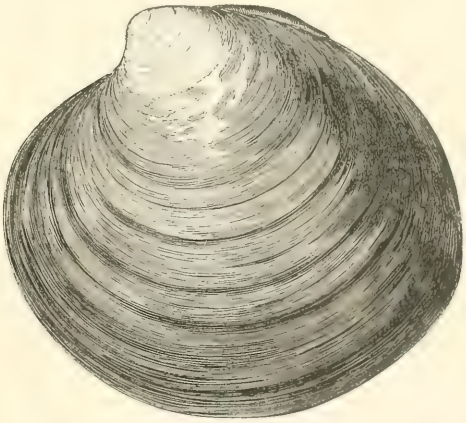


Fig. 2.

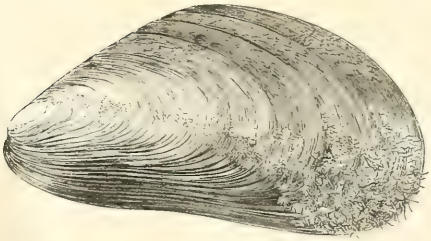


Fig. 6.

## MUSSELS AND SEA CLAMS.

FIG. 1. The Beach Clam or Hen Clam, *Spisula solidissima*, p. 708. Natural size.

FIG. 2. The Sea Clam, *Cyprina islandica*. Natural size.

FIG. 3. The Mussel, *Mytilus edulis*, p. 709.

FIG. 4. The Black Horse Mussel, *Modiola nigra*.

FIG. 5. The Rough Mussel, *Modiola plicatula*, p. 709.

FIG. 6. The Horse Mussel, *Modiola modiolus*, p. 709.

# PLATE 259.

## Explanation of Fig. 1.

A. Hinge or anterior umbonal end of the left valve of an adult oyster, upon which the soft parts of the animal are represented as they lie *in situ*, but with the greater part of the mantle of the right side removed.

*au*. The auricle of the right side of the heart contracted.

B. Posterior or ventral end of the left valve, which in life is usually directed upward more or less, and during the act of feeding and respiration is separated slightly from the margin of its fellow of the opposite side to admit the water needful for respiration, and which also contains the animal's food in suspension.

B*m*. Body-mass, traversed superficially by the generative ducts *ge*.

*bj*. The organ of Bojanus, or "renal" organ, of the right side of the oyster. (The ducts which it sends into the mantle are not shown, nor is its connection with the genito-urinary sinus *s* indicated.)

*bp*. The large branchial pores which open from the subdivided cavities of the pouch-like gills *g* into the cloaca *cl*.

*br*. The anterior branchiocardiac "vein," which conveys part of the blood from the gills to the auricle.

*c*. Right pericardiac membrane, which has been thrown back over M in order to expose the heart *ve* and *au*.

*cl*. Cloacal space, through which the water used in respiration passes out, and into which the excrement of the animal is discharged from the vent *v*.

*d*. Nervous commissure of the right side, which connects the parieto-splanchnic with the supra-œsophageal ganglion.

*g*. Gills, which extend as four flattened transversely subdivided sacs from the palps *p* to the point *y*, at the edge of the mantle.

*ge*. Superficial network of the generative ducts as they appear when the oyster is spawning.

*h*. Groove in the hinge end of the left valve, which receives the ridge developed in the corresponding situation on the right one.

*l*. Dark brown elastic body or ligament by which the valves are held together at the hinge.

M. Great adductor muscle, which is here viewed from the end, and which is attached to the inner faces of the valves over the dark purple scars. It opposes the elastic ligament and closes the valves, and corresponds to the posterior adductor muscle of dimyary molluska.

*m*. Mouth.

*mt*. Mantle of the left side fringed with two rows of tentacles.

*mt'*. Portion of the mantle of the right side.

*n* to *z* marks the extent to which the right and left leaves of the mantle are joined together; the hood thus formed above and at the sides of the palps is called the cucullus.

P. Palps exposed, a part of the cucullus on the right being cut away.

*pd*. Pedal muscle of right side, which is also inserted upon the shell of the same side.

*pg*. Parieto-splanchnic ganglion.

*s*. Genital opening of the right side.

*sg*. Supra-œsophageal ganglion.

*v*. Vent or anus.

*ve*. Ventricle of the heart, which is dilated, or in the condition of diastole.

*xxx*. Areas at the edge of the inner surface of the shell, where intruded mud has been inclosed by a thin lamina of shelly matter deposited by the mantle.

*y*. Point at the posterior extremity of the gills, where the right and left leaves of the mantle are joined together by the membrane which supports the gills.

## Explanation of Fig. 2.

This figure was drawn from a dissection of a hardened specimen which had been removed from the shell, and is viewed from the left side, the superficial tissues of the left half of the body-mass having been removed in order to display the surface of the "liver" L, with its large clusters of minute follicles, and part of the course of the intestine *i*. At *j* the widened pyloric part of the intestine is shown, which incloses the crystalline style. The ventricle *ve* and auricle are much contracted, and a spacious pericardiac space is shown on either side of it.

*ge*. Stratum of reproductive follicles. The remaining letters of reference are the same as in Fig. 1.

## Explanation of Fig. 3.

This figure of the viscera of the oyster is also drawn in part from the hardened soft parts, but is viewed from the right side. The great ducts *d* of the "liver" L are shown cut open longitudinally, and are represented as opening directly into the cavity of the stomach *st*, in front of which the œsophagus *oe* is also shown running back from the mouth *m*. This figure shows almost the entire intestine, with its widened anterior end *j*, and its course and curvature as here represented is what will be found constant, even when hundreds of specimens are examined. Nearly all the substance of the body-mass has been carefully removed from the right half of the body; and where the edges of the body have been cut through, the stratum of reproductive tissue *ge* is also shown. The corrugated outer surface of the inner or lower palp at P. The remaining letters have the same significance as in the previous figures.

## Explanation of Fig. 4.

This represents a section or slice cut from the soft parts of an oyster at the level of the dotted line *o* in Fig. 3, and viewed from its anterior surface. The tissues and structures, which have been cut across in this section, are as follows:

*a'*. The dorsal or posterior branch of the great splanchnic artery.

*a''*. The anterior or ventral branch of the splanchnic artery.

*br*. Branchial vessels.

*c*. The connective tissue which envelops the organs contained in the body-mass and forms the principal portion of the substance of the animal in winter.

*g*. The gills cut across, showing their hollow interiors.

*ge*. Stratum of reproductive follicles, which immediately underlies the mantle layer *mt*. Intestinal canal cut through at two points, *ii*, posteriorly and anteriorly, showing the manner in which the intestinal walls are folded inwards upon themselves.

LL. Right and left lobes of the liver, embedded in the connective tissue and most considerably developed at the sides and below the stomach.

*sb*. Suprabranchial space.

*st*. Stomach, showing its irregular form and connection by means of spacious ducts with the "liver."

*vc*. Vena cava.

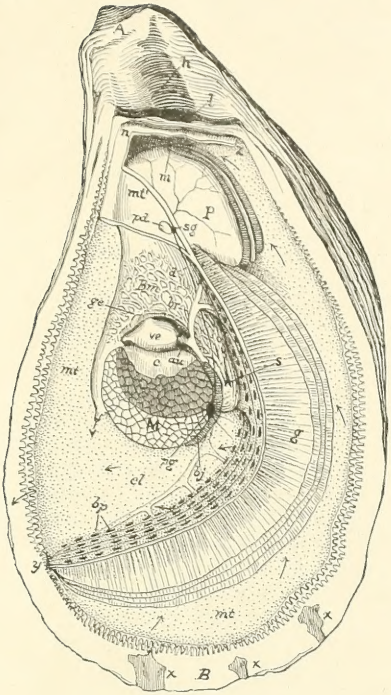



Fig. 1.

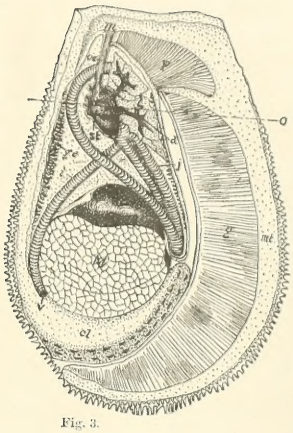



Fig. 3.

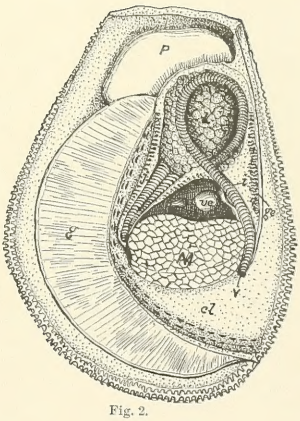



Fig. 2.

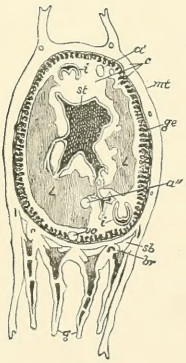



Fig. 4.

For explanation of figures see opposite page.