OYSTERS AND METHODS OF OYSTER-CULTURE.

BY

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INTRODUCTION.

This paper is designed to briefly set forth the principal facts relating to the subject of oyster-culture in the United States. It embraces the practices of proved commercial value as well as a summary of the methods and results of investigations which appear to give some promise of utility in certain places and under special conditions, or which indicate the lines along which profitable experiment may be carried on. It is intended primarily as a guide to those persons who are exhibiting an interest in the subject and who contemplate embarking in the industry, yet hesitate on account of unfamiliarity with the methods employed. To aid such persons to a more thorough understanding of the problem involved, certain matters are considered which do not strictly appertain to the practical side of the subject, but which may assist in explaining observed phenomena or in indicating the limitations and possibilities of experiment. Such are the chapters on development and anatomy.

Attention is directed chiefly to the eastern oyster, which is the species of principal, one might almost say only, interest in this country, and, practically, the great problem of oyster-culture applies to it alone. For comparative purposes, however, and to round out the information presented, it has seemed advisable to incorporate some facts regarding the native oysters of the Pacific Coast.

DISTRIBUTION.

ATLANTIC COAST.

Upon the eastern coast of North America there is but one species of oyster, *Ostrea virginiana,* which occurs along the northern side of the Gulf of Mexico, on the Atlantic coast from Florida to Cape Cod, and on the southern and western shores of the Gulf of St. Lawrence. In Massachusetts Bay and on the coast of New Hampshire and Maine it does not now occur, though it was found in abundance locally at the time of the settlement of the country, and the former existence of beds of great extent is indicated by the vast quantities of the valves in the ancient Indian shell-heaps. Oyster fisheries are located in every coastwise State from Texas to Massachusetts and in the Maritime Provinces, the most important being in Chesapeake Bay, mainly upon the natural beds, and in Long Island Sound, principally upon planted grounds. The Canadian oyster-beds are much depleted, and an effort is now being made to restore them to a productive condition.

PACIFIC COAST.

Upon the western coast of North America there are five, and perhaps six, recognized species of oysters, but only two of them are of present importance.

The eastern oyster was planted in San Francisco Bay about 1872 and has there formed the basis of a somewhat important industry ever since. The supply has been maintained by the annual planting of seed oysters from the east, and while the species appears to be propagating itself to a limited extent, no reliance has been placed upon this fact for the maintenance of the beds. The United States Fish Commission has recently planted oysters in Willapa Bay, Washington; Yaquina Bay, Oregon, and Humboldt Bay, California, but it is still too early to say with what success.

The native oyster (*Ostrea lurida*) of California, Oregon, and Washington is found at various places on the coasts of the States mentioned, but attains its greatest size and perfection in Willapa Bay. It is much inferior to the eastern oyster in size, but its flavor is esteemed by many.

In the Gulf of California is found a large species, *Ostrea iridescens*, which resembles the eastern species and is an object of some trade in the adjoining portions of Mexico. Attempts have been made to introduce this form in the markets of San Francisco, but the mortality en route has been large and the venture unprofitable.

Two smaller oysters, *Ostrea palumea* and *Ostrea palumea glomerata*, are also found in the Gulf of California.

DESCRIPTION.

EASTERN OYSTER, OSTREA VIRGINIANA.

The shell of this species is generally elongate, but varies much with age and the conditions under which it grows. In the younger stages it is often nearly round, with ear-like projections on each side of the hinge and stout radiating ridges near the margin, thus bearing some resemblance to the European oyster. In shells which are actively growing there is a broad fringe of yellow cuticle around the edge of the valves, which, however, soon becomes thickened by a deposit of lime.

The shell is subject to great variation in thickness, but it is rarely so thin as in the Pacific coast oyster. The exterior is marked by laminations and more or less concentric lines of growth; it is often covered by a yellowish cuticle, but is sometimes white and flinty in appearance. The inside of the shell is generally white, somewhat tinged with purple near the margins, and with a more or less pearly luster. The muscular impression is generally nearer to the posterior margin than to the hinge; it is a well-defined scar, kidney-shaped in specimens of ordinary size, but becoming more elongate in very large individuals; in young specimens it is pale, but it afterwards becomes purple or almost black. The left or lower valve is deeply concave within, the upper valve being flat or, usually, slightly concave. The animal portions are large, nearly filling the shell, and the mantle border is comparatively narrow. (Plate V.)

PACIFIC COAST "NATIVE," OSTREA LURIDA.

The shell of this species is thin and irregular, varying in shape from almost round to elongate elliptical; the surface is sometimes laminated, but is never ribbed; the color is variable, being sometimes purple, sometimes dirty green or gray; the inside of the shell is greenish, sometimes tinged with purple. The muscular impression or scar is purple, but paler than in the eastern oyster, and its greatest length is usually longitudinal rather than transverse; it is situated about midway between the hinge and the lips or nibs of the shell, and its ventral margin is usually prolonged toward the hinge. There is rarely a well-defined pit or excavation beneath the hinge, the inner face of the shell sloping off gently from the ligament. The lower valve is deeper than the upper one, but is rarely so strongly concave as in the eastern species. (Plate VI.)

REPRODUCTION AND DEVELOPMENT.

SEXUAL CHARACTERISTICS.

In the European oyster the individuals are hermaphrodites—that is, each is both male and female; in the common eastern oyster the sexes are separate, each individual being either male or female, but not both.

Although the sexes differ remarkably in physiology and minute anatomy, it is not possible to distinguish male from female by any known external characters. It is only by an examination of the genital glands, which in the male produce the spermatozoa or milt and in the female the ova, eggs, or spawn, or by examining the genital products themselves, that the one sex may be distinguished from the other.

The differences between the ovaries of the female and the testes of the male are explained in the section treating of the anatomy. When the animals are ripe, the distinction of the sexes is most conveniently made by an examination of the genital products. A drop of genital fluid is extracted from the oyster in the manner described under the head of artificial fertilization (p. 332) and let fall into a glass of clear sea water. If the individual be a ripe female, the drop will break up into a uniformly distributed cloud, which, if examined against a black background, will be seen to consist of separate minute white granules or eggs. If the eggs be unripe, they will remain aggregated in little compound masses. If the specimen examined be a male, the drop of milt will form an irregular, stringy cloud, showing a tendency to drift in streaks if the water be agitated, and with no particles distinguishable by the naked eye.

Another test is to spread out a drop of the genital fluid, mixed with a drop of water, in a thin film upon a piece of glass, such as a microscope slide. If the specimen be a female, an examination with a strong hand lens will reveal many minute pear-shaped or oval bodies or eggs, each with a clear spot, the nucleus or so-called germinal vesicle. If the specimen be a male, the film can not be resolved into distinguishable particles when viewed with the lens, but consists of a milk-white mass, having a quivering appearance owing to the effect of the combined movements of the indistinguishable spermatozoa.

The histological characters which distinguish the testes and ovary are considered under the head of anatomy.

According to Professor Schiedt, an hermaphroditic oyster occurs on our northwest coast, the specimens examined coming from the State of Washington, the exact locality not being mentioned. Sexually, therefore, this species resembles the common oyster of Europe.

RIPENING OF THE GENERATIVE ORGANS.

In spring, when the water begins to warm, certain changes begin to manifest themselves in the generative organs, preparatory to the act of spawning. In the female some of the minute eggs in the ovaries increase in size and become loosened in the follicles or little pockets of tissue in which they have undergone their early development. All of the eggs which are to be discharged in any one year do not ripen at the same time, so that the spawning of each individual extends over a greater or less period. An examination of the ovary at any time will always show great numbers of minute immature eggs, most of these being ova which will ripen and be discharged during some subsequent year. Other changes, which it is not necessary to mention here, take place in the eggs and tissues, but the ultimate result is that the ovary becomes enlarged by the growth of the ripening eggs and the latter pass into the oviducts, which stand out as milky-white and much-branched vessels on each side of the body.

The spermatozoa develop in somewhat the same manner, but the generative cells, instead of developing into eggs, undergo rapid division, each into a number of minute active bodies, which pass into the sperm ducts and gorge them with a white fluid, the milt, in general naked-eye appearance closely resembling the ovarian fluid.

SPAWNING.

The act of spawning consists in the discharge of the ripe genital products into the surrounding water, where fertilization is left to chance.

The genital ducts, one on each side, open into the chambers above the gills, and the ova in the one sex and the spermatozoa in the other, gradually oozing out of the openings, are caught up by the currents of water passing through the gill-canals and expelled from the body, together with the various waste products resulting from digestion and respiration.

The season at which oysters spawn differs with the latitude of the bed and with local conditions. As a general rule, it may be said that they ripen earlier in the south than in the north, and that in the same region the genital products mature earlier in shallow than in deep water. These facts appear to be dependent primarily upon the temperature, other things being equal, southern waters warming before the northern, and the shallows before the depths.

It is stated that the raccoon oyster of South Carolina spawns from the middle of March to the middle of August. Ripe individuals are found in shallow-water creeks during January and February, and it is probable that intermittent spawning may take place at any time during the year when favorable conditions prevail. In Chesapeake Bay oysters are found spawning from April to October, but apparently a few scattered individuals spawn at other times, though most of the spawn appears to be cast during the latter part of July or early in August. In Long Island Sound spawning takes place, according to the locality, during May, June, July, and August. Sometimes many oysters are found with well-developed ova during April, but this appears to be unusual, and Dr. Dean remarks that when it occurs "it will almost invariably be found that the spring has been warm and dry."

Not only the time of spawning, but the quantity of spawn, appears to be affected by the weather conditions. Sudden changes produce very marked results, and a transfer of the oyster from one place to another during the spawning season is almost certain to interfere with reproduction or even absolutely arrest it.

The age at which the oyster becomes capable of reproducing its kind varies with the locality, but it appears that in regions of rapid growth the generative organs ripen during the first year. The number of eggs discharged by the female is naturally dependent upon its size. According to Dr. Brooks, the Maryland oyster of average size produces 16,000,000 eggs each year, while a very large individual may produce 60,000,000. The spermatozoa, being extremely minute, are present in the milt in inconceivable numbers.

Notwithstanding the great fecundity of the individual oyster the reproductive power of the beds is not so vast as is generally supposed. If the oysters are scattered, or the number spawning at a given time is small, most of the genital matter will be wasted, as the contact of the male and female cells is entirely dependent upon chance, and the fewer such cells there are in a given body of water the smaller the probability of their meeting and fusing in the manner constituting the act of fertilization. Neither the eggs nor the spermatozoa live long after they are discharged from the parent, and if fertilization is to take place at all the two elements must be brought into contact promptly; and it will be seen, therefore, that nature must supply a vast number of germ cells to insure the survival of but a few.

EMBRYONIC DEVELOPMENT.

The following popular account of the early stages in the development of the oyster is slightly modified from the description by Dr. W. K. Brooks:

The ovarian eggs are simply the cells of an organ of the body, the ovary, and they differ from the ordinary cells only in being much larger and more distinct from each other, and they have the power, when detached from the body, of growing and dividing up into cells, which shall shape themselves into a new organism like that from whose body the egg came. Most of the steps in this wonderful process may be watched under the microscope, and owing to the ease with which the eggs of the oyster may be obtained this is a very good egg to study.

About 15 minutes after the eggs are fertilized they will be found to be covered with male cells, as shown in plate VII, fig. 1.* In about an hour the egg will be found to have changed its shape and appearance. It is now nearly spherical, as shown in plate VII, fig. 2, and the germinative vesicle is no longer visible. The male cells may or may not still be visible upon the outer surface. In a short time a little transparent point makes its appearance on the surface of the egg and increases in size and soon forms a little projecting transparent knob—the *polar globule*—which is shown in plate VII, fig. 3, and in succeeding figures.

Recent investigations tend to show that while these changes are taking place one of the male cells penetrates the protoplasm of the egg and unites with the germinative vesicle, which does not disappear but divides into two parts, one of which is pushed out of the egg and becomes the polar globule, while the other remains behind and becomes the *nucleus* of the developing egg, but changes its appearance so that it is no longer conspicuous. The egg now becomes pear-shaped, with the polar globule at the broad end of the pear, and this end soon divides into two parts, so that the egg (plate VII, fig. 4) is now made of one large mass and two slightly smaller ones, with the polar globule between them.

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

The upper portion of the egg soon divides up into smaller and smaller spherules, until at the stage shown in plate VII, figs. 5, 6, and 7, we have a layer of small cells wrapped around the greater part of the surface of a single large spherule, and the series of figures shows that the latter is the spherule which is below in plate VII, fig. 4. This spherule now divides up into a layer of cells, and at the same time the egg, or rather the embryo, becomes flattened from above downward and assumes the shape of a flat oval disk. Plate VII, figs. 10 and 9, are views of the upper and lower surface of the embryo at about this time. In a sectional view, plate VII, fig. 11, it is seen to be made of two layers of cells, an upper layer of small transparent cells, *e c*, which are to form the outer wall of the body and which have been formed by the division of the spherules which occupy the upper end of the egg in plate VII, fig. 6, and a lower layer of much larger, more opaque cells, *g*, which are to become the walls of the stomach, and which have been formed by the division of the large spherule, *a*, of plate VII, fig. 6.

This layer is seen in the section to be pushed in a little toward the upper layer, so that the lower surface of the disk-shaped embryo is not flat, but very slightly concave. This concavity is destined to grow deeper until its edges almost meet, and it is the rudimentary digestive cavity. A very short time after this stage has been reached, and usually within from two to four hours after the eggs were fertilized, the embryo undergoes a great change of shape and assumes the form which is shown in three different views in plate VII, figs. 12, 13, 14, and 15.

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* References to figures in quoted portions of this paper do not correspond with the originals, being altered to accord with their sequence in the present article.

A circular tuft of long hairs or cilia has now made its appearance at what is thus marked as the anterior end of the body, and as soon as these hairs are formed they begin to swing backward and forward in such a way as to constitute a swimming organ, which rows the little animal up from the bottom to the surface of the water, where it swims around very actively by the aid of its cilia. This stage of development, plate VII, fig. 12, which is of short duration, is of great importance in raising the young oysters, for it is the time when they can best be siphoned off into a separate vessel and freed from the danger of being killed by the decay of any eggs which may fail to develop. On one surface of the body at this stage, the dorsal surface, there is a well-marked groove, and when a specimen is found in a proper position for examination the opening into the digestive tract is found at the bottom of this groove. Plate VII, fig. 13, is a sectional view of such an embryo. It is seen to consist of a central cavity, the digestive cavity, which opens externally on the dorsal surface of the body by a small orifice, the primitive mouth, and which is surrounded at all points, except at the mouth, by a wall which is distinct from the outer wall of the body. Around the primitive mouth these two layers are continuous with each other.

The way in which this cavity, with its wall and external opening, has been formed will be understood by a comparison of plate VII, fig. 13, with plate VII, fig. 8. The layer which is below in plate VII, fig. 8, has been pushed upward in such a way as to convert it into a long tube, and at the same time the outer layer has grown downward and inward around it, and has thus constricted the opening. The layer of cells which is below in plate VII, fig. 8, thus becomes converted into the walls of the digestive tract, and the space which is outside and below the embryo, in plate VII, fig. 8, becomes converted into an inclosed digestive cavity, which opens externally by the primitive mouth.

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

The edges of the primitive mouth of the oyster continue to approach each other and finally meet and unite, thus closing up the opening, as shown in plate VII, fig. 16, and leaving the digestive tract without any communication with the outside of the body, and entirely surrounded by the outer layer. The embryo shown in plate VII, figs. 12 and 16, are represented with the dorsal surface below, in order to facilitate comparison with the adult, but in plate VII, fig. 17, and most of the following figures, the dorsal surface is uppermost, for more ready comparison with the adult.

In other lamellibranchs, and doubtless also in the oyster, the shell begins as a deposit in an invagination or pocket on the dorsal side of the body. In its manner of formation this shell-gland resembles the primitive mouth for which it has been more than once mistaken by investigators. In some forms the shell is at first single, but in the oyster they are said to be separated from each other from the beginning, and appear independently. Dr. Brooks says further:

Soon after they make their appearance, the embryos cease to crowd to the surface of the water and sink to various depths, although they continue to swim actively in all directions, and may still be found occasionally close to the surface. The region of the body which carries the cilia now becomes sharply defined, as a circular projecting pad, the *velum*, and this is present and is the organ of locomotion at a much later stage of development. It is shown at the right side of the figure in plate VII, fig. 17, and in plate VII, fig. 18, it is seen in surface view, drawn in between the shells, and with its cilia folded down and at rest, as they are seen when the little oyster lies upon the bottom.

The two shells grow rapidly, and soon become quite regular in outline, as shown in plate VII, fig. 17, and plate VIII, fig. 1, but for some time they are much smaller than the body, which projects from between their edges around their whole circumference, except that along a short area, the area of the hinge upon the dorsal surface, where the two valves are in contact.

The two shells continue to grow at their edges, and soon become large enough to cover up and project a little beyond the surface of the body, as shown in plate VIII, fig. 1, and at the same time muscular fibers make their appearance and are so arranged that they can draw the edge of the body and the velum in between the edges of the shells in the manner shown in plate VII, fig. 18. In this way that surface of the body which lines the shell becomes converted into the two lobes of the mantle, and between them a mantle cavity is formed, into which the velum can be drawn when the animal is at rest. While these changes have been going on over the outer surface of the body other important internal modifications have taken place. We left the digestive tract at the stage shown in plate VII, fig. 16, without any communication with the exterior.

Soon the outer wall of the body becomes pushed inward to form the true mouth, at a point (plate VII, fig. 17) which is upon the ventral surface and almost directly opposite the point where the primitive mouth was situated at an earlier stage. The digestive cavity now becomes greatly enlarged and cilia make their appearance upon its walls, the mouth becomes connected with the chamber which is thus formed and which becomes the stomach, and minute particles of food are drawn in by the cilia and can now be seen inside the stomach, where the vibration of the cilia keep them in constant motion. Up to this time the animal has developed without growing, and at the stage shown in plate VII, fig. 16, it is scarcely larger than the unfertilized egg, but it now begins to increase in size. The stages shown in plate VIII, fig. 1, and plate VII, fig. 18, agree pretty closely with the figures which the European embryologists give of the oyster embryo at the time when it escapes from the mantle chamber of its parent. The American oyster reaches this stage in from twenty-four hours to six days after the egg is fertilized, the rate of development being determined mainly by the temperature of the water.

Soon after the mantle has become connected with the stomach this becomes united to the body wall at another point a little behind the mantle, and a second opening, the *anus*, is formed. The tract, which connects the *anus* with the stomach, lengthens and forms the intestine, and soon after the sides of the stomach become folded off to form the two halves of the liver, as shown in plate VIII, fig. 1. Various muscular fibers now make their appearance within the body, and the animal assumes the form shown in plate VIII, fig. 1, and plate VII, fig. 18.*

What follows this stage may be best told in the words of Professor Huxley, who speaks of the European oyster, in which the metamorphosis from the free-swimming fry to the fixed spat and finally the adult oyster is essentially the same as in our species.

The young animal which is hatched out of the egg of the oyster is extremely unlike the adult, and it will be worth while to consider its character more closely than we have hitherto done.

Under a tolerably high magnifying power the body is observed to be inclosed in a transparent but rather thick shell (plate VIII, fig. 2, *L*), composed, as in the parent, of two valves united by a straight hinge, *h*. But these valves are symmetrical and similar in size and shape, so that the shell resembles that of a cockle more than it does that of an adult oyster. In the adult the shell is composed of two substances

*Report Maryland Fish Commission, Annapolis, 1880, pp. 19–25, in part.

of different character, the outer brownish, with a friable prismatic structure, the inner dense and nacreous. In the larva there is no such distinction, and the whole shell consists of a glassy substance devoid of any definite structure.

The hinge line answers, as in the adult, to the dorsal side of the body. On the opposite or ventral side the wide mouth *m* and the minute vent *v* are seen at no great distance from one another. Projecting from the front part of the aperture of the shell there is a sort of outgrowth of the integument of what we may call the back of the neck into a large oval thick-rimmed disk termed the *velum*, *vl*, the middle of which presents a more or less marked prominence. The rim of the disk is lined with long vibratile cilia, and it is the lashing of these cilia which propels the animal, and, in the absence of gills, probably subserves respiration. The funnel-shaped mouth has no palps; it leads into a wide gullet, and this into a capacious stomach. A sac-like process of the stomach on either side (the left one, *l*, only is shown in fig. 2) represents the "liver." The narrow intestine is already partially coiled on itself, and this is the only departure from perfect bilateral symmetry in the whole body of the animal. The alimentary canal is lined throughout with ciliated cells, and the vibration of these cilia is the means by which the minute bodies which serve the larva for food are drawn into the digestive cavity.

There are two pairs of delicate longitudinal muscles, *rs ri*, which are competent to draw back the ciliated velum into the cavity of the shell, when the animal at once sinks. The complete closure of the valves is effected, as in the adult, by an adductor muscle, *am*, the fibers of which pass from one valve to the other. But it is a very curious circumstance that this adductor muscle is not the same as that which exists in the adult. It lies, in fact, in the forepart of the body and on the dorsal side of the alimentary canal. The great muscle of the adult, fig. 3, *M*, on the other hand, lies on the ventral side of the alimentary canal and in the hinder part of the body. And as the muscles, respectively, lie on opposite sides of the alimentary canal, that of the adult can not be that of the larva, which has merely shifted its position; for in order to get from one side of the alimentary canal to the other it must needs cut through that organ; but as in the adult no adductor muscle is discoverable in the position occupied by that of the larva or anywhere on the dorsal side of the alimentary canal, while on the other hand there is no trace of any adductor on the ventral side in the larva, it follows that the dorsal or anterior adductor of the larva must vanish in the course of development, and that a new ventral or posterior adductor must be developed to play the same part and replace the original muscle functionally, though not morphologically.

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When the free larva of the oyster settles down into the fixed state, the left lobe of the mantle stretches beyond its valve, and, applying itself to the surface of the stone or shell to which the valve is to adhere, secretes shelly matter, which serves to cement the valve to its support. As the animal grows the mantle deposits new layers of shell over its whole surface, so that the larval shell valves become separated from the mantle by the new layers (plate VIII, fig. 3, *S*), which crop out beyond their margins and acquire the characteristic prismatic and nacreous structure. The summits of the outer faces of the umbones thus correspond with the places of the larval valves, which soon cease to be discernible. After a time the body becomes convex on the left side and flat on the right; the successively added new layers of shell mold themselves upon it, and the animal acquires the asymmetry characteristic of the adult.*

The horny convex shell of the fry (plate VIII, fig. 3, *L*) may be seen, for a considerable time after attachment, at the umbo or beak of the developing shell of the spat (plate VIII, fig. 3, *S*). The under or attached valve of the latter at first conforms closely to the surface to which it has become

*Huxley, Thomas H. Oysters and the Oyster Question. The English Illustrated Magazine, London, Oct. 1883 and Nov. 1883, vol. 1, pp. 47-55, and pp. 112-121.

attached, being usually flat, but afterwards, as a rule, becoming deep and strongly concave, through an upgrowing along the edges.

FIXATION, SET, OR SPATTING.

At the time of fixation the fry will, under proper conditions, attach itself by its left valve to any hard or firm body with which it may come in contact.

The first essential is that the surface should be clean and that it should remain so a sufficient length of time to enable the young oyster to firmly establish itself. So long as this condition obtains, the nature of the material seems to matter but little. In most bodies of water the spat fixes itself at all levels from the surface to the bottom, but in certain parts of the coast its place of attachment is confined to the zone between high and low water, the mid-tide mark being the place of maximum fixation. It has been suggested that this was due to the density of the water preventing the sinking of the fry. There are a number of objections to this theory, but no better one has been offered, and it may receive provisional acceptance.

GROWTH.

At the time of its attachment the oyster fry measures about one-eightieth or one-ninetieth of an inch in diameter. The valves of the shell are strongly convex and symmetrical, and are composed of a horny material quite different from the finished shell of the adult.

The mantle, a thin flap of tissue which envelops the body of the oyster on each side, projects freely from between the lips of the valves and is the organ which secretes the shell. Upon its outer surface successive layers of horny material are laid down, these becoming impregnated with calcareous matter arranged in a prismatic manner, and thus forming the stony shell which characterizes the adult.

The mantle increases *pari passu* with the growth of the soft parts in general, and as it is always capable of protrusion a little beyond the lips of the valves, it follows that each successive layer of shell is slightly larger than that which preceded it, and the shell increases in length and breadth as well as in thickness. From the nature of its growth, therefore, the youngest or newest part of the shell is on the inner face and at the edges, the latter always being sharp and thin in a growing oyster. The shell of the young oyster is always thin and delicate, and is generally more rounded than in the adult. The lower valve at first adheres closely to the body to which it is attached, but later its edge grows free and the valve, as a whole, becomes deeper and more capacious than its fellow. The small larval or fry shell remains visible at the beak of the spat shell for a considerable time, but becomes eroded away before the oyster reaches the adult condition.

The soft parts of the oyster assume their adult form in general soon after attachment, although the genital glands do not become functional until a much later period.

The rate of growth (plates X, XI, XII, XIII) varies with locality and conditions. It is more rapid when food is abundant and at seasons when the oyster is feeding most vigorously, these conditions being filled most thoroughly in summer and fall, when the warm water increases the vital activities of both oyster and food.

In South Carolina oysters not more than six or seven months old were found to have reached a length of 2½ inches, and in the warm sounds of North Carolina they reach a length of 1½ inches in from two to three months. In the coves and creeks of Chesapeake Bay they attain about the same size by the end of the first season's active growth, and by the time they are two years old they measure from 2½ to 3¾ inches long and from 2 to 3 inches wide. On the south side of Long Island the growth of the planted oysters is much more rapid than in Connecticut, it being stated that "two-year plants" set out in spring are ready for use in the following fall, while upon the Connecticut shore it would require two or three years to make the same growth. On the south side of Long Island oysters 1⅝ inches long in May have increased to 3 inches by November of the same year.

The amount of lime in the water is a factor in determining the character of the shell, and oysters growing in waters deficient in that respect have thinner shells than those which are well supplied, and are therefore more susceptible to the attacks of the drill.

The shape of the oyster to a certain extent determines its value in the market. Single oysters of regular shape with deep shells and plump bodies will bring a better price than those which are irregular and clustered. The shape depends largely upon the degree of crowding to which the oyster has been subject. When numerous spat become attached to a single piece of cultch, such as an oyster shell, there is often insufficient room for the development of all. Many will be crowded out and suffocated, while the survivors will be distorted through the necessity of conforming to the irregular spaces between the valves of their fellows. Sometimes the pressure exerted between the rapidly growing shells is sufficient to break up the more fragile forms of cultch, and the separated oysters then usually improve somewhat in shape.

The crowding of oysters reaches its climax upon the "raccoon" oyster beds. Raccoon oysters are usually found in localities where the bottom is soft and the only firm place which offers itself for the attachment of the spat is upon the shells of its ancestors. Temperature and other conditions are favorable, growth is rapid, the young oysters are crowded into the most irregular shapes, the shells are long, thin, and sharp-edged, and eventually the mass of young is so dense that it crowds out and smothers the preceding generations which produced it and offered means for its attachment. Oysters crowded in this excessive manner are poor-flavored as well as ill-shaped, but both defects are corrected if they be broken apart, as may be readily done, and planted elsewhere.

ANATOMY.

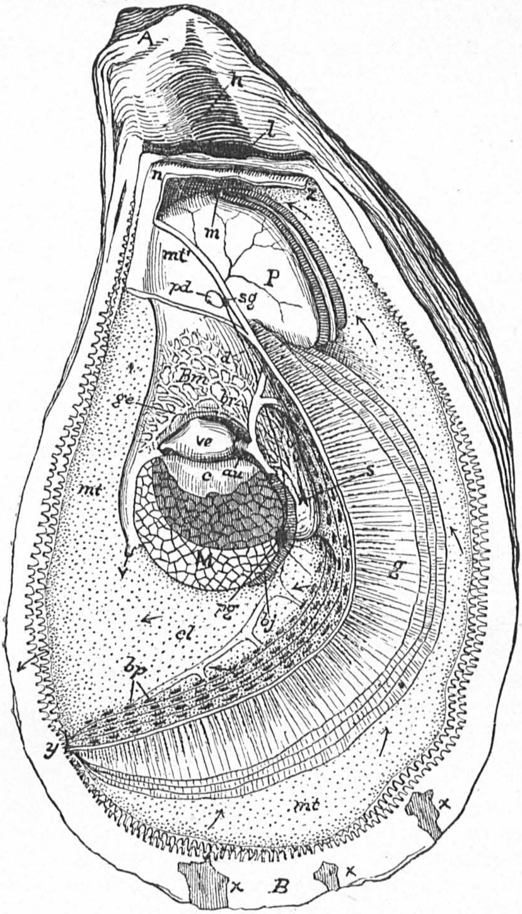
The following popular description of the anatomy of the oyster is extracted from the writings of Professors Brooks and Ryder:

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 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. (Plate I, fig. 1 *l*.) 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 (plate I, fig. 1, *mt*), 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, *g*, 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 (plate VIII, fig. 2), 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, *M*, 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, *g*, 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, *M*, 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



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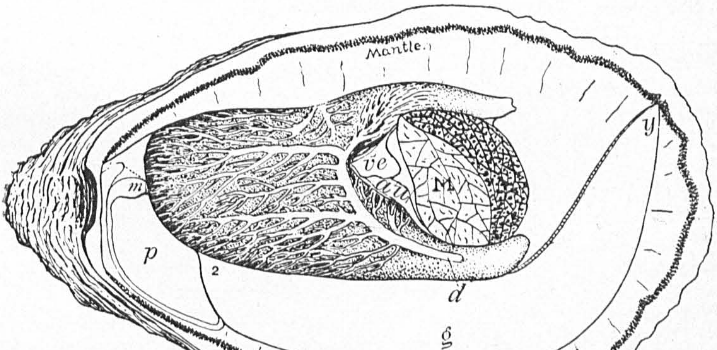

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FIG. 1. Oyster with right shell and mantle removed. *a* and *a*, origin of arteries from the ventricle; *au*, auricle of heart; *br*, vessel carrying blood from the gills to the auricle of the heart; *bj*, outline of organ of Bojanus, the so-called kidney; *bp*, pores from which the water issues into the branchial canals after passing through the gills; *cl*, cloaca; *d*, *pg*, and *sg*, connective and two ganglia of the nervous system; *g*, gills; *gc*, cavity between the two mantle folds; *h*, hinge; *l*, ligament; *M*, adductor muscle; *m*, mouth; *mt*, mantle, the arrows show the direction of currents produced by the cilia; *p*, palps; *p'*, outer end of right pedal muscle; *s*, external opening of sexual and renal organs of right side; *v*, anus; *ve*, ventricle of heart.

FIG. 2. Diagram to show sexual organs of the oyster. *d*, duct of sexual gland. Other letters as above.

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, *ve* and *au*, 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.

* * * * * * *

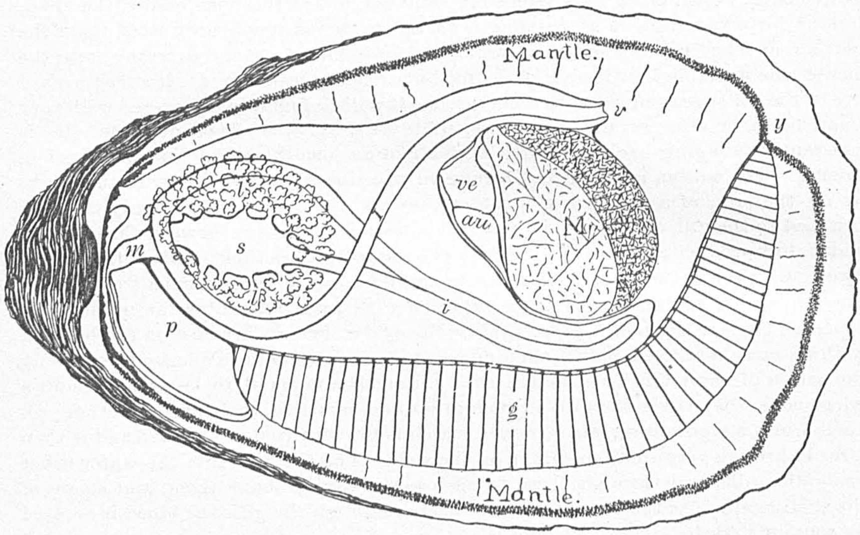
In front of the gills, that is, between them and the hinge, there are four fleshy flaps—the lips, *p*, two on each side of the body. They are much like the gills in appearance, and they are connected with each other by two ridges, which run across the middle of the body close to the anterior end, and between these folds is the large oval mouth, *m*, 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, plate VIII, fig. 3, *c*. 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 aerated by contact with it.

The food of the oyster consists entirely of minute animal and vegetable organisms and small particles of organized matter. Ordinary sea water contains an abundance of this sort of food, which is drawn into the gills with the water, but as the water strains through the pores into the water tubes the food particles are caught on the surface of the gills by a layer of adhesive slime, which covers all the soft parts of the body. As soon as they are entangled the cilia strike against them in such a way as to roll or slide them along the gills toward the mouth. When they reach the anterior ends of the gills they are pushed off and fall between the lips, and these again are covered with cilia, which carry the particles forward until they slide into the mouth, which is always wide open and ciliated, so as to draw the food through the œsophagus into the stomach. Whenever the shell is open these cilia are in action, and as long as the oyster is breathing a current of food is sliding into its mouth.

The cilia and particles of food are too small to be seen without a microscope, but if finely powdered carmine be sprinkled over the gills of a fresh oyster, which has been carefully opened and placed in a shallow dish of sea water, careful observation will show that as soon as the colored particles touch the gills they begin to slide along with a motion which is quite uniform, but not much faster than that of the minute-hand of a watch. This slow, steady, gliding motion, without any visible cause, is a very striking sight, and with a little care the particles may be followed up to and into the mouth.

In order to trace the course of the digestive organs, the visceral mass may be split with a sharp knife or razor. If the split is pretty near the middle of the body each half will show sections of the short, folded œsophagus, running upward from the mouth, and the irregular stomach, cut 1, *s*, with thick, semi-transparent walls, surrounded by the compact, dark-greenish liver, *l l*. Back of the liver and stomach the convoluted intestine, *i*, will be seen, cut irregularly at several points by the section.

There are no accessory organs of reproduction, and the position, form, and general appearance of the reproductive organ, plate I, fig. 2, is the same in both sexes. 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.*



CUT 1.

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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

* Brooks, W. K. Studies from the Biological Laboratory of Johns Hopkins University, No. IV, 1888, pp. 5–10 in part.

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 fecal matters are extruded in the form of a demi-cylinder, with one side excavated in a groove-like manner. This shape of the fecal matters is due to the presence of the double fold. The feces 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, *v*, 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 can not 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.

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, plate I, fig. 1, *sg*, which lie just over the gullet, and from these a pair of nervous cords, *d*, pass backward, one on each side, to join the hinder pair which lie just beneath the adductor muscle, *p g*. 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 bundle 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.*

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* Ryder, John A.; Fishery Industries of the United States, pp. 714-715.

PHYSICAL AND BIOLOGICAL CONDITIONS ON OYSTER-BEDS.

TEMPERATURE OF WATER.

The oyster lives in waters of widely varying temperature, both as to the average for the year and the extremes met with at different seasons. Perhaps the greatest divergence between the extremes is in Chesapeake Bay, where the range is from the freezing-point of brackish water, something below 32°, to 90° F. In New Jersey and in Chesapeake Bay the shallow-water oysters, which are exposed or nearly exposed at low water, are frequently frozen, an event which is not necessarily fatal if they are gradually thawed. Young oysters in shallow water are sometimes "winter-killed," or their vitality is seriously reduced, by exposure to exceptionally low temperatures. The remedy, or rather preventive, is to remove to deeper water in the fall, and seed oysters on natural spatting-grounds may often be saved by this means.

In deeper water, such as is found on the offshore beds of Long Island Sound, they are not subject to such severe trials, but are nevertheless called upon to withstand, during several months, a temperature not far from 32° F. In the Long Island oyster region the summer temperature of the water reaches 75° F., and from May 1 to November 1 probably never falls below 60° F. On the South Carolina oyster-beds the temperature appears to rarely fall below 55° F., but, on the other hand, the exposed banks of that region are subjected to the direct rays of the sun and therefore withstand a temperature considerably higher than that to which submerged oysters are liable.

The temperature has an important bearing upon the food supply. When the water is warm there is a rapid multiplication of the small forms upon which the oyster feeds, and at the same time the activities of the oyster itself are quickened. The two facts taken together result in a more rapid growth of the oyster than is likely to take place in colder waters.

It is often said that "plants do not spawn," and there appears to be some truth in the statement if we apply it to a period of a year or so after planting, and refer to cases in which the transplanting has induced considerable modification in the conditions under which the oyster is placed. This fact is no doubt largely due to the changes in temperature to which the oyster is subjected when transplanted. Dr. Ryder says:

> A very short exposure of the animal to water of an increased temperature caused a deterioration of the generative matter. I have tried to fertilize the eggs of numbers of oysters that had lain over night in the Quinnipiak River and invariably failed; the eggs in every case appeared to be overripe. Oysters taken from the bed at the same time and from the same locality, but kept in a basket over night, gave good results.

The same investigator found that at Beaufort, N. C., the best results in fertilization were obtained the nearer the temperature was to 70° F. Both at Beaufort and in Chesapeake Bay the embryos develop most rapidly in waters between 74° and 80° F., although the mortality is greater than at a slightly lower temperature. Under such conditions the embryos reach the swimming stage in from 3 to 10 hours, a fact which is, of course, advantageous to those undertaking artificial propagation. When the temperature falls to below 65° F., development almost ceases, and when it rises above 80° F. but few of the embryos reach the swimming stage. Sudden changes are usually fatal, and cold rains kill great numbers of the swimming fry.

Dr. Ryder recommends "that the prevalent temperature of the water during the spawning season shall range from 68 to 80° F." It is quite possible that in other regions, with oysters native thereto, or even those which have been acclimated therein, some other temperature may be found more favorable, but no data bearing upon the matter have been published.

TEMPERATURE; PLANTED BEDS IN SAN FRANCISCO BAY.

The temperature at San Francisco is usually not much higher in summer than in winter, but information upon the subject is limited. Upon the oyster-beds at Millbrae it is said to vary from 58° to 65° F., but at the extreme southern end of the bay it ranges from 67° to 74° F. In October, 1890, Mr. C. H. Townsend found 61° F. at Belmont; at San Mateo, nearer the sea, 60° F., and at California city, 57° F.

In midsummer the temperature was considerably higher; between July 12, 1891, and September 7, 1891, it ranged from 67° to 74° F., the means for 10-day periods during the same time being between 69.1° and 72° F. As Mr. Townsend points out, there is, therefore, a considerable period during the summer when the temperature, in portions of the bay at least, is favorable for spawning of the planted eastern oysters. The portions of the bay near the sea appear to have a temperature several degrees cooler than in the southern portions.

DENSITY OF WATER.

Oysters are found living in water ranging in salinity from 1.002* to 1.025, but the lower densities are always injurious, and prolonged exposure to their influence is fatal to oyster life. It is not possible to profitably maintain oyster-beds in waters where the density falls below 1.007 for any length of time, the oyster, if not killed, becoming poor in quality, pale, watery, and tasteless. Heavy freshets, such as occur in the rivers discharging into Chesapeake Bay and at various places on the Gulf coast, frequently so lower the density of the water as to practically exterminate the oysters on certain beds. Experience apparently indicates that the best oysters are grown in densities between about 1.011 and 1.022, the former being approximately the specific gravity over the Tangier Sound beds, the latter that over the deep-water oyster-grounds of Long Island Sound.

* The figures represent the specific gravity as measured with the salinometer, that of pure water being 1.000.

Change of density has an important effect upon the spawning of oysters. At St. Jerome Creek, Dr. Ryder found that the eggs could not be impregnated in a density much exceeding that in which the parent animals live. With oysters raised in water ranging from 1.007 to 1.0095 it was found that the milt was killed by a density greater than 1.013, the individual spermatozoa losing their mobility in a few moments when exposed to the greater density. The frequent failure of oysters to spawn in the season in which they are transplanted is perhaps in a measure owing to this cause. In Chesapeake Bay they are usually transplanted from deeper, denser water to more shallow and less dense, and when taken from the Chesapeake to Long Island Sound they go through a similar experience. There is at the same time, however, usually a change in temperature, and doubtless both factors combine to produce the effect noticed.

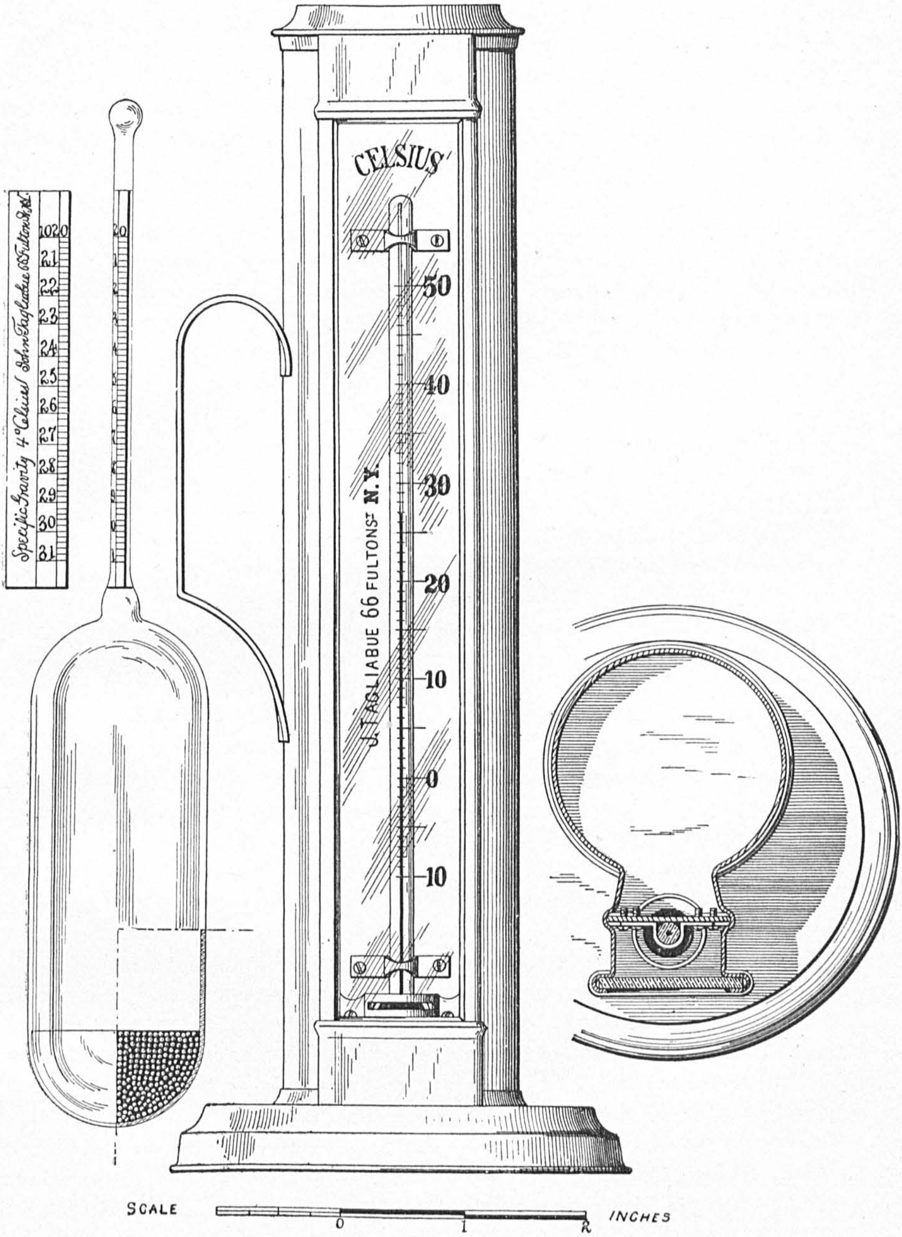
It has been suggested by Lieutenant Platt that the density of the water has an effect on the distribution of the set; that is, the specific gravity of the swimming embryo is such that it can not sink in dense water and therefore must become attached in marginal beds between tide marks, as is seen on the "raccoon" oyster-beds of South Carolina.

In some places it has been found that the best results in oyster-culture are to be had in brackish water, and Dr. Ryder suggests that this may be largely due to the fact that water of the lower densities is usually shallower, and consequently warmer and better adapted to the production of an abundant supply of the minute organisms which constitute the principal source of the oyster's food. There can be no doubt, however, that the eastern oyster is distinctively a brackish-water form. It has been found that it will not thrive in French waters perfectly adapted to the culture of the European species, and there is reason to believe that it will reproduce itself in a lower density than is necessary for the native oyster of California.

For determining the temperature and the density of sea waters the apparatus shown in plate II is used. It consists of a glass float with a long stem and a large bulb, weighted so as to sink in fresh water to a point near the top of the stem. The stem is graduated to read between 1.000 and 1.031, the figures representing the specific gravity; that is, they show the weight of the salt water, an equal body of fresh water being supposed to weigh 1.000.

In practice a scale having the entire range would be too long for safety and convenience, and therefore the salinometers are made in sets of three, reading from 1.000 to 1.011, from 1.010 to 1.021, and from 1.020 to 1.031, respectively.

There is also provided with them a deep copper cup or cylinder, at one side of which a thermometer is attached (plate II). The method of using the salinometer is as follows: The cup is filled with the water to be tested, the appropriate float is placed in the water, the density of



SALINOMETER AND SALINOMETER CUP.

The scale opposite the stem of the salinometer represents that of the high reading spindle as if unrolled. It registers densities between 1.020 and 1.031.

which will be the reading of the scale nearest the point where the surface of the water touches the stem. For purposes of oyster-culture the finer graduations may be neglected. To show the specific gravity, the number "1.0" should always be placed in front of the scale reading; for example, if the surface of the water should stand opposite the scale reading "15," the density would be 1.015. The test should be made immediately after the water specimen has been collected and a reading of the thermometer should be taken at the same time.

For practical purposes on the oyster-beds, a bottle or jar not less than 10 inches deep may be used instead of the copper cup, and any ordinary thermometer may be used for obtaining the temperature. The cheap, wooden-cased instruments known as "bath thermometers" serve very well, as they have no metal parts to be corroded by the salt water. In most oyster regions the salinometer reading from 1.020 to 1.031 will not be necessary, as the density on the oyster-beds rarely falls within its range.

The specimens of water should be from the bottom, or near it, and may be conveniently obtained by the following rough method: An empty jug or large bottle weighted and corked is lowered to the bottom by means of a line. The cork is then pulled out by jerking on a cord previously attached to it, the receptacle fills with a sample of water from or near the bottom, and if hauled rapidly to the surface it answers the practical purposes of more scientific and accurate apparatus.

SILT, MUD, AND SUSPENDED MATTER.

A bottom composed of soft mud, into which the young oysters would sink and become stifled, is unfavorable to oyster-culture or to the development of natural beds. If, however, hard objects are distributed over the bottom they will become collectors of spat so long as the surface remains clean and free from slime and sediment, and the importance of having water containing as little sedimentary matter as possible is manifest if it is desired to produce permanent beds or catch the floating fry.

Oysters will grow more rapidly on muddy bottoms, or in their vicinity, than they will elsewhere, as such situations are usually more productive of food materials. This food is in the form of suspended or swimming organic particles, and, therefore, filtered water, or that which is devoid of suspended matter of all kinds, lacks one of the essential requirements of successful oyster-culture. The most desirable water is that which contains an abundance of minute living particles with a minimum of suspended inorganic matter. An organic slime, however, such as rapidly forms on exposed surfaces in some localities, is as effectual in preventing fixation as is inorganic sediment. In many places in Chesapeake Bay and in the bays on the New Jersey coast the sediment, as well as the bottom mud, is largely composed of the finely comminuted fragments of vegetable matter, seaweeds, etc., the rapid deposit of which soon covers with a soft film the surface of all objects exposed to it, except when the currents are sufficient to exert a scouring influence.

Large oysters are not so susceptible as small ones to the effects of mud, but even those full grown may be stifled or buried by the rapid deposit of mud or sediment, whether this be of organic or inorganic origin. Freshets and heavy seas often cause great damage by the amount of mud, sand, and other debris which they carry upon the beds.

The question of the physical characters of a suitable bottom for oyster-culture is considered in another connection.

TIDES AND CURRENTS.

Tides and currents are important factors in the growth and culture of the oyster. They bring about the aeration of the water and oxidation of its dead organic ingredients; they have a scouring action upon the bottom and thereby cleanse the cultch, and at the same time serve as the vehicles for the transportation of food, of the genital products, and of the young. Stagnant water tends to become exhausted of its oxygen; it is heated by the sun, and the contained organic matter undergoing death and decomposition causes it to become foul and fatal to the oysters in the vicinity. With currents, however, a fresh supply of oxygen is constantly being supplied for respiration and for the combustion of the effete matter, which is thus rendered harmless.

Over densely-populated beds the food supply, unless unusually prolific, as in *claires*, would in time become exhausted. The oyster can not, of course, change its location, but the same purpose is subserved by currents constantly bringing a fresh supply of food-laden water within the influence of the ciliary action by which the oyster captures its food.

The genital products of the oyster, both male and female, are simply discharged into the surrounding water. The eggs are absolutely immobile, and while the spermatozoa, or male elements, possess the power of locomotion to some extent, they are obviously incapable of moving very far during the limited period of their mobility. In densely-crowded beds no doubt a considerable proportion of the eggs may become fertilized even without the agency of currents, but where, as upon most oyster-grounds, the oysters are scattered, the proportion must be exceedingly small. Oystermen are well acquainted with the fact that upon beds removed from the influence of the tides the rate of reproduction is very low.

Currents, however, will bring about a distribution of the genital products, more particularly the almost impalpable milt, and thus give an opportunity for obtaining better results by increasing the chances for spawn and milt to come into contact. Although the young spat is a free-swimming organism, yet its powers are not sufficient to carry it to any great distance from its original source. It is transported mainly by tidal currents, and, as a general rule, the more widely distributed a given lot of spat, the greater is the number liable to become successfully set. Currents, even of considerable strength, do not prevent the settling down of the larval oyster and its fixation upon a proper surface.

In the preparation of this surface the currents are also effective, inasmuch as by their scouring action they prevent the deposit of sediment and slime, which soon render collectors unsuitable for the fixation of the young oyster. Finally, where the fry are uniformly distributed in a body of water a collector placed in a current will collect more spat than one in quiet water, because a greater quantity of water and consequently a larger number of fry will be brought into contact with it. Points around which fry-charged water sweeps with sufficient velocity to prevent the deposit of sediment are good places for the location of collectors.

Freshets, for several reasons, usually have a bad effect upon the oyster-beds. When the volume of fresh water is large, the oysters suffer from the decrease in the density. Large quantities of mud and sediment are brought down by the floods and often deposited on the beds, covering up the cultch and smothering the young spat, and, if the amount of sedimentation is very great, even injuring or killing the adults.

DEPTH OF WATER.

The vertical range of the cultivated oyster beds is from the shore line to a depth of 15 fathoms. In New Jersey, Chesapeake Bay, South Carolina, and other places, there are beds which are partially exposed at low water, while in Long Island Sound successful oyster-culture is carried on in depths as great as 15 fathoms, the average over planted grounds in that region, however, being from 5 to 6 fathoms. In most places, however, the planting is done in shallow bays and coves.

WEATHER CONDITIONS—STORMS, GALES, AND ICE.

Gales rarely have any influence upon adult oysters in deep water, but they sometimes seriously affect shallow-water beds. Heavy surf occasionally carries away the oysters and throws them upon the beach, or they may be buried *in situ* by the sand and seaweeds which the waves lodge upon the beds. Sometimes, after the lapse of a short time, the beds are again uncovered by the eroding effects of currents, but in many cases they are practically destroyed, both old and young being smothered by the overlying deposits.

In winter, ice often grounds upon the beds during gales and does considerable damage. The oyster appears also to be temporarily affected by the mere freezing of the waters, and it is said that, in the Chesapeake, oysters on the deeper beds are more affected than those in shoal and brackish water, becoming dark, slimy, and worthless for the market. Ten days or a fortnight must elapse after the disappearance of the ice before they become again fit for use.

The fry are more affected by the weather than are the adults. Dr. Ryder found that in the swimming stage they were killed by thunderstorms, by cold rains, and by sudden falls in temperature, and the prevalence of such weather during the spawning season must have an important effect upon the set of spat.

FOOD.

The oyster feeds upon both animal and vegetable food, the particles of which are of microscopic dimensions. The fry and young spat consume relatively large quantities of bacteria and monads, among the most minute organisms known to microscopists. According to Dr. Ryder:

Many of the food balls found in the intestine of the recently attached spat will measure under $\frac{1}{10000}$ inch in diameter. The cavity of the little creature's stomach measures only $\frac{1}{2500}$ inch. Yet in this minute digestive cavity the food is actually found rotating in the form of minute rounded and oval bodies, which are kept in motion by the action of the cilia which line the stomach. That these bodies must have been of about the size noted when they were originally swallowed and as seen rotating in the stomach is evident from the fact that the young oysters, like the adults, are wholly without teeth or triturating organs of any kind.

This minute kind of vegetable and animal food is found more or less abundantly in all sea water, and is especially abundant during the spawning season, when the decomposition and disintegration of all kinds of minute organic debris floating about in the water is in rapid progress, owing to the prevalent high temperature of the air and water. It is, therefore, probable that very few otherwise suitable locations exist where it is not possible to find an abundance of the proper sort of food for the oyster during its very earliest stages of growth.

The food of the slightly more advanced spat and the adults is found to consist of diatoms, rhizopods, infusoria of all kinds, monads, spores of algæ, pollen grains blown from trees and plants on shore, their own larvæ or fry, as well as that of many other mollusks, of bryozoa and minute embryos of polyps and worms, together with other fragments of animal or vegetable origin, and sometimes even minute crustaceans. In variety of food the oyster, therefore, has a wide range of choice. There are also few locations otherwise well adapted which will not supply an abundance of food for the animal, which, it is to be remembered, captures and hoards millions of these minute plants and creatures in its stomach, where they are digested and incorporated into its own organization. It therefore follows that when we eat an oyster we are consuming what it required millions of the minutest organisms in the world to nourish. The oyster is consequently a sort of living storehouse for the incorporation and appropriation of the minute life of the sea, which could never be rendered tributary to the food supply of mankind in any other way except through the action, growth, and organization of this mollusk.*

The quantity of young oysters consumed by the adults is doubtless enormous, 200 fry having been found in the stomach of single individuals. Not only the free-swimming fry, but eggs and spermatozoa are fed upon, and an insight is here gained into the ultimate fate of some of the vast numbers of genital elements which the parents shed into the water.

While the oyster feeds upon both plant and animal organisms, it must be remembered that it is primarily dependent upon the former. That not only is the major portion of the food of the oyster itself of vegetable origin, but the minute animal forms are dependent for their sustenance upon the plants and are not to be found in abundance far removed from them.

* Rept. U. S. F. C. 1885, pp. 387-388.

In most regions which have been investigated the plants constitute by far the most important item of diet, usually over 90 per cent of the food contents of the stomachs being composed of vegetable matter. Of this diatoms are the chief constituents, and to a certain extent the food value of any given oyster region may be measured by the quantity of these minute plants which it is capable of producing.

Diatoms are numerous both in species and individuals, and all possess two interesting peculiarities: They are incased in a siliceous or flinty box and they possess the power of locomotion, the first permitting their ready identification in the stomach contents and the second aiding in their distribution. More or less regular diurnal migrations of swarms to and from the surface of the water take place with the variations in the light. During sunlight they rise from the bottom, and are then readily transported by the currents, again settling down as darkness comes on. They feed and grow in size most actively during the day, but multiply in number principally at night. Diatoms are important, not only in fattening the oyster, but they also have a profound influence upon its flavor and color.

The oyster is said to feed mainly during flood tide, opening its shell at that time to admit the influx of water with its contained organisms. Investigation by Dr. Bashford Dean showed that the stomachs were practically foodless in the morning, contained most food at midday, and a somewhat reduced quantity at evening, thus suggesting that feeding was most active during intense daylight.

Dr. Dean remarks:

> This suggestion, as to the feeding habits of the oyster, is not a surprising one when we remember that it is during the strongest sunlight than diatoms, as plants keenly sensitive to the sun, are most active and are known to migrate in floating clouds from the bottom of the surface.

As is mentioned in the section relating to the anatomy of the oyster, the water drawn into the mantle cavity by the action of the cilia is filtered through the rectangular openings in the gills into a chamber or tube lying above each gill, whence it passes backward and out of the shell in a current dorsal to the entering stream. The particles of food in the inflowing stream become entrapped in a sticky mucus covering the gills, and, together with this mucus, in part, are carried in a steady stream toward the mouth, the motion being imparted to the mass by the rhythmic action of the cilia. The palps and mouth are also ciliated, which insures the continuance of this current into the stomach, where the food particles undergo digestion. A very considerable proportion of inert matter, sand, mud, etc., of no nutrient value passes into the alimentary tract along with the food, the oyster having no means of making selection.

The temperature, depth, and density of the water have considerable effect upon the food supply. In clear, warm weather the amount of food matter is increased by the natural multiplication of the minute organic bodies which find such conditions favorable, but at the same time many of these organisms, particularly the diatoms and zoospores, are attracted to the surface by the sunlight and are thus placed beyond reach of the oyster. In rainy or stormy weather, however, they are driven down toward the bottom, where they may be brought within the influence of the cilia, and at the same time there is an increase in the amount of other organic sediment, much of which is available as food.

Shallow water, as a rule, produces more food than the greater depths, owing largely to the fact that it warms more quickly and thus increases the vitality of both the oyster and its food. The latter shows its greater vigor by a more rapid multiplication, and the former by its greater consumption of the food which is thus provided for it. In other words, the chemical and physiological changes resulting in the conversion of inorganic matter into oyster tissue through the medium of plant life go on more rapidly in the presence of warmth. It must also be remembered that the shallow waters are generally of a lower density than the deeper ones, and this approach to brackishness appears to be also favorable to the production of food.

Summer and fall, the seasons of most vigorous growth of aquatic vegetation, are in most localities likewise the best seasons for the growth of the oyster, while in winter the food supply is at a minimum, the vital activities of the oyster are much reduced, the ciliary action is weak, and the oyster in a state of semihibernation, both the waste and repair of tissue being reduced to a minimum.

That the oyster in many places reaches its greatest fatness and perfection late in fall is due partly to the quantity of food produced during the summer and partly to the cessation of the drain which the act of spawning entails. Shortly before and during the spawning season most of the nutrient matter in the food is utilized in the rapid growth of the sexual products, but after the cessation of spawning it is converted into surplus protoplasmic matter, which is stored up in the tissues and thereby renders the oyster fat and well flavored.

ENEMIES.

At all stages of its career the oyster is preyed upon by more or less dangerous foes. It might be supposed that an animal inclosed in a ponderous armor, which in times of danger is a complete encasement, would be free from the attacks of enemies, but no organism has ever evolved a protective device which some other organism has not found partially vulnerable; and it must be remembered that the oyster is not always as well protected as we find it in the adult and marketable condition. In the young state, before attachment, the minute and delicate fry is fed upon extensively by the adult oyster and by other mollusca, lingulas, worms, sponges, and hydroids. Upward of 200 young have been found in the stomach of an oyster, and there is but little doubt large numbers are so consumed on every oyster-bed. Probably the menhaden, the alewife, and other fish equipped with delicate sifting devices at times find the oyster fry of some importance in their dietary.

After the attachment of the spat other enemies, active and passive, wage war upon it. The passive enemies affect its welfare by consuming its food or by smothering it beneath their own more active growth. Of the former class, mussels, lingulas, etc., are examples, but as the food upon an oyster-bed is usually sufficient for all, this is not a very important consideration, particularly as in the end an equilibrium is established through the intimate reciprocity which exists between the various forms of life.

The conditions of life upon an oyster-bed are favorable to the rapid growth of dense sponges, mussels, barnacles, hydroids, and tube-building worms, which establish themselves upon the young growth, often increase more rapidly than their hosts, and, in many cases, overgrow them to such an extent as to cut off the supply of food and oxygen. (Plate XVII). Aquatic vegetation sometimes has the same effect when its growth becomes extensive. Certain worms, such as *Serpula*, and especially *Sabellaria* (plate XV, fig. 3), often build their tubes of lime or sand so rapidly as to produce dense accumulations upon the surface of the shells, thus forming a nidus for the collection of sand and mud. Considerable loss has at times resulted from the suffocation of oysters by sponges, worm tubes, and vegetable growths, but most of these passive forms have a compensatory use in the food which their spores, eggs, and young furnish to the oysters.

The active enemies of the adult oyster are those which injure it by direct attacks, such enemies being found in most of the classes of zoological life having aquatic representatives.

Fishes of several kinds are found habitually on the oyster-beds. Most of these offer no direct injury and they may even benefit the oyster by keeping down the crowding masses of hydroids and vegetable life, but a few species, of which the drumfish is apparently the most destructive upon the Atlantic coast, consume considerable quantities of oysters as food. At times much damage has thus been wrought to the beds in the vicinity of New York and along the New Jersey coast. In San Francisco Bay the stingray is the most feared enemy of the oyster, and schools of them frequently "clean out" the beds to which they gain access, their teeth being such that the shells are crushed into fragments in their grasp. Some of the skates and rays on the eastern coast no doubt have similar habits, but they do not appear in sufficient numbers to cause much harm.

The drills are the most destructive enemies of the oysters in the Chesapeake and adjoining regions, as well as upon most of the more important inshore beds northward. There are, perhaps, several species, but the most destructive is the form known to naturalists as *Urosalpinx cinerea* (plate XV, fig. 1). It is a snail-like mollusk, which, by means of its rasping tongue, drills a tiny hole in the shell of the oyster, through which it extracts the soft parts. It is only the younger oysters which are thus attacked, as after they become about 2 inches long the shell is stout enough to resist this foe. The loss sustained from this source is very great, as the drills are often present in large numbers and continue their work throughout the year.

The two large conch-like gasteropods of the Atlantic coast, *Sycotypus canaliculatus* and *Fulgur carica* (plate XV, fig. 4), also feed upon the oyster, from their size being capable of attacking the largest individuals. These periwinkles, "winkles," or conchs, as they are variously called, appear to do comparatively little damage, as they are not present in sufficiently large numbers anywhere except perhaps on the coast of Florida.

Other gasteropods doubtless feed upon the oyster, but not to an extent worthy of consideration.

Upon brackish-water beds the starfish (plate XVI) is not usually troublesome, and in Chesapeake Bay it is practically unknown, but in Long Island Sound, and especially upon the offshore beds in the more saline waters, it is the most destructive enemy with which oystermen have to contend. It is there extremely abundant at times, but it is a migratory form, and sometimes certain beds are unmolested while others nearby are almost ruined by its inroads. The appearance of this pest upon the beds is without warning, and frequently the ground is almost devastated before the owner is aware of their presence. Vast swarms or schools sweep across the beds, devouring the oysters in their path. The migration is said to take place in the form of a "winrow," moving in some cases at the rate of about 500 feet per day. Apparently the only way to stop the march of these hordes is to catch them up by some of the methods indicated in pp. 313–316. By energetic work the damage may often be confined to the beds at the edge of a cultivated area.

The starfish begins its destructive work soon after it abandons its free-swimming larval condition, at a time when it is hardly larger than a pin's head, and continues it through life. At first it feeds upon the tiny spat, but as it grows it increases the size of its prey, though even the full-grown stars rarely feed upon oysters over two, or, at most, three years old. Small oysters are often taken bodily into the stomach of the starfish, a proceeding which is of course impossible with large ones or those firmly attached to large cultch. It is not definitely known how the oysters are opened, but Dr. Paulus Schiemenz has pretty conclusively demonstrated the probability that they are actually pulled open by muscular effort on the part of the starfish.

If the common starfish be examined there will be found on the under surface of each arm four rows of closely crowded suckers or feet extending from the mouth to the tips of the arms. These feet are tubular and are extended by having a fluid pumped into their cavities by a special apparatus in the body of the starfish. The suckers at the ends may be caused to adhere to foreign bodies with great tenacity, and if the hydrostatic pressure be then relieved and the muscles of the stalks of the feet contract, a strong pull may be exerted by each foot, either independently of its fellows or in conjunction with them. As shown in plate XVI, the starfish feeding upon oysters or other lamellibranchs arches itself over the nibs or lips of the mollusk so that some of its arms are on one side and some on the other. In this position a large number of the sucker feet are attached to each valve, and when they contract a stress is produced in opposite directions and opposed to the force of the adductor muscle which tends to keep the valves of the oyster closed. Dr. Schiemenz has shown by actual measurement that in this manner there is exerted a force sufficient to overcome any resistance which the oyster may offer. It is eventually tired out by the persistence of its enemy, its shell is forced open, the stomach of the starfish is inserted, and within a few hours the valves only remain.

Another annoying and frequently very destructive enemy of the oyster is the boring-sponge, *Cliona sulphurea.* It differs from the enemies before enumerated in that it consumes the shell and not the soft parts of the unfortunate oyster. The young sponge lives in galleries excavated in the substance of either dead or living shells which are soon reduced to a honey-combed condition, when they may be crumbled to powder between the fingers. When they attack a living oyster, as the galleries penetrate the inner face of the shell, an irritation of the mantle is produced, causing an increased amount of shell deposit at that point. If the inside of such a shell be examined it will be found to be covered with blister-like shell deposits, sealing up the openings to the galleries, and many curious distortions follow from the destruction of the hinge area and the portion of the shell to which the adductor muscle is attached. Although the oyster itself is not attacked, yet it becomes poor, thin, and watery and often dies from the exhaustion induced by the constant effort to keep its shell intact.

The older specimens of the boring-sponge are large, dense, yellow masses, often 6 or 7 inches in diameter and usually inclosing the shells, etc., to which they were originally attached. All stages intermediate between those described can usually be found upon infested oyster-beds. The older, more massive forms often suffocate the oyster through the denseness of their growth.

In addition to the various forms already enumerated there is a large population upon the oyster-beds which is not injurious. This, of course, includes many of the minute food forms, together with some of the fishes and crabs. The latter, at least on the Atlantic coast, can not be regarded as very destructive, but on the contrary they serve as scavengers, removing dead matter from the beds when it might otherwise become foul and fatal to the oysters. It will be seen that the population of the oyster-beds is large and extremely complex. The social relations of the various forms are exceedingly intricate and have, in the course of evolution, become nicely adjusted in a system of reciprocity. The law of the oyster beds is "give and take," each of a large number of organisms giving something for the general welfare and taking what it needs for its own well being.

DESCRIPTION OF NATURAL BED.

Dr. Brooks thus describes a natural oyster bank:

An examination of a Coast Survey chart of any part of the Chesapeake Bay or of any of its tributaries will show that there is usually a midchannel or line of deep water where the bottom is generally soft and where no oysters are met with, and on each side of this an area where the bottom is hard, running from the edge of the channel to the shore. This hard strip is the oyster area. It varies in width from a few yards to several miles, and the depth of water varies upon it from a few feet to 5 or 6 fathoms or even more. But there is usually a sudden fall at the edge of the channel where the oysters stop, and we pass onto hard bottom; and a cross-section of the channel would show a hard, flat plane with oysters on each side of the deep, muddy channel. The oyster bottom is pretty continuous, except opposite the mouth of a tributary, where it is cut across by a deep, muddy channel. The solid oyster rocks are usually situated along the outer edge of this plateau, although in many cases they are found over its whole width nearly up to low-tide mark or beyond. As we pass south along the bays and sounds of Virginia and North Carolina, we find that the hard borders of the channel come nearer and nearer to the surface until in the lower part of North Carolina there is on each side of the channel a wide strip of hard bottom, which is bare at low tide and covered with oysters up to high-water mark, although the oysters are most abundant and largest at the edge of the deep water, where they form a well-defined reef. In our own waters there is usually a strip along the shore where no oysters are found, as the depth of water is not great enough to protect them in winter. The whole of the hard belt is not uniformly covered with oysters, but it is divided up into separate oyster rocks, between which comparatively few can be found.

The boundaries of a natural rock which has not been changed by dredging are usually well defined, and few oysters are to be found beyond its limits. The oysters are crowded together so closely that they can not lie flat, but grow vertically upward, side by side. They are long and narrow, are fastened together in clusters, and are known as "coon oysters."

When such a bed is carefully examined it will be found that most of the rock is made up of empty shells, and a little examination will show that the crowding is so great that the growth of one oyster prevents adjacent ones from opening their shells, and thus crowds them out and exterminates them. Examination shows, too, that nearly every one of the living oysters is fastened to the open or free end of a dead shell which has thus been crowded to death, and it is not at all unusual to find a pile of five or six shells thus united, showing that number two has fastened, when small, to the open end of number one, thus raising itself a little above the crowd. After number one was killed, number two continued to grow, and number three fastened itself to its shell, and so on. Usually the oysters upon such a bed are small, but in some places shells 12 or 14 inches long are met with. The most significant characteristic of a bed of this kind is the sharpness of its boundaries. In regions where the oysters are never disturbed by man it is not unusual to find a hard bottom extending along the edge of the shore for miles and divided up into a number of oyster rocks, where the oysters are so thick that most of them are crowded out and die long before they are full grown, and between these beds are areas where not a single oyster can be found. The intervening area is perfectly adapted for the oyster, and when a few bushels of shells are scattered upon it they are soon covered with young, and in a year or two a new oyster rock is established upon them, but when they are left to themselves the rocks remain sharply defined.

What is the reason for this sharp limitation of a natural bed? Those who know the oyster only in its adult condition may believe that it is due to the absence of powers of locomotion and may hold that the young oysters grew up among the old ones, just as young oak trees grow up where the acorns fall from the branches. This can not be the true explanation, for the young oysters are swimming animals, and they are discharged into the water in countless numbers, to be swept away to great distances by the currents. As they are too small to be seen at this time without a microscope it is impossible to trace their wanderings directly, but it is possible to show indirectly that they are carried to great distances and that the water for miles around the natural bed is full of them. They serve as food for other marine animals, and when the contents of the stomachs of these animals are carefully examined with a microscope the shells of the little oysters are often found in abundance. While examining the contents of the stomach of lingula in this way I have found hundreds of the shells of the young oysters in the swimming stage of growth, although the specimens of lingula were captured several miles from the nearest oyster-bed. As lingula is a fixed animal the oysters must have been brought to the spot where the specimens were found, and as the lingula has no means of capturing its food, and subsists upon what is swept within its reach by the water, the presence of so many inside its stomach shows that the water must have contained great numbers of them.

It is clear, then, that the sharp limitation of the area of a natural oyster bed is not due to the absence in the young of the power to reach distant points. There is another proof of this, which is familiar to all oystermen—the possibility of establishing new beds without transplanting any oysters. The following illustration of this was observed by one of your commissioners: On part of a large mud flat which was bare at low tide there were no oysters, although there was a natural bed upon the same flats, about half a mile away. A wharf was built from high-tide mark across the flat out to the edge of the channel, and the shells of all the oysters which were consumed in the house were thrown onto the mud alongside the wharf. In the third summer the flat in the vicinity of the wharf had become converted into an oyster-bed, with a few medium-sized oysters and very great numbers of young, and the bottom, which had been rather soft, had become quite hard; in fact, the spot presented all the characteristics of a natural bed. Changes of this sort are a matter of familiar experience, and it is plain that something else besides the absence in the oyster of locomotive power determines the size and position of a bed.

Now, what is this *something else?* If the planting of dead shells will build up a new bed, may we not conclude that a natural bed tends to retain its position and size because the shells are there? This conclusion may not seem to be very important, but I hope to show that it is really of fundamental importance and is essential to a correct conception of the oyster problem.

Why should the presence of shells, which are dead and have no power to multiply, have anything to do with the perpetuation of a bed?

We have already called attention to the fact that oysters are found on the hard bottom on each side of the channel, while they are not found in the soft mud of the channel itself, and it may at first seem as if there were some direct connection between a hard bottom and the presence of oysters, but the fact that no oysters are found upon the hard, firm sand of the ocean beach shows that this is not the case. As a matter of fact, they thrive best upon a soft bottom. They feed upon the floating organic matter which is brought to them by the water, and this food is most abundant where the water flows in a strong current over soft organic mud. When the bottom is hard there is little food, and this little is not favorably placed for diffusion by the water, while the water which flows over soft mud is rich in food.

The young oysters which settle upon or near a soft bottom are therefore most favorably placed for procuring food, but the young oyster is very small—so small that a layer of mud as deep as the thickness of a sheet of paper would smother and destroy it. Hence the young oysters have the habit of fastening themselves to solid bodies, such as shells, rocks, or piles, or floating bushes, and they are enabled to profit by the soft bottoms without danger.

Owing to the peculiar shape of an oyster shell, some portions usually project above the mud long after most of it is buried, and its rough surface furnishes an excellent basis for attachment. It forms one of the very best supports for the young, and a little swimming oyster is especially fortunate if it finds a clean shell to adhere to when it is ready to settle down for life. Then, too, the decaying and crumbling shells are gradually dissolved in the sea water, and thus furnish the lime which the growing oyster needs to build up its own shell. As long as the shell is soft and thin the danger from enemies is very great, and this danger is greatly diminished as soon as the shell becomes thick enough to resist attack. It is, therefore, very necessary that the shell should be built up as rapidly as possible, and an abundant supply of food in general will be of no advantage unless the supply of lime is great enough for the growth of the shell to keep pace with the growth of the body. All sea water contains lime in solution, but the percentage is, of course, greatest near the sources of supply. It is well known that on coral reefs, which are entirely made of lime, all kinds of shelled mollusks flourish in unusual abundance and have very strong and massive shells, and our common land and fresh-water snails are much larger and more abundant in a limestone region than in one where the supply of lime is scanty. In such regions it is not unusual to find the snails gathered around old decaying bones, to which they have been drawn in order to obtain a supply of lime for their shells.

From all these causes combined it results that a young oyster which settles upon a natural oyster-bed has a much better chance of survival than one which settles anywhere else, and a natural bed thus tends to perpetuate itself and to persist as a definite, well-defined area; but there is still another reason. As the flood tide rushes up the channels it stirs up the fine mud which has been deposited in the deep water. The mud is swept up onto the shallows along the shore, and if these are level much of the sediment settles there. If, however, the flat is covered by groups of oysters, the ebbing tide does not flow off in an even sheet, but is broken up into thousands of small channels, through which the sediment flows down to be swept out to sea.

The oyster-bed thus tends to keep itself clean, and for these various reasons it follows that the more firmly established an oyster bed is the better is its chance of perpetuation, since the young spat finds more favorable conditions where there are oysters, or at least shells, already than it finds anywhere else.

Now, what is the practical importance of this description of a natural bed? It is this: Since a natural bed tends to remain permanent, because of the presence of oyster shells, the shelling of bottoms where there are no oysters furnishes us with a means of establishing new beds or of increasing the area of the old ones.

The oyster-dredgers state, with perfect truth, that by breaking up the crowded clusters of oysters and by scattering the shells the use of the dredge tends to enlarge the oyster-beds. The sketch which we have just given shows the truth of this claim, but this is a very rough and crude way of accomplishing this end.*

This description, so far as it relates to the oysters themselves, gives a good idea of the average oyster-bed, though they differ somewhat in details in different localities. But, as shown in the sections which treat of the enemies and the food of the oyster, the latter is very far from constituting the entire population of the beds. The same causes which induce the growth of the oyster, the firm basis of attachment, the surrounding food-producing mud, the favorable density and temperature, all tend to make the oyster-bed a center teeming with aquatic life. Thus a single point of attachment, a firm nucleus projecting naturally above the surrounding mud, or a few shells thrown upon the muddy bottom may give rise to a community where life is as abundant and the struggle for existence as complex and strenuous as is anywhere found in nature.

* Brooks, W. K., Maryland Oyster Report, 1884, pp. 86 to 88, inclusive.

DESTRUCTION OF NATURAL BEDS—CAUSES AND REMEDIES.

Until a comparatively recent date our supply of oysters was drawn almost entirely from the natural beds, which were originally so vast that it was a common saying that they were inexhaustible. The fallacy of this view has been abundantly proven, and wherever reliance has been placed upon natural beds solely there has been a decreasing supply to meet an increasing demand. Many causes have been cited to account for the decrease in the productiveness of the oyster-beds, but wherever unprejudiced investigation has been brought to bear upon the subject the verdict has always been that the fishing upon the beds has outgrown their fecundity.

Vast as is the production of spawn, the chances against its growth to maturity are such as to limit the productiveness of the beds. Much of it fails of fertilization. Most which passes that critical stage becomes a prey to enemies or falls upon unsuitable bottom, where it fails of attachment and sinks in the ooze. Even after the vicissitudes of larval life are passed the infantile spat may be buried in an accumulation of organic or inorganic sediment, or it may be devoured by enemies against which it can present no adequate defense. Storms may tear the adult oysters from their attachment and cast them upon the shore, or they may become covered by sand and seaweeds drifted in by the waves; or, again, excessively cold weather may cause their death in exposed places by freezing.

Numerous as are the perils which beset them under their natural surroundings, they have, upon the whole, found the conditions favorable for their maintenance and increase until civilized man began his systematic attacks. It is true that before the appearance of the white man upon the scene they had disappeared from regions where they were formerly found, but upon our coasts such cases are isolated and rare.

Without here going into the evidence, it may be asserted as a demonstrated fact that overfishing is the cause of the depletion of our oyster-beds, and that it produces its damaging effect in several ways:

1. It removes the adult oysters, which are either spawning or are capable of spawning, and thereby reduces the reproductive power of the bed as a whole.

2. It removes the shells, and therefore decreases the available points of attachment of the spawn. When the oysters are not culled on the beds this effect is aggravated by the removal of the dead shells.

3. Spat and young oysters attached to the shells of the adults are removed from the beds, and as it is impracticable in many cases to detach them they are of necessity destroyed.

4. The quantity of oysters taken and destroyed from the several causes mentioned is greater than that which is permitted to annually grow up to take their places.

Many causes have been assigned as tending to deplete the oyster-beds, and many remedies have been proposed. Various phases of the oyster business have been cited to show cause why they should not be curtailed or abolished as destructive. It has been proposed to restrict the demand by prohibiting canning; to prohibit the use of this or that kind of apparatus, or to interfere in various ways, with more or less legitimate methods of meeting and increasing the demand.

The attempts that have been made to keep the demand upon the beds within the limit of their fecundity have so far been failures, and such attempts are also seen to be illogical when it can be shown that the reciprocal measure, increasing the supply, is perfectly feasible.

The dictates of sound economics require that no effort be made to restrict the demand until it can be shown that efforts to increase the supply are futile. A growing demand for a product is the most trustworthy indication of an industry's prosperity, and the only rational manner in which to bring the supply and demand into equilibrium is to increase the former. Only after the failure of all efforts to save the supply from total extinction, should a restriction be placed upon the demand.

The close season has been a favorite measure in protective legislation, as it has been in most legislation looking to the perpetuation of game and fish. It is usual to fix the close season during the spawning months, upon the theory that the reproductive act should be allowed to proceed unmolested. It really matters but little whether the oyster is taken during the season of spawning or a month or two before; the effect upon the fishery is the same, as in either case the bed is deprived of an individual capable of reproducing its kind. The only effect of a close season, whenever occurring, is to reduce the time during which the oyster is subject to attack from the oystermen. Even this is of little avail with the sedentary oyster, for it is possible for 365 men, fishing ten days, to as effectually "clean up" a bed as can be done by 10 men fishing throughout the year. This has been found to be the practical result of a close season in some places; the first few days of fishing removing so many oysters as to make it unprofitable to work the beds during the rest of the year.

The methods by which the increased demand resulting from a widening of the markets may be met will be treated of in another connection. It may become necessary in some parts of this country, as in Europe, to reserve the natural beds for the production of seed. Such a reservation would naturally excite the strenuous opposition of the oystermen; but should the industry ever be reduced to the desperate condition at one time found in France, correspondingly desperate remedies must be invoked.

INCREASE OF SUPPLY BY ARTIFICIAL MEANS.

In many countries in which oysters are an important item of food it has been found necessary to give nature some assistance in order to maintain or increase the supply of oysters available for the markets. The direction in which this assistance is rendered is governed by local conditions, but in general it may be stated that all methods of oyster-culture depend for their success upon the modification of the natural conditions in such a manner as to bring about one or several of the following results:

1. An increase in the number of eggs successfully fertilized.

2. An increase in the surfaces available for fixation, and consequently an increase in the number of spat which become fixed and pass through the early stages of spat existence.

3. The utilization and salvage of spat, which would otherwise fall victims to the several vicissitudes of their careers—storms, frosts, crowding, etc.

4. A decrease in the liability to attacks from enemies.

5. The utilization of otherwise neglected bottoms and food supplies.

Upon our coasts the objects set forth above, or some of them, have been best realized by the process of "planting." This consists in placing firm bodies in the water for the purpose of catching the spat or in spreading young oysters upon the bottom in places suitable for their growth. Vast as are our oyster-fields, but a small portion of the bottom available for the growth of this mollusk has been utilized by nature. This has arisen from the fact that in many cases where the other conditions are favorable the bottom is of such a character as to prevent the attachment of the young, though perfectly adapted to the rapid growth of the adults. If then the spat be caught on planted cultch, or partially grown oysters be placed upon such bottoms, the difficulty is overcome and nature has been assisted to the degree necessary and all or some of the conditions mentioned above are more or less completely fulfilled; the first by increasing the number of adult oysters in any region, and by their closer aggregation; the second, by the process of preparing the ground and sowing the shells; the third, by the use of seed from regions less favorable to its maturing; the fourth, from the greater care with which a bed under private ownership will be watched and guarded, and the fifth by the very act of planting upon virgin or depleted bottom.

Other and more complex plans of oyster-culture are employed in the countries of Europe, but have not yet been adopted in the United States. There are indications, however, that in certain portions of our oyster belt it may be necessary to follow some method of pond culture, not so much for the purpose of growing the oysters, but to fatten them for market. Should the feasibility of this be demonstrated under the conditions prevailing in the United States, a vast increase could be made to our oyster supply, as it is a well-known fact that certain large areas are capable of raising oysters which they rarely fatten and for which, therefore, no market can be found.

By some modification of pond culture it may also be possible to raise seed oysters in regions in which few or none are now produced, thus adding another considerable item to the wealth-giving powers of our coasts.

These several subjects are treated under their appropriate headings in the following pages.

PLANTING WITH SEED.

PRELIMINARY CONSIDERATIONS.

Preliminary to planting, the first essential is to determine whether private rights in oyster bottoms are recognized by law or countenanced by public opinion. Unless the planter is assured of exclusive ownership in the product of his labor and enterprise he will find more profit and peace of mind in devoting his energies to some other calling. Unless the law, backed by the public sense of justice, makes the theft of oysters from planted grounds punishable like theft of any other kind, it will be impossible to expect success in oyster-planting. Very remarkable views obtain in some places concerning the right to property beneath the sea, and in such places the planter will find it impossible to protect his interests.

Having determined that his rights in his riparian property may be successfully maintained, the next step is to select beds that present the proper conditions of temperature, density, bottom, food, etc.

Temperature.—If it is desired to establish a self-perpetuating bed the temperature should rise for a considerable time during the spawning period to between 68 and 80 degrees. If it be desired to merely increase the size of seed oysters obtained elsewhere, it is not necessary that the temperature should ever rise so high, although, as a rule, warm waters induce more rapid growth. The range of temperature to which adult oysters are subject will be seen on page 280.

Density.—The density should be above 1.007 at least, and the beds should be so located as not to be subject to the influence of freshets which would reduce the density below that degree for any length of time. A density over 1.023 is not advisable, although oysters grow in places in a somewhat greater salinity. (See p. 281.)

Bottom.—The character of the bottom is the most important consideration, and it is probable that, upon our coasts, the other conditions will be fairly met in any locality where suitable bottom is available. The selection should be made with care, and the methods employed should be adapted to the character of the ground. Otherwise the planter may be put to labor and expense without return.

Hard, rocky bottom is in general unsuited for the cultivation of the oyster. Such ground, while affording facilities for the fixation of spat, does not supply sufficient food to cause a rapid growth, such as is desired by the planter, unless there is abundant muddy bottom in the vicinity. Heavy clay is open to the same objection. Loose sand is liable to drift and bury the oysters, and deep, soft mud is absolutely fatal, as it allows even adult oysters to sink to such a depth that they are smothered.

The best bottom consists of a firm substratum, above which is a layer of soft flocculent mud. In Long Island Sound, firm, sandy bottom is often used with great success. The oysters do not grow so rapidly there, however, as they do upon the soft mud of Jamaica Bay and other places on the south shore of Long Island.

Food.—The question of food is a *sine qua non* in oyster-culture. Without a supply of suitable and proper food it is useless to attempt the growth of oysters. As a general rule, it will be found that where the proper conditions of temperature obtain the vicinity of a muddy bottom will be well stocked with the minute organisms upon which the oyster feeds. Reliance upon this fact, however, is placing dependence upon a "rule of thumb," never a profitable method where more accurate and scientific information can be obtained. Oystermen usually determine the best growing and fattening grounds by actual experiment, a proceeding often entailing the wasteful expenditure of time and capital, and the small cost which would be involved in making a preliminary biological survey would be, in most cases, well expended. The currents may be such as to carry the food organisms away, or for other reasons beds, apparently well situated, may be lacking in food, a fact usually not discovered until time and money have been wasted in experimental planting.

Marking bed, etc.—The boundaries of the planting-grounds should be marked with stakes in such a way that each planter will have no difficulty in distinguishing his own ground from that of his neighbor. In order to recover the boundary, should the stakes be carried away by storms or ice, it is usual to have ranges locating the most important marks, such as those at the corners of the beds, these ranges being either conspicuous natural objects, buildings, etc., or, preferably, signals erected especially for the purpose. In deep water, or upon bottoms where stakes can not be driven or held, buoys are commonly used for locating the beds. Some of the States have laws regulating more or less strictly the manner of describing and marking the private oyster-grounds, and to avoid trouble and disputes these should be strictly complied with.

It should be remembered that it is more difficult to lay out and mark areas beneath the water than upon the land. It sometimes happens that the planter is able to get control of an entire cove or brackish-water creek, in which case the question of marking the beds and of protecting them from poachers is much simplified. In some places it is customary for owners to subdivide their beds for purposes hereafter mentioned, and such subdivisions may be marked in the manner adopted for indicating the boundary of the right.

PREPARING BOTTOM.

Having located and marked the beds, the ground should be prepared for planting. In places such as San Francisco Bay, where the oysters are placed on beds which are more or less exposed at low tide, this usually consists of clearing away the snags and other debris at low water and leveling off the mounds and filling up the hollows. If it is necessary to build stockades to protect the oysters from fish, this should also be done before planting is begun, as otherwise the bed may be ruined before it is fairly planted.

In deeper water the clearing up of the grounds is usually done by means of the dredge, all debris being carefully removed. This work is best performed by steam, the larger planters owning vessels and the smaller ones hiring them for the purpose. The work with sailboats is more laborious and less rapid.

If the bottom is firm, or if there is a firm substratum an inch or two below the soft surface-layer, no further preparation is needed. When there is a soft mud of some depth, however, it is absolutely necessary that the surface be prepared in some way which will prevent the oysters from becoming completely submerged and suffocated in the soft deposit. This is usually done by distributing over the soft places various hard substances, which, resting upon the mud, give it a firm surface upon which the oysters may repose in safety.

In France, where the lack of suitable grounds frequently requires the use of very soft bottoms, this difficulty is sometimes overcome by the expensive means of macadamizing the bottom with gravel and clay. While this, of course, forms an excellent bottom, hard and smooth, it can only be used on grounds exposed at low tide.

American planters usually provide a firm surface by strewing oyster shells, clam shells, gravel, or sand over the bottom in such quantities as to have the desired effect. When shells or gravel are used the double purpose is often served of preventing the submergence of the adult oyster in the mud and offering a place of attachment for the spat. In certain places sandy and gravelly material resulting from dredging for harbor improvements has been utilized for this purpose, and much soft bottom, before valueless, has been made to yield a profitable return to the planter. Such material can often be obtained at a very small cost, sometimes merely for the expense of transportation to the beds.

In surfacing, care should be exercised that the firm layer be deposited uniformly, as otherwise the muddy bottom will be exposed in places and the oysters falling thereon in planting will be engulfed in the mud. Plenty of material should always be used, as it is poor economy to spend money for work and material which is insufficient to accomplish the end sought. The exact amount necessary will depend upon the character of the bottom. Where it consists of a very deep, pulpy or flocculent deposit it is useless in most cases to attempt to improve it, as the surfacing material will sink almost as fast as it is deposited. In places perhaps this might be overcome by the French system of macadamizing, but as more suitable bottom is abundant on our coast such an expensive procedure would be unnecessary.

When the bottom is properly surfaced with coarse sand or gravel it does not as a rule require another coat for four or five years. When there is a rapid deposit of mud it will, of course, soon become covered up, but a location where this takes place with much rapidity should perhaps be better left alone, as the seed oysters are liable to suffocation by the deposit of material upon them. A strong current will prevent the deposit and keep the surface scoured after it has been once prepared.

SEED.

After the ground has been thoroughly prepared according to its requirements, the next consideration is the actual planting of the oysters. Planters follow one of two methods, as their interests and experience may dictate; they either plant seed oysters and raise them to an adult or marketable size, or they use cultch to catch the spat, which may be either sold as seed or retained until it has grown. The former method is perhaps the simpler and more uniformly successful in most localities, and it will be, therefore, first discussed.

Seed oysters are young or immature oysters suitable for planting. They vary in size from minute "blisters" up to well-grown oysters, which will be ready for market in six months after they have been bedded. In most cases they run in size between 1 and 1½ inches, or from about the size of a silver quarter up to the size of a silver dollar.

The seed is obtained either from planters who make a specialty of raising it, or from the natural reefs, or from various places along shore where there may be an abundant set of spat. In certain localities gravel beaches often show a strong set in the area between tides, where it may be collected at low water, or beyond low-water mark, where it may be dredged or tonged from boats. In some parts of Long Island Sound there is an extensive fishery for seed oysters in localities such as described.

Some planters collect seed for themselves, but most of them prefer to buy from those who make a specialty of that branch of the industry. The price varies in different localities and with the character and size of seed, from 10 cents to $1 per bushel. The larger growth of seed brings a better price than the smaller, as it takes a shorter time to bring it to maturity and it is less susceptible to the attacks of enemies. The care with which the seed has been sorted is also a prime factor in the cost. Seed, just as it comes from the beds, contains much besides oysters; sometimes as much as 75 per cent consisting of old shells, sponge, and other rubbish. Though such material may be obtained at a low price, it is not generally regarded as economical, as a larger quantity must be planted than when good seed is used, the bed is littered with undesirable rubbish of all kinds, and is liable to become stocked with enemies which will cause trouble in the future. The unculled seed is liable also to grow into rough oysters, crowded into bunches and of undesirable shapes, which bring a smaller price when put upon the market.

When culled stock is selected—that is, seed consisting of separate individuals of good shape and uniform size—it is said to generally give satisfactory results. It is free from rubbish and enemies, and, being vigorous, it is able to at once avail itself of such advantages as the beds possess and its growth is correspondingly rapid. The oysters being separate from the beginning, when they reach maturity they are shapely and in good condition.

It has sometimes happened that good results have followed the sowing of spat-covered shells purchased from the canneries, but this method is precarious unless the shells are used in the process of spat-collecting to be explained hereafter.

The locality whence the seed is derived is also important. Oysters taken from a warm region, where food is plenty and growth rapid, to a colder region, where food is more scanty, are, it is stated, not always successfully acclimated unless the transfer is made when the oyster is very young. Some planters say that when southern oysters just about to spawn are taken to Long Island Sound, the generative products are not discharged and many of them die in the course of the season. The seed obtained from southern "plants," however, is as hardy as that obtained from the "natives," from which it can not be distinguished in either appearance or growth. The planting of southern seed oysters was formerly an important industry in Long Island Sound, but it has been almost entirely supplanted by shell culture. Each spring a comparatively small number of Chesapeake oysters are set down, as they have been found to fatten earlier in the fall than the native stock. There is no complaint of excessive mortality among the "Virginia plants," and it is claimed that they spawn freely in summer even if bedded in the preceding spring.

SOWING THE SEED.

The seed oysters are usually scattered over the beds from boats or scows. Care should be exercised to get them as equally distributed as possible, as experience has shown this to be advantageous to their growth. When thrown into heaps many are prevented from getting a proper supply of food, and the crowding may also cause irregularities in the shape of the shells, thus reducing their market value.

In order to secure a proper distribution over a bed, it may be roughly marked out into areas, say 50 feet square, in each of which an equal amount of seed should be planted, by scattering it broadcast with shovels or scoops from the boat or scow. In subdividing the bed a few rough stakes or buoys may be used as temporary guides.

Another method is to anchor the boat upon the bed, distribute the required amount of seed over the area which can be reached by throwing the oysters from a shovel, and then move on to the next station, where the boat is again anchored and the operation repeated. When the scow is emptied a buoy or stake may be used to mark the position of the last deposit, and operations can be resumed from that point with the next boat load. By such means the seed is rapidly and evenly spread over the bottom.

In planting on extensive beds where steam power is used the seed is distributed from scows, which are slowly towed back and forth, while a gang of 8 or 10 men shovel the oysters overboard as rapidly as possible. That is the most rapid and economical method, and is the one usually employed on the deep-water grounds of Long Island Sound.

It is not well to deposit the oysters very thickly. About 300 to 600 bushels per acre appears to be the usual amount in most places. The ground will, of course, support a larger number of yearling seed, but as they grow larger there will be more or less crowding and the demand for food will be greater.

In certain places where oyster-planting has greatly increased within recent years it is found that the oyster neither grows as rapidly nor fattens as readily as formerly, and it is supposed by many that the quantity of oysters has outgrown the ability of the region to supply them with food. The matter has not yet been investigated and the facts in the case are not definitely known, but the theory proposed is a plausible one to account for the difficulty with which the planter is beset in fitting his stock for market. It is well known that when the seed is sowed too closely upon a given bed the oysters grow and fatten more slowly than upon less thickly populated ground, and only in waters exceptionally rich in food can the quantity of seed planted exceed with safety the number of bushels stated. When the seed is sowed too thickly there is also a tendency to distortion from crowding.

WORKING THE BEDS.

When seed oysters of good quality are used it is generally not regarded as necessary to "work the beds," although care should be taken to prevent, if possible, the inroads of enemies. The various methods of attempted protection from enemies have been discussed in another connection.

It is sometimes advantageous to dredge over the planted beds to remove debris, seaweed, etc., which has drifted upon them, and which of itself and by the collection of sand, etc., would smother the oysters if allowed to remain. If the bottom is not perfectly fixed it may be necessary to shift the oysters during their growth in order to prevent "sanding," i. e., being covered with sand, etc., from the drifting bottom.

While oysters grow most rapidly upon or near muddy bottom, they are often in some respects objectionable if placed upon the market directly from such beds. Some planters, therefore, transplant them to hard bottom for several months before sending them to market, it being said that this improves their flavor and appearance by causing the muddy matter in the gills and mantle cavity, as well as in the intestine, to be gradually cleared out and disgorged.

In parts of Long Island Sound many of the planters take up a portion of their stock in spring and transplant it to such ground as may be available in the bays and harbors. Such transplanted oysters fatten and grow more rapidly than those left in the deeper water; the difference in condition is manifest to even the inexperienced, and a higher price is obtained and a more ready market found for the "harbor plants." The area available for this purpose, however, is insufficient to permit of the transplanting of more than a very small proportion of the "Sound stock."

The bottom from which the oysters have been shifted is, of course, cleansed of rubbish when the oysters are taken up and may be at once utilized for fresh seed. Some oystermen prefer to let it lie idle for a year, supposing that this increases its fitness for a further crop, but there appears to be no good reason for this, though it may be that this course permits of a recuperation of the food supply on the fallow beds.

The length of time during which the plants are allowed to lie depends upon the location of the beds, as affecting the rapidity of growth, upon the size of the seed planted, and upon the judgment of the planter. In many places "yearling" seed will be ready for the market in two or three years after being planted, i. e., when the oysters are 3 or 4 years old, but in exceptionally favorable localities, such as Jamaica Bay, Long Island, such seed is said to grow to marketable size in six months or a year. In some places it is said to now take a year longer for the oysters to mature than when planting was first practiced.

As large oysters bring a better price than small ones, it generally pays to allow them to grow for a year or two after they reach a marketable size, but this is a matter which the planter will determine for himself, as conditions vary with the locality.

As the planter generally wishes to harvest a portion of his crop each year, it is customary to divide the beds into sections, which are planted in successive years in such a manner as may suit the plan of operations of the particular grower concerned.

PLANTING WITH CULTCH OR STOOL.

PRELIMINARY CONSIDERATIONS.

This method of oyster-culture is that which was first adopted, and to it and its modifications we must doubtless look for future growth in the oyster industry. The method of planting seed oysters improves the size, shape, and flavor of the plants, and to some extent increases the quantity of oysters available for the markets, but, nevertheless, many of those which are raised from seed derived from the natural beds would have reached a marketable size if left to remain. Moreover, the natural beds are now being depleted at a rapid rate by the drain which has been made upon them. Not only are they compelled to supply oysters for market, but the young growth is now carried off to be planted elsewhere. As the number of spawning oysters on the beds is reduced and as the spawners become more scattered, the reproductive capacity of the beds is being lowered, and at the same time the removal of both oysters and shells leaves fewer points of attachment for the young spat. As the seed-producing power of the natural beds becomes reduced from these various causes, the planter must have recourse to other methods for obtaining his set of young oysters. Fortunately, there is a well-tried method which may be adopted. The oystermen long ago noticed that under certain conditions not only did natural objects of various kinds become covered with young oysters, but other objects accidentally dropped overboard would often, when recovered a few weeks later, show a heavy set of spat. Naturally they began to throw objects into the water for the express purpose of collecting the spat and thus increasing the amount of seed available, and from this beginning the present system of spat-collecting now in use in our waters was developed.

For this method of planting it is, of course, essential that there should be in the vicinity of the beds spawning oysters, either of volunteer growth or planted, and that the temperature of the water should be between 68° and 80° F. during a period of some weeks' duration.

PREPARING BOTTOM.

The bottom used for this method of cultivation should be firmer than that which will suffice for bedding well-grown seed, though soft bottom may be prepared so as to be satisfactorily used. If the bottom is very soft it may be overlaid with gravel or sand in the manner before described (p. 300), and upon this the collectors or cultch may be deposited. In a moderately soft bottom the cultch can be applied without previous preparation other than to clear the ground of all debris which would interfere with working it. Hard, gravelly bottom in shoal water, which may be of little use for the raising of adult oysters on account of the absence of food, may prove an excellent place for the collection of spat, and the same may be said of some places with a stiff clay soil.

One of the great difficulties in spat-collecting is to avoid the deposit of sediment upon the cultch, as an amount of sedimentation which would have no effect whatever upon the adult oyster would prove absolutely fatal to the young spat. At the time of attachment the infant oyster is about one-ninetieth of an inch in diameter, and the deposit of a very slight film either before or immediately after the falling of the spat would be sufficient to cause its suffocation. It will be seen, therefore, that a soft bottom upon which the large oysters will thrive, or an amount of sedimentation which may favor the rapid growth of the adults from the food matter which it contains, will effectually prevent, in many instances, the cultivation of spat.

CULTCH, COLLECTORS, STOOL.

By these terms is understood any firm and clean body placed in the water for the purpose of affording attachment to the spat or young oyster. A great variety of objects have been suggested and used for this purpose, both here and abroad, and some of these will be now discussed.

Oyster shells.—In this country oyster shells are the oldest and most generally used form of cultch. They are usually merely spread upon the bottom, being thrown broadcast from boats in the manner which is described for planting seed oysters (p. 302). When the bottom is sufficiently hard to prevent the submergence of the shells, it is customary to spread them as uniformly as possible over the ground, so as to offer the largest available area for the attachment of the spat. Where the bottom is so soft, however, that the shells would tend to sink before the young oysters have reached a size to enable them to successfully combat such conditions, it is preferable to surface the bottom in the manner described for planting seed oysters, or the shells may be thrown over so as to fall in flat heaps, those at the base forming a foundation support for those above, leaving only the upper shells available for the set of spat, those below soon becoming buried in the mud.

Shells may be planted in all depths of water with equal facility. They are cheap and readily obtainable in all oyster regions. Clam and scallop shells are also used in the same manner. The quantity required to properly "shell" a bed depends upon the nature of the bottom. When the ground is soft a larger number is necessary than upon hard ground, because in the former case many become buried in the mud or covered up by the others, whereas in the latter instance they all become available as collectors.

Upon soft ground some planters, instead of preparing the bottom with sand or gravel, apply a layer of oyster shells a couple of months before it is time to distribute the cultch proper. Those first applied sink a short distance into the mud where they become suspended so as to form a more or less solid substratum which supports the cultch applied later. A bed so prepared simulates the natural banks, which in most places overlie a mud bed that, in its upper portions, has acquired some consistency and firmness by the shells lying buried in it.

After a muddy bed has been shelled for a number of successive years it will be found to become gradually firmer. Each year some of the planted shells become covered up and are left remaining when the oysters are removed and thus it happens that the bottom of a well-handled planting-ground improves with use.

When the oyster or clam shells are thrown from the boats they will be found to fall so that the convex side rests upon the bottom. There is nothing very remarkable or inexplicable in this, as it is entirely in accordance with the ordinary laws of the resistance of fluids to the passage of a solid body through them; but in sowing the shells, however, it is important that they so fall. In most cases, if such cultch be examined, it will be found that nearly or quite the entire set of spat is upon the convex or lower side. As the shell falls its greatest convexity rests upon the bottom, its edge being held clear of the mud in the form of a projecting ledge, sheltered on its under side from the suffocating sediment deposited upon the upper surface. In ordinary situations perfectly flat pieces of tile, shale, etc., would be vastly inferior to shells, for the lower surface would lie close to the bottom while the upper would become covered with a muddy deposit from the water, between the two the young oyster having but scant opportunity for fixation.

It has been observed that when shells and gravel are spread upon the same beds the former usually catch the larger amount of spat, especially in years in which there is but a moderate set. The planters and oystermen attribute this to the fact that the shells project a greater distance above the bottom and that therefore the fry come into contact with them first in their descent for attachment, but as the set is mainly upon the convex side of the shell and therefore *underneath*, it will be seen that the true explanation of the superiority of the shells is that given above.

The quantity of shells sowed upon any given bottom will depend upon the judgment of the planter, the general rule being to sow more on soft than upon hard bottom, for the reasons before stated. The usual quantity appears to be from 250 to 500 bushels of shells per acre, most of the planters using about 400 bushels per acre, except upon very muddy bottom; but in Long Island Sound there is an increasing tendency to use greater quantities.

In some places the shells may be obtained for the cost of transportation. This was the general rule years ago, but with the increase in planting a charge of from 2 to 5 cents per bushel is now made for them. Many planters who operate canneries or ship "shucked" oysters have ready at hand an abundant supply of shells for use as cultch. The cost of spreading ranges from ½ to 2 or 3 cents per bushel, according to the location of the beds and the cost of labor, etc.

The principal objection to the use of oyster shells is that they are of such large size that many more spat attach themselves than have room to grow and, at the same time, they are so strong and massive that it is difficult to break them in pieces so as to allow for the expansion of the young. As a consequence many young oysters which have successfully passed through the early stages of their fixed conditions are smothered or overgrown by their more vigorous fellows, which are themselves distorted by the crowding to which they are subjected. Many are thus wasted which would, under better conditions of attachment, have grown to a marketable size. (Plate IX.)

For the reasons mentioned scallop, "jingle," and other fragile and friable shells (plate XVIII, figs. 1 to 6) are, when they can be obtained in quantities, to be preferred. Such shells will break up under the mutual pressure exerted by the oysters during their growth and the latter will then be liberated from the bunches and will tend to grow into shapely and desirable forms, with a smaller rate of mortality. When the currents or waves are very strong such frail shells as jingles may prove too slight to withstand their action and the planter using them may find, to his surprise, that much of his cultch has been carried away. Upon some portions of the Pacific coast it is said that the wave action and the currents are so strong that the light, thin shells of the native oyster are swept away or thrown upon the shore. Otherwise, and for the reasons before stated, these shells appear to be well adapted to the process of sowing and they can also be obtained cheaply and in large quantities.

Other methods of using shells.—It has been recommended or suggested that shells of various kinds could be strung upon wires, etc., and suspended in festoons from stakes planted in the bottom. This would, of course, prevent their submergence in places where the mud was very soft, but as each shell would have to be separately handled it will be found that this method is too expensive to be warranted by the present condition of the oyster business. Another method of utilizing oyster shells as cultch is treated of in connection with the subject of pond culture (pp. 322–330).

Gravel and pebbles.—This is a form of cultch which is much favored by the planters in some parts of Long Island Sound, its principal advantages being the small size of its constituent particles and its cleanliness. As a rule the pebbles are so small that but few spat fix themselves to each (plate XVIII, fig. 7) and, consequently, there is little or no danger of crowding. Not only do a larger proportion of the young oysters survive their infancy, but they develop into deeper, more regular shapes, are free from bunches, and, consequently, bring a higher price in the markets. Where the trade in "shell stock" is large the shape of the oysters is a consideration of importance, but where only shucked oysters are shipped irregularities in shape are less undesirable. The gravel is more cleanly than shells, because it is not attacked by the boring sponge, which gives rise to much of the debris found upon the oyster-beds. There is also less liability to the introduction of oyster enemies than when shells are utilized.

The bottom used for obtaining a "pebble set" must be firmer than that which will suffice for the sowing of shells, the gravel being heavier in proportion to its surface and therefore more liable to sink. It also presents less surface on muddy bottoms, where the pebbles will soon become buried to their equators, and if there is any sedimentation there is left no surface available for the attachment of the fry. Rounded, water-worn pebbles are usually preferred, such offering more surface free from sediment than flat stones. They afford, perhaps, the best form of cultch for use upon firm bottoms, when there is sufficient current to prevent the rapid deposit of sediment. It is observed that gravel beaches, when these conditions obtain, are often the most valuable of natural spatting-grounds. In some places gravelly material dredged from harbors and channels during the improvement of waterways is used to advantage. Crushed stone, averaging about the size of a walnut, is also an excellent collector. Gravel or crushed stone is generally more expensive than shells, costing from 5 to 7 cents per bushel. The custom is to sow from 25 to 30 cubic yards (from 500 to 600 bushels) per acre when used alone, but a smaller quantity if shells are also used.

Scrap tin, tin cans, etc.—In some places old tin cans and scrap tin of various kinds is found to give good results when used as cultch. It has the advantage of becoming corroded and gradually dissolving in the salt water, thus releasing the young oysters before they begin to crowd one another and allowing them to grow into well-shaped adults. Moreover, as the cultch each year disappears in solution, there is no debris from this source to litter the ground and to cause the expense of culling. It seems that, in the form of old tin cans, this type of cultch might have some advantage on muddy bottom where there is a rather rapid sedimentation. Such cultch is light in proportion to the surface presented, it would not readily sink, and the upper half of the interior, and to some extent the lower half of the exterior would present surfaces protected from sedimentation upon which the young oyster could lodge itself. By the time the can disintegrated the oysters would no doubt be sufficiently grown to withstand the action of the mud. The tin is distributed over the bottom as in the case of shells and gravel.

Brush for soft bottom.—Where the bottom is so soft that ordinary methods can not be used, it will sometimes be found that fagots and brush make most efficient collectors. The brush is thrust firmly down into the mud in such a manner that the small branches are at some distance above the bottom. They will offer a large surface to the water, a slight current will tend to keep them free from destructive deposits of sediment, and in water well charged with the swimming fry will almost certainly yield a full set of spat. The brush is lifted at the proper time by means of a crane or boom and windlass. This method was used with some success at the town of Groton, Conn. The seed was left to grow to a marketable size on the brush, but owing to the liability of the large oyster to drop off into the soft mud below, it was sold as soon as possible.

Brush, straw, etc., may also be used by collecting the material into bundles, sheaves, or fagots, which may be anchored by stones or suspended from stakes. As it is usually unnecessary to resort to such very soft bottom, it will be found in most cases that shells, gravel, or scrap tin will be more serviceable and satisfactory. Brush collectors would be difficult to use in regions of violent wave action.

Other collectors.—Many materials have been suggested as suitable for collectors, but the foregoing appear to be the only ones which have proven practical on a large scale in our waters. Tiles and roofing slates arranged in various forms have been found satisfactory by European culturists, but are apparently not adapted to use here where labor is high and oysters are cheap. These collectors will be discussed in another connection. Pieces of bricks, broken pottery, and similar materials may suggest themselves to the planter as local substitutes for shells and gravel. Hard-wood chips and bark might prove useful, but are hardly to be recommended.

COATING CULTCH.

To overcome the difficulty, which has been mentioned, of the set upon collectors being so dense as to interfere with its subsequent growth, it has been proposed to coat the cultch with some material which will flake off, either under the mutual pressure exerted between the growing oysters, or when it is scraped with a suitable instrument. This device was apparently first used in France, where it was adopted to avoid the theretofore necessary breakage of the tile collectors. The coating is detached from the tiles with a chisel-shaped instrument, somewhat resembling a putty knife.

Apparently this method has never been used in our waters, but where it is necessary to use oyster shells for cultch it might perhaps be applied to advantage. In this case the fry could not be economically detached by hand, but there is little doubt that the growing oysters would automatically liberate themselves. The coating used in France consists of a mixture of sea water, lime, and sand, or hydraulic cement, "stirred to the consistency of thick cream." Various formulæ are used by different culturists, three of them being as follows:

1. One part quicklime, 3 parts fine sand.
2. One part quicklime, 1 part fine gray mud.
3. First a light coating of quicklime, and, after drying, a coat of hydraulic cement.

The coating should be such as not to readily wash off, yet sufficiently brittle to flake under the mutual pressure exerted between the growing oysters, and about $\frac{1}{25}$-inch in thickness.

For convenience in coating, Dr. Ryder recommended that the shells be placed in a wire basket and dipped into the cement vat, the mixture being then allowed to set before the shells are used.

GENERAL CONSIDERATIONS ON SPAT-COLLECTING.

Whatever may be the character of the cultch, it should invariably be clean and without any surface deposits which might tend to prevent the fixation of the spat. For the same reason the cultch should not be placed upon the beds long before the season for setting.

In almost any body of water, except where the currents are swift, there is more or less sedimentation, and it is obvious that the shorter the time that a body is exposed to such action the thinner must be the deposit. If the cultch is placed in the water long before it is needed the deposit of sediment is often so thick as to stifle the young oyster, but on the other hand if the time be well chosen a practically clean surface is presented and a good set is more likely to reward the planter. The latter's aim should, therefore, be to determine as nearly as possible the time when the maximum amount of spawn falls, and to so regulate his operations that his cultch is laid down but a few days before. The time will vary somewhat with the locality, and if there is no local experience to guide the beginner he may be compelled to experiment a little to find the most favorable time for exposing his collectors. It should be remembered that while the spawning season in any given locality extends over a number of months, the majority of the oysters spawn within a more circumscribed period, usually about midway between the two extremes.

If the time at which the collectors are exposed be well chosen, and the location of the beds properly selected, the planter may or may not obtain a good set. Sometimes one bed will show a strong set, while its neighbor appears to have been entirely passed over by the fry. Often the cultch in one part of the bed is thickly incrusted with spat, while another portion, apparently equally well located and upon which an equal amount of care has been expended, will prove utterly sterile. While in many such cases the causes are not known, yet the experience of planting has thrown some light upon the matter. It is known that cultch can not be thrown down at random with any strong expectation of success. The water is not everywhere charged with the swimming fry, and the experience of planters has shown that they are often distributed in streaks or belts, which appear, to some extent, at least, to be conditioned by the currents. If cultch be placed in a current it will, other things being equal, be more likely to catch a set than when in still water. Even a strong current does not appear to interfere with the fixation of the young, and as it brings a greater body of water into contact with the collecting surface, some of it is more likely to contain fry at the stage for fixation.

It is also obvious that the water is not likely to contain many fry unless there are spawning oysters in the vicinity, and it is, therefore, the part of wisdom to locate the collectors in the vicinity of natural or artificial beds containing mature oysters. Even where the oysters are so scattered as to hardly pay for working, it will be usually found that there is sufficient spawn fertilized to provide considerable seed if it be given proper facilities for attachment. For reasons readily seen, it will be advantageous to locate the collectors so that the predominating current sweeps from the spawning oysters toward the collectors. In some localities it will be found that the entire set occurs in the tidal zone; that is, in the area between low and high water. The reason for this is not yet fully understood, but if it should prove to be because the embryo oyster is lighter than the dense sea water, and therefore can not sink to the bottom, or because the sedimentation is too rapid below low-water mark, or almost any other reason except the softness of the bottom, then the cultch must be confined to the area between tides if it is to be effectual as a collector of spat. The most careful and uniformly successful oyster-culturists do not depend entirely upon the spawn derived from neighboring beds, but usually distribute over the spatting-beds a number of mature spawning oysters in the proportion of 30 to 60 bushels per acre, these being usually put down before the cultch, so that the oysters will become to some extent acclimated before the spawning season.

As the cultivated area increases it becomes unnecessary to use so many brood oysters, and in some places where they were formerly used reliance is now placed solely upon the floating fry derived from the mature oysters on neighboring beds. Upon theoretical grounds it would appear to be preferable not to scatter these "mother oysters" too widely. There would seem to be greater certainty of fertilization when the oysters are grouped, and there are ample time and superior facilities for securing distribution over the beds in the embryonic condition. The embryo exists for a period as a free-swimming form, and during that time it may be carried considerable distances by its own exertions and by the action of the currents. On the other hand, the eggs, and especially the spermatozoa, will probably die unless they fulfill their destiny within a much shorter period, and the sooner they are brought into contact with one another the better, and the smaller the bulk of water through which they are at first distributed the larger the number which will accomplish successful union.

Upon these considerations is based the advice not to scatter the "mother oysters" too widely. Fifty bushels of oysters, 250 to the bushel, scattered evenly over an acre would allow one oyster in every 22½ linear inches in each direction, plenty near enough if they were to all spawn at one time, but it must be remembered that the proportion ripe at any one time is not so large, and there is a possibility of all of the oysters over a considerable space being of one sex.

The "mother oysters" used for this purpose are preferably obtained from the neighborhood of the planting-ground. It has been remarked in another connection that transplanting mature oysters, especially from a warmer to a colder region, may have the effect of checking the development of the genital products, and Dr. Ryder has commented upon the fact that the spermatozoa of ripe oysters are killed by being changed to much denser or warmer water than that in which they have been living. The endeavor should be, therefore, to study the conditions on the planting-grounds, and to procure the spawners from beds as nearly as possible similar in the conditions of temperature and density. Where this consideration can not be closely followed, as for instance in the shipment of eastern oysters to places on the Pacific Coast, the brood oysters should be sent during the fall preceding the season at which the cultch is to be put down. They will then be pretty well disgorged of their ripe genital products and the time intervening before the next period of sexual activity will probably be sufficient to acclimatize them.

WORKING THE BEDS.

Many planters are content to allow their beds to remain unworked until they are ready to market their crop, whether this be one, two, three, or more years. In some instances this may be satisfactory, but often, and perhaps usually, it is better to go over the beds with tongs or dredges, cleaning up the debris and separating the oyster clusters or even in some cases removing the seed to localities in which the conditions are more favorable for rapid growth, for in many cases the best spatting-grounds are not the most favorable for subsequent growth.

The stage at which the planter will find it most profitable to sell his oysters will depend much upon circumstances. Sometimes the set of spat will be greater than could be advantageously grown upon the area covered and some of it could be manifestly removed to advantage. Some planters find it more profitable to sell their oysters as seed, thus receiving quicker returns for their investment and also lessening the possibility of losses due to the appearance of enemies or the advent of untoward conditions. In many cases it will pay the planters to specialize, some raising seed for sale to others who devote their capital and enterprise to the work of raising the oysters to a marketable size.

Even if the oysters are to be left upon the spatting-bed, it is often better to work over the ground during the first year, removing the debris and breaking up the clusters of young oysters, so as to insure a greater survival and superior shape. As has been already mentioned in treating of the planting of seed, it is often advisable to shift the oysters to other ground during the last few months before marketing in order to fatten them, improve the flavor, and cause the gradual disgorgement of mud from the intestine and mantle chamber.

A keen watch should be kept at all times to detect the presence of enemies, some of which may be with more or less success combated by the methods mentioned on pp. 313-319. The spatting-beds are especially subject to the attacks of various enemies which find in the vast numbers of thin-shelled young an abundant and readily obtained food supply. The starfish, especially, at times appear in vast schools or swarms, and often a bed is almost completely destroyed before the planter is aware of what is taking place.

PROTECTION FROM ENEMIES.

In the case of most of the enemies of the oyster it is impossible to indicate efficient means of protecting the beds from their inroads. The impossibility of knowing at all times the exact conditions prevailing upon the bottom, the suddenness with which many of the enemies appear upon the beds, and the insidious character of their attacks all add to the difficulty which the planter finds in preventing the destruction of his property.

PROTECTION FROM FISH.

It is possible to protect oysters in shallow water from the attacks of fishes by surrounding the beds with palisades of stakes driven into the bottom at sufficiently close intervals to prevent the passage of fish between. Upon the Atlantic coast the inroads of fish are not sufficiently formidable to require such protection, although the drumfish causes some loss to planters in the vicinity of New York. Upon the Pacific coast, however, and especially in San Francisco Bay, stockades are necessary to prevent the absolute destruction of the planted beds by the stingray, the stakes being driven at intervals of about 4 inches. It is necessary to keep the inclosure in good repair, as a school of rays entering through a small breach may utterly ruin the bed.

PROTECTION FROM STARFISH.

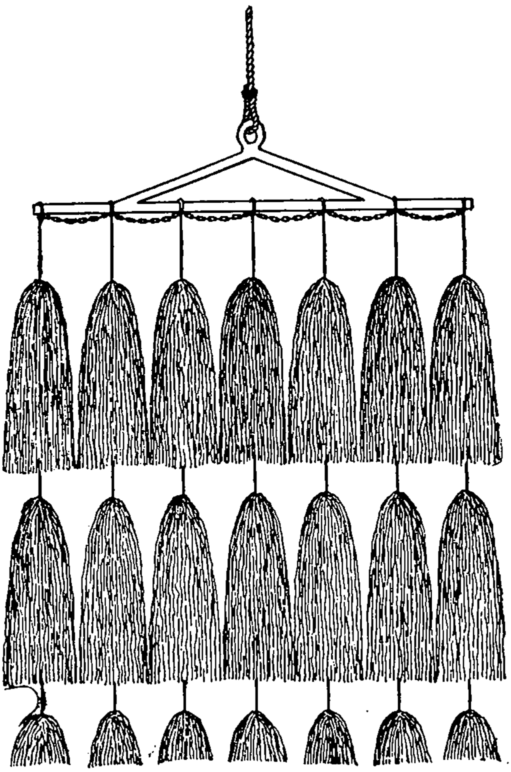
Many methods have been suggested for combating this destructive enemy of the oyster, most of them being of no practical utility. Barriers are utterly useless, for the very small starfish are among the most destructive and the largest ones are able to pass through an orifice of such small dimensions that it is impracticable, for manifest reasons, to build a barrier so close in structure as to exclude them. Some attempt has been made to catch them in traps, made of laths and baited with fish, crab meat, clams, etc. These traps are constructed and tended like lobster pots, and while it has been found that the starfish can be taken through their agency, the method is too laborious and inefficient to be used for the protection of extensive beds. Various devices for catching starfish have been patented from time to time, but none of them appear to have been of practical value.

Upon the theory that the starfish prefers the mussel to the oyster as food, it has been proposed to surround the oyster-beds with a growth of mussels with the expectation that the starfish will not pass over the mussel bed to obtain the less desired oysters. Investigations in Long Island Sound show that this expectation is not realized in practice, and, moreover, in favorable locations, the growth of mussels is so rank that they themselves become a menace to the planter by overgrowing his beds and suffocating the oysters. This method of protection is also wrong in principle, for by supplying the starfish with additional food we better its conditions and thereby aid in increasing its numbers.

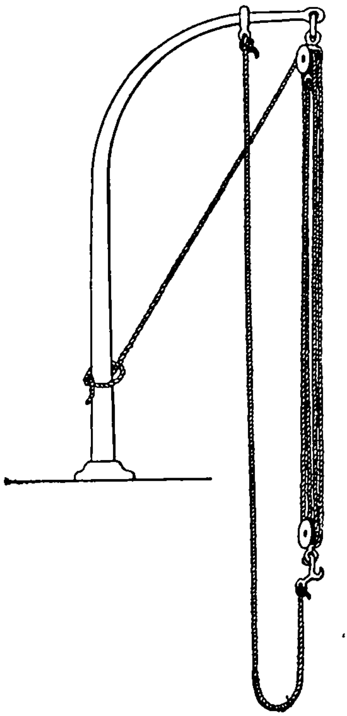
For catching starfish some planters use the ordinary oyster-dredge, an implement which has some advantages when it is desired to cull the stock, but, in general, it involves unnecessary labor and also crushes and kills many young oysters. A lighter dredge of similar construction is also used, and on the shallow beds tongs may be sometimes employed to advantage.

The oyster-growers of Long Island Sound, who have had more experience in fighting starfish than those of any other section, find that eternal vigilance is the price which they must pay for even the comparative safety of their beds. The beds are closely watched and worked over with dredges and tangles. Tugs are kept more or less constantly at work, and all starfishes taken, either in the ordinary work of oyster dredging or during "starring," are carefully destroyed. Thousands of bushels are caught during the year and much money is expended in the work, the result being that many beds, through timely and unceasing attention, are saved from utter destruction. The tangles or mops employed are an adaptation of a device long used by naturalists for collecting spiny forms from the sea bottom, and their use in fighting the starfish was first suggested by the United States Fish Commission. They consist essentially of an iron bar to which small chains or wires are attached at intervals of about a foot, mops or bundles of rope yarn, cotton waste, or similar material being distributed at short distances along the chains. The bar is fastened to the ordinary dredge line or chain and is dragged over the bottom, being hauled in at frequent intervals for the removal of the starfish which have become entangled. Most of the tangles used in Long Island Sound have frames weighing from 100 to 150 pounds, and to prevent this heavy mass of metal from crushing small and thin-shelled oysters they are provided with a hoop, 12 or 14 inches in diameter, at or near each end of the bar. These hoops ride over the bottom like runners and the crushing surface is thus much reduced. The general construction of these tangles is shown in cut 2. The weight appears to be unnecessarily great, all that is actually required being that which is sufficient to hold the tangles upon the bottom when in motion, a condition which is largely insured by the sagging of the chain used in towing.

A vessel-owner at New Haven, Capt. Thomas Thomas, who has been very successful in "starring," uses a much lighter tangle constructed as follows: To a half-inch chain, about 8 feet long, stout wires 12



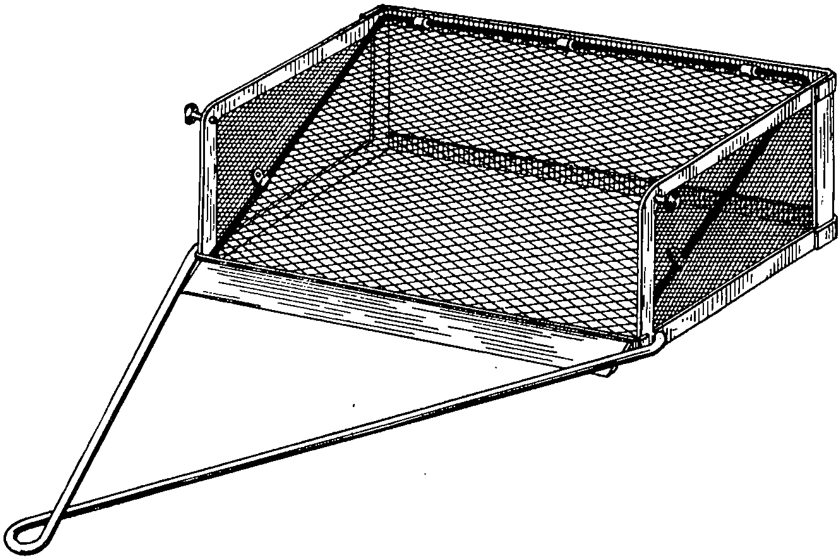
CUT 2.—Tangle.



CUT 3.—Tackle.

or 14 feet long are attached at regular intervals, and to these wires are fastened mops or swabs of cotton waste. The chain is securely lashed to a bar about 7 feet long by 1½ inches wide and half an inch thick, provided with a bracket and eye for the attachment of the drag chain, as shown in cut 2.

When in use this tangle covers an area about 7 feet wide and 12 feet long, forming a dense mat of snarled cotton threads. One of these is towed on each side of the vessel, like a dredge, and, sweeping over the bottom, entangles the starfish with which it comes into contact. The length of time during which the mops are towed depends upon the abundance of the stars, being greater when they are few than when they are plenty. The starfish are killed by being momentarily immersed in a tank of boiling water, the bath being heated by a steam tap connected with the boiler. The tanks are about 7 feet long by about 18 inches wide and deep, and are located one on each side of the main deck, just inboard of the roller over which the tangle chain runs. To facilitate the immersion and handling of the tangles, a davit, with block and fall, is rigged on the hurricane deck over the tank, as shown in cut 3. A lanyard is rove through an eye welded to the back of the hook on the fall and the other end is fastened to the davit, its length being so adjusted that the hook is automatically tripped by the weight of the tangle when the hauling part of the tackle is eased and the mops lowered to near the surface of the water.



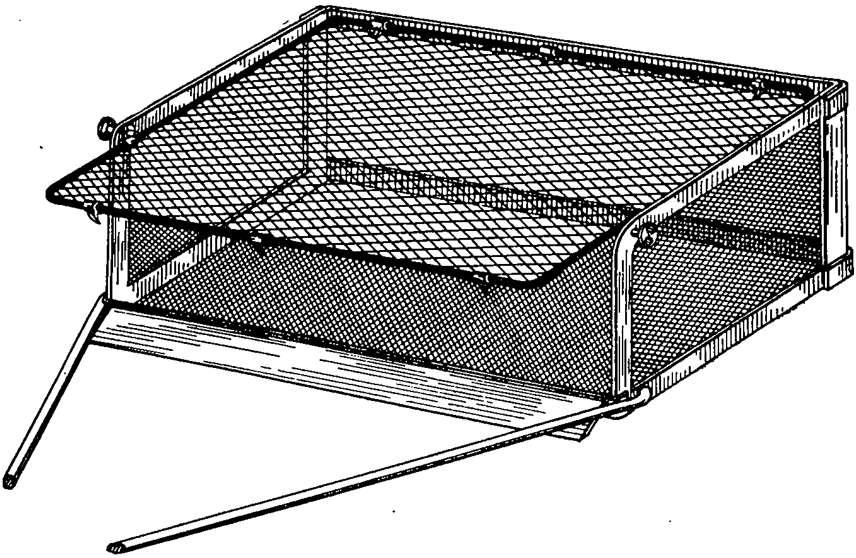
CUT 4.—Drill-dredge in position for work.

Some of the oystermen pick the starfish out by hand, but this is a slow and laborious process and, moreover, it is almost an impossibility to so remove all of the small ones. By using the arrangement just described the labor is lightened and the killing of the stars assured. By using a tangle on each side of the vessel one is always at work while the other is being hoisted. It is stated that upward of 100,000 starfish have been caught in a single day by a boat using the apparatus described. It is usual to work on the beds until not over half a bushel of starfish can be caught in a day, the beds then being considered safe, although at any time a host may arrive from a neighboring bed.

United effort on the part of the planters is necessary for success in fighting starfish. A neglected bed is, in a measure, a menace to others in the vicinity; for if starfish are left to multiply without hindrance they will move to neighboring beds as soon as they have exhausted the supply of food upon the first.

PROTECTION FROM DRILLS.

No method of proved efficiency has yet been devised for protecting oyster-beds from the inroads of the drill, but by systematic attention something could, no doubt, be done to lessen its destructive effects. In culling the oysters brought up in the dredge or tongs care should be exercised to destroy the drills. Most of them, however, will pass through the intervals of the ordinary oyster-dredge, and to obviate this a finer bag might be used within the dredge. This could be used especially in cleaning up the beds preparatory to planting. It should be remembered, in this connection, that it is possible to infect new grounds with the drill by its transportation thereto with the seed. The deep-water beds of Long Island Sound have of recent years suffered more and more from this pest, and it is supposed that this is accounted



CUT 5.—Drill-dredge open for emptying.

for by the use of seed from the drill-infested beds in the less saline inshore waters. The use of tangles for catching starfish also, no doubt, aids in the distribution of the drills by dragging them from place to place.

The most promising method which has yet been proposed for catching this enemy is the invention of Capt. Thomas Thomas, of New Haven, Conn., who has applied for letters patent thereon. It consists of a rectangular frame of iron bars about 4 feet long, 2 feet wide, and 18 or 20 inches deep. The bottom, ends, and rear are covered with an iron wire screen, having a mesh of about half an inch, the top and front being left open. To the upper rear edge of the frame is hinged a stout wire screen of about 1-inch mesh, its length being such that it may fall between the ends and its breadth being equal to the diagonal of the end pieces when in place; therefore it extends from the lower front edge to the upper rear edge of the frame. Attached to the lower front bar is a broad blade of iron or steel, inclined somewhat downward and forward from the plane of the bottom of the box. The whole is attached to a dredge frame, to which the chain used in dragging is made fast. (See cuts 4 and 5.)

When this appliance is dragged over the bottom the oysters and other inhabitants of the beds, together with shells and debris of all kinds, are lifted from their resting-places by the blade and deposited upon the inclined screen or apron. The motion of the trap and the pressure exerted by the accumulating material in front gradually pass the mass backward across the screen, the smaller particles, drills, etc., sifting into the box, while the oysters, being too large to pass through, finally fall over the edge behind.

By this means the varied material on the beds undergoes a process of screening, the oysters being automatically returned to the bottom, while a large part of the debris is held and brought to the surface. That the device will accomplish this has been demonstrated, but whether the drill can be successfully fought by this means has still to be shown, although the prospects are favorable.

PROTECTION FROM WINKLES.

The conchs or winkles have never been a serious menace to our oyster-beds. Their small numbers and large size and the large size of their egg cases make it possible to successfully fight them by destroying all winkles and egg cases brought up in the process of dredging or tonging.

PROTECTION FROM SPONGES, HYDROIDS, MUSSELS, ETC.

The growth of sponges, hydroids, etc., when so rank as to threaten the welfare of the oysters, may be kept down by working over the beds with the oyster dredge and culling out the debris. A thorough cleaning up of the ground before planting and the use of clean seed and cultch go far toward the prevention of trouble from this source.

PROTECTION FROM STRONG VEGETABLE GROWTHS.

In places where eelgrass (*Zostera*), etc., grow so rapidly as to cause stagnation of the water and suffocation of the oysters some means must be adopted for its removal. Sometimes it may be removed with an ordinary scythe at low water. A grower in New Jersey has invented for this purpose what has been termed an "aquatic mowing machine."

It is described as follows:

Eelgrass grows abundantly in some parts of the Navesink River and, as in other localities where it is found, acquires in due time full possession of the areas where it grows, rendering them useless for oyster-culture. In combating this enemy of the oyster-planting industry, Mr. Charles T. Allen, of the firm of Snyder & Allen, Oceanic, N. J., has achieved a degree of success heretofore unequaled. After expending much fruitless labor in efforts to mow the eelgrass with a scythe, a method which proved impracticable because the water was sometimes too deep and also on account of the difficulty of cutting grass growing under water, he invented in 1885 and has since used a device which may be termed an aquatic mowing machine. The machine is rigged on a square-ended scow 20 feet long by 8 feet wide. On the forward end of the scow is suspended, by a framework, a double set of knives, each set being similar to those of mowing machines used by agriculturists. The object in having double knives is to enable the machine to cut when moving backward as well as when moving forward, thus avoiding the necessity of having to turn the scow around when the end of the swath is reached. The knife bar is 12 feet long and consequently cuts a swath 12 feet wide. The power of propelling the machine is supplied by a 6-horsepower high-pressure condensing engine, which is located in the middle of the scow. A line 1,000 feet in length is passed with three turns around a winch head and drawn taut by an anchor at each end, placed a short distance beyond the extreme boundaries of the area to be mowed. It is held in position by a fair-leader or chock having a shive on each side similar to the shive of an ordinary tackle block. The shives facilitate the passage of the line through the leader by lessening the friction and correspondingly decrease the wear upon it. The leader or chock is placed on the forward end of the scow, and not only serves to hold the line in position, but also keeps the scow straight in its course.

When the engine is started, the winch-head revolves, and the pressure of the line, encircling it in three turns tightly drawn, forces the scow through the water. The rate of speed at which it can be operated is 1,000 linear feet in 5 minutes, thus enabling it to mow an area of 2,000 square feet or more per minute, or 1 acre in from 20 to 22 minutes, making allowance for time spent in moving anchors or otherwise adjusting the machinery.

When fitted for work, with coal and water, and manned with three men, including an engineer, which is the number requisite to operate the machinery and attend to shifting the anchors, the draft of the scow is about 8 inches of water. When the anchors have once been adjusted, several swaths can be mowed before they require to be shifted over toward the uncut grass, as the line can not easily be drawn so taut—nor does it need to be—as not to allow the scow to be moved (pushed with a pole) sidewise for a short distance. When necessary, the anchors are shifted by the use of a small boat. Thus the scow is guided back and forth across the lot, cutting the grass with equal facility in both the forward and backward movements. When the grass is cut, it floats to the surface of the water and is carried away by the current. The knives are set in motion by a vertical iron shaft which passes through a horizontal cogged wheel. This wheel is geared to a pulley which is run by a belt from the engine. The vertical shaft is so arranged as to slip up or down in order to gauge the machine to any depth of water within the range of its capacity. The extreme depth of water in which mowing can be successfully done, as it is now adjusted, is about 8 feet. It could doubtless be so arranged as to operate in deeper water.

If there are no obstacles in the way, the grass can be cut within 1 inch of the bottom. If there are oysters on the ground, some allowance for that fact has to be made, and while the grass can not be sheared so close to the bottom, it can be mowed sufficiently close to the oysters to answer all practical purposes. The only thing requisite is to mow it short enough to preclude the possibility of any large quantity of sediment settling in it and choking the oysters. This object is easily attained, as grass a few inches long will not injure the oyster crop. It is when its length is measured by feet and it is filled with sediment that it becomes dangerous.

In the locality where this machine is used the water is about 6 feet deep. It has been customary to mow the oyster-beds quite frequently, five or six times, perhaps, during the growing season, from the first of May to the last of October. The result has been that tracts of bottom that would have otherwise been worthless for oyster-growing purposes have been converted into beds as productive as any in the river. The cost of building a similar machine is estimated by Mr. Allen to be from $450 to $500.*

* Hall, Ansley, Rept. U. S. Fish Commission 1892, pp. 477 and 478.

INCREASE ON PLANTED BEDS.

The percentage of seed oysters which reach maturity depends upon local and seasonal conditions, upon the care with which the oysters have been planted and worked, the size of the oysters when planted, and the length of time which they have been left to lie. Under the very best conditions there is a considerable mortality among the plants, and while the individual oysters have increased greatly in size the loss from one cause or another is such that there is by no means a corresponding increase in the total quantity as measured in bushels. In some places the planter is satisfied if he can market a bushel for each bushel planted, depending for his profit upon the increased price brought by the larger growth, but the usual average yield in many localities is two or three times this amount, and cases are known where 500 bushels of shells yielded 3,000 bushels of salable oysters.

GROWING OYSTERS IN PONDS.

In Europe pond culture has been commercially successful for many years, and in some countries practically the entire product of oysters has been derived from this source. Small inclosed ponds, *claires*, have been used in France for greening and flavoring the oysters and parks or partially inclosed ponds, admitting the tides, are used for growing the oysters from seed, but all experiments heretofore made with a view of raising the seed in closed ponds have been attended with failure or scanty success.

Over a large area of our oyster-producing territory the difficulty of obtaining seed is usually not a pressing one and an utter failure to secure a set is rarely confronted upon more than occasional years. Under such conditions, in several regions, the practice of sowing shells has grown to great proportions, but with the vast increase in the planted area an increasing difficulty has arisen in preparing the oysters for market. Growth is slower than formerly, and during some seasons the oysters either do not fatten at all or else so slowly that months are wasted before they can be brought into proper condition. It is significant that complaints of this difficulty come from regions which were at one time famous for the fatness and flavor of their product and that the trouble was not manifested until the population of the beds far outgrew that which was found in their natural condition. The causes leading to the difficulty complained of have never been studied, but the explanation will probably be found in the fact that the quantity of oysters in such regions has outgrown the ability of the waters to supply them with food.

As is elsewhere pointed out, the rate of the growth depends primarily upon the relative richness of the food supply, and a quantity which may be sufficient to cause a moderate growth may still be inadequate to produce the degree of fatness upon which the oyster's toothsomeness so largely depends.

It is manifestly impossible to propose efficient means for increasing the abundance of the food organisms over any very extended area of open waters, where ownership is vested in the many and the conditions are not subject to control. Only in inclosed or semi-inclosed bodies of water could there be any hope of such regulation of temperature, density, and other factors as to conform to the best conditions for the rapid multiplication of such organisms as constitute the preponderance of the oyster's food. If it were possible for the planter to have at his command a body of water extremely rich in food he could, in a short time and at will, fatten oysters which had grown to a marketable size upon other and less favorably situated beds. It is probable that under intelligent direction a comparatively small area could be made to serve as a fattening bed for all of the oysters produced on a great area of ordinary shelled ground, and that the cost of preparing and maintaining the rich food-producing beds would be returned many-fold in the ready sale and high price which the superior product would be able to command. In many places in the United States this plan is followed with success by transplanting the oysters from offshore beds to harbors and coves, but so far as known no practical and conclusive test of culture in artificially prepared ponds has been made, and it is therefore not possible to give full and practical directions concerning the method to be followed in attempting it.

The European methods are generally not economically adapted to use in our waters, but the experience of French culturists has established certain principles which are of general application, and may serve as a guide to those working upon somewhat similar lines here.

There are many localities within the limits of the oyster-producing region of the United States where pond culture for the purpose of growing and fattening oysters would probably prove successful, and salt ponds, connected with tide water by natural or artificial channels, could often be made to return a good dividend to their owners if converted to the uses of oyster-culture. In other cases low and swampy land might be dredged or excavated so as to answer the purpose, and thus be made to return a revenue in perhaps the only possible manner. Such ponds should be well protected by embankments sufficient to prevent the entrance of water except when desired, the supply being regulated by flood-gates which can be opened or closed at will, or the height of the embankments may be so adjusted that the water from the sea will enter during very high tides only, say once or twice a month. When the ponds are large it has been found that the surface aeration is sufficient to supply the oxygen required, but in smaller ponds it is necessary to attain this end by more or less frequent interchanges of water between the pond and the main body of salt water with which it is connected. In the case of practically inclosed ponds it is necessary to provide for the addition of fresh water to make good the loss occasioned by evaporation. If this precaution be neglected the density of the water will rise above the maximum in which the oyster flourishes.

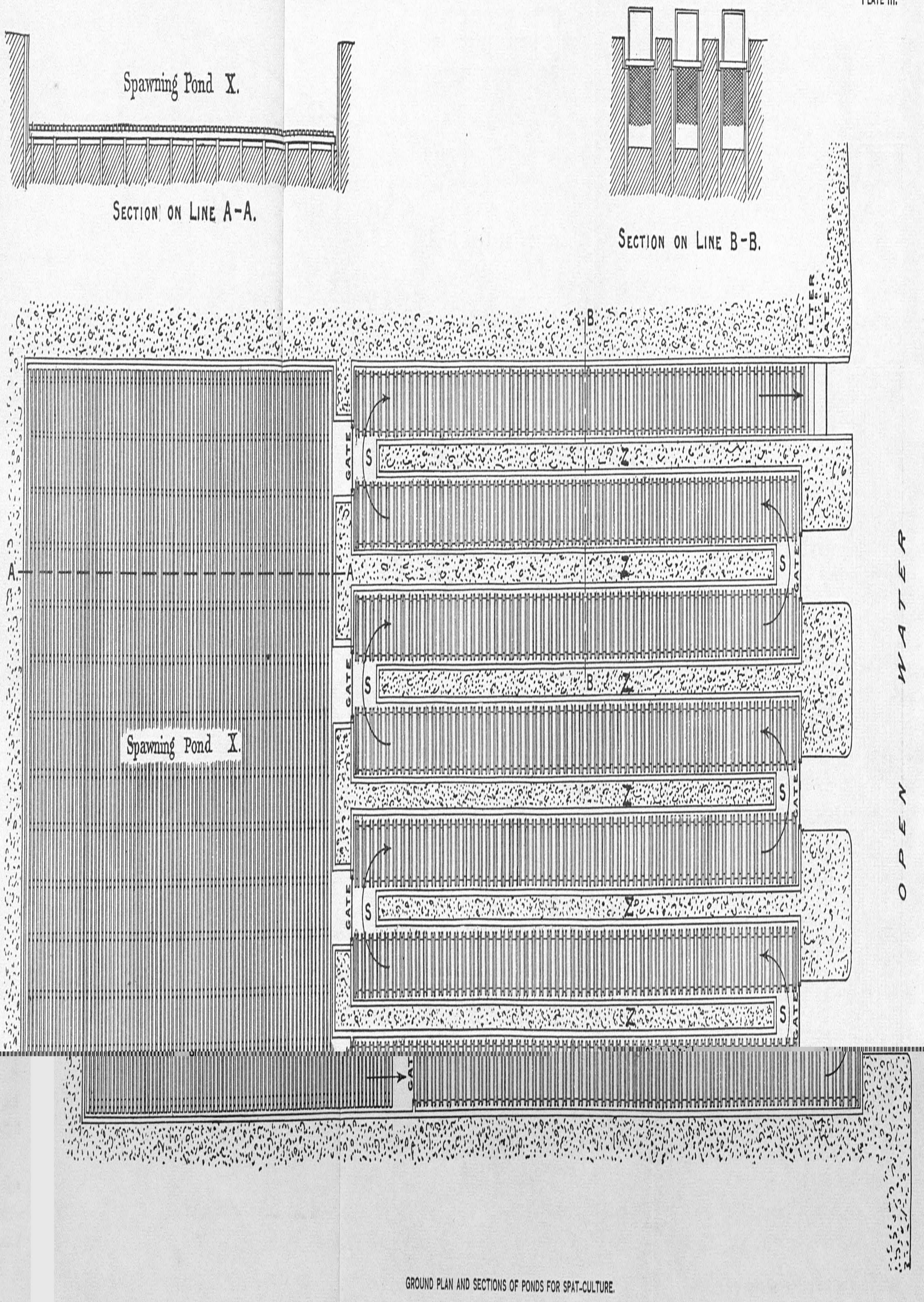
It may be advisable in some places to reduce the density in the ponds below that of the open waters, as it is well known that the more brackish waters are generally most favorable to the rapid multiplication of diatoms and other minute vegetable forms valuable to the oyster-grower. Experiment could be made to demonstrate approximately the best density for the purpose, and where the water supply is under control the pond could be maintained at nearly or quite the degree of salinity required. The ordinary surface drainage into many natural salt ponds is sufficient to reduce the density below the level in the main waters, and by merely regulating the inflow of sea water the grower will probably find that almost any degree of brackishness may be maintained at will. Such ponds will be found to possess all the requirements for the production of food in abundance, the density will be favorable, their shallowness will cause them to warm early in the season, and thus stimulate the growth of microscopic vegetation, and their immunity from the influences of tides will prevent the carrying away of the food which they produce.

There are, of course, many places where the natural conditions for the production of oyster food are all that could be desired, and there pond culture would doubtless be unnecessary, but in other localities, such as are mentioned at the beginning of this section, it seems to offer the most promising field for experiment.

BREEDING OYSTERS IN PONDS.

While in some of our most important planting regions there is rarely any difficulty in obtaining seed oysters, there are places, otherwise admirably adapted to the industry, in which the supply of seed is extremely precarious. The most remarkable fluctuations in the set of spat take place, and often where there is one year an abundance the following season may exhibit a dearth. In certain localities on Long Island a set of spat rarely occurs, and the planters long ago abandoned the attempt to raise seed and now procure it from some other region more favored in that respect. In still other places, as over the larger part of Chesapeake Bay, the seed oysters are obtained mainly from the natural beds, but with the depletion of these there will be an increasing difficulty in obtaining it, and before long it will no doubt be necessary to derive it from some other source. There is an increasing tendency in the region last mentioned to follow more closely the method of sowing shells practiced in Connecticut; in some places the experiment has met with great success so far as the procuring of a set is concerned, but in other localities the results are too uncertain to permit it to be followed with profit.

Where a "strike" occurs each year with tolerable certainty this method is without doubt the best available to our oystermen, but where the spat may fail to set for several years in succession, the expense of putting down the shells without return will soon eat up the profits of



GROUND PLAN AND SECTIONS OF PONDS FOR SPAT-CULTURE.

Adapted from John A. Ryder.

more successful years, and the irregularity of his crop may cost the planter his market.

It is obvious that in order to obtain more certain results the conditions upon which the spatting depends should be subject to some control. It is useless to expect such control in any adaptation of the ordinary method of planting shells, and the only direction which promises success in such an attempt is some modification or form of pond culture. The culturists of Europe have shown that a very considerable control can be exercised over the conditions in parks used for growing oysters from seed, and with proper modifications the same success could doubtless be attained with breeding ponds for raising seed. "To actually come into competition with the system of shell sowing in deep water we must proceed to abandon all old methods, condense our cultch so as to have the greatest possible quantity over the smallest possible area, and finally have that so arranged that the currents developed by the tides, in consequence of the peculiar construction of a system of spawning ponds and canals, will keep the cultch washed clean automatically. Unless this can be done, all systems of pond or cove culture for the purpose of obtaining spat must unhesitatingly be pronounced failures."*

Impressed by these facts, Dr. Ryder, in 1885, devised a very ingenious method of spat-culture, which he described as follows:

(A) *The method as adapted to canals or sluices in which the cultch is placed in masses, with jetties at intervals.*

The first form in which I propose to inaugurate the new system of spat-culture which has grown out of the principles already developed consists, essentially, in condensing the cultch or collecting apparatus in such a way as to expose the maximum amount of collecting surface for the spat to adhere to within the least possible area. This may be achieved in the following manner: A pond, *X*, as shown in plan and elevation in plate III, is constructed with a long zigzag channel, *s*, connecting it with the open water. The pond ought to be, say, 40 to 60 feet square; the channel, *s*, may be, say, 3 feet 3 inches wide, as shown in the diagram. The vertical banks, *z*, between the zigzag canals running to the open water might be 3 feet in width. The sides of the canals ought to be nearly or quite vertical, and the earth held in place with piles and rough slabs or planks. The direct inlet to the pond at *I* might be provided with a gate, and the outlet of the canal, where the latter connects with the open water at *o*, might be provided with a filter of moderately fine galvanized wire netting and a gate; the first answering to keep out large fish and débris and the latter to close under certain circumstances, or when violent storms develop strong breakers. The accompanying plan and sectional elevation, as shown in plate III, will render the construction of such a pond and system of collecting canals clear.

Into the pond, *X*, I would put an abundance of spawning oysters, say 100 bushels, if the pond were 40 feet square, and 200 bushels if it were 60 feet square. But instead of throwing the oysters directly upon the bottom, I would suggest that a platform, of strong slats be placed over the bottom of the pond at a distance of 8 to 10 inches from the earth below, upon which the oysters should be evenly distributed. This arrangement will prevent the adult oysters from being killed by sediment, and also afford a collector, in the form of a layer of shells, to be spread

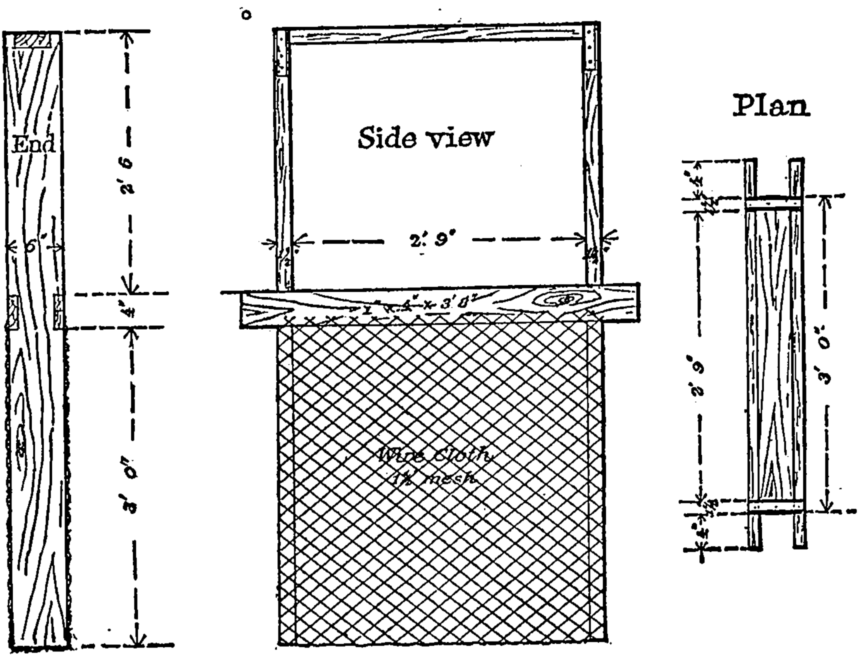
*Rept. U. S. F. C. 1885, p. 392.

over the platform, and give the fry a better chance to escape without immediately sinking into the ooze below.

The mean depth of water in the pond and canals ought not to be less than 3½ feet and the bottom of the pond and canals should be cut to the same level, with a view to get the full benefit of the tides.

The method of operating such a system will now be explained. The pond, X, is supplied with the above specified quantity of good spawning oysters, which at a low estimate ought, at the rate of 50 females per bushel, to yield from 100,000,000,000 to 200,000,000,000 of fry during the time the cultch may be in position in the canals. If, however, the oysters were very large selected ones, fully twice as much fry ought to be thrown out by them, or fully 200,000,000,000 to 400,000,000,000.

This enormous quantity of embryos must, unless it finds some objects to which to attach itself, be irrevocably lost. In order, therefore, to provide it with a nidus for



CUT 6.—Receptacle for cultch.

the purpose of fixation, an extensive system of collectors is provided in the channel, *s*. These are figured in detail above, the first being an end and the second a side view and the third a plan. These are essentially flat baskets, with wooden ends, and with the bottoms and sides formed of a very coarse kind of galvanized iron wire netting with 1 to 1½ inch mesh. At the top they are open, and on either side a strong strip or scantling is secured and projects out past the ends of the box or receptacle, to afford a means of supporting the whole upon scantling or ledges secured near the tops of the sides of the canals, *s*. These projections of the strips are also intended to afford handles by which two men may lift and move the apparatus about. The uprights at the ends and the horizontal crossbars are intended to enable the culturist to vibrate the box and its contents in the water of the canal without lifting it out, and in such a way as to wash off any injurious accumulation of sediment not swept away by the action of the jetties presently to be described.

These baskets or receptacles are open at the top and are intended to be filled with clean oyster or clam shells as cultch for the spat. They are each to hold about 3 bushels of shells, a quantity as large as can be conveniently handled by two men. One hundred of these will therefore contain 300 bushels of cultch, though I actually believe that 400 such boxes, or 1,200 bushels of cultch, through which sea water charged with fry thrown off by 100 bushels of spawning oysters would pass, would not afford too great an amount of spatting surface, because we have shown on the basis of actual observation that a body of water adapted to oyster-culture is capable of yielding spat throughout all of its three dimensions.

These boxes or frames, after they are filled with the cultch, are suspended in the canals, the cross section of which they should nearly fill at low tide. They are placed with their widest dimension across the canal, so that during the rise and fall of the tide the water has to rush through them no less than four times daily, and as the water is thoroughly charged with embryos, the greatest possible opportunity is afforded the young fry to affix itself.

In order to still further guard against the accumulation of sediment it is proposed to place jetties across the canals. These may consist of boards, forming a frame, which may slide into or be secured by vertical ledges fastened to the sides of the canal. These jetties may have one or two wide vertical slots in them, through which the tide will be compelled to flow with augmented velocity, and thus scour the sediment off of the cultch contained in the suspended boxes or frames on either side of them. Such jetties may be placed at intervals along the canal, and they might be made movable, so as to be changed in order to affect other sets of boxes of cultch at other points along the sluice.

The system of canals, as shown in the plans, should hold about 400 receptacles filled with shells, or at least 1,200 bushels of cultch. In practice I think it probable that even a longer system of canals will be found available; but it must always be borne in mind that the area of the pond must not very greatly exceed the total area of the system of canals, or else so much more water will run out of the pond at every ebb of the tide that a great many embryos will be carried past the system of collectors in the canals into the open water and be entirely lost. There is, consequently, a very good reason for having the areas of the two nearly equal.

The preceding system of culture, it will be obvious, is only an application of principles well established and based upon the observation of the actual behavior of oysters under natural conditions, as observed at Fortress Monroe, St. Jerome Creek, Woods Hole, Cohasset, and Long Island Sound.

The spawning ponds, after the season is over, may be used for fattening choice oysters for market, as they will actually hold about the quantity stated at the outset of this chapter. They may also be used in connection with another modification of the method of using cultch much crowded together or condensed, to be described later on.

The cultch may, without harm to the spat, be allowed to remain in the suspended receptacles in the canals until the first or middle of October, when it should be taken out and spread upon the bottom on the open beds where it is to grow larger. The reason for allowing the cultch to remain so long in the boxes is because spatting under favorable conditions continues for not less than ninety days, or from July 1 to October 1, so that all of this plant should be in working order by the 1st of July.

* * * * * * *

What we must do to-day is to adapt such means to the solution of the oyster problem as will render them applicable in practice. The American cultivator does not get the price obtained by the French or Dutch oyster-farmer, nor can he for a long time to come expect to, for the reason that the aggregate area upon which the American oyster is cultivated or indigenous exceeds by many times that upon which the European species is either native or cultivated. The European methods of using cultch, such as tiles, slates, brush, fagots, etc., are too expensive, too elaborate, for our practical people. We must reap in quantity what they reap out of the high price of their product. Under the circumstances there is no possible way of solving the greatest question which now exercises the oyster-growers of this country but to put into their hands a method by the aid of which they can get all the spat they want on their *own* lands and from the spawn of their *own* oysters.

* * * * * * *

The advantages of the method of using the cultch in concentrated bodies, giving an enormous amount of surface for the spat to adhere to, are that it can be conducted on the land owned by the culturist himself and with the spawn thrown off by the oysters belonging to him. He is, therefore, not bound by any arbitrary oyster laws now existing to conform to what are, generally speaking, very inefficient and often absurd conditions. The new method puts it in the power of the culturist to rear his own seed for planting, and if he is so disposed he may put down an excess of cultch, which he can sell after it is covered with spat to the owners of the open beds in his vicinity. It involves comparatively little outlay to put down a plant which will accommodate 5,000 bushels of cultch, or enough to seed from 20 to 30 acres for the first year. Such a system would be of great practical utility in the region of the Chesapeake Bay, where there are very extensive areas upon which, with very inexpensive excavation, the plant for conducting this method of culture could be organized.

* * * * * * *

The plan of the small establishment given in the preceding pages is to be regarded as typical. In the use of the system with crowded or condensed cultch in different localities, modifications of the typical plan may often be advantageously employed. For example, an oyster-planter may have a large pond of 2 or 3 acres thickly planted with spawning oysters and connected with the open water by way of a narrow canal. The pond, if it has a firm bottom over its whole extent, may, if not already used for the purpose, be planted throughout with good seed or "plants," which, in the course of two years, will be mostly well-grown, marketable oysters. In such a case, several systems of canals could be fed from the single large inclosure; that is to say, instead of having only a single canal, several zigzag canal systems, each 3 feet in width, might be made to carry the water flowing in and out of the large inclosure, instead of the original channel, which might then be filled up and closed. Or, if it were practicable, the channel connecting the natural pond with the open water might be utilized for the same purpose as artificially constructed canals, provided the cost of modifying it for the purpose were not too great. In some cases, by digging, filling, and dredging, as might be indicated in the course of such a natural channel, it could be prepared for the reception of cultch. Were such a channel wide enough, a system of parallel rows of light piles, the rows being 3 feet 3 inches apart and running lengthwise throughout the course of the channel, might be used to support the receptacles for the cultch, the latter being of the form used in the design of the typical system and supported, as in the latter, upon ledges or scantling spiked horizontally to the rows of piles just below the level of low tide.

In other cases where there existed narrow points in the course of such a canal these might be used as jetties, still further narrowed in some cases, perhaps, by filling in the sides, after which a system of parallel rows of piles with their horizontal supports of scantling might be constructed between the jetties, and upon which the receptacles filled with cultch could be supported. In this way the fry now discharged by spawning oysters from coves through their outlets, sometimes by the thousands of billions annually, can be caught upon cultch and permitted to develop into available spat.

In many cases the cost of digging out the proper channels or canals to be used in the system of applying the cultch in concentrated form would be greatly diminished by the nature of the ground upon which the canals were dug out. If the level of the earth is not much above that of high water, so much the better, for then the labor to be expended in making the necessary excavations will be proportionally diminished, and no assistance from a skilled engineer will be required.

Whether the spawning pond is excavated or not, the principle upon which the system is constructed and operated remains the same, namely, that the area of the canal systems and the ponds be about the same. In order that the fry be not carried past the collectors, the area of the pond should not much exceed the total area of the canals. In order that the fry may be wafted to the outermost collectors, the area of the canal system ought not to greatly exceed that of the pond or ponds.

Canals constructed between a series of spawning ponds may also be utilized; in fact, a great many other modifications of the system are available, which would become apparent only after a study of a given location. The plans for carrying out this system would, in fact, have to conform to the demands of the location, so that it may be said that each establishment would have to be designed in conformity with local conditions.

* * * * * * *

If cultch in the form of shells is the best (for which conclusion we have assigned reasons), it follows that such material should be so utilized as to obtain the largest possible return for the least possible outlay. In other words, if shell cultch is to be used at all, let it be expeditiously and economically, and not wastefully and unscientifically, employed. It has been found that even the sowing of shells is profitable, as has been conclusively demonstrated, and in one type of culture, namely, that which is practiced in deep water, it is probable that it is the only practicable method which will be devised for a long time to come. While it is to a great extent wasteful and at times uncertain, for the present, at least, there seems to be no other which can be so economically and successfully operated over large, open, navigable areas. Large areas operated by one individual or corporation can not always be commanded, or only exceptionally, under the existing laws of the States of Maryland and Virginia. In those States, however, where it is possible to command the right to natural areas of water which are more or less nearly landlocked, the system of merely sowing shells would be positively wasteful and not in conformity with the results attainable under the guidance of the proper knowledge.

It is found in the practice of shell sowing that extensive areas will sometimes fail to produce any spat. This is apparently due to the presence of currents which have swept the fry off the beds, or to the presence of sediment, which has put an end to the first stages of its fixed career. Even after the spat is caught, great destruction may occur through the inroads of starfishes, or a too rapid multiplication of worm tubes over the cultch and spat. The latter is sometimes smothered in vast numbers from the last-mentioned cause, as has been recently discovered by Mr. Rowe. Such casualties are rendered either impossible or readily observable during their early stages by the method of inclosing the cultch in suspended receptacles, as suggested in this paper. The netting will effectually protect the young spat against the attacks of large starfishes, and no growth of barnacles or tunicates, worm tubes or sponges, would be rapid enough during the spatting period, judging from an experience extending through several seasons, to seriously impair the spatting capacity of the cultch used in the suspended receptacles. Any of the larger carnivorous mollusks, fishes, or crustaceans which could prey on the young oysters can also be barred out and kept from committing serious depredations by means of the netting around the cultch, as well as by means of screens placed at the mouth of the canal.

The maximum efficiency of the cultch is not realized in any of the old forms of collectors, for the reason that the cultch can not be kept clean; secondly, because both sides of the cultch can not be exposed to the passing fry; thirdly, because the fry can not be compelled to pass over and amongst the cultch repeatedly; fourthly, because the cultch is scattered over too great an area and throughout only two dimensions of a body of water, namely, its horizontal extent, where it is possible, as I have shown above, to do all this and more—that is, to avail ourselves of the possibility of obtaining spat through the three dimensions of a body of water charged with embryo oysters in their veliger condition. These are good and sufficient reasons for my assertion that cultch has hitherto been wastefully and unscientifically applied. With this I must conclude this exposition of the principles of a rational theory of oyster-culture, a subject which has received the attention of many investigators, none of whom have, however, struck at the root of the question and allowed themselves to be guided by readily verifiable facts. In the hope that I have made both the theory and the practice of my new method clear to the reader, who, if he should happen to be an oysterman, will, I hope, at least give me the credit of being honest and sincere in my intentions, and, whether he feels inclined to ridicule or to adopt my conclusions, I feel very certain that what I have formulated in the preceding pages will become the recognized doctrine of the future. *

A trial of this method was made by the Fish Commission at St. Jerome Creek, Maryland, but it was found that Dr. Ryder's expectations regarding the freedom of his apparatus from sedimentation were unfounded. St. Jerome Creek is admirably adapted, from its rich food supply, to growing oysters from seed, but its very advantages in this respect militated against the success of the experiment of spat-raising. A small set was obtained upon some of the cultch exposed, but the deposit of sediment was so rapid that the young oysters were unable to fix in quantities sufficient to make the experiment a commercial success.

It seems probable that under more favorable conditions with respect to sedimentation the apparatus would prove a useful one, and it is to be hoped that it will be given a further trial. The writer witnessed Dr. Ryder's experiment at Sea Isle City, N. J., with a modification of this arrangement, and, although the trial was made on a scale too small, the results were such as to impress him with the feasibility of the device under more favorable conditions than existed at St. Jerome Creek.

One of the principal defects in Dr. Ryder's apparatus appears to be the lack of suitable arrangements for flushing the cultch with currents of water sufficiently strong to scour away any sediment which may accumulate. It was supposed that this could be accomplished by means of jetties, but the current induced in the long canal by the ebb and flow of the tide is apparently too gentle to have the effect sought. This end might be gained by providing the inner loops of the canal with gates communicating with the pond, the outer loops having similar means of communication with the exterior waters, as shown in plate III, which is adapted from Dr. Ryder's plans. If the water in the pond at high tide be held back until the canal has nearly emptied, a strong current could be directed into any loop by opening the appropriate gates. On the other hand, if the gates at the outer end of the loops be closed at low water, a strong current could be thrown into the canals by opening them at high water. By thus occasionally flushing each pair of loops in succession it is believed that the injurious collection of sediment can be prevented in even quite muddy water. The end is accomplished,

* Rept. U. S. F. C. 1885, pp. 381–423, pls. I–IV.

however, by some loss in simplicity of construction and operation of the apparatus and at the expense of the escape of some of the embryos. Plate III shows the original plans modified by the addition of sluice-gates.

It is thought that this method of utilizing cultch may solve the problem of the culture of the eastern oyster upon the Pacific coast. Two chief difficulties there interfere with the obtaining of a strong set: the temperature of the water is in most places too low to insure active spawning, and, secondly, the young of the imported species is crowded out by the rank growth of the native oyster. It is probable that both of these difficulties might be overcome by the use of Dr. Ryder's method or some modification thereof. There is little doubt but that the ebb and flow of the tides through the channels could be so regulated that a sufficient quantity of water would remain at low tide to temper that which would flow in at flood tide. The shallowness of the pond should render it so susceptible to the effect of the sun's rays that a temperature several degrees higher than that of the neighboring water could be maintained, and in some places these two or three degrees are perhaps the measure between success and failure in obtaining a set of spat.

The eastern oyster spawns at 67° or 68° F., but does better at 70°. Ponds such as that described might be located in connection with the sloughs communicating with the bays, and, as Mr. C. H. Townsend says that the native Pacific coast oyster does not flourish in such places, the imported species would doubtless have a better opportunity of survival during its early career, the period when it is especially liable to suffocation by foreign organisms. If necessary, a filter, such as is described on pp. 330–332 of this paper, might be introduced into the mouth of the canal. This would to some extent interfere with the ebb and flow of the tides between the pond and the slough or bay, but it might be the very thing necessary to retard the interchange sufficiently to allow the water in the pond to become warmed by the sun.

The experiment is at least worthy of a trial, and it may be the means of saving to the planters of the Pacific coast the large sums of money which are now annually expended in transporting seed oysters across the continent. The experimenter, if successful, would reap the benefit of his own success. The brood oysters used in stocking the pond should preferably be plants of several years' standing, as such would be more likely to be acclimated than those brought from the East but a short time prior to the experiment.

ARTIFICIAL PROPAGATION.

Artificial propagation in the fish-culturist's sense, the raising of oyster fry from artificially fertilized eggs, has, at the present time, no place in practical oyster-culture. It may perhaps sometime demonstrate its applicability to a system of spat production in small closed ponds, but it can have absolutely no use in the present methods of oyster-growing. It is futile to expect any results from deposits of the swimming fry upon beds planted in the open waters of the bays and sounds where the conditions are usually such as would bring about a wide distribution. Fry so deposited would be, no doubt, largely carried to other beds, and be lost to the man who planted them, or else would fall upon unsuitable bottom. Their fate after being deposited in the water is so uncertain that, in our present state of knowledge, it would be a waste of effort for either Government hatcheries or private individuals to attempt to increase the oyster by such means.

If, however, there can be devised some successful method of closed-pond production, then artificial propagation may find a field of usefulness. Dr. Ryder suggested that the available amount of fry in his method of spat-culture might be increased by adding embryonized water to the inlet to the sluice at the beginning of flood tide, the embryos being carried up through the cultch upon the flood and back again upon the ebb, thus giving a double chance for fixation. There is no doubt but that the proportion of eggs successfully fertilized can be increased by the artificial mixture of the ova and spermatozoa according to methods which science has demonstrated.

Another experiment by the same investigator showed that spat could be raised in a practically closed pond from artificially fertilized eggs. The experiment was briefly as follows: The pond was excavated in the salt marsh on the shore of Chincoteague Bay. It was about 20 feet square and 3½ feet deep, and communicated with the bay by a canal 10 feet long, 2 feet wide, and the same depth as the pond. The mouth of the canal was closed with a filter composed of boards perforated with auger-holes and lined inside with gunny-cloth or bagging. The boards constituted two diaphragms, an inner and outer, the interval of 2 inches between being filled with clean sharp sand. Through this the tide ebbed and flowed, giving a rise and fall of from 4 to 6 inches during the interval between successive tides.

This filter, like most structures of its class, showed a tendency to clog after it had been in use for some time, and as, from its shape, it was difficult to cleanse, Dr. Ryder devised the following arrangement, which is accessible at all times and in which the sand may be renewed at will:

My improved permeable diaphragm is placed horizontally within an oblong trunk or box, A, fig. 1, of plate IV. The box is made of inch planks, to which strong horizontal sidepieces, *a*, figs. 2 and 3, are secured, and to which are fastened the

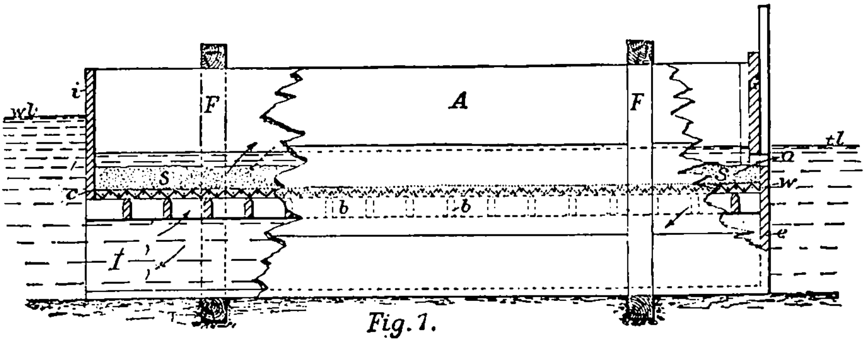


Fig. 1.

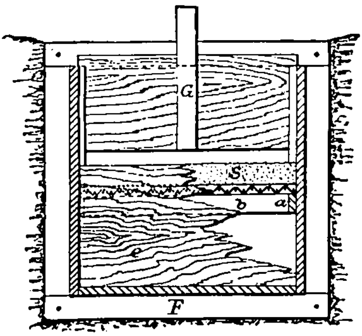


Fig. 2.

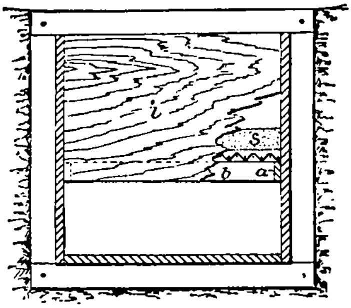


Fig. 3.

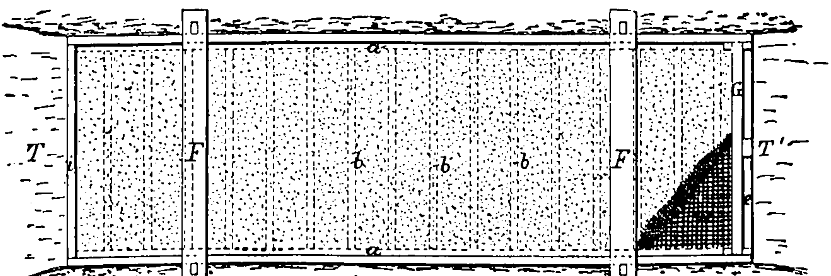


Fig. 4.

DETAILS OF FILTER FOR PONDS USED FOR OYSTER-CULTURE.

After John A. Ryder.

transverse crossbars *b b*, of figs. 1, 2, 3, and 4, upon which the permeable diaphragm rests. Fig. 1 represents the trunk A secured within a pair of quadrangular frames, *F F*, and partially in sectional elevation in place in the trench or canal leading from the pond to the open water; fig. 2 represents the construction of the end of the trunk next the open water, and fig. 3 that of the end next the pond, while fig. 4 shows the trunk as viewed from above.

On the crossbars *b b* a single screen of galvanized wire cloth, W, fig. 1 (galvanized after it is woven), is superimposed, having meshes, say, one-half inch in diameter; upon the wire screen a layer of gunny-cloth, *C*, figs. 1 and 4, is laid, upon which a layer of fine, clean sand, *S*, is spread evenly from one end of the trunk to the other. The end board *e*, extending halfway up at the outer end of the box, runs up past the level of the wire and cloth to confine the sand at that extremity, as shown in fig. 2, while the sand is confined by the board *i* at the other end of the trunk next the pond, as shown in fig. 3. The wire cloth and bars *b b* constitute the support for the sand as it lies upon the gunny-cloth, which is supported in turn by the wire cloth or screen *W*. This is essentially the construction of the filtering apparatus in which the layer of sand, *S*, is at all times accessible, so that it can be removed if it becomes clogged with ooze carried in by successive tides under the gate *G*, figs. 1, 2, and 4. This layer of sand can also be increased or diminished in thickness so as to strain the inflowing and outflowing water more or less effectually, as may be desired, or in order to more or less effectually prevent the escape of any eggs or embryos of oyster which may be developing within the pond and wafted to and fro by the ebbing and flowing currents which are carried in and out of the pond through the diaphragm by tidal action. The gunny-cloth, *C*, fig. 4, may possibly be replaced by, first, a layer of coarse gravel, then a layer of finer gravel superimposed upon that, which would prevent the fine sand from sifting through the supporting wire screen *W*. Gravel would be more durable than gunny-cloth or sacking, which, like all other textile fabrics, will rot if immersed in salt water for a few weeks. In practice, however, a mode of getting over all such difficulties would soon be devised. A coarse sacking to be used for the purpose might be saturated with a drying oil or with tar diluted with oil of turpentine, which when dry would act as a preservative of the material, but not cause it to become impervious.

* * * * * * *

When the trunk *A* is put in place (which should be done before the water is let into a freshly excavated pond, and also before the water is let into the trench from the sea end), it should be securely placed in position and the earth tightly rammed in along the sides so as to prevent any sea water from finding its way into the pond, except such as passes through the filtering diaphragm. It is also unnecessary to insist that the trunk be constructed in such a way that it will be practically water-tight, and not liable to leak between the planks or at the corners. The wire cloth, sacking, or gravel, and sand having been got into place, and when complete forming a stratum having a total thickness of 5 or 6 inches, the operator is ready to cut away the barrier at the sea end of the trench and let in the water.

If then the trunk *A* has been let down into the trench deep enough the sea level at low tide ought to be somewhat above the upper edge of the board *e*. The water will then, as the tide rises, flow back over the sand as far as the board *i*, and will percolate through the diaphragm into the space *I*, under the latter, and so find its way into the pond. After a day or so the pond will be filled with sea water which has practically been filtered, and filtered more or less effectually in proportion to the thickness of the stratum of sand constituting the diaphragm. After the pond has once been filled with the rise and fall of the tide in the open water the level of the latter and that in the pond will be constantly changing; in other words, when the tide is ebbing the water level in the pond will be higher than that of the water outside, as in fact represented at *wl* and *tl* in fig. 1. Under these circumstances there will be a supply of water flowing out through the under division *I* of the trunk *A*, up through the sand and out over its surface through the outlet *O* under the gate *G*. After the ebb tide is over and flood tide begins these levels will be reversed and *wl* in the pond will be lower than it in the open water, and under those circumstances there will be an inflow of sea water into the pond through the diaphragm instead of an outflow, as is the condition of the water level during ebb tide. Under such conditions there will be four alternating periods during every twenty-four hours of inflow and outflow, lasting, we will say, four hours each, not reckoning the nearly stationary intervals between tides or during slack water. This almost constant partial renewal of the water will unquestionably maintain the water inclosed in the pond or ponds by means of diaphragms in a condition fitted to support oysters colonized therein, provided its density is not too great or too slight, and if there is also some microscopic vegetation present.

It will be readily understood from the preceding description how it is intended that the apparatus is to be operated. The figures also give a very good idea of how the diaphragm and trunk are to be constructed, the first four figures being drawn to a common scale of 1 inch to 3 feet.*

The water in the pond remained at about the same density and temperature as that in the open bay and soon developed a greater abundance of food organisms, both plants and animals. Artificially fertilized ova were placed in the pond at intervals during the spawning season, and forty-six days after the beginning of the experiment young spat from one-fourth to three-fourths of an inch long were found attached to the bunches of shells which had been hung upon stakes to serve as collectors. Great difficulty was experienced from sedimentation. The experiment demonstrated that spat could be raised in ponds from artificially fertilized eggs and that it would grow as rapidly as the spat reared in the open bay. As the conditions are stated by Dr. Ryder, it appears probable that equally good or better results might have been attained with less labor by placing a quantity of spawning oysters in the pond.

Not only would there be a saving of labor in the direct use of the spawning oysters, but there would also be no necessity for the sacrifice of the parents, as must be done under the method of artificial fertilization. The increase in the size of the spawners under the favorable conditions of growth would probably go far toward the payment of expenses.

The method which promises the best results is that in which the eggs are deposited in the pond within from three to five hours after fertilization. There is apparently nothing to be gained in holding the eggs a longer time, the chief gain of the culturist being not in the protection of the embryo, but in the increase of the proportion of eggs fertilized.

The method of fertilization used by Dr. Ryder was as follows:

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

*Bull. U. S. F. C. 1884, pp. 19, 21, 22, 23.

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 envelops 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 toward 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 (plate I, fig. 2 *d*). 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 toward 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 90 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 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 20 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 50 to 200 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 aeration and prevent the suffocation of the embryos. *

ARTIFICIAL FEEDING.

There is no practical way now known of furnishing oysters with an artificial food supply.

Experiments have been made with a view to feeding the adult oysters upon corn-meal or some similar substance, but such attempts have been of no practical value. There is no doubt that they would eat corn-meal or any other substance in a sufficiently fine state of division to be acted upon by the cilia. The oyster is incapable of making a selection of its food, and probably any substance, nutritious, inert, or injurious, would be swept into the mouth with complete indifference except as to the result. Corn-meal and similar substances would doubtless be nutritious, but their use must be so wasteful that the value of the meal would be greater than that of the oyster produced.

The only way in which the amount of oyster food can be increased is by so regulating the conditions in ponds or parks that the natural food may grow in greater luxuriance. In artificial propagation the life of the young has been prolonged beyond the early embryonic stages by feeding upon certain marine algæ reduced to a powder by pounding them in a mortar, but such successes have been purely experimental and are of no significance from a practical standpoint. Even if artificial propagation were to obtain a place in practical oyster-culture, the fry would doubtless be liberated before resort to artificial feeding would become necessary.

* Fisheries Industries, Sec. I, pp. 723, 724, 725.

FATTENING, PLUMPING, FLOATING.

As has been frequently pointed out, the so-called "fattening" of oysters for a short time previous to sending them to market is not a fattening process at all, but is a device of the trade to give to the oysters an illusive appearance of plumpness. It adds nothing whatever to the nutritive qualities of the oyster, but on the contrary injures its flavor and extracts certain of its nutritious ingredients. However, as long as the public desire such oysters the dealers can not be blamed for supplying them.

The process of plumping consists in changing oysters from denser to less dense water, causing an interchange of fluids through the walls of the animal, the denser fluids in the tissues passing slowly outward, the less saline water in which the animal is immersed passing more rapidly inward. The net result is to cause a swelling of the tissues by an increase in the fluid contents, in much the same manner as a dry sponge swells when moistened. The oysters are not usually placed in absolutely fresh water, which would kill them if exposed too long, but in fresher than that in which they have been living. The fluids which have passed out from the tissues carry with them salts and some fats, chemical experiment showing that the oyster, although larger after plumping, has lost 13 per cent of its original nutritious substances, protein, fats, carbohydrates, and mineral salts. Sufficient water will be taken up, however, to increase the total weight of the oyster from 12 to 20 per cent. The same result is produced by placing the oysters in fresh water after they have been removed from the shell. It will be seen that what the oysters have gained is simply water, of no value as food.

If the living oysters are left too long on the floats they will again become "lean," leaner than before, in fact, owing to the state of equilibrium which is finally established between the density of the juices within the tissues and without. If oysters are taken from brackish water to that which is considerably more saline they become shrunken, tough, and leathery, owing to the converse process to that of plumping.

Various forms of floats are used. One of the simplest consists of trays 8 feet by 16 feet by 2 feet deep, with perforated bottoms, these being raised from the water for filling and emptying by means of a chain attached to each corner and a pair of windlasses supported upon piles.

While not harmful in itself it may be well in this connection to sound a word of warning. Oysters may, and no doubt sometimes do, consume pathogenic bacteria, or disease germs, with their food; and such germs, transferred to the human economy with vitality unimpaired may upon occasions have serious results. Care should be exercised to construct the floats in such places as are free from the contaminating influences of sewer discharge and other sources of pollution.

In France the oysters are subjected to a true fattening process in inclosed ponds or claires, their flavor and appearance being much improved thereby.

GREENING.

Notwithstanding that almost every recent writer upon the subject has insisted upon the harmlessness of the green coloration which is frequently observed in certain portions of the oysters, there is still considerable misapprehension of the subject by consumers and oystermen alike. The prejudice is confined to America, in Europe such oysters being regarded as superior, and much trouble being taken to impart to them their peculiar viridity. In our waters the greening is liable to occur in certain localities and at irregular times. Rather shallow waters appear to be more susceptible to the production of this effect than the greater depths, but it has recently appeared on the deep-water beds of Long Island Sound.

When oysters become so colored the oystermen find great difficulty in disposing of them, owing to the popular belief that they are unfit for food, or even poisonous. They often have what is described as a coppery taste, and uninformed persons usually assume that the green color is due to the presence of copper. A number of careful investigations have shown that such oysters contain no copper whatever, but that the green color is derived from a harmless blue-green substance, phycocyanin, which is found in certain of the lower plants.

Under proper conditions these unicellular vegetable organisms multiply in brackish or saline water with great rapidity and provide an important item of food to the oyster. The green matter is soluble in the juices of the oyster and passes into the tissues, affecting principally the blood corpuscles.

An oyster usually shows the first indication of greening in the gills and palps, and frequently this is the only portion of the animal which is colored, a fact which is explained when we remember that this is the most highly vascular portion. When the supply of greening food is abundant and long continued, the mantle, liver, and eventually the entire organism, with the exception of the muscle, acquire a green hue. Such oysters are usually, but not always, fat and well fed, the result of the abundant supply of nutritious food, and such a condition could hardly obtain were the dye a copper product, such as has been popularly supposed.

The color may be removed from the oysters by transferring them for a short time to waters in which the green food is deficient, a fact which may be available in preparing for market oysters which popular prejudice refuses to use in the green state.

In conclusion, it may be again insisted that the greening is not a disease, nor a parasite, nor a poisonous material in any sense.

TRANSPORTATION AND LENGTH OF LIFE WHEN REMOVED FROM THE WATER.

Under proper conditions the oyster will live for a long time after its removal from the water. Professor Verrill records a case in which marketable oysters survived for over ten weeks while hung up in the window of a shop, during the months of December, January, and February. The temperature was variable, but upon the whole rather cool. He says:

The remarkable duration of the life of these oysters is undoubtedly due to two causes:

1. The perfect condition of the edges of the shells, which allowed them to close up very tightly.

2. The position, suspended as they were with the front edge downward, is the most favorable position possible for the retention of water within the gill cavity, for in this position the edges of the mantle would closely pack against the inner edges of the shell, effectually closing any small leaks, and the retained water would also be in the most favorable position to moisten the gills, even after part had evaporated. It is also possible that when in this position the oyster instinctively keeps the shell tightly closed, to prevent the loss of water.

This incident may give a hint as to the best mode of transporting oysters and clams long distances. Perfect shells should be selected, and they should be packed with the front edge downward and kept moderately cool in a crate or some such receptacle which will allow a free circulation of air. Under such favorable conditions selected oysters can doubtless be kept from eight to twelve weeks out of water.

So far as is known, Professor Verrill's suggestion has not been followed by shippers, who seem to have no difficulty in making shipments to distant points.

Oysters are usually transported in barrels or sacks. To far inland or transcontinental points shipment is made in refrigerator cars. In the transportation of American oysters to Europe the same method of packing is followed, and they are carried in the cold-storage chambers of the vessels.

Several devices for locking the oysters, so as to prevent the gaping of the valves and the escape of the fluids, have been patented, but they do not appear to be in extensive use at the present time.

It is stated by some dealers that oysters which have been "plumped" or "fattened" stand shipment better than those which have not been subjected to the process.

The oyster, of course, can not feed during the period of its deprivation from water, and to maintain its vitality it makes draft upon its own tissues and gradually becomes poorer in quality. As the vital activities are apparently reduced at such times, the waste of tissue is small.

NOTES ON CLAM-CULTURE.

Owing to the importance of several species of clams as food for man and as bait in the line fisheries, it is deemed desirable to append a few facts relating to them and to their culture.

Two species are in common use upon the Atlantic coast, one of them also being an introduced species upon the Pacific coast. The quahog, hard clam or round clam (*Mercenaria mercenaria*), is perhaps the more important. It is the "clam" of the markets of New York, Philadelphia, and southward, and it is also utilized to some extent in New England. It is a heavy-shelled form living on the muddy bottoms, principally below low-water mark, where it is taken by means of rakes or by the process of "treading out," the clammer wading about and feeling for the clams with his toes and then picking them up by hand or with a short rake.

The long clam or *mananose* (*Mya arenaria*) is the principal species in the markets north of New York, and, on account of the comparative lightness of its shell, is often called the "soft" clam. This species was introduced on the Pacific coast with oysters brought from the East, and has now become widely distributed there and an important food product. It is found principally on sandy shores or in a mixture of sand and mud, between tide marks. Its long siphons permit it to burrow to a considerable depth, and it is dug from its burrows by means of spades, stout forks, or heavy hoes or rakes.

The soft clam appears to be the only species which has been the object of attempted cultivation, although no doubt the quahog is equally favorable for the experiment.

In Chesapeake Bay the soft-shell clam spawns from about September 10 to October 20. The eggs are of about the same size as those of the oyster, and in their early development pass through practically the same stages. At the end of the free-swimming stage the clam is still very small. It settles to the bottom, but instead of becoming attached to shells or other firm bodies in the water it soon burrows into the bottom until it is completely hidden with the exception of the tips of the siphons, through which it derives its supply of food and oxygen from the currents of water induced by the action of cells provided with hair-like processes (cilia). Upon very soft bottom the young clam, like the young oyster, is liable to become suffocated in the mud, but as it grows larger its powers of locomotion, which, though limited in degree, persist throughout life, enable it to extricate itself.

Owing to its free-living habit, the methods in use for catching oyster spat can not be utilized for the growing of seed clams. Although so far as known no successful attempt has been made to obtain clam spat, it seems probable that a moderately soft bottom naturally devoid of clams could be made available by covering it with a coating of sand of sufficient depth to prevent the sinking of the young during the early stages after it falls to the bottom. Later in life they are better able to care for themselves.

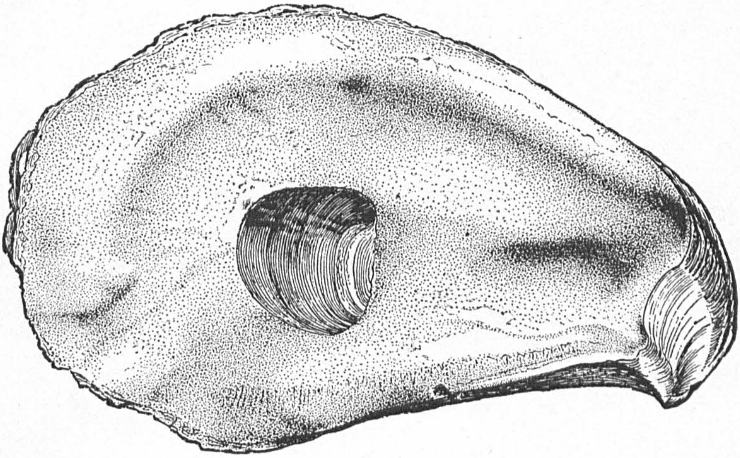
In certain places the planting of seed clams has been attended with some success, as is shown in the following account:

Quite an interesting feature in connection with the clam fisheries at Essex, Mass., was found in the shape of clam-culture. In 1888 an act was passed by the legislature authorizing the selectmen of the town to stake off in lots of 1 acre or less each of the flats along the Essex River, and let them to persons desiring to plant clams for a rental of $2 per acre or lot for five years and an additional fee of 50 cents. Thus far 37½ acres have been taken up and seeded with clams. Small clams are dug on the natural beds and planted on these hitherto unproductive flats. About 500 bushels are required to plant an acre properly. During the first two years (1889 and 1890) the people were slow to avail themselves of the privilege of planting for fear that after they had spent their time and labor they would not be able to secure protection from trespassers. But in 1891 and 1892 lots were obtained and planted. The principal difficulty encountered has been the loss of the clams by the sand washing over them, the bottom in some localities being soft and shifting. In 1892 there were 25 acres that were quite productive, about one-third of the entire catch of the section being obtained from them. The catch from these lots is not definitely known, but is estimated at about 2,500 barrels.

The cultivated clams possess some advantage over the natural growth from the fact that they are more uniform in size and are as large as the best of the natural clams. They bring $1.75 per barrel, while the natural clams sell for $1.50 per barrel This is the price received by the catchers. One acre of these clams is considered to be worth $1,000 if well seeded and favorably located so as not to be in danger of being submerged with sand. This valuation would be too high for an average, since all the acres are not equally well seeded and located. The clammers are generally impressed that the industry can be extensively and profitably developed, and their only fear is that they will not be able to secure lots permanently. The greater part of the land available for this purpose is covered by the deeds of people owning farms along the river, and the consent of the land-owners has to be obtained before lots can be taken up. It seems probable, however, that the business will continue to progress unless checked by complications that may arise relative to the occupancy of the grounds.—Report U. S. Fish Commission, 1894, pp. 139, 140.

It was hoped that these planted clams would propagate on the new beds, but the expectation has not been realized, owing, no doubt, to the unsuitableness of the bottom, a fact which would also account for the absence of the species in the first place.

The growth of the soft clam is quite rapid, and Dr. Ryder has shown that at St. Jerome Creek, Maryland, the shells reach a length of between 1¼ and 1⅞ inches within several months of the time of spawning.



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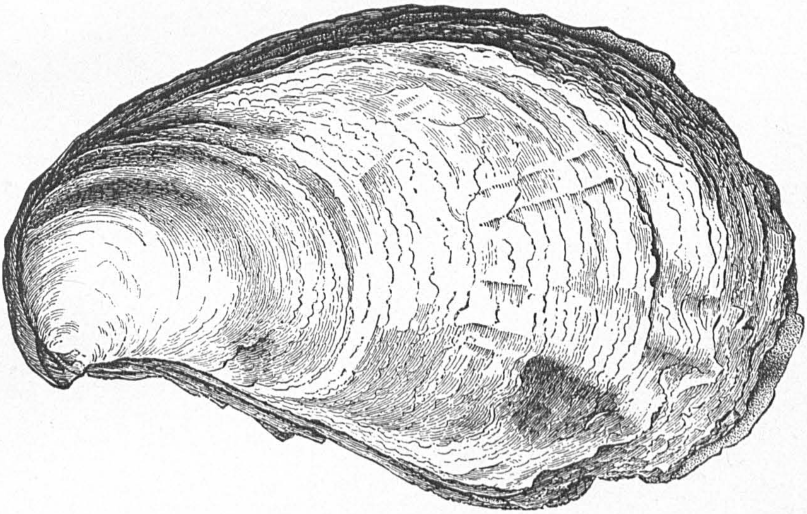

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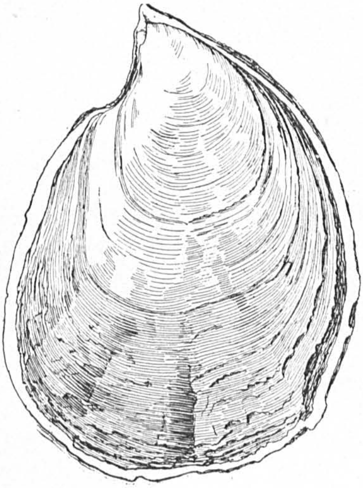
FIG. 1, INNER FACE, AND FIG. 2, OUTER FACE OF SHELL OF TYPICAL AMERICAN OYSTER.

From Fourth Annual Report, U. S. Geological Survey.



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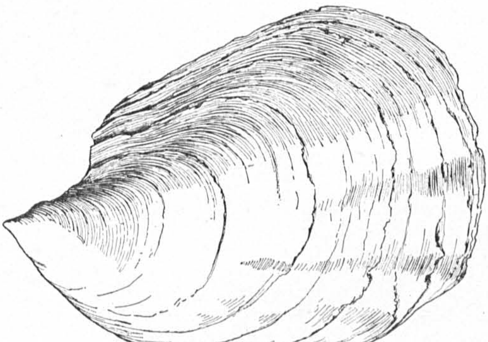

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FIG. 1. Upper view of closed valves of Pacific oyster, *Ostrea lurida*.
FIG. 2. Inner face of ventral valve of same specimen.
FIG. 3. Outer face of ventral valve of same specimen.

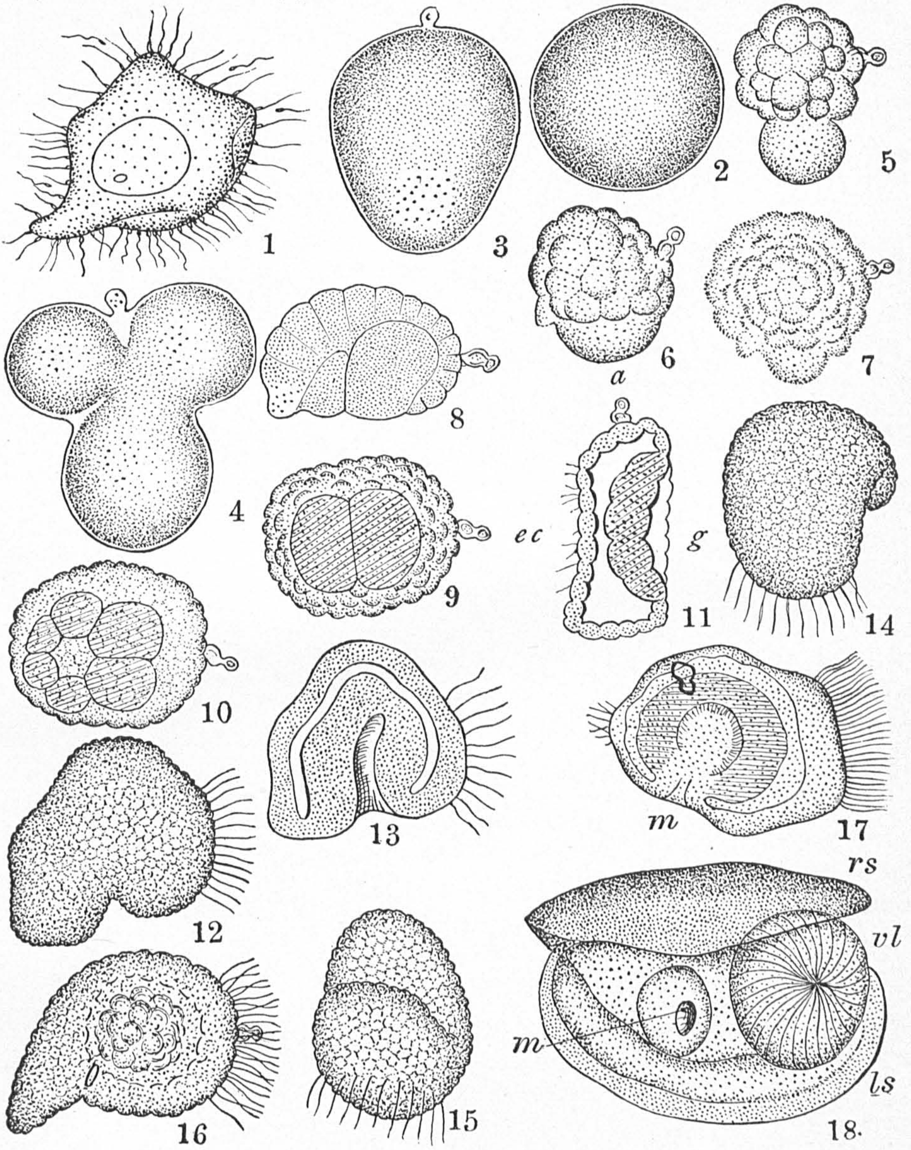
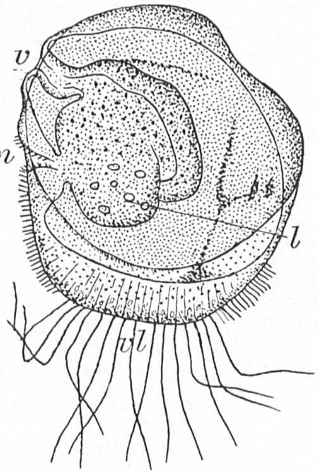


FIG. 1. Unfertilized egg shortly after mixture of spawn and milt; spermatozoa are adhering to the surface.
FIG. 2. Egg after fertilization.
FIG. 3. Same egg 2 minutes later. Polar body at broad end.
FIG. 4. Same egg 6 minutes later.
FIG. 5. About 6½ hours later.
FIG. 6. Another egg at about the same stage. Mass of small cells growing over large cell or macromere *a*.
FIG. 7. Egg 55 minutes later. Macromere almost covered by small cells of ectoderm.
FIG. 8. Optical section of egg 27 hours after impregnation, showing two large cells, derived from *a* in fig 6, covered by a layer of small ectodermal cells.
FIG. 9. Egg a few hours older, showing large cells viewed from below.
FIG. 10. An egg somewhat older viewed from above, showing further subdivision of large cells as seen through cells of upper layer.
FIG. 11. An older egg, now become flattened from above downward. Viewed in optical section.
FIG. 12. Surface view of an embryo just beginning to swim.
FIG. 13. Optical section of same.
FIG. 14. Surface view of same from another position.
FIG. 15. Surface view of same from another position.
FIG. 16. An older embryo in same position as in fig 12.
FIG. 17. A still older embryo showing spherical ciliated digestive cavity opening by mouth, *m*.
FIG. 18. An embryo with well-developed larval shells, older than fig. 1, Plate VIII. *rs*, right shell; *ls*, left shell; *vl*, velum; *m*, mouth.

After W. K. Brooks.



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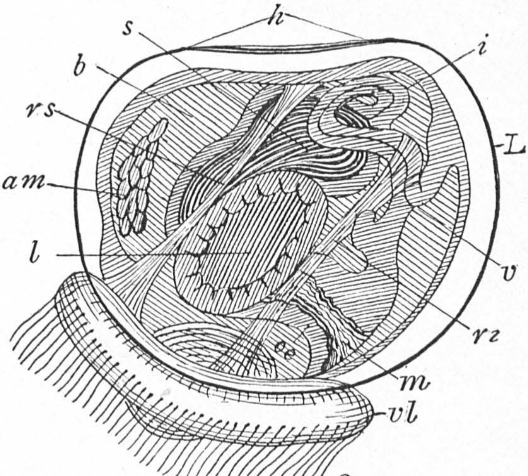

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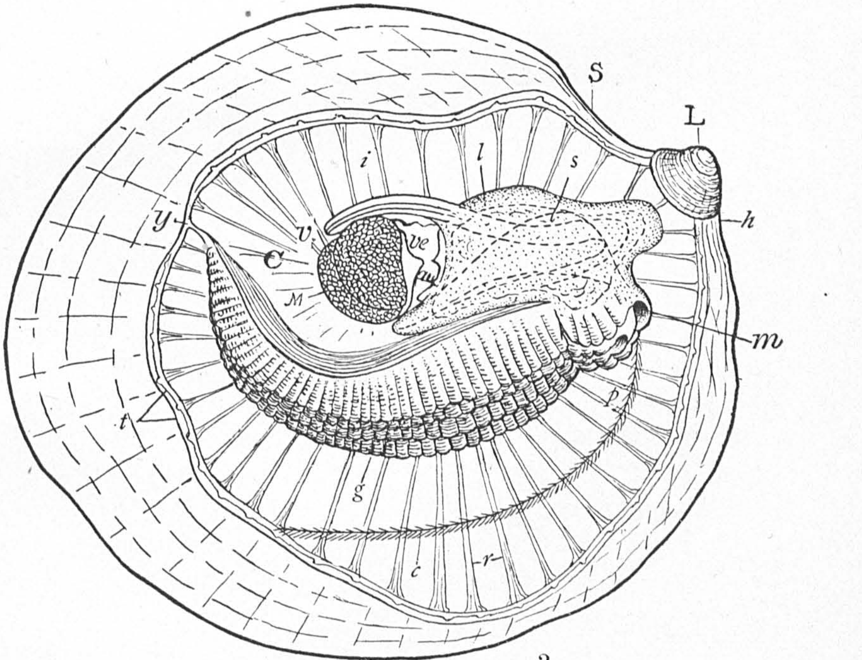


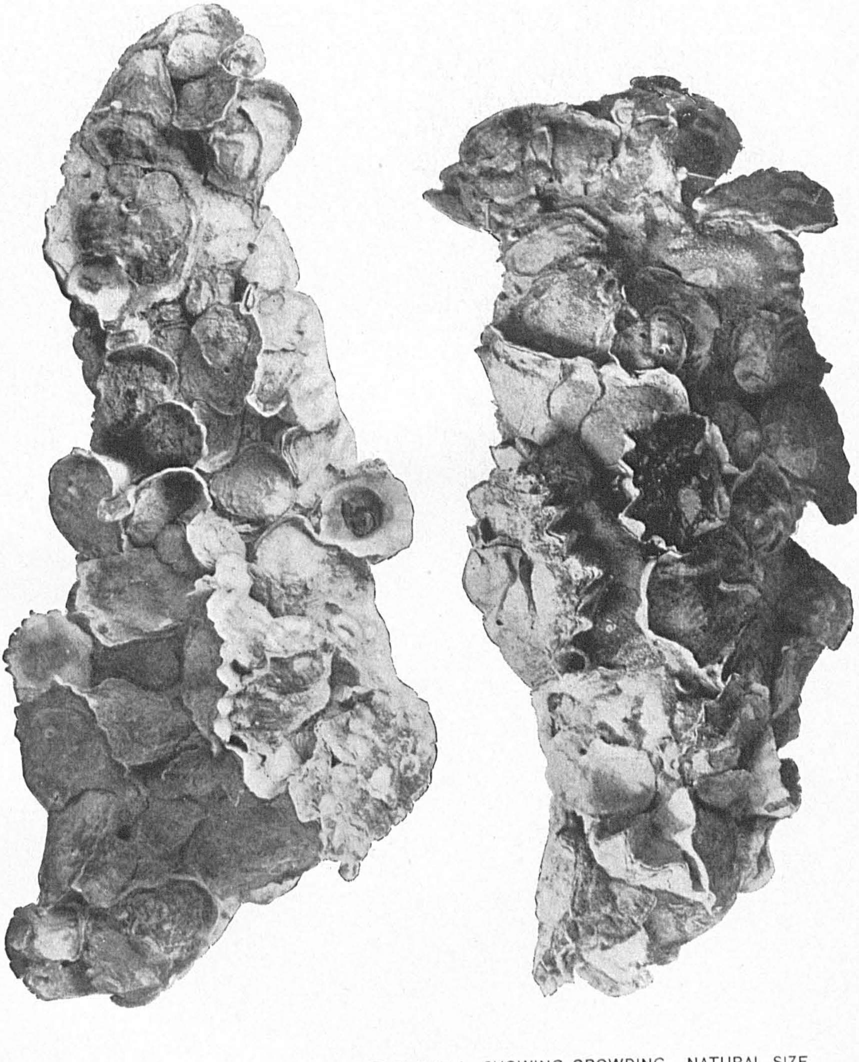
3

FIG. 1. View of right side of embryo about 6 days old. *m*, mouth; *v*, vent; *l*, right lobe of liver; *vl*, velum.

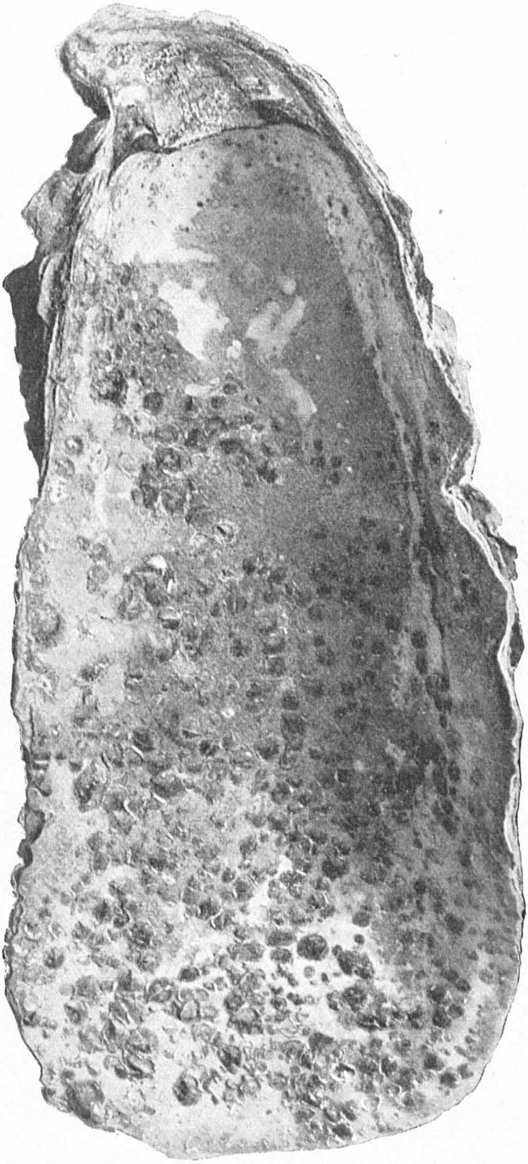
FIG. 2. Older larva of European oyster, *Ostrea lurida*. *L*, shell; *h*, hinge; *rs* and *ri*, retractor muscles of the velum, *vl*; *s*, stomach; *i*, intestine; *am*, larval adductor muscle; *b*, body cavity. Other letters as in the preceding.

FIG. 3. Attached spat of *Ostrea virginiana*. *S*, shell of spat with larval shell, *L*, at the beak or umbo; *p*, palps; *g*, gills; *c*, diagrammatic representation of a single row of cillia extending from the mantle border to the mouth *m*; *r*, radiating muscle fibres of mantle; *t*, rudimentary tentacles of mantle border; *M*, permanent adductor muscle; *C*, cloaca; *ve* and *au*, ventricle and auricle of the heart; *y*, posterior extremity of the gills and junction of the mantle folds. Other figures as above. Compare this figure with Pl. I, fig. 1.

Fig. 1 after W. K. Brooks. Fig. 2 after Thomas H. Huxley. Fig. 3 after John A. Ryder.



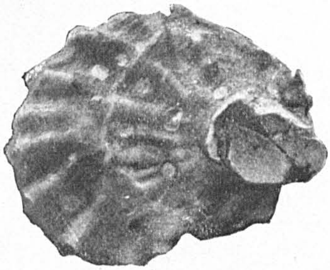
SET OF OYSTERS ON RACCOON OYSTER SHELL, SHOWING CROWDING. NATURAL SIZE.



OYSTER SPAT TWO OR THREE WEEKS OLD ON INSIDE OF OYSTER SHELL.
NATURAL SIZE.

OYSTER SPAT ABOUT TWO MONTHS OLD, ON A STONE. NATURAL SIZE.

PLATE XII.



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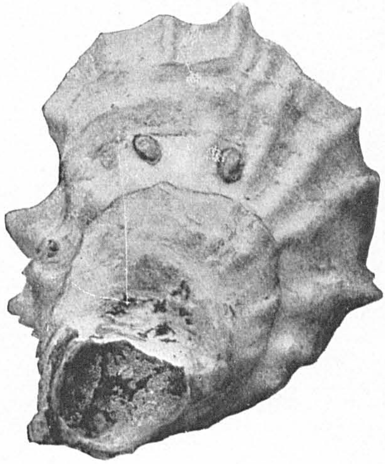

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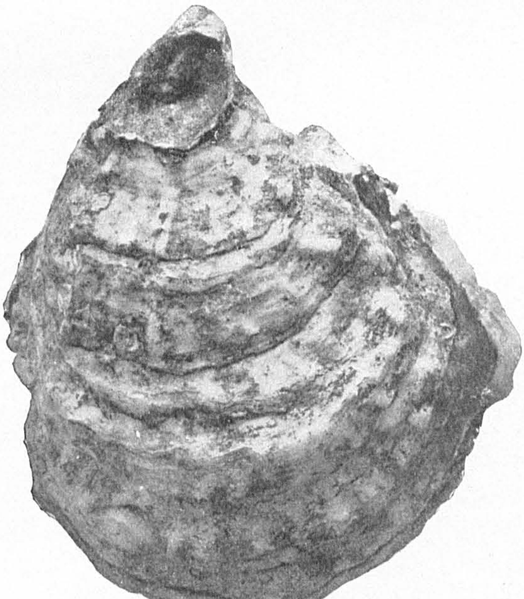

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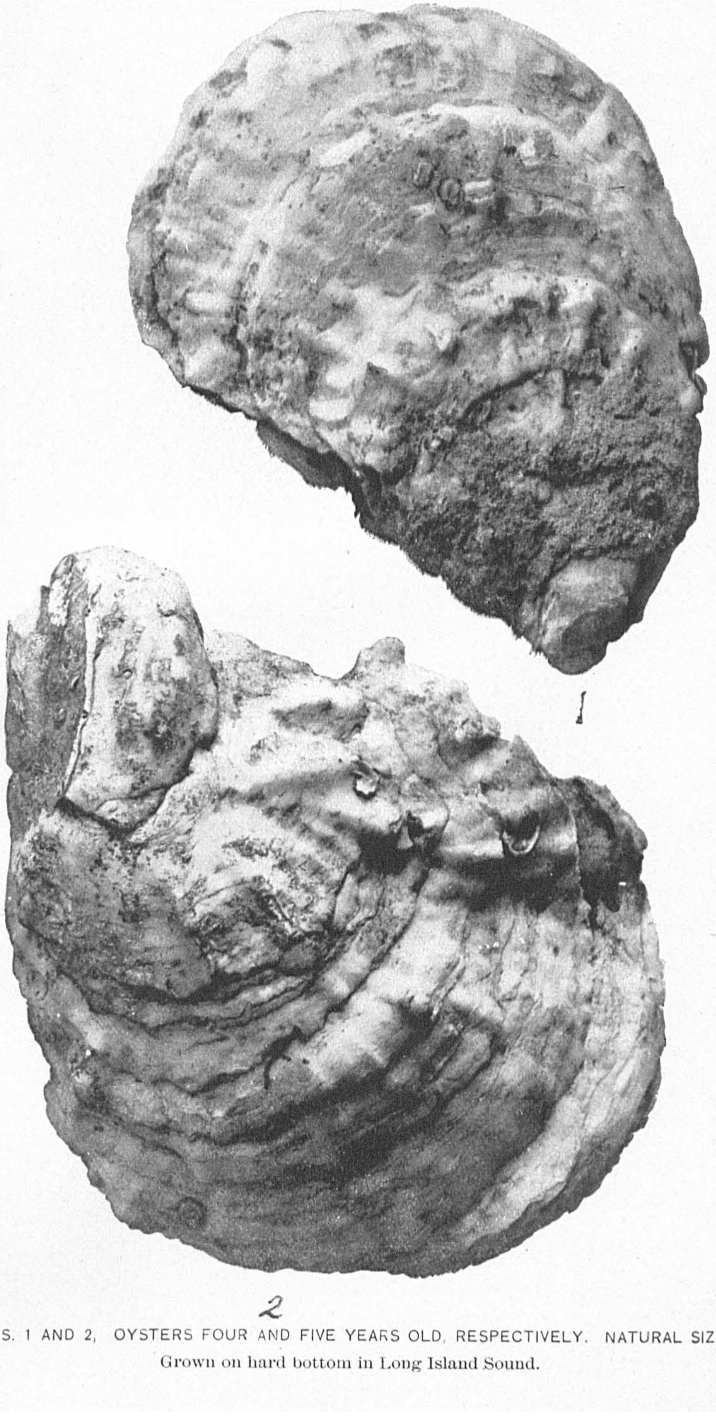
FIGS. 1, 2, AND 3, OYSTERS ONE, TWO, AND THREE YEARS OLD, RESPECTIVELY. NATURAL SIZE.

Grown on hard bottom in Long Island Sound.

PLATE XIII.



2

FIGS. 1 AND 2, OYSTERS FOUR AND FIVE YEARS OLD, RESPECTIVELY. NATURAL SIZE.

Grown on hard bottom in Long Island Sound.

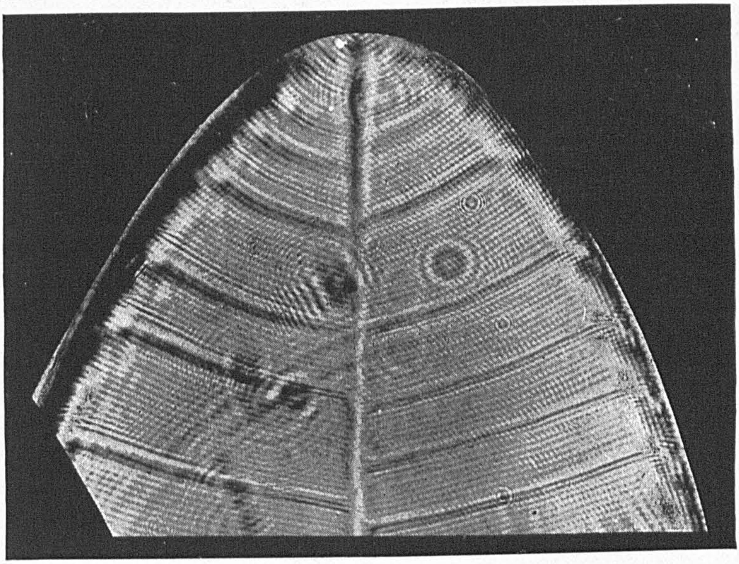


Fig. 1. PHOTO-MICROGRAPH OF THE DIATOM, SURIRELLA GEMMA, ENLARGED ABOUT 1,600 DIAMETERS.

The tip of the frustule is alone given, to indicate the character and texture of the glassy surface.

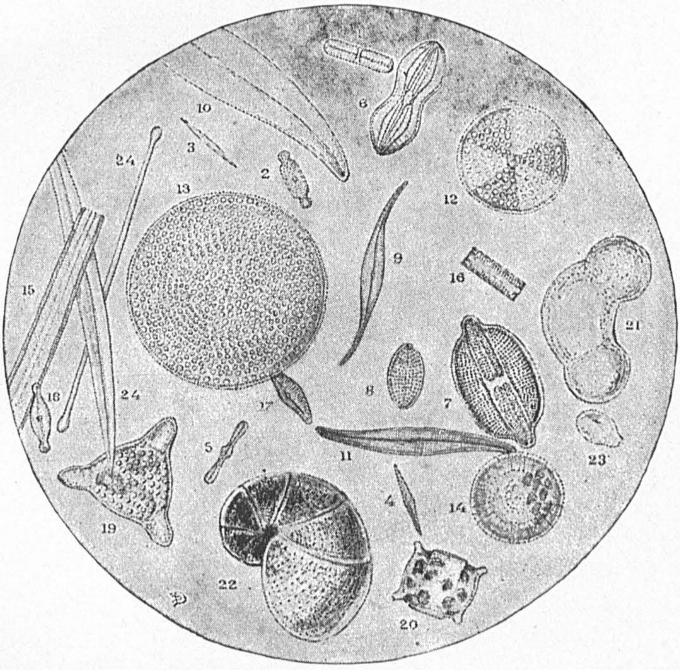


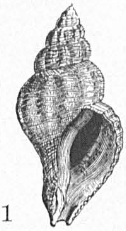
Fig. 2. FOOD OF SOUTH CAROLINA OYSTER. A FEW TYPICAL ORGANISMS (× 225).

Numbers 1 to 20 are diatoms.

1-5. Navicula (Bory).
6. N. didyma (K.).
7. Pinnularia radiosa (?) (K. S.).
8. Amphora sp. (K.).
9. Pleurosigma fasciola (E. S.).
10. P. littorale (S.).
11. P. strigosum (S.).
12. Actinocyclus undulatus (K.).
13. Coscinodiscus radiatus (E.).
14. Cyclotella rotula (E.).
15. Synedra sp. (E.).
16. Diatoma sp. (De C.).
17. Cymbella sp. (Ag.).
18. Mastogloia smithii (Thw.).
19. Triceratium alternans (Br. Bai.).
20. Biddulphia sp. (Gr.).
21. Grain of pine pollen (Pinus rigida).
22. Foraminifera (Rotalia).
23. Zoöspore (Ulva ?).
24. Spicules.

(After Bashford Dean.)

PLATE XV.



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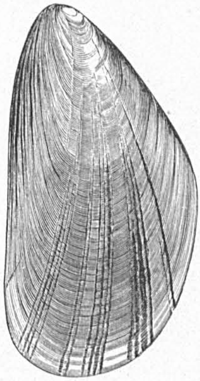

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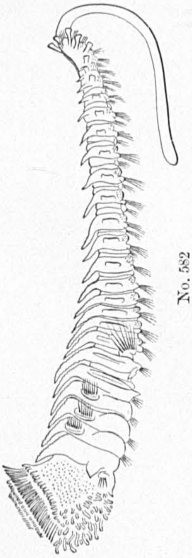

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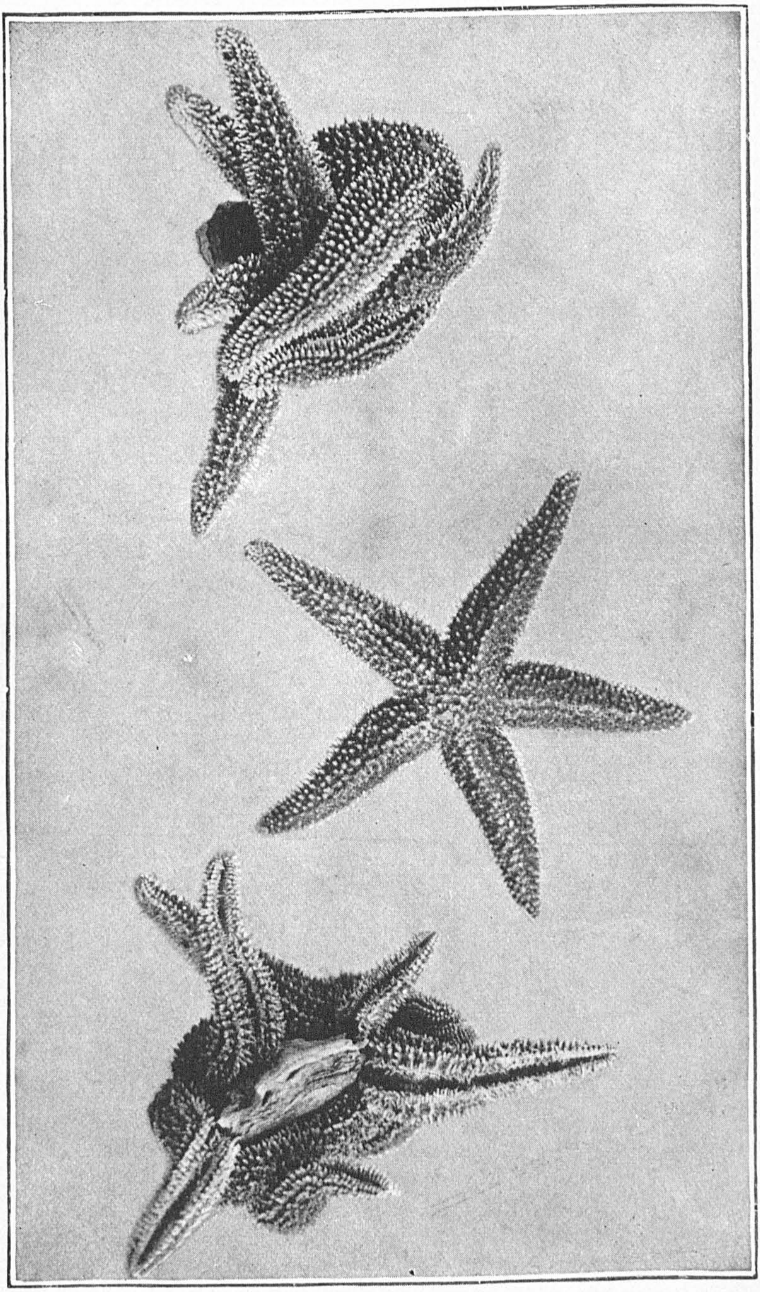
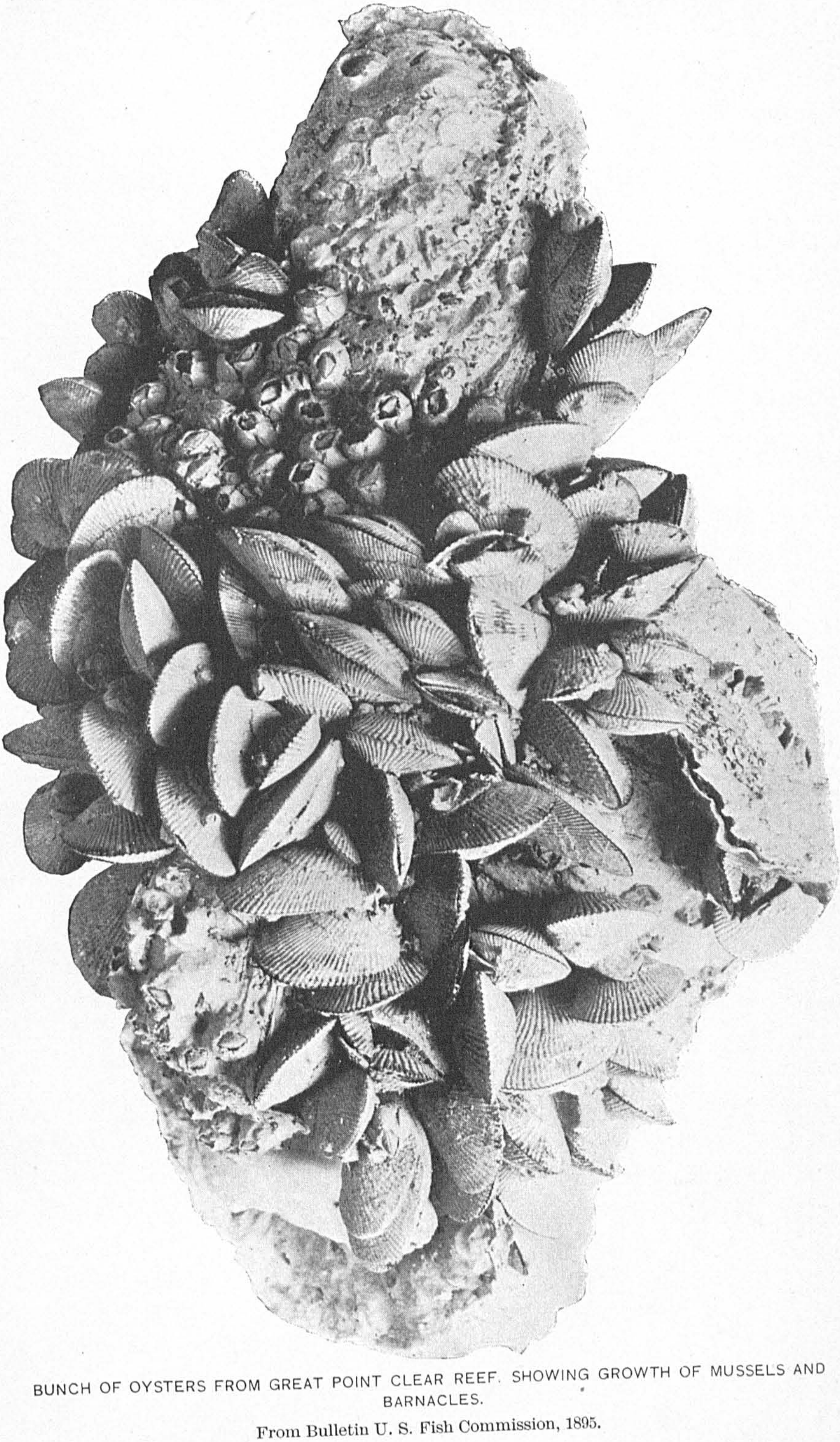
FIG. 1. Drill, *Urosalpinx cinerea*.
FIG. 2. Mussel, *Mytilus edulis*.
FIG. 3. *Sabellaria vulgaris*.
FIG. 4. Periwinkle, *Fulgur carica*.



STARFISH ATTACKING OYSTERS.

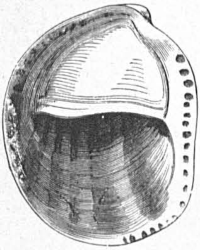
[From Fifth Annual Report of Connecticut Bureau of Labor Statistics.]



BUNCH OF OYSTERS FROM GREAT POINT CLEAR REEF, SHOWING GROWTH OF MUSSELS AND BARNACLES.

From Bulletin U. S. Fish Commission, 1895.

PLATE XVIII.



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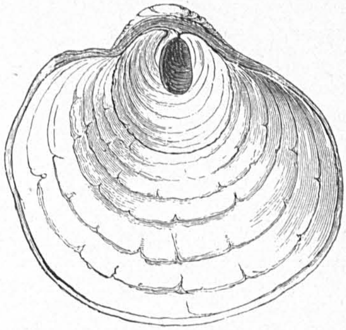
3



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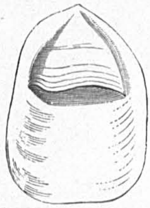

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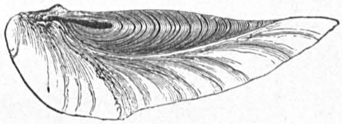

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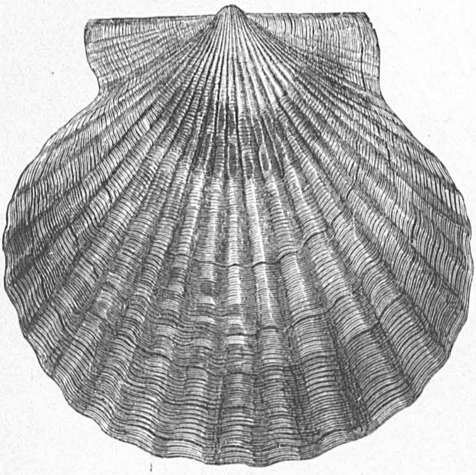

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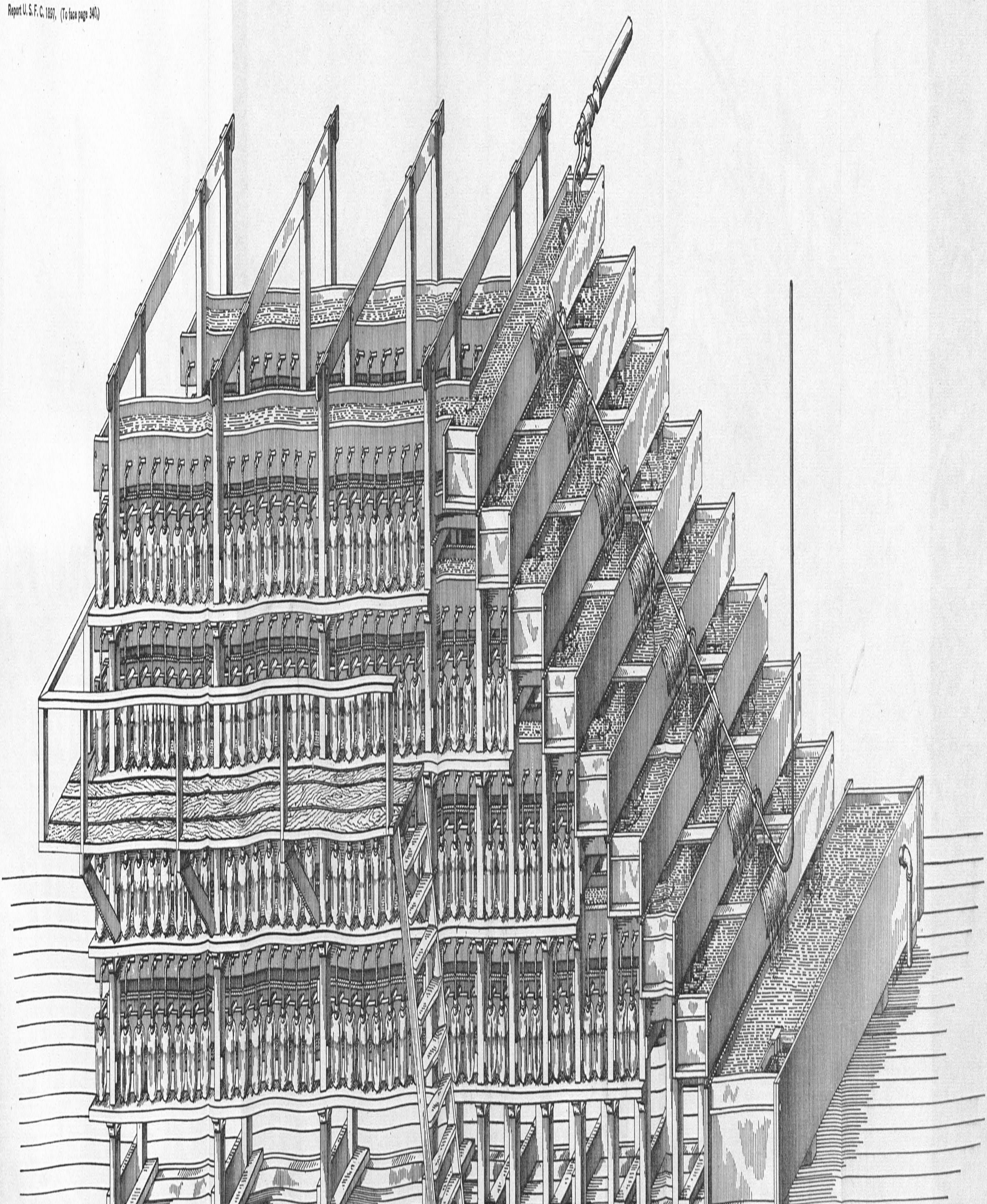
FIG. 1. "Quarter-decker," *Crepidula fornicata*.
FIG. 2. "Quarter-decker," *Crepidula plana*.
FIG. 3. "Quarter-decker," *Crepidula convexa*.
FIG. 4. Jingle, *Anomia glabra*, profile view.
FIG. 5. The same, lower side.
FIG. 6. Scallop, *Pecten irradians*.
FIG. 7. Oyster attached to pebble.



VIEW OF BATTERY FOR HATCHING WHITEFISH.