XXVII.—THE OYSTER AND OYSTER-CULTURE.

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INTRODUCTION

Since the first attempt in France, in 1858, to raise oysters by artificial means, very much has been written concerning the oyster and its culture. Authors, themselves astonished, have endeavored, by displaying long rows of figures indicating the great number of oysters that could be produced, to awaken like astonishment among their readers and arouse the inhabitants of the coast to propagate extensively in all their countries this most valuable of all sea invertebrates. These accounts of the immense production resulting from the artificial culture of the oyster went from paper to paper and book to book, and carried with them such an appearance of credibility that even practical oyster-breeders and acute biologists believed that, with little labor, great sums might be realized by raising oysters for the table. This is comprehensible, for the reason that the official reports of England, France, and America concerning oyster-culture, from which the large figures were taken, present either no information as to their true significance, or that only of a scattered nature, intelligible to those alone who are already acquainted with the subject. In order to gain this acquaintance and comprehend the true significance of such figures it is necessary to become informed as to the nature and the condition of life of the oyster; and in regard to both of these subjects biologists, as well as breeders and consumers of oysters, will find in the present work all that is necessary to enable them to form an opinion upon the questions which will arise in regard to the breeding and rearing of oysters. I believe I have clearly demonstrated that true oyster-culture must be conducted according to the same principles that are employed in the extensive cultivation of any other living commodity. If I have done so, then I have accomplished what should not have been necessary; for what is more natural than that both oysters and oyster-culture should be subject to the same universal, controlling, biological laws. And yet an explanation was

* Die Auster und die Austernwirthschaft; von Karl Möbius, Professor der Zoologie in Kiel. Mit einer Karte und neun Holzschnitten. Berlin, Verlag von Wiegandt, Hempel & Parey. 1877. Small octavo; pp. 126. Translated by H. J. Rice, B. Sc., by permission of the author, by whom electrotypes of the original cuts have been furnished.

necessary, for not only the ignorant in natural science, but men also who teach and write upon biological subjects have, even in our day, expected the most impossible results from the artificial breeding of oysters. The investigator has seldom to seek for new facts and ideas alone; generally, in the first place, he must be able to recognize and expunge from the system any errors which may exist in the knowledge previously acquired, and in their places establish those facts and ideas which he has found to be true. And while I am well aware that the little book hereby presented to the world contains but a very modest share of what we wish to know with certainty concerning oyster biology and oyster culture; still I have allowed it to appear because, incomplete as it is, it will give welcome information to many biologists and oyster-breeders, and will serve as a safe basis for the operations of those governments which have within the limits of their territories natural oyster-banks which they desire to have managed in the best interests of the general public. Those, of course, who delude themselves with the belief that, by means of artificial cultivation, oysters can be bred in great quantities wherever there may be sea-water, will scarcely agree with my book, and it is indeed quite certain that it will not convince them of their error. But the most dazzling error does not become transformed into truth, however long and firmly one may believe in it.

KARL MÖBIUS.

KIEL, *July* 8, 1877.

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1.—THE SEA-FLATS.

Among those oysters which are produced in the waters of the west coast of Europe the Holstein oyster has, for more than a hundred years, maintained a well-merited celebrity. The beds which furnish them lie along the west coast of Schleswig-Holstein, in a territory only 74 kilometers long by 22 broad. The most and the best oysters are found on the east side of the island of Sylt and in the neighborhood of the islands of Amrum and Föhr.

Along the northern boundary of the German oyster-territory, near the island of Röm, and along the southern boundary, near the islands of Pellworm and Nordstrand, opposite the city of Husum, there are only a few insignificant beds. And since the flavor of the oyster is entirely dependent upon the quality and quantity of food in the water in which it grows, it becomes necessary, first of all, to examine into the character of the soil and water of the Schleswig-Holstein Archipelago. In comparison with the open North Sea this portion of our coast is a very shallow division of the ocean. Along the entire southern portion of the open North Sea, between Germany, Holland, England and Scotland, the general depth is from 35 to 45 meters. In no place in the Schleswig-Holstein Archipelago is the water as deep as this, the greatest depth being 15 to 20 meters, and this only in the channels which connect it with the open sea. The floor of this archipelago is raised above the deep

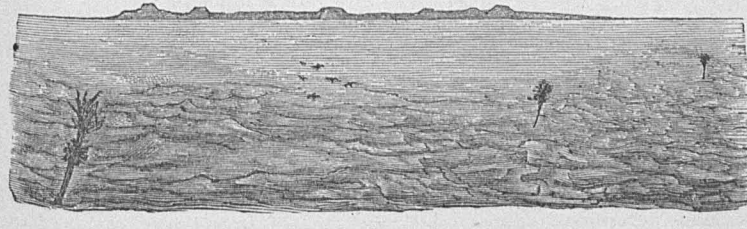
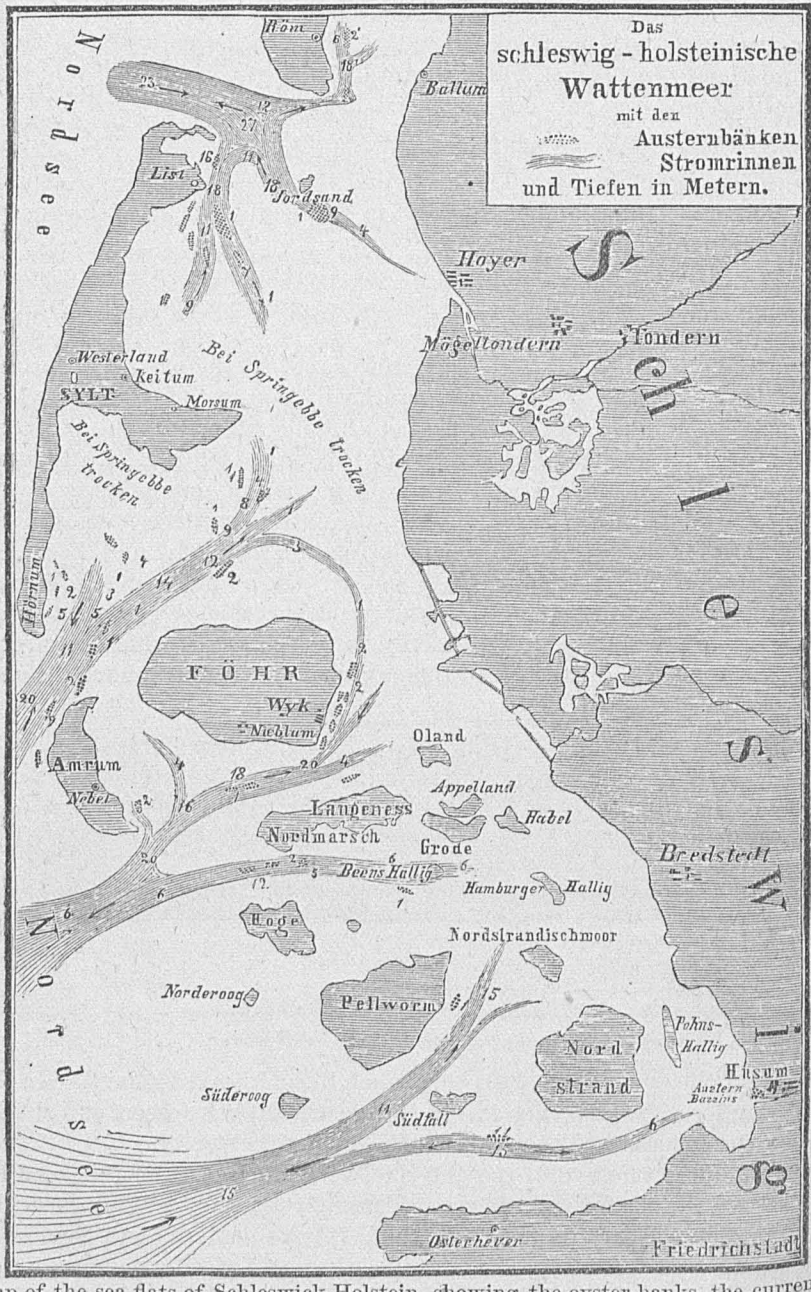


FIG. 1.

The *sea-flats*, with three buoys indicating navigable water. In the background the Hallig Langeness is seen above the surface of the water.

bottom of the open North Sea, very much like a high table-land. In this table-land valleys, varying in depth and width, have been cut out between the islands and the mainland. At high water, the entire floor is covered, but at the end of the ebb-tide, very much of this table-land lies dry above the surface of the sea. These stretches of sea-bottom which thus become dry are termed "Watten," (plains or flats,) and from these "Watten" this archipelago has received the name of "Wattenmeer," (sea-flats.) The water, which during the ebb-tide runs off from the flats, flows in both shallow and deep channels, called by the sailors "Leien" and "Tiefen," partly in a northerly, partly in a southerly direction, into the

open sea, until the incoming flood-tide, which flows in from both sides twice daily, stops the ebbing water and turns it back. The water now



Map of the sea-flats of Schleswick-Holstein, showing the oyster-banks, the currents, and the depths in meters.

rises once more. The Leien and Tiefen can no longer hold it, and it pours over their banks and over the flats, finally flooding them to

such a depth that small vessels can pass over places where only a few hours before men and wagons might travel with perfect safety. In an investigation of the oyster-beds our little steamer got into too shallow water between the island of Föhr and the mainland, and ran fast aground about nine o'clock in the morning. The water was falling, and in a few hours it was entirely out. We descended and went on foot to Hallig Oland,* which lay like a green plate, upon the level, grayish sea-bottom, about one kilometer to the eastward of our vessel. While upon this Hallig we visited a hill which had been formed by artificial means. Upon the hill was a fresh-water pond surrounded by a small group of dwellings, among which was a church encompassed by graves. We then returned to our vessel before the water had again flooded the flats. At about seven o'clock in the evening the water had risen so high that our vessel began to rock; it soon floated, and we steamed to Föhr, to anchor for the night in the harbor of Wyk.

Along the entire German coast, from Röm in the north, upon the Danish border, to Borkum in the west, near the islands of Holland, the sea is of a similar character. Thus, before the mouth of the Elbe, from Cuxhafen to the island of Neuwerk, the sea-bottom is laid bare with every ebbing of the tide, for a breadth of 7 to 8 kilometers. At such times one can reach the island on foot, on horseback, or with a wagon. In passing over this flat one finds himself at such times on a level with the sails of vessels which are passing by upon the sea, and along the border of the retreating waters and the emerging sea-bottom one sees scattered flocks of sea-birds hunting the uncovered worms, mussels, and crabs before they withdraw into the earth. When the flats, at the time of the lowest ebb, are lying, dry and silent, above the water, one can already hear in the distant depths the roar of the incoming flood. First it comes in slowly, then faster and faster, and finally more slowly again, until at the full flood the water stands over the northern por-

* *Halligen* is a name given to small, low islands in the Schleswig-Holstein Archipelago, composed of marsh land, and not protected by dikes from high tides. They are green plains, enlivened by pasturing cattle and sheep, and lie only a foot above ordinary high-water level. They are overflowed by the water during storms. The word *Hallig* is perhaps derived from *Haf-lik*. That portion of the coast which is dry during the ebb and covered during the flood tide is called *Haf; lik* means like, similar. No other land is so similar to the *Haf* land as the land of the Halligen.

The islands of the Schleswig-Holstein sea-flats consist either of low marsh land protected by dikes, or of higher sand tracts and downs.

Nordstrand and Pellworm are marsh islands; Föhr is marsh and sand together, and Sylt and Amrum have high sand tracts and downs.

The marsh soil is a gray, uniform, fine mass without any stones; when wet it becomes tough and sticky. It originated from muddy material brought down by rivers and streams and deposited in quiet places along the sea-coast. The high sand tracts are composed of old raised sea-bottoms. They are uneven, consist principally of coarse sand, and are much less fertile than the rich marsh soil, which, without manuring, yields abundant harvests.

tion of the flats nearly 2 meters higher, and over the southern portion, out from the mouth of the Elbe, nearly 3 meters higher than at the ebb. The tide generally attains three-fourths of its entire height about three hours after turning. In this short time immense masses of water move towards the coast, and in many places currents are formed as swift as the current of the Rhine between Coblenz and Bonn, the rate of which is from 1.5 to 2 meters per second. Yet the ebb-currents are nearly everywhere stronger than the flood-currents, since they not only carry off the sea-water which has been brought in, but also the fresh water from the land, which was checked in its flow during the flood. Hence the ebb-currents bring about much greater changes in the soil of the sea-flats than the flood-currents, and they displace and transport the constituents of the flats in the most powerful manner, wherever great fresh-water streams enter the sea, as at the mouths of the Eider, Elbe, Weser, and Ems. Here the floating buoys and the implanted buoy-stakes (Baken), which indicate navigable water for vessels, are changed nearly every year because of the changes in the channels.

The principal ingredient of the bottom of this changeful sea is quartz sand. In many places there are accumulations of mud, which is very slimy and sticky, and contains much organic matter. This mud is found along the shores of the mainland and on the east side of the island of Sylt, principally at those points where, after the changing of the currents, the water does not flow fast enough to carry away all of the muddy material which was deposited upon the bottom as the tide ran out. Along the slopes which lie between those portions of the flats, which the tide leaves dry, and the deep channels are long dry stretches of soil where the ground is covered with coarse sand, small and large stones, and shells. At such places colonies of oysters, so-called oyster-beds, are found, along with many other sea-animals.

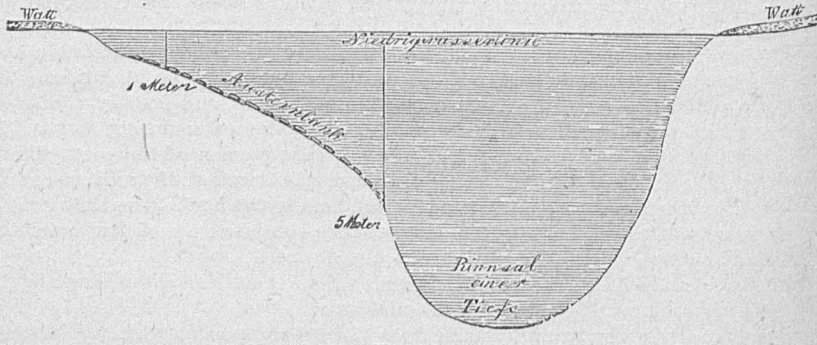


FIG. 2.

Diagram of a cross-section of a deep channel in the sea-flats, upon the left bank of which lies an oyster-bed. Upon both sides are flats which are left dry by the ebb-tide. (The breadth of the channel is drawn upon a much smaller scale than the depth.)

2.—OYSTER-BANKS AND OYSTERING.

By far the greater number of our oyster-beds are never exposed to view on account of the muddiness of the water of the sea-flats, from the continual stirring up of the sediment upon the bottom. Only when, during the lowest ebb of the spring-tides, easterly winds drive off a great deal of water from the land, does the sea along the border of many beds become so shallow that the oysters can be seen, and even taken up with the hand. This state of affairs occurs upon the oyster-beds which are numerous along the east coast of the island of Föhr, and in one autumn as many as 20,000 oysters could be gathered from these beds by hand and transplanted into deeper waters.

Generally one is obliged to use measuring-sticks or dredge-nets in order to tell when he is over a desired oyster-bed. The measuring-sticks are poles, five to six meters long, with the lower half divided off, by different colors, into feet. They are used from vessels, in shallow portions of the flats, in order to ascertain during the journey whether the depth increases or diminishes, so that the vessel may not run aground. The measuring-rod is pushed down to the bottom, and one can thus easily tell whether the bottom is composed of soft mud or pure sand, or whether it is covered with shells.

The dredge used by the oyster-men (Fig. 3) consists of an iron frame upon either side of which there is a shank. These shanks, or side-pieces, are brought together and united, at a short distance from the frame, so as to form a ring in which the dredge-rope is fastened. Fastened to the frame upon the opposite side from the shanks is a net whose upper half consists of coarse yarn or cord, and the lower half, that which drags along the sea-bottom, is, for greater durability, made of iron rings united together, each of which has a diameter of from six to seven centimeters. The entire net weighs from 50 to 60 pounds.

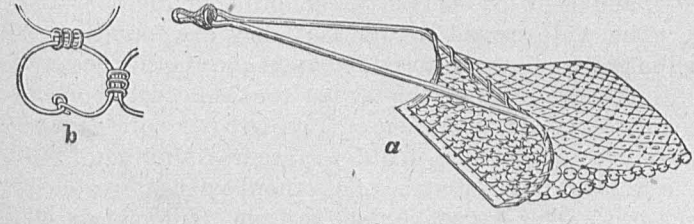


FIG. 3.

Oyster-dredge. The frame and handles are made of iron. The upper portion of the bag is made of coarse net-yarn, the under portion of iron rings from six to seven centimeters in diameter. The form of the rings and the method of uniting them is represented with greater exactness at *b*.

The older oyster-dredgers know the position of all the oyster-beds with great precision, and they guide their vessels to the desired places by reckonings from high-lying points of the coast and islands, from light-

houses, churches, windmills, and houses. Their vessels are yacht-like, with a capacity of from three to six tons. Each one generally carries two sailors in addition to the owner.

Upon the Schleswig-Holstein banks there are fourteen vessels engaged in the oyster business. When the wind is favorable and brisk, four dredges can be used at the same time; but with a light wind, two, or one only can be dragged. They are fastened by means of strong ropes to the windward side of the vessel. One hand is kept upon the dredge-rope, in order to tell by the feel whether it is passing over smooth ground or over oyster-beds, for the rope is given an irregular, jerking motion upon rough bottom. Generally the net is allowed to drag from five to ten minutes; then it is drawn up by two or three men, and the entire contents of the bag emptied upon the deck. This mass consists of old oyster-shells, mussels of various kinds, living oysters, snails, crabs, worms, star-fish, sea-urchins, polyps, sponges, and sea-weeds, which are generally mixed up with sand and mud. From this heterogeneous heap all the matured oysters are now picked out. As they pass singly through the hands of the fishermen, the coarsest of the foreign material is cut and scraped from the shells with a knife, and then the oysters are thrown into baskets. In these they are shaken about, in order to get off any material which has escaped the knife. Ropes are then fastened around the baskets, which are put overboard, and raised and lowered in the sea until all dirt is completely washed from the oysters. They are now for the first time in the condition in which they appear in commerce. Despite these manifold cleansings, many oysters when they are exposed for sale are covered with dead and living animals, and the peculiar odor which oysters have when carried into the interior arises from the death and decay of the organic material upon the outside of the shells, and does not pertain to the living oyster itself. In no place upon the sea-flats do oysters grow upon rocky bottom. They grow best where there is a substratum of old oyster and other shells. The most of them lie singly, and they are seldom found growing together in clumps or masses. The wide-spread notion that they are found growing firmly attached to the sea-bottom, and piled upon one another, layer upon layer, is accordingly false. Upon the best of the Schleswig-Holstein beds the dredge must drag over a surface of from 1 to 3 square meters, and often over a still greater distance, in order to secure a single full-grown oyster. Over the Schleswig-Holstein sea-flats there exist 50 oyster-beds of very different sizes. The largest is not far from 2 kilometers long, but the greater number are shorter than this. Their breadth is much less than their length, which is in the same direction as the channels along the slopes of which they lie. The greater number of the beds have a depth of water of at least 2 meters above them when the ebb-tide has left the neighboring flats dry.

There are no beds upon our sea-flats which have a greater depth of water over them than from 6 to 9 meters. Although all the beds

lie within an area 74 kilometers long by 22 broad, yet the nature of the oysters, and especially the form and solidity of the shell and the flavor of the animal, differ very greatly. Upon two beds inside of the south point of the island of Sylt are found oysters which in fullness and delicacy of flavor are not inferior to the best English "natives."

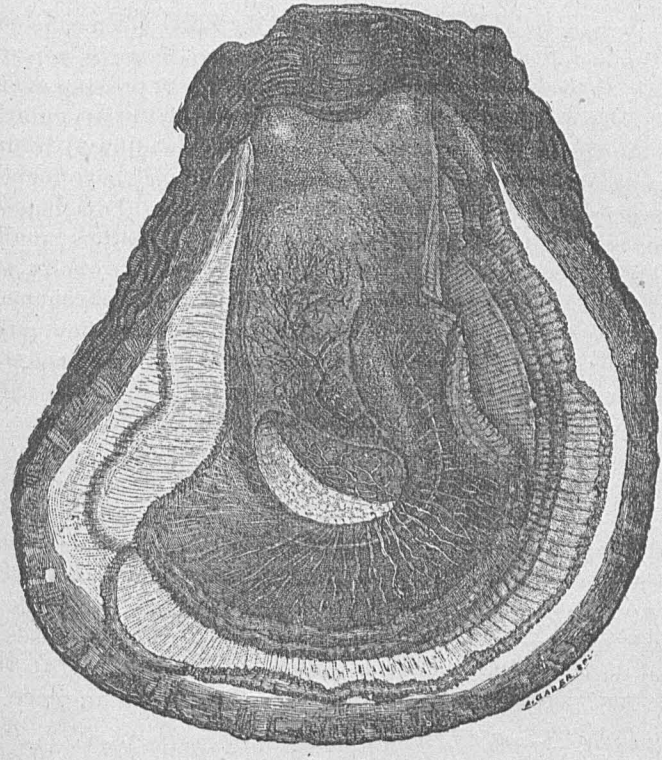


FIG. 4.

A full-grown Schleswig-Holstein oyster, about ten years of age. It is a female with eggs, and was drawn from life, on the 14th of June, 1871, by Mr. J. Wittmaack. The right, or upper, valve of the shell has been removed. The oyster lies in the hollow of the left valve, in its natural position. On the upper side the thickened layers of the shell can be seen. Each year new shell-layers are formed. The inner surface of the shell is white to near the edge, where it becomes of a brownish color. Above, close to the back of the animal, which is somewhat curved, is a crescent-shaped brown mass, the shell band or ligament. In separating the valves this band is broken across in the middle. The right side of the animal is exposed to view; the left rests upon the inner hollow surface of the left valve. The upper layer, with its edge turned back, is the mantle-lobe or fold of the right side. The white lines seen in it are muscular fibers. The left mantle-lobe lies close upon the shell, and is more expanded than the right. The gills are to be seen just below the inverted edge of the right mantle-lobe. In the oyster they are four in number. The outer gill of the right side is the most exposed; a narrow border of two others can be seen. All four have furrows running from the inside to the edges. Upon these furrows are situated cilia, by the motion of which water is driven over the gills for the purposes of respiration. Along the

upper portion of the gills hang two pairs of furrowed folds, or lobes (the labial palps), between which is the mouth opening. The swollen upper portion of the body contains the generative organs, the liver, stomach, intestine, and heart. The bean-shaped organ near the center of the body is the adductor muscle, the so-called *stool*. This muscle which closes the valves consists of an upper grayish and a lower whitish portion.

3.—THE REPRODUCTION OF THE OYSTER.

If the surfaces of all the Schleswig-Holstein oyster-beds should be united together they would not cover a space equal to the one-hundredth part of that portion of the sea-flats which remain under water. Why is this? Is it because from a lack of oyster-broods all the places between the banks are yet to be peopled? I cannot accept this view for the following reasons: The entire number of full-grown oysters existing upon the Schleswig-Holstein beds I estimate to be not far from five millions. According to my observations, 44 per cent. at least of these oysters will bring forth broods of young oysters in the course of a summer.

*The data from which I arrived at the conclusion that at least 44 per cent. of full-grown oysters spawn during each spawning season were derived from the following observations:

I opened on—	Oysters.	These contained—		In all.	Per cent.
		White germs.	Bluish germs.		
June 16, 1873	112	5	4	9	8
July 6, 1873	03	7	6	13	20.6
August 12–17, 1869	480	.....	.....	72	15.8
Total	.....	.....	.....	.....	44.4

I do not know the length of time of development, from the beginning of segmentation of the egg until all the embryos have passed out from the mother animal, but it is probably less than four weeks; for while, in the last weeks of May in the years 1871 and 1874, from June 4 to 6 of the year 1873, and June 6 to 9 of the year 1876, in hundreds of oysters which I opened, I found no embryos in the beard, yet of 112 oysters dredged on the 16th of June, 1873, five contained germs of a white color, and four contained germs already bluish, and possessed of shells and vela.

If by the end of the first week in June no eggs have been laid, but by the beginning of the third week germs are found of a bluish color, then the transformation of the white germ into the blue cannot consume more than a week, and these germs will hardly remain in the beard for an additional period of more than two weeks. Those oysters, then, which are found with eggs during each of the following months must be different individuals from those which spawned during the earlier periods; hence, it is right to add together the percentage of egg-bearing oysters found separately in June, July, and August in order to arrive at the percentage of egg-bearers for the entire summer. And since many oysters are found upon the Schleswig-Holstein beds with germs of a bluish color in the mantle even in the beginning of September, then the percentage of 44.4 per cent. surely cannot be too high. Oysters are hermaphrodite. In a large number of oysters which I examined I found ova in the generative organs, but no

Longitudinal cross-section of a seven or eight years old oyster.

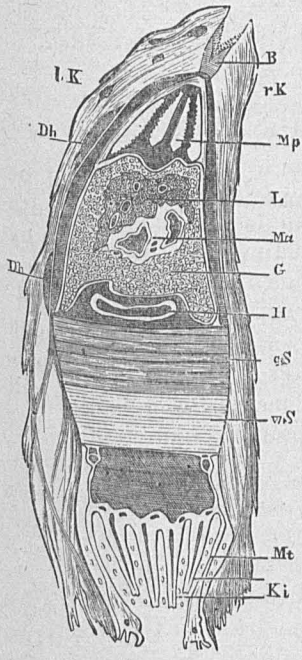


FIG. 5.

The curved left valve (*lK*) of the shell is, as usual, somewhat thicker than the right (*rK*). They are bound together by the ligament *B*, which keeps them separated a certain distance from each other so long as the adductor muscle (*gS* and *wS*) does not by its contraction stretch the ligament and close the valves. The shell-muscle consists of fine gray (*gS*) and coarse white muscular fibers (*wS*). In the neighborhood of the ligament, in the left valve, are four small perforations made by a sponge (*Clione celata*) which lives housed in the oyster-shells of the sea-flats. Other larger holes are often found in the shells of old oysters. They are filled with water, which has a rank, gaseous smell; hence they are called "gas-holes." The thickest part of the shell is near where the shell-muscle is attached. The shell consists principally of carbonate of lime, arranged in firm, glistening layers. Close above the shell-muscle lies the heart (*H*). The mass over the heart, which in life is of a bright color, consists principally of the organs of generation (*G*). These surround the stomach (*Ma*) and the liver (*L*), which during life is brown in color. In the space above the intestines is seen the sections of the four mouth-plates (*Mp*). Under the shell-muscle and close to the shell are the two mantle-lobes (*Mt*), whose edges are thickened and beset with fringes. They contain muscle and nerve fibers. During life the mantle-lobes can be thrust out over the edge of the shell. From the edges of the mantle-lobes all the shell material is secreted. Between the two mantle-lobes there is a wide space, in which hang the four gills (*Ki*). Each gill-

spermatozoa; in many others I found spermatozoa, but no ova; and in seven oysters which bore embryos of a blue color upon the beard I found spermatozoa in the generative organs.

Three oysters with embryos of a white color attached to the beard had no spermatozoa in the generative organs. Most mature oysters produce either ova or spermatozoa, and not both at the same time. Of 309 oysters which were dredged on the 25th of May from four different beds along the east side of the island of Sylt, and which were examined from the 26th of May to the 1st of June, the sex of 18 per cent. could not be determined; of the remaining 82 per cent., one-half were males and one-half females In none of them were the generative products completely matured. From these results I conclude that the ova and spermatozoa do not arise in the generative organs of the oyster contemporaneously, but that one follows the other. The spermatozoa can arise very soon after the expulsion of the ova, and probably one-half of the oysters of a territory during any spawning period produce eggs only, the other half spermatozoa only.

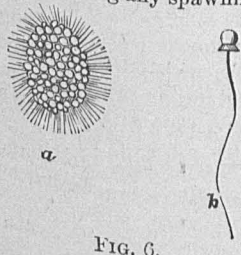


FIG. 6.

a. A mass of spermatozoa, still clustered together just as they arise in the generative organs, enlarged 275 times.

b. A single spermatozoan, enlarged 1,000 times. By the motion of the tail the body is driven forward.

The ripe spermatozoa pass from the generative organs into the water, with which they pass into the brood-chamber of the female oyster, where they impregnate the freshly-laid eggs by penetrating the yolk and uniting with it.

lobe consists of two plates, which grow together above and below. The mantle-folds and the gills taken together form the so-called "beard" of the oyster. In the spaces between the layers of the beard the development of the eggs takes place. In the figure a few germs are represented in this brood-cavity.

Now, a mature egg-bearing oyster (Fig. 4) lays about one million of eggs, so that during the breeding season there are upon our oyster-beds at least 2,200,000,000,000 young oysters, which surely would suffice to transform the entire extent of the sea-flats into an unbroken oyster-bed; for if such a number of young oysters should be distributed over a surface 74 kilometers long by 22 broad, 1,351 oysters would be allotted to every square meter. But this sum of 2,200,000,000,000 young oysters is undoubtedly less than that in reality hatched out, for not only do those full-grown oysters which are over six years of age spawn, but they begin to propagate during their second or third year, although it is true that the young ones have fewer eggs than those which are fully developed. At a very moderate estimation, the total number of three to six years old oysters which lie upon our beds will produce three hundred billions of eggs. This number added to that produced by the five millions of full-grown oysters would give for every square meter of surface not merely 1,351 young oysters, but at least 1,535. In order to determine how many eggs oysters produce, they must be examined during their spawning season. This begins upon the Schleswig-Holstein beds in the middle of June, and lasts until the end of August or beginning of September. The spawning oyster does not allow its ripe eggs to fall into the water, as do many other mollusks, but retains them in the so-called beard, the mantle, and gill-plates (Fig. 5) until they become little swimming animals (Fig. 7). The eggs are white, and cover the mantle and gill-plates as a semi-fluid, cream-like mass. As soon as they leave the generative organs the development of the germ begins. The entire yolk-mass of the egg divides into cells, and these cells form a hollow, sphere-like body, in which an intestinal canal arises by the invagination of one side (Fig. 7). Very soon the beginnings of the shell appear along the right and left sides of the back of the embryo, and not long afterwards a ciliated pad, the velum, is formed along the under side. This velum can be thrust out from between the valves of the shell at the will of the young animal, and used, by the motion of its cilia, as an organ for driving food to the mouth, or, in swimming, as a rudder. During these transformations the original cream-white color of the germ changes into pale gray, and finally into a deep bluish-gray color. At this time they have a long-oval outline, and are from 0.15 to 0.18 of a millimeter in breadth. Over 300,000 can find room upon a square centimeter of surface. If an oyster in which the embryos are in this condition is opened, there will be found upon its beard a slimy coating thickly loaded with grayish-blue granules. These granules are the embryo oysters, and if a drop of the granular slime be placed in a dish with pure sea-water the young animals will soon separate from the mass, and spread swimming through the entire

water. When the embryos are at this stage their number may be estimated in the following manner: The whole mass of embryos is carefully scraped from the beard of the mother oyster by means of a small hair-brush. The whole mass is then weighed, and afterwards a small portion of the mass. This small portion is then diluted with water or spirits of wine, and the embryos portioned out into a number of small glass dishes,

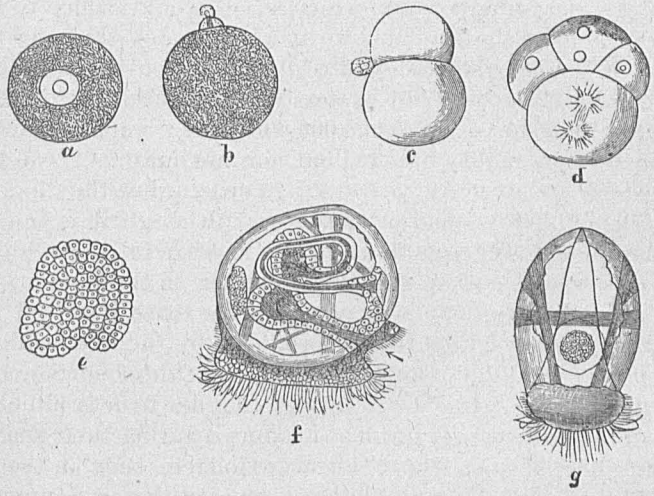


FIG. 7.

A few stages of development of the embryo oyster; *a* to *e* enlarged 125 times, *f* and *g*, 150 times.

a. The freshly-produced egg. In the yolk-mass is seen the germinative vesicle, with its nucleus.

b. Commencement of development. A part of the vesicle has passed out.

c. Division of the egg into two unequal portions.

d. A later stage.

e. The germ now consists of a layer of cells, which have arisen by repeated divisions of previous cells. They form a hollow vesicle, with a depression upon one side, which is the beginning of the digestive system.

f. The embryo is now represented at about the stage at which it leaves the brood-cavity. It has a transparent two-valved shell, and inside of the body the course of the digestive tract can be made out. An arrow shows the position of the mouth, and those within the body indicate the course which the food takes. Behind the œsophagus is the stomach, with two enlargements. The end of the intestine is shown over the mouth. To the left of the first enlargement of the stomach is the shell-muscle. On the under side is the velum, which is the locomotive organ of the young oyster. The young oyster can, by means of muscles, draw the velum entirely within the shell.

g. An embryo, seen from behind. Upon the sides are seen the valves of the shell, and across the body, from one valve to another, passes the shell-muscle. Below this muscle is the velum, with the muscles, one on each side, which serve to withdraw it into the shell.

so that they can be placed under the microscope and counted. Thus, knowing the weight of the small portion and the number of embryos in

it by count, we can estimate the total number of embryos from the weight of the entire mass, which is also known. In this manner I estimated the number of embryos in each of five full-grown Schleswig-Holstein oysters, caught in August, 1869, and found that the average number was 1,012,955.

4.—WHY ARE OYSTERS NOT FOUND OVER ALL PORTIONS OF THE SEA-FLATS?

It is now clear that the fruitfulness of the oyster is extraordinarily great, and that the extension of oyster-beds over the entire surface of the sea-flats does not fail of being accomplished from a lack of young oysters, but from other causes. It then becomes our duty to investigate into the characteristics of our sea-flats; in order to determine whether some portions are more suitable for the growth of oysters than others; and whether the saltness, temperature and movement of the water, the amount of food which it contains, and the nature of the ground composing the oyster-banks, differ in any respect from these same features as observed in other places over the bottom.

The saltness of the upper layers of the water of the open North Sea is from 3.47 to 3.50 per cent.* The water of the sea-flats is slightly less salt, being only from 3 to 3.3 per cent.† Here upon our sea-flats, and in other European coast-seas, where the water is less salt, the oysters acquire a much finer flavor than upon the ground of the open North Sea,‡ where they live in water 35 meters or more in depth, with a percentage of salt of about 3.5.

That coast-water is, then, the most desirable for oyster-culture which

*Dr. H. A. Meyer has published a paper concerning the *saltness, temperature,* and *currents* of the North Sea in the "Bericht der Commission zur Untersuchung der deutschen Meere über die Expedition zur chemisch.-phys. und biologischen Untersuchung der Nordsee, 1872. Berlin, 1875." (Report of the commission for the investigation of the German Ocean upon the expedition for the chemico-physiological and biological investigation of the North Sea.) (Specific weight and saltness, page 18.)

†I have myself repeatedly determined the temperature and saltness of the water during investigations of the oyster-beds of the sea-flats; and since 1872 the commission for the investigation of the German Ocean have caused regular stated observations to be made, which, since 1874, have appeared under the title "Ergebnisse der Beobachtungs-Stationen an den deutschen Küsten über die physik. Eigenschaften der Ostsee und Nordsee. Berlin, 1874, 1875, 1876." (Results of investigations into the physical characteristics of the North and East Seas made at observation stations along the German coasts.)

‡Many oysters are taken north of Germany and Holland, east of England, and in the channel between England and France. The German fishermen of Blankenese and Finkenwärder, near Hamburg, who fish with great dredge-nets for flounders, turbots, and soles out from the mouth of the Elbe, often dredge oysters along with their fish. The oyster-grounds of the open North Sea lie mostly from 33 to 34 meters beneath the surface of the water. They begin with a small stretch to the southeast of the island of Heligoland, extend from this island in a west-northwest direction, and form a territory 15 to 22 kilometers broad, which spreads out far to the west. Fishermen from Holland and Germany dredge for oysters here, especially during the months of August,

contains about 3 per cent. of salt; and since not only over our oyster-beds, but over our entire sea-flats, the water possesses this degree of saltness, neither a lack nor an excess of salt can hinder the extension of the beds over the whole area. Even less can the temperature of the water hinder their extension, for the variation is the same over the oyster-beds as at other points, and it fluctuates, during the course of the year, from 20° C. above zero to 2° C. below. Nor can a lack of motion of the water or of nutriment be the cause why the oyster-beds have not during the past hundreds of years extended themselves beyond certain definite limits, for floating everywhere, in the ebbing and flooding water, are microscopic plants and animals, and much dead organic matter, which would nourish large numbers of oysters, just as they do multitudes of soft clams (*Mya arenaria*), edible mussels (*Mytilus edulis*), and cockles (*Cardium edule*). There remains, then, as the single natural hinderance to a further extension of the oyster-beds, the unfavorable condition of the ground over the greater portion of the sea-flats. Oysters cannot thrive where the ground is composed of moving sand, or where mud is being deposited, and one of these conditions or the other is found over the greater part of the sea-flats. The number and size of those places where, notwithstanding the daily ebb and flood currents, the ground remains unchanged and free from mud are very limited. Only along the slopes of certain channels to the north of the mouth of the Eider do we find united all the conditions favorable for such places, and only within these limited districts can young oysters grow to complete maturity.

When the young oysters attached to the beard of the mother have reached a diameter of 0.15 to 0.18 of a millimeter, when their digestive organs have reached such a stage that the young animal can receive nourishment through them, and when the velum, by means of its cilia, is in a condition to enable them to move about, they leave the brood-cavity, swarm at the surface, and after swimming about for a short time finally sink once more to the bottom. If the swarm of young oysters settles upon a spot covered with clean stones or mussel shells to which they can become attached, they have a prospect of growing to maturity; but if, on the contrary, they settle upon a changing sand-bank or upon a muddy bottom, they will surely be lost; for at the close of their swarming period their velum, which is their swimming organ, is absorbed, and

September, and October, and often catch, at a single drag of the dredge, as many as 1,000 oysters. Sometimes great bunches of oysters growing attached to one another are gathered into the net.

The deep-sea oysters grow much larger than those found along the coasts. Specimens are taken with shells 13 centimeters broad. Their flesh is tough, yet large numbers are consumed in England, France, and Germany; in England and France chiefly in pastries and sauces, but in Germany many are eaten fresh, especially in Hanover and Bremen. For general winter use they are kept under water in certain places adapted to them, especially near the island of Wangeroog. (S. Metzger's Beitrüge zu dem Jahresbericht d. Commiss. zur Unt. d. deutschen Meere, 1873, page 171, u. 1875, page 252.)

no muscular foot, as an organ of locomotion, is formed in its place, as with most other bivalves. The oyster must thus remain upon that spot where it settles at the close of its swimming career. If currents and waves cover it with sand, if, during tidal changes, the quiet water allows mud to sink down upon it, if plants luxuriate over it, then, being unable to work its way out into free water, and wander to a better place, it must remain as it is, and, from lack of air and nourishment, soon perish.

5.—ARTIFICIAL OYSTER-BREEDING IN FRANCE.

The yield of many once rich oyster-beds along the west coast of France had fallen off to such an extent from 1850 to 1860 that Prof. P. Coste* of Paris, the originator of the celebrated fish-breeding establishment near Hüningen, in Alsace, presented, in 1859, to the Emperor Napoleon III, a plan for the artificial breeding of oysters, by which means he would prevent the destruction of a large number of young oysters at the beginning of their lives as independent animals. The first attempt to render the impoverished oyster-beds once more fruitful was made in the Bay of Saint-Brieuc, upon the north coast of Brittany. Here, where 1,400 men were formerly engaged yearly in fishing for oysters, and where the yield was of the annual value of from 300,000 to 400,000 francs, the oyster-fishery, during the ten years from 1850 to 1860, had become almost entirely valueless.

In the months of April and May, 1858, under the direction of Professor Coste, vast numbers of the old shells of oysters and other mollusks were scattered over the ground, and great numbers of fascines were sunk and anchored with stones so as to float in the water just free above the bottom. After 1,000 hectares of sea-bottom had thus been excellently prepared for the reception of the young oyster-broods, three millions of mature oysters were planted upon it.

In the autumn all the shells and the twigs of the fascines were found so thickly covered with young oysters that even the wildest expectations were more than realized.

This abundance of young oysters was something indeed entirely natural. Professor Coste, in his report to the Emperor, January 12, 1859, says, when speaking of this experiment in the Bay of Saint-Brieuc, that every mature oyster produces from two to three million embryos, but he does not inform us as to his authority for this statement. If we allow that those oysters which were planted for breeding purposes in the Bay of Saint-Brieuc produced each only the same number of embryos as are produced by a Schleswig-Holstein oyster, the entire progeny would amount to the enormous sum of 1,320,000,000,000, young oysters. Such a number would allow 132,000 to fall upon every square meter of sea-bottom, and for the reception of this number

* *Professor Coste* died in 1873. His chief work, upon the artificial breeding of oysters, mussels, and fish, appeared under the title: "Voyage d'Exploration sur le Littoral de la France et de l'Italie, 2. éd., Paris, 1861."

there was enough suitable material already spread out about the mother oysters.

This experiment at Saint-Brieuc was considered to completely demonstrate the possibility of artificial oyster-breeding. It was believed by many that the whole coast of France might be bordered with oyster-beds, and they began already to reckon, according to the market-price of oysters at that time, which was 20 francs per thousand, how many millions of francs would be the result of this sea-harvest. Capitalists hastened to form companies for the purpose of engaging in the business, and obtain from the government the right to lay down oyster-beds upon certain definite portions of sea-bottom along the coast. But in not a single case were the rich earnings which had been reckoned upon beforehand as resulting from the sale of marketable oysters ever realized; and not only this, but the money which had been paid for the preparation of the ground and the purchase and transportation of breeding oysters from natural beds gave no returns, and for the most part proved an entire loss. The young oysters were nearly all covered up by sand or mud, or eaten by other sea-animals. This explains why, in the year 1869, I found in the Bay of Saint-Brieuc nothing remaining of the beds which had been thus artificially formed in 1858. The bottom of the bay had become unsuitable for the growth of oysters because of the wide-spread distribution of sand and the changes which it was constantly undergoing.

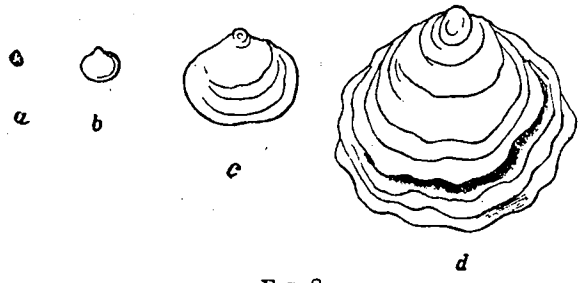


FIG. 8.

Outline figures of young oysters, natural size.—*a*. About one month old. *b*. About two months old. *c*. About four months old. *d*. From twelve to fifteen months old.

At the present time the extensive propagation of oysters by this method of breeding is carried on with success only in certain places along the French coast where the natural conditions are especially favorable. The Bay of Arcachon, south of Bordeaux, is one of the favored places. There, as I myself have observed, the soil and the saltness of the water are very similar to that of our sea-flats. We find there wide-spread shallow sand and mud banks which are covered with vast numbers of bivalve-shells. These banks are left dry by the ebb-tide, and between them are deep channels through which the water at ebb and flood tide flow out and in. In places which remain always under water natural oyster-beds are found, and at other places longer stretches along the soft, bare slopes of the water-courses are made use of as breeding-beds. Here mother oysters from natural beds are planted, and among them, towards the end of May, are placed old shells and tiles with a covering easily detached, as objects of attachment for the young broods.

In October the young oysters, which have become firmly attached, are freed by means of chisels from the larger of these objects of attachment, and are then placed in flat boxes, 2 meters long, 1 meter broad, and 15 to 30 centimeters high. In detaching the young oysters about one-third are destroyed.

The boxes into which the young oysters are placed are made of thick plank, with wire-sieve bottoms, through which the water can pass in and out. At the corners of each box are fastened stakes which serve to raise the box above the sea-bottom, so that there will be a depth of water of about 10 centimeters between the ground and the wire netting. The object of this protection is to guard the young oysters against small crabs (*Carcinus mœnas*), "drills" (*Murex erinaceus*), and other enemies, which formerly destroyed great numbers of young, as the breeders of Arcachon found out by bitter experience. At this period the shells of the young oysters are too thin to protect their soft bodies from their enemies. While in these breeding-boxes the young oysters must be kept continually under water, so as not to be destroyed, either by being left dry, by the heat of summer, or the cold of winter. In order to accomplish this square trenches, from 30 to 40 meters long and 4 to 5 meters broad, are dug in those portions of the oyster-territory which are left dry by the ebb-tide. The side walls of these excavations are made firm by means of posts and planks, and the spaces between the planking and the banks are packed with clay. The bottom is covered with sand and gravel to serve as a bed for the oysters. At one of the four sides a canal, with a gate, is formed, through which, at the pleasure of the breeder, water can be allowed to flow in during the flood or to pass out during the ebb-tide. In these artificial ponds, called *claires*, the boxes containing the young oysters are placed, nourishment being brought to them by the water which forces its way in through the sieve-bottoms. As often as the condition of the water renders it possible, the breeder opens the tops of the boxes, in order to permit the free entrance of air and light and to remove any accumulations of dirt which may have lodged upon or around the oysters. Two months later he takes the oysters from the boxes and strews them about upon the bottom of the breeding-pond. In these ponds they must not be placed too close together if their best growth is desired. Even into these ponds their numerous enemies will make their way, and in order to protect the oysters from these hordes of spoliators a small-meshed net is drawn over them. It is very desirable to change the oysters, once or twice during the course of the year, into neighboring ponds which have been purified by lying entirely dry for several months. During the warmest and also during the coldest months, especially during ebb-tide, a depth of water of at least 20 centimeters must be retained over the oysters. This troublesome and tedious handling is demanded for at least two years before the oysters can be brought to market. At least this is the case in the Bay of Arcachon. In the year 1874–'75 there were produced in this bay 112,000,000

artificially grown oysters, and in 1875–'76 about 196,000,000. This important yield of the last year, as compared with the poor returns of former years, may be accounted for principally through two causes:

First. The natural oyster-beds in the Bay of Arcachon had had complete rest for the entire two years immediately preceding these rich harvests. During the years 1870–'71 they had produced only 4,897,000 oysters, but after this period of rest, in November, 1874, 8,500 persons assembled, and in the space of three hours, during which time the gathering was in progress, 40,360,000 oysters were taken from the sea. A great number of these were transplanted, as breeding oysters, to the prepared beds, which covered altogether an actual area of sea-bottom of 2,669 hectares (about 5,338 acres).

Second. The former imperfect method of caring for the oysters had been improved to the extent that the young oysters were protected from their enemies, and care was exercised that during hot and cold weather they should always be kept under water.

With the earlier methods very many of the young oysters were destroyed by their enemies, and often, during a few unfavorable summer or winter days, when a low tide left the beds dry, all the young oysters died. The extraordinary yield of oysters in the Bay of Arcachon and at other points along the coast of Brittany, as a result of the improved method of artificial oyster-breeding, has very materially lessened the price of oysters in France, despite the greater consumption occasioned by this abundance. In 1873 oysters sold for 43 francs per thousand, while in 1876 the price was 25 francs per thousand. On this account only those oyster-breeders who attend personally to the work and are assisted in it by their families make anything over and above all expenses. Those who undertake the breeding of oysters, relying upon outside help to do the great amount of work necessary, can gain returns scarcely worthy of the name; at least this is the case in the Bay of Arcachon, as I know from trustworthy sources.

The cost of transforming a hectare of sea-bottom along this coast into an oyster-bed, together with the necessary apparatus for oyster-culture, and a guard-vessel as required by the government, is not less than seven to eight thousand francs.*

* Besides the works of Coste, which have already been mentioned, the following also treat of oyster-breeding in the Bay of Arcachon:

K. Möbius. Ueber Austern- und Miesmuschelzucht und die Hebung derselben an den norddeutschen Küsten. (A report to the hon. minister of agriculture.) Berlin, 1870. pp. 8.

A. Tolle. Die Austernzucht und Seefischerei in Frankreich und England. (A report to the hon. minister of agriculture.) Berlin, 1871. pp. 8.

De Bon. Notice sur la situation de l'ostréiculture en 1875. Paris, 1875. (Extract from the Maritime and Colonial Review.)

6.—ATTEMPTS TO INTRODUCE THE FRENCH SYSTEM OF ARTIFICIAL OYSTER-BREEDING INTO GREAT BRITAIN.

In Great Britain a large number of men are employed in oyster-dredging and in the oyster-trade, and, according to the published official estimate for the year 1870, the yearly value of oysters sold in the kingdom is not far from £4,000,000 sterling. If we take the average price of oysters as one penny (two cents) apiece, which is rather too much than too little, this amount would account for 960,000,000 of oysters.

In the year 1864 there were brought to the London market alone more than 495,000,000 of oysters, which were worth over £2,000,000 sterling. The culture of oysters being thus of so much importance to Great Britain, it was very natural that attempts at artificial oyster-breeding in France should be watched with intense interest, and imitated at various points along the British coast. It was carried on most extensively upon the coast of the small island of Hayling, east from Portsmouth, by the South of England Oyster Company, organized in 1865 with a capital of £50,000. Inside of a dike upon the west side of the island five oyster-beds were prepared, having an extent of sea-bottom of about 32 hectares (about 80 acres). May 11 and 12, 1869, when I visited these beds, several of them had not been overflowed. The natural bottom, which was a sticky mud, had been covered with gravel and mussel-shells, and upon the largest bed hurdles, each 2.4 meters long by 75 centimeters broad, and composed of birch twigs, had been placed so as to rest horizontally at about one-half a meter above the ground. Besides these hurdles, laths, with oyster-shells and bundles of small rods nailed to them, were stuck about over the ground, so that there should be plenty of objects of attachment for the young oysters. The inward and outward flow of the water was regulated by means of a sluice and gate. The mother oysters are generally placed in the beds just before the breeding season.

In 1869 they expected to place upon the beds 50,000 breeding oysters. The water is generally changed every day, except during the winter months, when there would be danger of freezing the oysters, and also except during the swarming period, when the young would be liable to escape into the sea with the changing water. In 1867, 600,000 mature deep-sea oysters were placed on an oyster-bed which covered a surface of 7.3 hectares, and over which 10,000 hurdles were placed as objects of attachment. Upon an average over 12,000 young oysters were found attached to each hurdle, making for all the hurdles a total of more than 120,000,000. In these and other experiments at artificial oyster-breeding in England all the experiences of French oyster-breeders were made use of as far as possible, but, notwithstanding this, at no single breeding station were the expectations of a great yield of marketable oysters ever realized. In London, on the 4th of May, 1876, Mr. Blake, the inspector of fisheries, made, before the commission for the investi-

gation of the oyster-fisheries, the astounding statement that every oyster grown by means of artificial culture near Reculvers, at the mouth of the Thames, cost £50 sterling, that every one grown in Herne Bay cost £100, and in a third place about £500, and that he was prepared to furnish several other examples of a like character. Mr. Blake, who is very well acquainted, from personal observation, with French and English oyster-culture, considers artificial oyster-breeding according to the French method impossible along the British coast, on account of the unfavorable character of the climate.

The most important source whence I have drawn my information in regard to the culture of oysters in England is the report of the select committee on oyster-fisheries, together with the proceedings of the committee, minutes of evidence, appendix, and index, ordered by the House of Commons to be printed July, 1876. This report contains 3,941 questions and answers concerning oyster-culture.

What I have been able to learn, through my own observations, of the English oyster industry I have described in a work referred to in chapter 4. To this, Mr. A. Tolle, who accompanied me as hydraulic engineer of the commission of the Prussian minister of agriculture, has, in a report to the honorable minister, issued a supplement, which is also referred to in the same chapter.

7.—CAN THE FRENCH SYSTEM OF ARTIFICIAL OYSTER-BREEDING BE CARRIED ON IN THE WATERS OF THE GERMAN COAST?

What German who loves oysters has not wished that the whole German coast might be bordered by fruitful oyster-beds? For this reason we wish to investigate as to whether the necessary conditions for artificial oyster-breeding are to be found in the coast-waters of Germany. As regards the saltness of the water, the currents, the food, and even the composition of the soil, our sea-flats will compare as favorably for the artificial gathering of the young broods and for the raising of the same as the Bay of Arcachon, but not as regards temperature and the depth of water.

In the Bay of Arcachon the difference between ordinary high and low tide is 4.5 meters, and during a storm a meter more. But along our North Sea coast during a storm the water rises with the tide even more than twice as high as during ordinary flood-tide. The power of the water during a storm, as compared with the power of the water during an ordinary flood-tide, is much greater along our coast than in the Bay of Arcachon. Hence, we would be obliged to give to our oyster-beds a much greater firmness than the French breeders have to give to theirs. We would also be obliged to place them so far out in the sea that they would be entirely covered with water, even at the lowest ordinary tide, and also give them sufficient stability to withstand, during a storm, a

rise of water of from 2 to 2.5 meters, as well as the great and powerful force of this water-mass. Beds thus laid down would cost much more than the ditched and planked ones of Arcachon. But even if they were so placed as to bid defiance to the most severe flood-storm, they would indeed hardly suffice to protect the breeding oysters from being covered with mud and sand; and thus one flood-storm, or storm in connection with a flood-tide, might destroy the accumulated oysters of many generations. A visit made to the island of Norderney showed us how destructive nature can be to the oyster-beds of our sea-flats. Upon the inner side of this island, early in the year 1869, a surface of 825 square meters was dug out, and made firm by double-planked walls to about the height of half tide. The space between the walls and banks was filled in with sand and mud, and the inclosure itself was divided into two compartments, one of which was longer than the other.

In the smaller division the water was detained to enable it to deposit its coarser materials before it was allowed to pass into the larger one. In the beginning of June, 20,000 mature oysters were placed in these artificial beds, with the expectation of reaping a rich harvest of young oysters; but the harvest never came. Star-fish and crabs attacked the oysters, in the beginning of August flood-storms broke down the walls, and the storms of autumn completed the work of destruction, so that very soon nothing was left of the entire enterprise. If the situation of the free sea-flats is not suitable for the formation of oyster-beds, perhaps there is still a possibility of artificial oyster-breeding being carried on inside of the dikes which protect the fertile marsh-land along the German coast from the encroachments of the waters of the North Sea. For this purpose basins would have to be dug out inside of the dike and placed in connection with the sea by means of canals. Where these canals cut through the dike it would be necessary to build a gate, in order to prevent the sea-water from passing in during high-tide. Then, oyster-beds could not be laid down in the neighborhood of this gate, because it would serve not only as an inlet for salt water, but as an outlet for the fresh water from the marsh-land, and so fresh water instead of sea-water would cover the oyster-beds. But even if it is admitted that oyster-beds might be laid down inside of a dike without danger to the diked lands, and with sluices and gates to permit the inflow of sea-water, there are yet several questions to be answered. How will oysters thrive in such beds? Will they receive enough nourishment to become fat? How will they exist during continued cold weather? And will they produce young in such a place? It is certain that they will not receive as much food as in the open sea, since they cannot have nearly as much water as will pass over them upon the natural beds; and the quantity of nourishment varies in proportion to the amount of water which passes over the beds. In these beds the oysters would also be in danger of being buried in the deep mud, and in order to prevent this they must either be changed very often into clean beds, or else a cleaning-pond must be formed beside

the breeding-pond. But while the water is rendered clear by being allowed to stand quiet, yet by this means a large amount of organic matter which serves as food for the oysters is taken from it. Especially dangerous, however, to oyster beds within the dikes would be the cold during winter weather, for along our North Sea coasts the water is lowest during an east wind, and at the same time such a wind is accompanied by the lowest degree of temperature. Hence, at such times, when a great depth and a constant change of water over the beds would be the best protection from freezing, we cannot have high water, nor can the water then standing over the oysters be constantly changed; thus during every cold winter, a large number of oysters would be sure to perish in their beds. Even now, upon the shallow oyster-beds of our sea-flats, oysters are frozen exactly in proportion to the depth of the water over them during these cold spells; the shallower the water the greater the destruction upon the beds during a severe winter. During the severe winter of 1863–'64, when, on account of ice, no oysters could be taken from December 21 to February 17, and during the winter of 1864–'65, when the fishing was interrupted from January 24 to March 26, dead oysters were found upon a large number of the banks. The greatest destruction of oysters within the memory of the oldest fishermen took place during the severe winter of 1829–'30, when Schleswig-Holstein was visited by an unusually low temperature, which continued from the middle of November until the beginning of the next February. Most of the beds suffered greatly, and it was many years before they again recovered their former fruitfulness. In cold weather slime collects upon the gills and mantle-lobes of the oyster, the power of the muscles and cilia being weakened by the cold. Accordingly, the oyster is no longer in a condition by means of its rapidly-moving cilia, and the quick closing of the valves of its shell, to drive out the particles of slime brought in with the water. But the power of the cilia and the elasticity of the muscles are again restored as the water becomes warmer, providing the cold has not lasted too long. The gills become clean once more, and respiration and nourishment, which have been disturbed by the sliming, proceed again as before. If the cold spell is prolonged, then, in addition to the sliming of the gills and mantle, there are yet other pernicious results. The shell-muscle becomes so soft that it can no longer close the valves. The cilia move slower and slower, and finally, when the shell-muscle has allowed the valves of the shell to gape wide open, cease moving altogether. The mantle and gills become pale in color, infusoria nest in them and hasten their destruction, and soon their ciliated layer separates and disappears. The softest portions of the body, the generative organs, the liver, and the stomach quickly vanish, probably consumed by snails, crabs, worms, and star-fish as soon as they can make their way unhindered into the open shell. The last part of the mollusk which is to be found in the shell is the shell-muscle. It remains free between the two valves, or attached

to only one of them, until finally but a trace of its fibers is to be seen at the points of attachment, the so-called muscular-impressions. During the latter part of March, 1870, I was able to follow out for myself, at the Schleswig-Holstein beds, the entire course of the changes produced in the oyster by freezing. Long-continued east winds had kept the water extraordinarily low, and for more than a month thick ice had covered the flats, so that from the 4th of February to the 7th of March no oysters could be taken. On the 14th of February the water in the neighborhood of an oyster-bed at the north end of the island of Sylt was found to be of a temperature of 2° C. below zero. At this point the depth of water was 3.5 meters. Of those oysters which were taken in my presence from the shallower beds 7 to 8 per cent. were frozen. Upon beds which lay in deeper water, nearer the open North Sea, the cold had killed only from 2 to 3 per cent. Evidently, then, these latter beds had suffered less damage because at every flood-tide they received water of a somewhat higher temperature from the open sea. I have frozen the mantle and gill lobes of oysters in North Sea water and allowed them to remain inclosed in ice for an hour at a time, with the temperature of the water varying in degree from 4° C. to 9° C. below zero. When the ice had melted, the cilia began to move feebly, and four hours later, when the temperature of the water had risen to 5° C. above zero, their movements were once more fully established. Other gill and mantle lobes which had been three hours in water of a temperature of 1° C. to 2° C. below zero moved quite lively on the following day. This recalls to me a very weighty difference between fresh and salt water, which is often overlooked. It is generally known that fresh water is densest and heaviest at a temperature of 4° C. above zero. When any portion has arrived at this temperature during freezing weather, it sinks to the bottom of the body of fresh water, where it remains until the entire mass above it is of the same density. That portion which first becomes lower in temperature than 4° C. then expands, rises to the surface, and stiffens into ice as it reaches the temperature of 0°.

The fact is less known that with sea-water the lower the temperature the greater the density and weight of the water. Therefore, it also sinks to the bottom until it has reached the temperature at which it forms ice, which, when it holds 3 per cent. of salt in solution, is 2.28° C. below zero. It is evident, then, that water may be found at the bottom over the sea-flats of a temperature of 2° C. below zero, while, during the most severe cold, water at the bottom of the lakes and deeper rivers of North Germany is found to be constantly several degrees warmer than this. When, finally, the sea-water, from the surface to the bottom, has reached its freezing point, it does not become solid ice for the whole thickness, but thin layers of ice, at greater or less distances apart, are formed in it. These layers, which are crystallized from the salt water, are free from salt, are hence lighter than the surrounding water, and accordingly ascend to the surface; consequently, those animals which live upon the

ground of the deeper portions of the sea-flats remain surrounded by water whose temperature is 2° C. lower than the freezing point of fresh water. In shallow places which the ebb-tide leaves dry, the frost kills all animals which have not the ability to dig their way to such a depth in the sand and mud that they will be beyond the influence of frost, and where the water remains liquid.

Here only a few kinds of mussels, worms, and crabs possess this ability; hence all of those sand and mud banks of the sea-flats which are left dry by the ebb-tide are comparative "barrens," occupied only by very few animals and plants.

Our investigation, then, has led to the grievous conclusion that profitable artificial oyster-breeding, according to the French system, is not possible along our North Sea coasts. Whoever should attempt to carry out this system, despite the unfavorable conditions of our waters and climate, would be certain to find that his breeding oysters were more costly than many English oyster-breeders have found theirs to be; for upon the English coasts the difference between ordinary high tide and the tide increased by a storm is much less than upon our sea-flats, the lowest water does not occur simultaneously with the coldest winds, as along the southeast shore of the North Sea, and the climate there is milder than upon our coasts.

8.—CAN NATURAL OYSTER-BEDS BE ENLARGED, AND CAN NEW BEDS BE LAID DOWN, ESPECIALLY ALONG THE GERMAN COAST?

It will thus be seen that the German oyster industry remains dependent now, as ever, upon the natural oyster-banks of our coast-seas, where oysters have lived for thousands of years, and where they exist to-day fruitful and well-flavored. And in regard to these beds we have now to consider the important questions:

First. Is it possible to increase their size?

Second. Can we still farther increase the surface of our oyster-territory by laying down new beds?

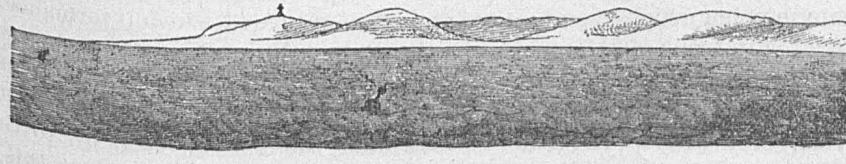


FIG. 9.

In the foreground are the *sea-flats*, with two can-buoys which indicate the course of the channel for vessels. In the background are seen the dunes or sand-hills of Hörnum, the southern point of the island of Sylt.

The water in the neighborhood of the banks, and over all the stretches between them, has the same character as over the banks themselves. All that is necessary, then, in order to increase the size of these beds is

to render the sea-bottom between them habitable for oysters. Old beds increase naturally in size whenever the shifting and slimy sea-bottom which borders them becomes changed into stable and clear ground. This can take place if changes occur in the force and direction of the ebb and flood currents. In such cases the extension can be hastened artificially by placing upon the newly forming ground shells of oysters and other mollusks, in order to furnish just outside the borders of the old bed the most judicious objects of attachment for the young broods as they swarm out from the mother oysters. For the establishment of new beds, within the limits of the German sea-flats, in places where no oysters are found at present, it will be necessary to find stretches of sea-bottom which are free from mud, where the soil is not being constantly shifted about by currents, and where the ebb-tide will leave at least one to two meters in depth of water over the beds. But nearly all such places are at present occupied by oyster-beds. In the year 1876 the buoy-tenders, who are best acquainted with the bottom over the entire Schleswig-Holstein sea-flats, and who have to mark out the channels for vessels, by means of cask and stake buoys (Figs. 1 and 9), sought to find some places upon the flats suitable for oyster-beds, where no oysters yet existed. They found within their whole territory only eight such places where it might be possible for oysters to thrive; and it would be very hazardous to immediately distribute over all these places a great number of breeding oysters, since it is yet doubtful whether new beds would be able to flourish there or not. It would be much wiser to experiment with one only of these places at first. Upon this let oyster and other mollusk shells be scattered in May and again shortly before the breeding period; then, upon the ground thus prepared place several thousand mature oysters. If, by next fall, a deposit of young oysters is found to have taken place, it will not be certain even then that the experiment will prove successful, but only after three or four years, when a large number of half-grown oysters are found lying beside the old mother oysters, and when these young are found in turn to have produced other broods which locate upon the new bed. Over the entire German sea-flats lying south and southwest of Schleswig there can hardly be found a single place which is suitable for the formation of a profitable oyster-bed; for in front of the mouths of the Eider, Elbe, Weser, Jahde, and Ems the sea-bottom is so covered with mud, or so subject to change, that oysters could not live and multiply there. In the fall of 1868, when I investigated with a dredge-net the sea along the German coast from the Eider to Borkum, I found over this entire territory but one single locality upon the coast of Hanover, between the mainland and the island of Juist, west of Norderney, which in any manner would be suitable for such an experiment. Here, in the spring of 1869, a large number of breeding oysters from the Schleswig-Holstein beds were distributed. But no permanent bed has been established there, for in June, 1875, during an investigation of the bottom near Juist and Borkum, only seven oysters

were taken, notwithstanding the dredge was used for three whole days. The sea-bottom in the neighborhood of Juist is, therefore, not suited to the growth of oysters. It is too muddy, and already in possession of the edible mussel (*Mytilus edulis*). During the last century, and the first half of the present one, the Hanoverian Government was accustomed to lease the oyster-fisheries along its coast. These fisheries were principally in the neighborhood of Juist and Borkum, and from 1841 to 1846, inclusive, 193,684 oysters were taken there, making an average yield of 38,727. In 1851, in a survey of the beds, very few oysters were found, and in 1855 the beds were so impoverished that no one would rent them.

The exhaustion of the beds resulted from excessive fishing and from the increase of mud upon the ground occupied by the oysters. Whoever, therefore, would establish new oyster-beds along the German portion of the coast of the North Sea, between the Eider and the mouth of the Ems, must begin his difficult work by changing the ebb and flood currents in the southern portion of the North Sea, in order to prepare a surface upon which oysters can thrive; for to attempt to adapt oysters to a bottom of shifting sand or mud is not natural, nor is it conducive to an industry which is to last for a hundred years. For thousands of years innumerable young oysters have been scattered from the oyster-beds over changing mud and sand banks, and yet not one has so altered its organization as to become adapted to such a bottom and transmit its new nature to its progeny; they have all been destroyed.

Since the sixteenth century, along the west coast of France, on both sides of the mouth of the Seudre, near Marennes and La Tremblade, the oyster-breeders have been in the habit of transplanting oysters, one year old, from natural oyster-beds to prepared ponds in order to fatten them and improve their flavor. These ponds, called *claires*, are shallow excavations of various shapes and sizes. The greater number are square or rectangular, and cover from two to three thousand square meters of surface. They lie near together, but irregularly, and are divided off into sections by deep trenches or canals, by means of which the sea-water flows in and out during spring-tides. The bottom of the ponds is somewhat higher near the center than around the edges. The walls surrounding the ponds are formed of the earth dug from within, and are about one meter in height. The neighboring ponds are placed in communication with one another by means of ditches or wooden pipes in the walls. Flood-gates are placed in the larger trenches, by means of which the water can be retained in the ponds from one spring-tide to another. In the fall, when fishing upon the sea-beds is permitted, young oysters are taken and transplanted to these ponds. From August until the breeding season next year, these transplanted oysters acquire a cloudy, dark-green color in the tissues of the mantle, gills, liver, and stomach. The delicate flavor, for which the green oysters of Marennes are especially famous in Paris, is only acquired after three or four years. During this time they must often be cleansed from the mud which has accumu-

lated upon them, and transferred to fresh ponds, if they would be kept healthy. In these feeding-ponds the oysters spawn well, and at times, when there are any objects of attachment free from mud, such as stones, shells, and pieces of wood, the young oysters become attached, but they do not mature into marketable oysters. Oyster breeders, after three hundred years of practice in rearing young bank-oysters in the mud of feeding ponds, have not as yet been able to transform the oyster into a mussel which can live and propagate in the mud. The breeders of Marennes and La Tremblade have been able to change the color and flavor of mollusks, but they have not been able to give the oyster a foot for the purpose of locomotion. Along the German coast, in the East Sea, the sea-bottom, over many extensive tracts, is firm, and also free from mud. These places possess, then, in this respect, one of the most important conditions for the successful formation of oyster-beds. Yet several attempts to plant oysters in the Baltic have proved entire failures. In 1753, 1830, and 1843, oysters were planted along the coast of Pomerania. The last of these attempts was made by a company, of which the Kings of Prussia and Hanover and the Prince of Putbus were members. Fifty thousand oysters, taken in the northern portion of the Cattegat, near Frederikshavn, were placed, on the 6th and 13th of April, 1843, in the waters southeast of the island of Rügen, near Greifswalder Oie. Two years later, investigations showed that they were all dead, since not a single living one could be found. The much talked-of attempt at oyster-breeding by Coste gave a new impulse to the question of planting oysters in the Baltic. In the Bay of Kiel, on the south coast of the island of Laaland, in the neighborhood of Korsör, and in the Isefjord, on the coast of the island of Seeland, mature oysters were planted, upon apparently suitable ground, but the desired result was not attained in either place. The water of the Baltic is not salt enough for the propagation of the oyster. East of the island of Rügen the water at the bottom contains only 1 per cent. of salt, and near the surface still less, since the rivers bring in much fresh water. West of Rügen, south from the Great Belt, to near the coast of Mecklenburg, the water at the bottom contains indeed as much as 3 per cent. of salt, but here also the surface-water everywhere contains a less degree. The young oysters, as soon as they had left the mother oysters, would then ascend to the surface, and thus come into water which throughout the entire southern portion of the Cattegat contains less than 2 per cent. of salt, while they need water with at least 3 per cent. of salt. This I infer from the fact, that such a degree of saltness is to be found at all places along the European coast where natural oyster-beds exist. There are two other conditions of the Baltic besides the low percentage of salt, which certainly hinder the growth of the oyster—the long-continued low temperature of winter, and the lack of regular tidal-currents; for in the North Sea, where there are strong and regular tidal-currents, the oyster, which is a stationary animal, will receive daily a greater

quantity of oxygen and food in the water brought to it than it will in an interior sea, where the water is in less regular motion. These chemical and physical differences between the North and East Seas render it not only impossible for the oyster to live in the latter, but also for many other North Sea animals, of which I will mention only the lobster, the larger punger (*Platycarcinus pagurus*), and the edible sea-urchin (*Echinus esculentus*).

If nothing further were necessary in order to establish a permanent settlement of oysters in the Baltic than to plant there several thousand fresh and healthy mature oysters, why then cannot lobsters, crabs, sea-urchins, and all the other animals which are found associated with the oysters upon the banks, and indeed the entire fauna of the North Sea oyster-banks, flourish in the Baltic? If this could have been accomplished, I should long ago have had a large number of the animals of the North Sea naturalized in the Bay of Kiel, in order to facilitate my own investigations, and for the purpose of instruction to students. Nature has already made frequent efforts to introduce not only oysters, but other North Sea animals, into the Baltic. Nearly every year fish and other animals from the North Sea appear in the Baltic, but they are not permanent, and soon disappear again from our fauna.

The great storm-flood of the 13th and 14th of November, 1872, brought *Noctiluca scintillans* from the North Sea into the harbor of Kiel in such numbers that for weeks they made the waters of the harbor brilliant with their phosphorescent flashes, but very soon they had entirely disappeared. Under the present geognostic and physical conditions the oyster can advance no farther towards the Baltic than into the south-western part of the Cattegat. Here a line drawn from Samsöe over the island of Anholt to Gothenburg represents the limits of those conditions suited to their welfare. Along this extreme border of their existence one could not expect such productiveness and size among the oysters as a costly artificial system of breeding would demand in order to be profitable.

Every change in the saltness of the water below the general mean, or in the temperature of the sea-water, would incur heavy loss to any artificially conducted system of oyster-breeding which might be carried on here. That oysters of their own accord spread out from their great breeding home in the North Sea into all places where they find the external conditions favorable, is proven by their substantial immigration into Lim Fiord, in the north of Jutland. This fiord, up to the year 1825, consisted of a number of connected brackish-water lakes, with an eastern out-flow into the Cattegat. During the last century futile efforts were made to establish oyster-beds in these seas; but on the 3d of February, 1825, a fearful storm-flood broke through the dam which separated the western portion of the Lim Fiord from the North Sea, and after this the water of the fiord became more salt every year, the brackish-water ani-

mals and plants which had lived there vanished, and in their place came North Sea animals, and among them, in 1851, the oyster was first noticed. From year to year they spread over more surface. In 1860 only 150,000 were dredged; presently 98 places were known where oysters had become established, and in 1871–'72 the oystermen were able to take for foreign consumption seven millions of mature oysters from the beds of Lim Fiord. Their distribution was very rapid. In 1851 the first were found; had there been many there before this time, they would certainly have been noticed by the fishermen. The water must first contain a percentage of salt of 3 per cent before they can enter a new territory. If we admit the first appearance of oysters here in 1840, then in an interval of thirty years they had spread over an extent of surface 15 miles (German) in length, which shows a yearly advance, in territory covered of about one-half mile in length, or rather more, about 3,700 meters. The beds of the Lim Fiord are from 1 to 8 kilometers from one another. Their length is from 1 to 7 kilometers and their breadth somewhat less. These facts show that the young swarming oysters are capable of moving over a stretch of bottom 8 kilometers in length. In the same manner as it has thus immigrated into the Lim Fiord the oyster would have established itself in the Baltic had the water been similar in its characteristics to that of the North Sea, and this would be the condition of affairs if the connection between the North Sea and the Baltic were broader and deeper than it is at present. At one time it was broader and deeper, and, for this reason, oysters once lived four miles east of the point where the city of Kiel now stands. This is proven by the fossil oyster-beds found near Waterneversdorf, in the eastern part of Holstein, which, together with the entire bottom of the western portion of the Baltic, have been raised more than 30 meters. By this elevation the Cattegat, the Belt, and the Sound were made shallower and smaller pathways for the water coming in from the North Sea than they were in olden times, when the oyster-beds of Waterneversdorf still produced oysters. Yet, by this elevation of the sea-bottom, which took place thousands of years ago, the percentage of salt in the water has been lessened but very little. Thousands of years later, when the oyster-beds of Waterneversdorf had been dry land for a long time, oysters were found in such abundance along the coast of the Danish Islands that they served as food for the people of the Stone Period who lived in this vicinity, since great masses of oyster-shells are found in the heaps of kitchen refuse of that time.

And since the oyster-shells of Waterneversdorf and of the kitchen-heaps of the Stone Age fully agree with those of to-day, since they are also bored like ours by the boring sponge (*Clione celata*), and since the whelk (*Buccinum undatum*) and other animals at present found upon the sea-flats lived with them, conditions favorable to their growth must have existed at that time in the meridian of the present Cimbrian Peninsula, the same as now to the west of Schleswig-Holstein. The

oyster has thus not changed during the course of at least ten thousand years. It has not accommodated itself to the changes which have taken place in the territory occupied by it, but has yielded to those changes, although they were brought about very slowly. Hence it is impossible for any human power to change their nature in a short time and accustom them to the water of the Baltic as it is to-day.

The following Danish works treat of the oyster-beds of the Lim Fiord, the extension of the oyster into the southern portion of the Cattegat, and of the unsuccessful attempts to plant oysters in the Baltic:

Jonas Collin. Om Östersfiskeriet i Limfjorden. (With a chart of the oyster-beds.) Copenhagen, 1872.

G. Winther. Om vore Haves Naturforhold med Hensyn til konstig Östersavl og om de i den Henseende anstillede Forsög. Copenhagen, 1876.

F. Krogh. Den konstige Östersavl og dens Indförelse i Danmark. Hadersleben, 1870.

In the royal archives at Stettin and Stralsund are to be found the acts under which the attempts to locate oysters along the coast of Pomerania in 1830 and 1843 were made.

9.—SIZES AND PRODUCTIVENESS OF THE OYSTER.

The delightful hopes of bordering the entire German sea-coast with fruitful oyster-beds, and of seeing German oysters as food upon every table, must, therefore, be given up. The nature of our waters, as well as the nature of the oyster itself, forces us to do so. Yet it is especially difficult for those to understand this who share the widespread opinion that all eggs which are spawned by oysters are destined to become transformed into young mollusks. Most animals, however, whose ova and young are exposed to attacks and liable to be destroyed, produce a large number of eggs, while those animals, on the contrary, which guard their broods until they can take care of themselves, as is the case with mammals, birds, and some invertebrates, generally produce but few eggs; but in those cases where care for the brood is entirely lacking, or lasts for a very short time only, eggs are produced in such great numbers that the numerous enemies which regularly attack them are not able to destroy them all. A certain number escape destruction and arrive at maturity. The tape-worm of man (*Tænia solium*) produces from its eight hundred segments not far from forty million germs, and the parasite *Ascaris lumbricoides* forms in its ovary about sixty million eggs. Under the normal condition of affairs for the development of these worms, only a very few of the great number of eggs laid ever go so far in growth that they in turn produce eggs. This is satisfactory to everybody, since none desire that all of the forty million eggs of the tape-worm or the sixty million eggs of the "itch-insect" should ever become mature parasites. It would be a horrible state of affairs if such a thing should happen. On the contrary, every one very much desires that all the young broods which the oyster sends forth into the water should become mature table-oysters, since, when fully grown, they become one of the most

delicious of delicacies. But in observations and investigations which have for their object the discovery of the methods and means by which nature brings these things about, such desires as these must not be allowed to have an influence upon our opinion; for whoever would have nature especially attractive, beautiful or useful, whenever he is in immediate contact with her becomes easily led away from the pathway of strict scientific investigation and lost in the dark and boundless territory of speculation.

Nature accomplishes at every place just what she is obliged to accomplish there with her united forces, according to the conditions upon which the development of the world has proceeded. Throughout her entire limits there are no such distinctions as useful or injurious. The terms agreeable or disagreeable, beautiful or frightful, useful or harmful, as applied to the workings of nature, exist only in the thoughts and comprehension of intelligent and sensitive beings. Yet very frequently we hear it said, when speaking of the fossil oyster-bed which now lies near Blankenese, below Hamburg, 80 meters above the level of the Elbe, that it did not make any difference that oysters should once have lived there and produced young, of which only a small proportion should ever come to maturity, since no human beings were there at that time who could have fed upon them.

Oysters belong to that class of animals which secures the continuance of the species, not by guarding the young for a long time, but by producing a vast number of embryos every season. They are able to produce so large a brood that enough of the number will be certain to arrive at maturity to maintain the status of the bed, and supply the places of those old oysters which die or are destroyed; and this result takes place notwithstanding many of the young are destroyed by sand, mud, or unfavorable temperature, and many others are eaten before their shells are thick and large enough to protect them from the numerous enemies which live upon the same banks with them. The number of descendants from any one oyster which thus arrive at maturity is so small even upon the best beds, where for more than a hundred years the finest and most productive Holstein oysters have been caught, that I am persuaded no one would give credit to my words if I was not able to substantiate them by means of figures. In 1587, Frederick II, King of Denmark and Duke of Holstein-Gottorp, appropriated the oyster-beds of Schleswig-Holstein as royal prerogatives.* They

* The public order by which the Ducal-King Frederick II took possession of the oyster-beds of the sea-flats along the coast of Schleswig-Holstein and Jutland, is printed by H. Kröyer in his work "De danske Östersbanker," Kjöbenhavn, 1837, page 110. Translated into English, through the German, it reads as follows: "We, Frederick, &c., make known to all by these presents, that since it has been brought to our knowledge that in the waters of the West Sea, in the fief of Ribe, a kind of fish called an oyster can be found and caught, therefore we have commanded our liege Albert Friis, superintendent and guardian at our castle at Ribe, that he permit this kind of fish to be caught in our name and sent to us; and in order that a future lack of them may not occur, we forbid one and all, whoever he may be, from taking oysters or allowing

were then leased, generally for a long term of years. From time to time the government caused the banks to be officially examined, in order to find out their condition and prevent their depletion by overfishing. The examination was conducted by commissioners appointed by the government, and the dredging carried on in their presence was performed by fishermen specially sworn for the purpose. The smaller beds were dredged in three, the larger in six, different places, and all the oysters taken were divided, according to size and age, into three classes, known as—

1. Zahlbar Gut, or marketable.
2. Junggut, or medium (half grown).
3. Junger Anwachs, or young growth.

The *marketable* oysters are those which are large and full grown. Their shell is at least 7 to 9 centimeters in length and breadth, and when closed the greatest thickness must be more than 18 millimeters. The left valve, or the one which is most curved, is from 6 to 9 millimeters thick at the point of attachment of the shell-muscle, and also under the ligament.

The greater number of full-grown oysters are from seven to ten years of age, yet many older ones are found, which can be distinguished from the younger ones by the greater thickness of their shell. Oysters more than twenty years old are seldom seen. The oldest which I have personally examined I estimated to be from twenty-five to thirty years old. The left valve, at the muscular impression and below the ligament, was 20 to 25 millimeters in thickness.

The shells of the half-grown oysters, when closed, show a thickness of from 16 to 18 millimeters. The valves, where thickest, are, at the most, only 5 millimeters thick, and their breadth is less than 9 centimeters. They are cleaner than the old oysters, upon whose shells are generally to be found many animals and plants. The *young growth* are those small and thin oysters which are not older than from one to two years (Fig. 8 *d*).

In the record of each inspection we find indicated the number of marketable and the number of medium oysters caught in each haul of the dredge, but the number of the young growth is not given, mention only being made as to whether there were many or few.

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them to be taken in that place. We except, however, those who take them in our name by the authority of our liege at Ribe. Whoever shall dare to act contrary to this command, and he can be justly convicted of so doing, shall be punished according to his deserts. Each one is then to govern himself accordingly, and guard against transgressing. Given at Skanderborg, the 4th day of February, 1587."

* The work of Kröyer contains also a tabular review of the numbers of mature and medium oysters of the official investigations which took place from 1709 to 1830. This table, and also tables for which I have to thank the royal government at Schleswig, have furnished me the numbers from which I have estimated the proportions between half and full grown oysters. I have not considered the investigations previous to the year 1730, partly because in the beginning of the eighteenth century a number of beds were unknown, and partly because the numbers of the first five inspections (1709 to 1728) give no positive results. On six official investigations made between the years 1869 to 1876 I have participated myself. The results of these I will give later.

During the period from 1730 to 1852 ten records were made of all the oyster-beds of the Schleswig-Holstein sea-flats. If from these records the numbers of all the marketable and all the medium-sized oysters are taken and added together, we will have a series of very different totals, showing no particular general law. But if for each of these reports the proportion of marketable to medium oysters is taken, then we will arrive at the surprising result that this proportion fluctuates but very slightly during all the records.

The following table gives a summary of the marketable and medium oysters recorded as caught during each of the ten investigations. From these numbers I have reckoned for each record the proportion of medium oysters to every thousand of those which were full grown.

Year of record.	Number of marketable oysters.	Number of medium oysters.	Proportion of marketable to medium.	
1730	5,304	2,602	1,000	486
1734	16,770	5,205	1,000	310
1740	7,185	3,007	1,000	418
1756	6,793	3,333	1,000	490
1795	2,078	1,006	1,000	484
1799	2,705	831	1,000	307
1819	2,828	1,087	1,000	388
1830	1,950	797	1,000	417
1839	3,272	1,552	1,000	440
1852	3,534	1,673	1,000	473
Total			10,000	4,218
Mean proportion			1,000	421.8

The following table gives the quantities of oysters which were taken during these investigations from two of the largest and most productive beds of the Schleswig-Holstein coast, the Huntje and the Steenack Banks:

Year of record.	Huntje.		Steenack.	
	Marketable.	Medium.	Marketable.	Medium.
1730	355	164	158	69
1734	1,353	874	405	90
1740	323	158	26	110
1756	736	99	149	85
1771	931	66	607	197
1795	87	461	261	106
1799	183	119	236	56
1819	363	178	53	79
1830	40	3	11	4
1852	128	64	116	58
Total	4,499	2,181	2,082	804
Proportion	1,000	484	1,000	385

The proportion of marketable to medium-sized oysters is thus seen to be almost the same upon single beds as in a mean of all the beds taken together.

In this similarity of proportions between the marketable and medium oysters in different years and upon different beds a natural law is very strikingly manifested. The medium-sized oysters of any bed consist of the descendants of the marketable ones. They are those members of the young broods which have escaped the numerous enemies living upon and around the beds, and which, despite the numerous attacks made upon their lives, have grown into very respectable-sized animals.

The medium oysters thus represent the total number of embryos from the bed which, in the struggle for existence, have continued to exist. A thousand mature oysters will produce during a breeding period, as I have already shown in chapter 2, at least 440,000,000 of young; but upon the beds alongside of these 1,000 mature oysters are to be found, on an average, not more than 421 half-grown ones; so that, as a rule, for every Holstein oyster which is placed upon the table more than 1,045,000 young are destroyed or die; and indeed even more than this, for not only do those oysters which are over six years of age produce eggs, but those which are two and three years old also reproduce their kind to a certain extent. The younger oysters, however, produce much less spawn than those which are mature, so I estimate that those half-grown oysters lying beside the mature ones on the same banks, and which are their offspring, will produce 60,000,000 young oysters.

We thus have, upon a surface of oyster-bed occupied by 1,000 full-grown and 421 half-grown oysters, at least 500,000,000 of young produced during the course of the summer, and of this immense number only 421 arrive at maturity. *The immolation of a vast number of young germs is the means by which nature secures to a few germs the certainty of arriving at maturity.* In order to render the ideas of germ-fecundity and productiveness more easily understood, I will make a comparison between the oyster and man.

According to Wappäus,* for every 1,000 men there are 34.7 births. According to Böckh,† out of every 1,000 men born 554 arrive at maturity, that is, live to be twenty years or more of age; thus, on an average 34.7 children are produced from 554 mature men, or 62.6 children from 1,000 mature men. Since 1,000 full-grown oysters produce 440,000,000 of germs, then the germ-fecundity of the oyster is to the germ-fecundity of man as 440,000,000 to 62.6, or as 7,028,754 to 1. On the other hand, the number which arrive at maturity, is 579,002 times as great with mankind as with the oyster; for of 1,000 human embryos brought into the world 554 arrive at maturity, or of 440,000,000 newly born 243,760,000 would live to grow up, while of 440,000,000 young oysters only 421 ever become capable of propagating their species. The proportion is then 421 to 243,760,000, or as 1 to 579,002. I am fully per-

* Wappäus, Handbuch der Geographie und Statistik. Band I, 1855, Abth. I, p. 197.
† R. Böckh, Sterblichkeitstafel für den Preussischen Staat im Umfange von 1865. Jena, 1875.

suaded that these figures represent the number of oysters which arrive at maturity more favorably than is really the case, since from every thousand of full-grown oysters it is certain that, on an average, more than 440,000,000 young are produced. The correctness of my argument that the number of oysters which arrive at maturity is very small indeed as compared with the exceedingly large number of germs produced is corroborated by the experience of those who have engaged in oyster-culture in France and England. In the year 1870 a small oyster-bed was discovered at the mouth of the Thames, northeast from Whitstable.* It was about 18 meters long by 6 meters broad. Forty-eight hours later 75 boats were there, close alongside of one another, fishing up the oysters. Upon every old oyster which was taken were found only from nine to ten young ones of different ages. This bed had never been previously disturbed, and the oysters were accordingly found in their natural condition. Whoever is not informed in regard to the small number which arrive at maturity, but knows only of their immense fecundity, will, in thinking of the growth and production of oysters, consider the oyster-beds as inexhaustible. It has, indeed, really been thought that if millions and millions of oysters were taken from a bed no harm would be done to its prosperity, since it was the opinion that the dredges would leave everywhere as many breeding oysters as would be necessary to supply the place of those taken away, by means of the immense number of young which would be produced. In accordance with this view, the oyster-fisheries were made entirely free in England in 1866. But the consequence of the continuous fishing which followed was everywhere a quick impoverishment of the beds, concerning which result the official reports upon the oyster-fisheries in France and England contain a vast number of authentic proofs. According to the statement of Mr. Webber, mayor of Falmouth, 700 men, working 300 boats, were profitably employed in oyster-fishing in the neighborhood of Falmouth so long as the old laws of close-time were observed. But since the year 1866, when those old laws were set aside, the beds have become so impoverished that now, in 1876, only about 40 men, with less than 40 boats, can find employment, and even with this greatly diminished number of boats no single boat takes daily more than from 60 to 100 oysters, while formerly in the same time a boat could take from ten to twelve thousand. About the year 1830 an oyster-bed was discovered upon the English coast near Dudgeon Light, containing an immense number of oysters, among which were very many old ones.

* The statistics concerning English and French oyster-fishing were taken partially from my own notes, made during a visit to the English and French coasts, and partially from two official English reports: I. Report on the Oyster and Mussel Fisheries of France, made to the Board of Trade by Cholmondeley Pennel, Inspector of Oyster-fisheries. London, 1868. II. Report from the select Commission on Oyster-fisheries. 1876.

These reports are attached to summaries of the profits arising from oyster-fishing in France, which were delivered to the authorities at the French department of marine and fisheries.

During the next three or four years this bed was fished so perseveringly and disastrously that since then it has not produced enough oysters to be worth recording. Between the years 1840 and 1850 there were in the harbor of Emsworth so many oysters that one man in a single tide (five hours) could take from 15 to 20 casks, each containing 1,600 oysters. Later, 70 to 100 sailing vessels from Colchester came into the harbor and fished up so many young and old oysters during the two or three weeks they were there that, in the year 1858, scarcely ten vessels could load there, and in 1868 the beds were so impoverished by this fishing that a dredger in five hours could not gather more than 20 oysters. These figures are taken from the statement of Mr. Messum, oyster-dealer, and secretary of an oyster company at Emsworth, made before the commission for the investigation of the British oyster-fisheries, on the 1st of May, 1876. From the beds of the districts of Rochefort, Marennes, and the island of Oléron, on the west coast of France, there were taken, in the years 1853–'54, ten millions of oysters, and in 1854–'55 fifteen millions. By means of long-continued and exhaustive fishing they were rendered so poor that in 1863–'64 only 400,000 oysters were furnished for market.

The very celebrated rich oyster-beds of the Bay of Cancale, on the coast of Normandy, have produced, according to official reports, the following numbers of oysters:

Year.	Number of oysters.	Year.	Number of oysters.
1800		1835	43, 000, 000
1801	1, 200, 000	1836	40, 000, 000
1802	1, 500, 000	1837	36, 000, 000
1803	1, 300, 000	1838	44, 000, 000
1804	900, 000	1839	42, 000, 000
1805	1, 400, 000	1840	52, 000, 000
1806	800, 000	1841	56, 000, 000
1807	500, 000	1842	63, 000, 000
1808	1, 090, 000	1843	70, 000, 000
1809	1, 800, 000	1844	68, 000, 000
1810	1, 200, 000	1845	67, 000, 000
1811	700, 000	1846	65, 000, 000
1812	1, 130, 000	1847	71, 000, 000
1813	1, 100, 000	1848	60, 000, 000
1814	600, 000	1849	52, 000, 000
1815	400, 000	1850	50, 000, 000
1816	800, 000	1851	47, 000, 000
1817	2, 400, 000	1852	20, 000, 000
1818	5, 600, 000	1853	40, 000, 000
1819	5, 300, 000	1854	20, 000, 000
1820	6, 800, 000	1855	20, 000, 000
1821	0, 700, 000	1856	18, 000, 000
1822	0, 000, 000	1857	10, 000, 000
1823	11, 800, 000	1858	24, 000, 000
1824	18, 000, 000	1859	16, 000, 000
1825	20, 000, 000	1860	8, 000, 000
1826	20, 000, 000	1861	0, 000, 000
1827	25, 000, 000	1862	3, 000, 000
1828	28, 000, 000	1863	2, 000, 000
1829	33, 000, 000	1864	2, 200, 000
1830	31, 000, 000	1865	1, 100, 000
1831	36, 000, 000	1866	1, 960, 000
1832	42, 000, 000	1867	2, 000, 000
1833	38, 000, 000	1868	1, 079, 000
1834	41, 000, 000		
	46, 000, 000		

The records of inspections of the Schleswig-Holstein oyster-beds have furnished the means by which such an impoverishment of these rich

beds can be explained. From 1800 to 1815 there were taken yearly from the beds of Cancale less than two million oysters. The oysters, both marketable and spawning, had thus an opportunity to accumulate in greater quantity to form the increased production which occurred in 1822. If the French oysters live as long as those of the Schleswig-Holstein beds, some of this stock, which had accumulated during the period of comparative rest at the time of the Napoleonic wars, would have been lying upon the banks as late as about 1830. From this time on for nearly a score of years it is probable that the ever-increasing yield was the produce of only those oysters existing upon the beds from 1820 to 1830. From 1840 to 1847 the number of oysters taken was extraordinarily great—evidently too great for the productiveness of the beds, since from this time they produced fewer oysters each year.

The total number of oysters taken between the years 1840 and 1847 was about 512,000,000, being on an average about 64,000,000 per year. If this average represents the natural stock of marketable, full-grown oysters upon the beds of Cancale, then the number taken yearly should not have been over twenty-six to twenty-seven millions, if it was desired that this degree of productiveness should be maintained. This I assert upon the supposition that the productiveness of the oysters in the Bay of Cancale is no greater than upon the Schleswig-Holstein banks. If this productiveness was higher than upon our sea-flats, then we ought to have at Cancale, not 421 half-grown oysters for every 1,000 full-grown ones, but, for example, 500. Under these circumstances the presence of 64,000,000 matured oysters would permit the fishing of 32,000,000 yearly, but no more if the fruitfulness of the beds would be kept at that number, since such a stock would be absolutely necessary in order that a sufficient number of young should be produced to secure the maturing of 32,000,000 yearly.

After the impoverishment of the beds of Cancale the inspection officers enforced once more the laws protecting the oyster, since they did not believe that all the mature breeding oysters had been taken off the beds. Upon some of these beds there has already been a very significant increase of oysters through this action; for in 1872–'73, 7,300,000 oysters were taken, in 1873–'74, 9,056,000, and in 1874–'75, 9,342,000. To preserve oyster-beds a stock of full-grown oysters, for the purposes of propagation, must be left lying upon the banks. The number thus left must depend upon the fruitfulness of the oysters of each section, or, still better, of each single bed. According to the experience of oystermen, the most fruitful as well as the largest of the Schleswig-Holstein oyster-beds is the Huntje Bank. The proportion of medium oysters upon this bed is 484 per thousand, which is thus greater than the mean productiveness of the whole Schleswig-Holstein oyster-beds. The productiveness of smaller beds is belowthe average of 421 per thousand. As examples, we give the proportions of the following beds: Steenack, 385 per thousand; Hörnum, 319 per thousand; West Amrum, 165 per thousand.

These beds are only from 1,000 to 1,050 meters long by about 300 meters broad, while the Huntje Bank is more than 1,800 meters long by about 900 broad. The speedy extension of oysters in the Lim Fiord has taught us that young swarm-oysters can wander from 4 to 8 kilometers away from their home-bed before they become attached to any object. So if the oyster-bank is of small extent, the young oysters are in danger of swimming out beyond the limits of the bed and settling upon unsuitable ground, and thus of being destroyed in much larger numbers than upon a larger bed. Of such broods of swarm-oysters the large banks will retain many more than the small beds; and if upon both all other conditions are the same, a much larger number of young will grow to maturity upon those beds which have a large extent of surface than upon the smaller beds.

10.—AN OYSTER-BANK IS A BIOCŒNOSE, OR A SOCIAL COMMUNITY.

The history of the impoverishment of the French oyster-beds is very instructive. When the beds of Cancale had been nearly deprived of all their oysters, by reason of excessive fishing, with no protection, the cockle (*Cardium edule*) came in and occupied them in place of the oyster; and vast hordes of edible mussels (*Mytilus edulis*) under similar circumstances appeared upon the exhausted beds near Rochefort, Marennes, and the island of Oléron. The territory of an oyster-bed is not inhabited by oysters alone but also by other animals. Over the Schleswig-Holstein sea-flats, and also along the mouths of English rivers, I have observed that the oyster-beds are richer in all kinds of animal life than any other portion of the sea-bottom. As soon as the oystermen have emptied out a full dredge upon the deck of their vessel, one can see nimble pocket-crabs (*Carcinus mœnas*) and slow horn-crabs (*Hyas aranea*) begin to work their way out of the heap of shells and living oysters, and try to get to the water once more. Old abandoned snail-shells begin to move about, caused by the hermit-crabs (*Pagarus bernhardus*), which have taken up their residence in them, trying to creep out of the heap with their dwelling. Spiral-shelled snails (*Buccinum undatum*) stretch their bodies as far out of the shell as they can, and twist from side to side, trying, with all their power, to roll themselves once more into the water. Red star-fish (*Asteracanthion rubens*), with five broad arms, lie flat upon the deck, not moving from the place, although their hundreds of bottle-shaped feet are in constant motion. Sea-urchins (*Echinus miliaris*), of the size of a small apple, bristling with greenish spines, lie motionless in the heap. Here and there a ring-worm (*Nereis pelagica*), of a changeable bluish color, slips out of the mass of partially dead, partially living, animals. Black edible mussels (*Mytilus edulis*) and white cockles (*Cardium edule*) lie there with shells as firmly closed as are those of the oysters. Even the shells of the living oysters are inhabited. Barnacles (*Balanus*

crenatus), with tent-shaped, calcareous shells and tendril-shaped feet, often cover the entire surface of one of the valves. Frequently the shells are bedecked with yellowish tassels a span or more in length, each of which is a community of thousands of small gelatinous bryozoa (*Alcyonidium gelatinosum*), or they are overgrown by a yellowish sponge (*Halichondria panicea*), whose soft tissue contains fine silicious spicules. Upon many beds the oysters are covered with thick clumps of sand which are composed of the tubes of small worms (*Sabellaria anglica*). These tubes, called "sand-rolls," resemble organ-pipes, and are formed from grains of sand cemented into shape by means of slime from the skin of the worm. The shell forms a firm support upon which the worms can thus live close together in a social community. Upon certain beds near the south point of the island of Sylt, where the finest-flavored oysters of our sea-flats are to be found, there lives upon the oyster-shells a species of tube-worm (*Pomatoceros triqueter*) whose white, calcareous, three-sided tube is very often twisted about like a great italic *S*. The shells of many oysters upon these beds also carry what are called "sea-hands" (*Alcyonium digitatum*), which are white or yellow communities of polyps of the size and shape of a clumsy glove. Often the oyster-shells are also covered over with a brownish, clod-like mass, which consists of branched polyps (*Eudendrium rameum* and *Sertularia pumila*), or they may be covered with tassels of yellow stems which are nearly a finger long and have at their distal ends reddish polyp-heads (*Tubularia indivisa*). Among these polyps, and extending out beyond them, are longer stems, which bear light yellow or brown polyp-cups (*Sertularia argentea*). Within the substance of the shell itself animals are also found. Very often the shells are penetrated from the outside to the innermost layer, upon which the mantle of the living oyster lies, by a boring sponge (*Clione celata*), and in the spaces between the layers of the shell in old oysters is found a greenish-brown worm (*Dodecaceræa concharum*), armed with bristles, and bearing twelve large tentacles upon its neck. I once took off and counted, one by one, all the animals living upon two oysters. Upon one I found 104 and upon the other 221 animals of three different species. The dredge also at times brings up fish, although it is not very well adapted for catching them. Soles (*Platessa vulgaris*), which seek by jumping to get out of the vessel and once more into the water, stone-picks (*Aspidophorus cataphractus*), and sting-rays (*Raja clavata*), which strike about with their tails, are abundant upon the oyster-banks. Besides those already mentioned, there are many other larger animals which are taken less frequently in the dredge. There are also a host of smaller animals covered up by the larger ones, and which can be seen only with a magnifying glass. Very few plants grow upon the banks. Upon only a single one of the oyster-beds of the sea-flats has eel-grass (*Zostera marina*) taken root. Upon other beds reddish-brown algæ (*Floridiæ*) are found, and, floating in the water which flows over the beds, occur microscopic algæ (*Desmidiæ* and *Diatomaceæ*),

which serve as nourishment to the oysters. If the dredge is thrown out and dragged over the sea-flats between the oyster-beds, fewer and also different animals will be found upon this muddy bottom than upon the sand. Every oyster-bed is thus, to a certain degree, a community of living beings, a collection of species, and a massing of individuals, which find here everything necessary for their growth and continuance, such as suitable soil, sufficient food, the requisite percentage of salt, and a temperature favorable to their development. Each species which lives here is represented by the greatest number of individuals which can grow to maturity subject to the conditions which surround them, for among all species the number of individuals which arrive at maturity at each breeding period is much smaller than the number of germs produced at that time. The total number of mature individuals of all the species living together in any region is the sum of the survivors of all the germs which have been produced at all past breeding or brood periods; and this sum of matured germs represents a certain quantum of life which enters into a certain number of individuals, and which, as does all life, gains permanence by means of transmission. Science possesses, as yet, no word by which such a community of living beings may be designated; no word for a community where the sum of species and individuals, being mutually limited and selected under the average external conditions of life, have, by means of transmission, continued in possession of a certain definite territory. I propose the word *Biocœnosis** for such a community. Any change in any of the relative factors of a biocönose produces changes in other factors of the same. If, at any time, one of the external conditions of life should deviate for a long time from its ordinary mean, the entire biocönose, or community, would be transformed. It would also be transformed, if the number of individuals of a particular species increased or diminished through the instrumentality of man, or if one species entirely disappeared from, or a new species entered into, the community. When the rich beds of Cancale, Rochefort, Marennes, and Oléron were deprived of great masses of oysters, the young broods of the cockles and edible mussels which lived there had more space upon which to settle, and there was more food at their disposal than before, hence a greater number were enabled to arrive at maturity than in former times. The biocönose of those French oyster-banks was thus entirely changed by means of over fishing, and oysters cannot again cover the ground of these beds with such vast numbers as formerly until the cockles and edible mussels are again reduced in number to their former restricted limits, because the ground is already occupied and the food all appropriated. The biocönose allows itself to be transformed in favor of the oyster, by taking away the mussels mentioned above, and at the same time protecting the oysters so that the young may become securely established in the place thus made free for them. Space and food are necessary as the first requisites of every so-

* From βίος, life, and κοινόειν, to have something in common.

cial community, even in the great seas. Oyster-beds are formed only upon firm ground which is free from mud, and if upon such ground the young swarming oysters become attached in great numbers close together, as happened upon the artificial receptacles in the Bay of Saint-Brieux, their growth is very much impeded, since the shell of one soon comes in contact with that of another, and they are thus unable to grow with perfect freedom. Not only are they impeded in growth in this manner, but each oyster can obtain less nourishment when placed close together than when lying far apart.

In an oyster-breeding trench upon the island of Hayling, in the south of England, I saw, in May, 1869, oysters three years old which had grown thus far towards maturity attached to hurdles. Nearly all had twisted shells, which were not larger in diameter than from 2 to 3 centimeters, while a Holstein oyster three years old is from 5 to 6.5 centimeters broad. Evidently, the reason for their small size is to be found in the fact that in the trench they receive less nourishment daily than they would in the open sea. In the Bay of Arcachon the breeders are obliged to loosen the oysters from their artificial points of attachment and place them in boxes and trenches where they can grow to maturity, and in these the oysters must not be placed too close together or they will not grow to the best advantage. Even upon the best beds the oysters will remain poor if they are allowed to lie too thick upon the bottom; but if a portion of these poorly nourished oysters are taken away, those which remain—as has been found out by experience upon the Huntje Bank, the largest and most fruitful of all the Schleswig-Holstein beds—will soon become fatter, that is, their generative organs will become larger because more eggs or spermatozoa are produced than with poorer oysters. Thus, if a bed is above its mean in productiveness, every single one of the excessive throng of full and half grown oysters will not receive sufficient nourishment to enable them to generate a full number of germs, so that the number of germs produced and the number of young which arrive at maturity being thus regulated the entire bank will very soon be brought back to its former or normal condition. Since this law is in operation upon even the most productive of the Schleswig-Holstein beds, where the number of young which arrive at maturity is 484 for every thousand of mature oysters, while the average for all the beds is only 421 to each thousand, then a productiveness of 484 to the thousand is the highest which can be reached and maintained among the oysters existing under the biocönotic conditions of our sea-flats. Near Auray, in Brittany, the oyster-breeders collect many more young than they can grow to maturity, since they possess comparatively little oyster-territory, and this territory is not supplied with sufficient suitable food to nourish large numbers of oysters; so that whenever the breeders fail to find a purchaser for their extra stock of young they lose all the profits of their labor. Thus, it is with oysters as with all other animals; their increase in size and numbers depends upon the quantity

of food which they get and consume. The peasants of Jutland are great breeders of horned cattle, but they have not sufficient food to grow and fatten all their calves. Accordingly, many are sold to the peasants of the marsh-lands on the west coast of Schleswig-Holstein, and upon these extensive pasture-lands great numbers of cattle can be raised. Upon the estate of Hagen, near Kiel, there is a carp-pond of more than 80 hectares in size which is drawn off every three years, and while in this condition sown with oats and clover. It is afterwards refilled with water and 30,000 yearling carp placed in it. In three years from this time, as a rule, the production is 40,000 pounds of food-fish. In order to obtain a still greater profit, another lot of young carp was once placed in the pond, and this time more than 30,000. In three years the produce is indeed a larger number of fish than before, but they weigh, taken all together, only 40,000 pounds. The quantity of food which the pond supplies in three years is thus sufficient only for the growth of 40,000 pounds of carp.

I do not consider it practicable to fatten oysters by artificial means, although in North America and Europe an effort should be made to fatten planted oysters upon corn-meal. The food of oysters consists of very small organic particles which float in the water, and if one should attempt artificial feeding by carrying to the oysters of a bed water containing pulpy pulverized flesh, bone-meal, fish-guano, or corn-meal, it would be necessary to prevent the water from flowing off from the bed until all the organic matter had been eaten. But by so doing a large quantity of foul gas would certainly be generated upon the bed and remain there, so that the oysters, instead of fattening, would become sick and die. Among the external life conditions of a biocönose, temperature plays an important part.

In our seas, with their equitable temperature, a mild winter, followed by a spring and summer with the temperature much higher than usual during spawning time, is especially favorable to the production of a vast number of embryos. All living members of a social community hold the balance with their organization to the physical conditions of their biocönose, for they live and propagate notwithstanding the influence of all external attractions, and notwithstanding all assaults upon the continuance of their individuality. Although every species is differently organized, in each the different forces act together for the growth and maintenance of the individual, and although each species has from this fact its own organic equivalent, yet they all possess the same (balancing) power for the totality of the external conditions of life of their biocönose. Hence all species must respond to a deviation in the conditions of life from the ordinary mean by a corresponding action of their forces, so that their efficacy may increase or diminish uniformly. If favorable temperature makes one species more fruitful, it will, at the same time, increase the fertility of all the others. If more young oysters exist upon an oyster-bed because the old ones receive more warmth and

food than during ordinary years, then the snails, crabs, sea-urchins, and star-fish, and all other species living together upon the bank, will also produce more young, as repeated observations have shown to be the case. But since there is neither room nor food enough in such a place for the maturing of all of the excessively large number of germs, the sum of individuals in the community soon returns to its former mean. The surplus which nature has produced by the augmentation of one of the biocönotic forces is thus destroyed by a combination of all the forces, and the biocönotic equilibrium is by this means soon restored again. Where it is possible for one to furnish suitable ground and food for an excessive number of young germs, a greater proportion of them can arrive at maturity than in an entirely natural biocönose. The oyster-breeders of Arcachon and Auray increase very much the mean number of oysters which arrive at maturity upon their beds by placing tiles in the water, upon which the young can attach themselves. These young are then provided with a suitably prepared ground over which water containing food is allowed to flow. If in a community of living beings the number of individuals of one species is lessened artificially, then the number of mature individuals of other species will increase. Thus, upon the west coast of France cockles and edible mussels took the place of the oysters which had been caught from the beds; and upon the fertile prairies of North America herds of tame horses and cattle are now pastured where immense throngs of wild buffaloes (*Bos americanus*) once ranged in full liberty.

If the germ-fecundity of a species is lessened by the artificial distinction of many mature breeding individuals, while all the other forces of the community are working with their accustomed vigor, so surely must there be a decrease in the number of individuals of this species which arrive at maturity. A large number of the most productive oyster-beds upon the west coast of Europe have been devastated by overfishing, and many fresh waters have, through the incessant catching of half-grown fish, been almost entirely depopulated. It is very natural that those years during which a large number of herring, salmon, or sturgeon are caught upon a certain stretch of territory should be followed by years when fewer fish appear, because in the years when large catches are made very many breeding individuals are destroyed.

If in a case of subtraction the minuend is lessened while the subtrahend remains the same, the remainder will be lessened also. By the continued artificial destruction of breeding individuals, the fecundity of any one species of a community may sink so low that it is no longer able to produce sufficient germs to insure in all cases the maturing of a sufficient proportion which shall escape the ordinary natural assaults to which they are subject in the community; the species therefore dies out. In this manner the dodo (*Didus ineptus*) became extinct upon the island of Mauritius in the seventeenth century, after the Portuguese, in 1507, had disturbed the biocönose of the island by the introduction

of swine and other animals, and after the Dutch, still later, had ruthlessly killed many of these birds. Also, at present, there are no turtles at Mauritius, while up to the year 1740, according to written testimony, hundreds were caught there for the provisioning of ships. Certainly many young dodos and turtles must have been devoured by the pigs. The beaver (*Castor fiber*) will perhaps very soon have vanished from our biocönotic transformed portion of the earth. The Greenland whale (*Balæna mysticetus*) is now seldom seen in the neighborhood of Spitzbergen and Greenland, on account of the persecution to which it has been subjected since the seventeenth century. Every biocönotic territory has, during each period of generation, the highest measure of life which can be produced and maintained there. All the organic material which is there ready to be assimilated will be entirely used up by the beings which are procreated in each such territory. Hence at no place which is capable of maintaining life is there still left any organizable material for spontaneous generation. If, in a biocönose the number of individuals which arrive at maturity would be maintained at the highest point, even though the number of breeding individuals is being artificially lessened, the natural causes which act towards the destruction of the embryos must be diminished at the same time. In the Bay of Arcachon the breeders raise to maturity an unusually large number of young oysters by guarding them artificially from their enemies.

In an example in subtraction the remainder may be kept unchanged, or even increased, if the subtrahend is decreased at the same time as the minuend; and the mass of individuals of any species may be increased permanently if the biocönotic territory is extended. Thus, when the Lim Fiord became filled with water from the North Sea, the number of mature oysters over the territory of the North Sea coast of Denmark increased to more than seven millions (chapter 8, p. 30). The oyster-beds in the Bay of Arcachon and the *claires*, or fattening-ponds, at the mouth of the river Seudre (p. 27), are artificial extensions of oyster-territory.

The individual number of cultivated plants and animals has been immensely increased because man has artificially extended their biocönotic territory; and this artificial increase in the number of plants and animals by means of cultivation is the foundation for the increased fecundity of the human species and the greater number of individuals which arrive at maturity—that is, for the extension of the biocönotic territory of *Homo sapiens*. The average yield of our woods, fields, and gardens is the result of natural force and human labor, for in addition to the chemical and physical forces of earth and air, and the organic forces of wild and cultivated plants and animals, the bodily and mental forces of man play an important rôle in the culture of field and forest, and a very significant share of the large yields of harvests is due not only to the numerous workmen of the woods and fields, but also to the makers of implements of labor, to the mechanics and opticians who produce instruments for the investigation of natural phenomena, and to the care-

ful studies of the many investigators of nature and of those interested in land and forest culture. And these manifold interdependent human powers must unceasingly oppose the average uniform workings of natural forces if a permanent mean profit would be derived from the artificial communities of cultivated lands, or if Nature would be prevented from introducing again into each such territory her own communities. This was entirely disregarded in the case of the banks along the west coast of Europe. Millions and millions of oysters were taken from these beds, and great astonishment arose when it was noticed that their productiveness had diminished. Notwithstanding that the number of breeding animals was extraordinarily diminished at each annual gathering, yet every succeeding year an equally large number of mature descendants would be harvested. Oystermen wish the oyster to be exempted from the workings of those communal laws, according to which field and forest culture must be conducted in order to achieve a certain measure of success; and there are oyster-breeders in England who desire, for the entire satisfaction of their great yearly demands upon both the oyster-banks and the oyster-beds, that every year, during the breeding period, the temperature of the water should remain at from 18° to 20° C., that no wind should blow, and that no storm should suddenly disturb the good weather, in order that none of the young swarming oysters may be destroyed.

In France they expected that all of the million germs produced by a full-grown oyster would grow into marketable oysters, if only suitable objects were provided to which they could attach themselves. It was thus believed that some miracle would be wrought by means of which oysters would reach maturity, for there existed in the water which passed over the beds where the millions of young oysters were laying not a particle more food than was brought there years before, and that was only enough to feed the much smaller number of oysters existing there at that time. In Germany they desire that oysters should live and thrive upon changing sand-banks and mud-bottoms, and accustom themselves to the brackish water of the Baltic, and that at the same time they should remain animals of the same tenderness and delicacy of flavor as the oysters of the good Schleswig-Holstein beds. Such desires could only be realized by means of miracles or by the exemption of certain single cases from the necessary workings of Nature's laws. There must be an entire change in the form of our coasts and in that of the islands lying along them, in the direction of the mouths of the rivers and in the flood and ebb currents, before oysters can be made to thrive over our entire sea-flats. It would thus be necessary to supersede the natural oyster biocönose by an artificial one, which would have to be cultivated as farmers and gardeners cultivate their fields and gardens; and in order that oysters should be able to live in the waters of the Baltic to-day, their physiological activities would have to be so changed that they could thrive in water in which the percentage of salt is much

more vacillating than in the water of the North Sea; that is to say, it must become another animal, and yet, at the same time, retain the flavor of the oyster. People have experienced a thousand times that the best-flavored and most agreeable animals and plants are brought to perfection only under entirely definite external conditions of life, yet they wish an exception to this law of nature in favor of the oyster. They wish for miracles in order that oysters may be supplied to the many who are now oyster-eaters, as cheaply and plentifully as they formerly were to the few who at that time appreciated their value.

II.—CONCERNING THE INCREASE IN THE PRICE OF OYSTERS AND THE NUMBER OF CONSUMERS, AND THE DECREASE IN THE NUMBER OF OYSTERS.

In England there are breeders of oysters and others who are well versed in oyster economy who maintain that the oyster-banks have become impoverished because of a long series of seasons which have been unfavorable as breeding years, and not because of overfishing upon the beds. According to their observations, there have been no large broods of young oysters since 1857, 1858, and 1859. This may be the case in regard to a number of localities, but it has no significance in the management of a permanent, profitable oyster-culture, since such culture is not conducted according to an unusually favorable summer, but according to the average of climatic conditions. And that these conditions have not changed in the west of Europe in our century, and thus during the time of the impoverishment and exhaustion of many beds along the west coast of Europe, is proven by the temperature observations which have been made at the Observatory at Paris since the year 1806. According to these, the mean yearly temperature of Paris during this century has remained, up to present time, at 10.8° C., from which it follows that the climate is the same now as before any impoverishment took place. In 1859 there were many young oysters spawned upon the beds along the west coast of France. In 1860 there were many young broods upon the beds near the island of Ré and near Rocher d'Aire, and but few broods at Arcachon; 1861 was a good brood year for all three places; 1862 bad for the island of Ré and good for both the others; and in 1865 there were very many young in the Bay of Arcachon and but few near Rocher d'Aire and the island of Ré. These facts show that local conditions can either favor or prevent the production of broods of young oysters in one and the same year.

On the 6th of April, 1876, Mr. F. Pennell made a communication to the commission for the investigation of the British oyster-fisheries, and at the same time remarked that, according to his experience, the number of young oysters in each brood period was dependent upon the number of breeding oysters, but that, nevertheless, at times, extraordinarily large

numbers of young were produced.* Whoever has followed thus far the detailed statements which I have made must be obliged to confess that Nature is not to blame for the impoverishment of the oyster-beds along the western coast of Europe during the last century, for neither have the external conditions of life for the oyster become less favorable nor has the fecundity of single animals become less.

Nothing else but excessive fishing, without protection, has depopulated the beds. Most of the oystermen and those thoroughly acquainted with oyster industry, who reported their experience and opinion, in London, in 1876, to the commission for the investigation of the British oyster-fisheries, were entirely of this opinion. But the question will be asked, Why were the beds of the west of Europe not overfished in olden times? Because, before the time of steamboats, locomotives, and railroads, there was a much smaller number of consumers than at present. Then genuine connoisseurs were rarely to be found except along the coast where the oyster lived.

In the autumn, when oyster-fishing began, those only were very costly which were first caught, but as more were brought in the price rapidly fell. On the 21st of September, 1740, the first hundred fresh Schleswig-Holstein oysters sold in Hamburg for 1.42 marks (about 35 cents) of present money. Later the same day 900 were sold at 1.20 marks (30 cents) per hundred; then 3,400 at 15 cents; and finally 10,800 at 7½ cents per hundred. On the 15th of October of the same year, and at the same place, the first hundred fresh, newly arrived oysters sold for 2.40 marks; the second hundred for 2.10 marks; then 1,025 were sold for 1.80 marks per hundred; then 1,000 at 1.50 marks; then 2,000 at 1.20 marks; and finally 12,500 at 60 pfennige (15 cents) per hundred. These numbers are taken from the report upon the Schleswig-Holstein oyster-banks,† and show that it was necessary to lower the price of oysters very soon after the arrival of a large importation into Hamburg harbor, if they were to be disposed of in an eatable condition and not entirely lost, because there was no adequate means of transporting them into the interior. Such a fall in price guarded the oyster-beds from too destructive fishing. Soon, by means of steamers and railroads, oysters fresh from the beds could be spread far and wide into the country; then oyster-eaters began to increase in number; and so, despite the rapid advance in price, the demand for oysters increased from year to year. This demand was very much in proportion to the spreading of the network of railroads in England, France, and Germany. It did not come into the heads of the oystermen that a more exhaustive fishing would tend to depopulate the beds. Year after year they had found an ever-ready supply of oysters upon the same beds; why should they not, then, take away whatsoever came into their dredge?

* Report on Oyster-fisheries, 1876, p. 116, Nos. 2386 and 2387.

† *H. Kröyer.* De danske Oystersbanker. In this work several examples are given, at pages 92 and 93, taken from the reports of oyster-culture in Schleswig-Holstein, of the decrease in price of oysters upon one and the same day at Hamburg.

In former times, fishing was carried on only in those places where the oysters lay thickly together, for where only a few oysters could be caught it did not pay to fish, because of the low price; hence all of those banks which were covered only with scattered oysters were left to rest until a sufficient number of mature oysters had accumulated upon them to repay the labor of fishing. But when, however, the number of oyster-eaters increased, and likewise the price of oysters, it became profitable to fish upon less fertile stretches, and the dredges were used so persistently that finally very little more could be found upon the banks. Before the time of railroads the decline in price of oysters regulated the fishing in favor of a good condition of the beds; but since the time of railroads the ever-increasing price has acted as an incentive to the oystermen to depopulate their banks. The official reports upon French and English oyster-breeding contain abundant proofs of this, as evidenced by the facts there set forth. The oyster-fishers of Cancale were made happy by receiving, each succeeding year, for those oysters which they sent fresh to Paris, more money than they had received the year before, and the possibility of depopulating their rich banks was not thought of.

Learned authorities had said that every mature breeding oyster produced from two to three millions of young. They believed, then, that if they left upon the beds only a hundred breeding oysters they would be doing all that was necessary in order, in a short time, to find upon the overfished beds two hundred to three hundred million descendants of the same. Up to 1854, the oyster-beds of Rochefort, Marennes, and the island of Oléron were fished with some regard to their preservation, since their oysters found a market only in those places which were situated along the neighboring coast. But in 1854 Rochefort was placed in connection with the interior by means of the network of railroads, and the market for these oysters, and the profits from them, increased so much that they were taken until these beds were almost entirely depopulated. From 15,000,000 in 1854–'55, the catch fell off to 400,000 in 1863–'64. (See chapter 9, p. 37.)

The last report upon the English oyster-fisheries in the year 1876, contains many instructive instances of the great advance in price as the result of the decrease in number of oysters. At Whitstable, where the finest kinds of native oysters are produced, the price for a bushel, 1,400 to 1,600 oysters, was, during the period from 1852 to 1862, never higher than £2 2*s.* sterling. In 1863–'64 it had risen to £4 10*s.*, in 1869 to £8, and in 1876 to £12 sterling. Thus, in 1876, a single oyster cost there about 16 pfennige (3 to 4 cents) in our currency.

At Colchester, another celebrated market for oysters on the east coast of England, a bushel of oysters cost, during the years 1856–'63, 66*s.*; 1864–'65, 80*s.*; 1865–'66, 95*s.*; 1866–'67, 100*s.*; 1867–'68, 130*s.*, English money.*

* Report upon oyster-fisheries, 1876, p. 63.

At Falmouth, a tub of oysters (1,600) cost, in 1830, 1*s.*; 1860, 2 to 2½*s.*; 1863, 4 to 14*s.*; 1867, 9 to 37*s.*; and in 1869, 45*s.* A cask of Schleswick-Holstein oysters (700 to 800) was sold, in 1875–'76, to oyster-dealers, for 105 marks (about $26.25).

Fifteen years previous the price was only a third of that sum. By the incorporation, in 1864, of Schleswig-Holstein in the German tariff union, the territory into whose markets the Schleswig-Holstein oysters could be brought free of duty was very significantly increased, and at this time English oysters were becoming very rare in German markets. The political changes in Germany, and at the same time the great increase in the consumption of oysters, evidently increased the incentive to a more complete fishing of our oyster-beds than in former times, and this accounts for the extraordinary decrease in the number which arrive at maturity to-day, for at the inspection of these beds in 1869 there were found only 282 half-grown oysters for every 1,000 full-grown, and in five inspections during the years 1872 to 1876 there were found, on an average, only 107 half grown. This is in striking contrast to former inspections, where the average was 421 half-grown oysters for every 1,000 full-grown, as has been shown in chapter 9, p. 35.

12.—THE CHEMICAL CONSTITUENTS AND THE FLAVOR OF OYSTERS.

The heaviest portion of an oyster is its shell, and this, on an average, constitutes about 84 per cent. of the total weight of an ordinary Holstein table-oyster. Internally, the oyster is a soft animal; externally, it is a stone animal. The dried shells of very old oysters weigh from 250 to 320 grams. In such heavy, thick-shelled oysters the soft portion is generally very poor, and the body-space is smaller than at the time when it first attained its complete maturity. From this it follows that the edges of the last-formed shell-layers do not pass over those which were formed earlier, but lie under them. The principal constituent of the shell is carbonate of lime, which forms about 96 to 97 per cent. of the whole weight. The shell also contains 1.2 to 1.3 per cent. of sulphate of lime, 0.09 per cent. of phosphoric acid, 0.03 per cent. of oxide of iron, and traces of magnesia and aluminum. If these inorganic constituents of the shell are dissolved in acid, there will remain undissolved brownish bits and flakes of an organic substance which has been named *conchyolin*. This contains the elements oxygen, hydrogen, nitrogen, and carbon. The left or arched valve of a Holstein oyster contains from 1.01 to 1.025 per cent. of conchyolin, the right somewhat more, from 1.10 to 1.15 per cent. This increase in the percentage of conchyolin makes the right valve less brittle than the left.

At times pearls are found in oysters. They generally lie in the mantle, but also in the shell-muscle. Pearls are isolated deposits of shell-material. Their chemical constituents are accordingly the same as those of

the shell. In some pearls taken from Schleswig-Holstein oysters there has been found a proportionally greater amount of carbonate of lime than is found in the shells themselves. Brilliant pearls, suitable for ornaments, are seldom found in oysters, those generally taken being white and without brilliancy. However, an oyster-eater in Hamburg once discovered, by means of his tongue, a pearl which he sold to a jeweler for 66 marks (about $16.50). Nearly all mussels have more beautiful shells than that of the oyster, but in delicacy and fineness of flavor the oyster surpasses every other mollusk. Only those materials can be tasted which, dissolved in fluids, come in contact with the organs of taste. Hence the flavor of the oyster depends upon substances which are either in solution in the juices of the body of the oyster or which become dissolved in the mouth of the eater. Fresh, living oysters, as is the case with all sea-animals, contain very much water. In order to estimate the proportion of water the greatest care must be taken in removing the oyster from the shell, especially when the shell-muscle uniting the two valves is cut. The exterior of the body must first be dried with blotting-paper, the body then weighed and finally placed under the air-pump and all the water drawn out. Two Schleswig-Holstein oysters which were taken from the shell and dried, weighed together 14.70 grams, and after all the water had been drawn from them they weighed only 3.05 grams. They thus contained 79.25 per cent. of water and only 20.75 per cent. of solid material. Two other large oysters, which had been previously deprived of their gills and mantles, weighed together 20.55 grams; after being thoroughly dried they weighed 4.809. Thus, their edible portion contained 76.64 per cent. of water and 23.36 per cent. of solid material.

A large number of investigations upon Schleswig-Holstein oysters demonstrated that the entire animal contained from 21.5 to 23 per cent. of solid material, while the body, without the gills and mantle, contained from 23 to 24.5 per cent. of solid material.* Making due allowance for size, there is a somewhat greater difference in the proportion of solid material between oysters and fish than between oysters and birds and mammals, for—

	Per cent. of solid material.
Trout-flesh contains	19.5
Carp-flesh contains	20.2
Pork contains	21.7
Veal contains	21.8
Beef contains	22.5
Fowl-flesh contains	†22.7

*I am indebted to Prof. O. Jacobsen, of Rostock, for all the information that I have given in chapter 12 in regard to the chemical constituents of the Schleswig-Holstein oysters. In June, 1871, when he lived in Kiel, he analyzed, at my request, a number of oysters which I had received fresh from the Schleswig-Holstein beds.

†The figures quoted in the comparison of the amounts of solid materials in different kinds of flesh are based upon the analyses of Schlossberger and Von Bibra. They were taken from the Elements of Physiological Chemistry of Gorup-Besanez, third edition, 1874, p. 682.

One hundred parts of dried oyster-meat contain 7.69 to 7.81 parts of nitrogen, and 100 parts of fresh oyster-meat contain 1.85 to 1.87 parts of nitrogen. By burning the dried oyster-meat we can obtain the amount of inorganic material which it contains. By this method it has been found that the meat of completely dried Schleswig-Holstein oysters, when deprived of the beard, contains 7.45 per cent. of inorganic substances, while in those which have not been dried the amount is only 1.79 per cent. According to these determinations, 100 parts of the bodies of fresh edible Schleswig-Holstein oysters, contain—

77.00 parts of water.
21.21 parts of organic material.
1.79 parts of inorganic material.

The principal inorganic substances are salt (*sodic chloride*) and phosphoric acid. The proportion of salt in fresh oysters is 0.58 per cent., and of phosphoric acid 0.38 per cent. In fresh beef the proportion of salt is 0.49 per cent., and of phosphoric acid 0.22 per cent. From these results it is evident that the oyster contains as much food substance as the better sorts of meat used for food, or even somewhat more. In addition to this, it is still farther distinguished from the greater number of animal foods by being more easily digested. But if we compare the price of oysters with the price of equal quantities of the best kinds of ordinary meats, we find that, with us, the oyster furnishes a much more costly means of nourishment than the others. If the edible portions of a dozen Holstein oysters weigh 125 grams, or one-fourth of a pound, and if that number cost 2 marks (50 cents), then the oyster, as a means of nourishment, is 6¼ times more expensive than beef-steak, at 1 mark 20 pfennige (30 cents) per pound. The value of an oyster does not depend principally upon the amount of nourishment which it contains, but chiefly upon its delicacy and uniformly fine flavor. Oysters form the finest article of food which our seas produce—food which can be eaten fresh from the water, and which requires no artistic cooking to develop its excellencies. They resemble the noble pearls, which attain their greatest perfection in the place of their growth. What particular constituent of the oyster it is which gives it its flavor is as little known as the origin of the flavor of various other kinds of food. The liver and the generative organs contain glycogen and grape-sugar. Pure glycogen has no taste, and it is composed, as is grape-sugar, of carbon, hydrogen, and oxygen. Probably the fatty matters aid greatly in giving flavor to the oyster. I have repeatedly found that in May and the first half of June, when the generative organs are very much developed, the females have a much finer, nut-like, and full flavor than the males.

I have repeatedly placed fresh oysters, whose sex I had previously ascertained by means of the microscope, before different people in order to get their opinions of the flavor. They also, without knowing anything about the difference in sex, found the female superior in flavor to the male. Those females which are well developed are generally some-

what thicker and more cream-like in color than the males, whose bodies are more transparent and watery. In the middle of winter these differences are not so apparent as shortly before the breeding season. Immediately after the emission of the generative products, oysters are poorest and they are more watery then than at any other time. After the breeding period their size increases from month to month, and, in case their nourishment is not interrupted by long-continued severe cold, their flavor becomes fuller and richer in proportion to the rapid development of the generative organs. From this it follows that winter, but more especially spring, are the periods of the year for the enjoyment of oysters. I have repeatedly heard people, who rated themselves as genuine oyster-eaters, say that "oysters ought never to be bitten, but should be swallowed whole." If this were so, then one might better use, in the place of the high-priced oyster, a succedaneum made of tasteless thin paste, and having merely the form of the oyster.

As with all other kinds of food, the flavor of the oyster is more effective and can be better appreciated the more intimately its constituent elements come in contact with the surface of the organs of taste. Therefore, if one would obtain the full flavor of the oyster, it must be bitten to pieces and chewed, in order that all the constituents may be free to produce their greatest effects. The Schleswig-Holstein oyster-banks produce oysters of very different flavors. Those having the finest flavor exist upon beds which lie not very far from the deeper channels, through which the water passes in and out during the flood and ebb tides. (See the chart of these beds on page 4.) Thus, very superior oysters are found upon the beds at the northern and southern ends of the island of Sylt, and upon a single bank north of the island of Röm; but the very finest oysters are found upon the beds near Hörnum. The oysters of these beds are especially distinguishable by the large growth of their organs of generation. Their flavor is very delicate, and never bitter and watery, as is the case with the oysters of many other beds. This superiority in form and flavor must be the direct result of the action upon the oysters of these banks of the external conditions of life under which they exist. The oysters upon the beds near Hörnum lie deeper and nearer the open sea than those farther in upon the flats. The water, also, which flows over them during the course of the day and year is less subject to fluctuations in temperature than that which flows over the beds lying nearer the mainland, and there is here a somewhat greater percentage of salt than in the water over the beds of the shallower portions of the sea-flats. To these external physico-chemical properties of the Hörnum banks are also united faunal peculiarities. Here are to be found the three-sided worms (*Pomatoceros triqueter*), and colonies of polyps which, from their form, are called "sea-hands" (*Alcyonium digitatum*). Both of these forms are found abundantly upon the bottom of the open North Sea. They are not to be found upon any other beds of the sea-flats, and it is very evident that they cannot live

upon the inner beds, since these do not furnish the necessary conditions for their growth. Thus, just in those places where the extreme limiting line of the territory inhabited by the "sea-hands" and three-sided worms passes across our oyster-beds, the most favorable conditions exist for the growth of the finest-flavored oysters. A three-sided worm upon the shell of a Schleswig-Holstein oyster is, therefore, a sign of its arrival from one of our best beds. A pastor living upon the island of Sylt was fond of good oysters, and was also well acquainted with this external indication of them; so he was accustomed to say to the out-going oyster-fishers: "Bring me some fresh oysters when you return, but only such as the good Lord *has marked.*" In Paris the green oysters of Marennes and Tremblade are especially prized on account of their delicious flavor. This cannot come from the green constituents of their body, for if old oysters are taken there during the winter months and placed in a fattening-pond, they will, indeed, become green, but by no means so well-flavored as those oysters which were placed there when young and have lived there several years. (See chapter 8, p. 27.)

The flavor of oysters is best at the banks themselves, if they are opened very carefully and all the sea-water which is inclosed in the shell when shut is allowed to escape. This can be done most judiciously if the oyster is placed upon the flat right valve, after the loosening of the shell-muscle. This valve is a superior natural plate for the oyster, since it has no cavities like those of the left valve, filled with disagreeably smelling water, which flows out when the shell is opened and contaminates the flavor of the oyster. (See Fig. 5, p. 11.) The oyster can live for days perfectly dry without dying, but it gradually loses its softness, and soon begins to smell, from the dying of the animals which inhabit the outside of its shell. It is very seldom that these can be entirely removed by the usual means of purification (p. 8), so that the flavor of the oyster inland is almost always affected by these contaminating odors.

In order that oysters may be furnished to those who want them, in the freshest and best-flavored condition possible, only such a number should be caught at any one time, and for any one market, as can be disposed of in a very few days. But since wind and weather are often so unfavorable, just in the height of the oyster-season, that vessels cannot go out to the beds and fish, the oystermen are obliged to dredge a large supply of oysters during good weather and plant them in some place where they will live and at the same time be available whenever they are wanted. For this purpose large reservoirs have been built near Husum. These consist of four four-sided ponds, with perpendicular walls, lined with plank. The length of the ponds is 14 meters, the breadth 12 meters, and the depth about 2 meters. The bottom is paved with tiles. The ponds can be divided into compartments by means of perpendicularly placed wooden partitions. In these compartments the oysters are planted as soon as they are brought from the

banks. They are then covered with water which has stood for a while in a neighboring pond, the clearing-basin, in order to let the mud settle. During cold weather 500 tons, or 350,000 to 400,000 oysters, can be kept in these storage-ponds, but during warm weather only 200 tons. If it be necessary, oysters can be stored in the clearing-pond and in the trenches which lead to the ponds. In order to preserve the oysters in the storage-ponds in a healthy condition they must not be placed too close together, especially in warm weather. They must also be changed very often from the compartment which they have occupied to a clean one, and be subjected to a rapid flow of water in order to wash off all the dead material from their shells. Most of the English oysters which are eaten in Germany come from Ostend. They are kept there in basins similar to those at Husum, which have been built behind the walls of the old fortress. In 1869 I found there nine of these basins, which could be filled to a depth of about 2 meters with sea-water, supplied through sluices which connect the basins with the sea. In these ponds oysters are only stored and fattened. Those not sold by the close of the oyster-season are generally sent back to the English beds, because they are kept with difficulty during the summer, but principally because, after lying in the ponds for a long time, they become very poor from the lack of food. In the years 1875-'76 it is reported that a weekly supply of 500 bushels (750,000 oysters) were received at Ostend from England.

The most celebrated oyster-port in England is Whitstable, situated on the southern side of the mouth of the Thames. Here the best natives are found. Their shells are indeed not very large, but their bodies are thick and very full, on account of the great depth of the cavity of the left valve.

The oysters which are sent over to Germany, by way of Ostend, are smaller varieties than the celebrated Whitstable oysters. These last are seldom sent to the continent, nearly all being demanded for the London market, where they command a higher price than any other kind. Oysters for exportation are packed in casks. In these they are placed with the left valve always undermost, and are packed so close together that, when the cask is closed, no room is left for them to open the valves of their shells. Upon many oyster-beds along the west coast of France those oysters which have very nearly arrived at a marketable size are at frequent intervals left uncovered, and longer and longer each successive time. As long as they are deprived of water they will keep their shells closed, and thus they are trained to retain, while in the dry casks, and until the knife prepares them for the table, the water which they inclosed in their shells when taken up. If ice is used to keep oysters fresh, care must be exercised that the water from the melting ice does not come in contact with the mollusks, or their flavor will be injured. Care should also be taken, especially with shelled oysters, that

the ice used to cool them off does not entirely cover them.* Preserved oysters, packed in tin cans, are brought into the markets from North America. In these the natural flavor, for which the fresh oyster is so highly prized, is as much destroyed as is that of the tropical fruits which come to us cooked in sugar. If they were not preserved oysters they would hardly find purchasers. They serve merely as suggestions of fresh oysters.

13.—THE OBJECT AND RESULTS OF OYSTER-CULTURE.

The object of a good oyster industry is to gain from the territory cultivated the greatest possible profit, and at the same time to render the industry permanent. From a bed of inanimate material one can take away as much of the mass as he can use with profit. Such a proceeding does no harm to the prosperity of the bed, since what is left has nothing to do with the production of a new supply. With living objects, on the contrary, it is different. They are not quiet, immovable masses, but combinations of materials and active forces, which are engaged among themselves in a continual renewal; and if one is to derive the greatest possible benefit from them, their mass must not be indiscriminately reduced, as with minerals in a mine, but care must be taken that their powers of renewal are not weakened by a lessening of their available forces and materials. A breeder of cattle who would maintain a certain definite degree of productiveness in his herd must keep a definite number of breeding animals. If it is desired to have a definite permanent production of wood from a given extent of forest, only such an amount must be cut yearly as will be offset by the yearly growth. If a permanently larger quantity is desired, the forest surface must be increased. A profitable permanent system of oyster-culture is also dependent upon these same laws. Hence its foundation is the preservation of a stock of mature breeding oysters. No artificial system has yet succeeded in bringing to maturity, in inclosed parks, generation after generation of oysters, and the most clever breeders are obliged to rely upon the natural banks in order to obtain breeding oysters or young for their fattening-ponds. Hence the foundation of all oyster production, whether artificial or natural, is *the preservation of a stock of full-grown breeding oysters upon the natural oyster-banks.*

In France, ever since the government undertook to retain upon the natural banks along its coast a sufficiently large number of breeding oysters to keep up the stock, artificial oyster-breeding has maintained a secure basis. By this means the French Government has been enabled, through its fishery commissioners, to determine the beds which are in a suitable condition to be fished and the time at which they can

* The Romans were in the habit of cooling their oysters with ice from the mountains: "Addiditque luxuria frigus (ostreis) obrutis nive, summa montium et maris ima miscens." C. Plinii Sec., naturalis historia, lib. xxxii, 6, 21.

be profitably worked. In the rich oyster-regions of Cancale and Saint-Vaast-de-la-Hogue, on the coast of Normandy, and in the Bay of Arcachon, there are great banks which, during spring-tide (at the time of full and new moon), run dry, or are covered with so little water that people can wade over them and pick up the oysters with their hands. Near Cancale crowds, resembling caravans, of from 500 to 1,000 persons, mostly women and children, fish for oysters upon these exposed banks. One of the best of these beds in the Bay of Arcachon, called Le Cés, has an extent of 11 hectares (about 26.73 acres). When oyster-fishing is permitted on this bank, it is generally performed by women, who are placed in rows of about ten each, and, headed by two men, proceed over the bed. The oysters are gathered into sacks which are carried by women following behind the others, and who empty the sacks, as they become filled, into larger baskets. The gathering cannot continue longer than from two to two and one-half hours in any one spring-tide, because the bank is not exposed for a longer time. Yet, in this time, 40 to 50 persons can gather about 60,000 oysters. Immediately after any place is fished in this manner it is marked by four cask-buoys, so that it may not be fished again the same year, and in order that it may be readily found later, when they scatter oyster and mussel shells over the ground for the attachment of the young oysters. About the year 1870, the beds in the Bay of Arcachon had become almost entirely exhausted, but by this strict method of protection, the fecundity of the 19 beds which are located there has once more become so great that the water of the bay, from June till into August, is filled with swarms of young oysters. Hence it is no wonder that at times, and in favorable places, single tiles can be found to which from 1,000 to 1,200 young oysters have become attached. According to an official report* upon French oyster-culture which appeared in January, 1877, there were, in 1876, in the fattening-ponds upon both sides of the mouth of the Seudre, 80,000,000 oysters; near Oléron, 7,000,000; near Sables-d'Olonne, 10,000,000; near Lorient the same number; and near Courseulles-sur-Mer, 20,000,000 to 30,000,000. This extraordinary fruitfulness of the oyster-beds along the west coast of France is the result of the careful preservation of a rich stock of mature breeding oysters upon the natural banks, especially in the Bay of Arcachon, on the coast of Brittany near Auray, and on the coast of Normandy near Saint-Vaast-de-la-Hogue, Cancale, and Granville. Thousands of persons are industriously employed, during the season, in taking, upon shells, tiles, &c., the im-

*Rapport adressé au ministre de la marine et des colonies sur l'ostréicultur, par M. G. Bouchon-Brandely, Published in the official journal of the French Republic, January 22, 1877. Under an act of Parliament of May 17, 1877, an English translation of this appeared, with the title: Copy of translation of a report made to the minister of marine in France, by M. G. Bouchon-Brandely, relative to oyster-culture on the shores of the channel and of the ocean.

From this report I have taken all the remarks which I have made in chapter 13, in regard to the latest condition of the French system of oyster-breeding.

mense swarms of young oysters which are produced upon these beds, in guarding them from their enemies, and then in transplanting them to the numerous fattening-ponds along the coast, where, at last, by careful rearing, they are brought to marketable size. The number of persons employed daily in oyster-culture near Saint-Vaast-de-la-Hogue is 300, and near Cancale 4,000. In the district of Auray, for the year 1876, the total number of days' employment for all the men, women, and children who were engaged in this industry was 89,678. In Arcachon an oyster-breeding company laid out 110,000 tiles as objects of attachment for the young oysters. In 1876, 300,000 tiles were used for the same purpose near Vannes, and as many at Oléron. At Auray, in 1874, as many as 2,580,000 tiles were employed as objects of attachment for the young broods. At Lorient 60,000 troughs of cement, each trough 50 centimeters long by 30 to 40 broad, are used in rearing and fattening young oysters. In these the water remains constantly, during the lowest tides, 10 to 12 centimeters deep. Near Saint-Vaast-de-la-Hogue there are 185 oyster-beds, which cover an area of 88 hectares (about 213.84 acres); near Cancale the amount of surface which has been artificially changed into oyster-beds is 172 hectares (about 411.96 acres).

At Auray the amount of oyster-ground is over 300 hectares. Here there are 277 storage-beds and 20 fattening-ponds. In 1876, in the neighborhood of Marennes and Tremblade, on the Seudre, there were 13,526 artificially prepared beds, covering an area of 4,000 hectares (9,720 acres), and at the same time the Bay of Arcachon contained 3,317 such places. The production of oysters from these beds is so great that machines have been invented to sort them. With the help of a machine two women can sort in a day 30,000 to 40,000 oysters. Railroads connect the feeding-ponds with the cleansing-basins, packing-houses, and landing-places of the boats which bring the young oysters from the banks and brood-beds for fattening. From these accounts it will be seen how large a surface of sea-bottom, how much money, and how much human labor are requisite in order that the embryos which under natural conditions originate in the sea shall be transformed into the immense number of full-grown oysters which the French oyster-breeders now place upon the market. The original plan of Coste to line the entire coast of France with a network of oyster-beds has indeed not been carried out; but in consequence of his exertions and experiments many oyster-parks have been established in favorable places along the coast from Normandy to south of the mouth of the river Gironde. The French, favored with innumerable bays and with a mild sea temperature along their coast, have, by diligence, perseverance, and the invention of new methods, brought oyster-culture to such a high degree of perfection, and given it such wide range, that now, in that favored land, it is to be reckoned as one of those cultured industries in which man converts to his service vast numbers of plants and animals. The large number of oysters produced as a result of the French system of oyster-culture has

been held up very often to the inhabitants of the German coasts, in order to incite them to establish in their seas similar places for the artificial harvesting of oysters. The writers who did so knew neither the nature of the oyster nor the character of our seas. They might just as well have said to the inhabitants of the lower portion of the Elbe: "Lay out vineyards, for in 1874 the department of the Lower Loire produced 1,914,427 hectoliters of wine, and the department of Gironde 5,123,643 hectoliters." In Egypt there is nothing lacking, except water, in order to produce dates and wine in abundance upon the desert which stretches from Cairo to Suez. So it is with us; all we lack in order to carry on successfully artificial oyster-breeding upon the mud-flats of the North Sea are mild winters, with no ice, and security against the force of storm-floods. There is food enough there to feed billions of oysters. The old English method of oyster-culture was much simpler than the new French method. The work consisted chiefly in transplanting young oysters from the natural banks along the coast to suitable beds in the mouths of rivers, where they became fat and well flavored. They also removed the mud and plants from these new beds, destroyed as many of the enemies of the oyster as possible, and improved the ground by scattering over it the shells of oysters and other mollusks. This industry is carried on in a much better manner at Whitstable, where there is an oyster company which, it is claimed, has been in existence for six or seven hundred years. It numbers over 400 members, who work 120 vessels. Only the sons of those who are, or have been, members are admitted into the guild. In 1793 an act of Parliament adjudged to this company, as their property, an extent of oyster-ground about two miles long and the same in breadth, situated in the mouth of the Thames, and which they had claimed up to that time only by right of possession. This territory consisted partially of natural oyster-banks, partially of beds upon which oysters from the open sea had been placed to spawn, and partially of beds upon which oysters from along the coast had been placed to fatten. In order to still further improve these beds, empty oyster-shells, sent back principally from London, were often scattered over them. The Whitstablers consider that a thick layer of oyster-shells forms the very best bed for oysters, and they pride themselves that they possess the "best oyster-grounds in the world," as I myself have heard them say. The fecundity of the oysters upon their fattening-beds is very small. The cultivation of the oyster is carried on at Colchester, Burnham, and other places along the coast of England very much as it is at Whitstable. From these places many oysters are taken to Ostend. The efforts which have been made to bring living oysters from North America to England and plant them there have not succeeded well enough to warrant imitation. But if they could succeed in transplanting large quantities of young oysters from the breeding-stations of Normandy and Brittany to the excellent feeding-grounds of England, English oyster-breeding would probably soon take a very significant upward tendency.

The oyster industry is conducted in North America very much as it is in England. In protected muddy bays and mouths of rivers near the coast, great quantities of young oysters, which have been taken from the natural beds, are planted for the purpose of fattening, the method thus resembling that in vogue at Whitstable and at other places along the west coast of Europe. In North America places are also chosen where the oysters will be protected from frost and heat. In localities rich in food they arrive at marketable size in from two to three years. The North American oyster is a different species from that of Europe. Its scientific name is *Ostrea virginiana*. It is longer from the hinge-ligament to the shell-muscle than is the European oyster, *Ostrea edulis*, and the left valve is generally more curved than with our oyster. Very few efforts have ever been made in North America to catch and grow oysters artificially according to the French system. The natural banks produce such an abundance of young oysters that all the beds artificially planted can be abundantly and cheaply supplied from them. During late years the North American beds have furnished an annual average of about thirty million bushels of oysters for market; this is about nine to twelve billions of oysters, since there are from three to four thousand oysters in a bushel. In 1859 the number of oysters sold amounted to from six to eight billions.

The principal markets for North American oysters are New York and Baltimore. In 1867 there were over 10,000 men employed in the oyster-trade in Baltimore. The yearly capital employed in this business in New York was, about 1870, over $8,000,000.* The North American oysters are so fine and so cheap that they are eaten daily by all classes; hence they are now, and have been for a long time, a real means of subsistence for the people. This enviable fact is, however, no argument against the injuriousness of a continuous and unprincipled fishing of the beds. The size of the territory over which oysters are found, and the number of inhabitants, must not be left out of account, however, if a right judgment would be formed in regard to those great sums which appear in the oyster statistics of North America. The territory of the North American oyster-beds is of very great extent, comprehending the greater portion of the east coast of the United States. Oysters occur from Cape Hatteras, in North Carolina, to the mouth of the river Saint Lawrence, and Chesapeake and Delaware Bays are especially rich oyster localities. In the United States there are now 52,000,000 of people; in Germany, France, and England, altogether, over 109,000,000. Hence, in North America, with a less number of inhabitants, there is a much greater supply of oysters per person than there is in Europe. But as the number of consumers

*In the following works will be found more detailed statements in regard to oyster-culture in North America:

P. de Broca. Études sur l'industrie huitrière des Etats-Unis. Paris, 1865.

Spencer F. Baird. Report on the condition of the sea-fisheries of the south coast of New England in 1871–'72. Washington, 1873. Oyster-beds, p. 472, by A. E. Verrill.

increases in America, the price will also certainly advance, and then the desire will arise to fish the banks more severely than hitherto; and if they do not heed in time the unfortunate experiences of the oyster-culturists of Europe, they will surely find their oyster-beds impoverished from having defied those biocönotic laws which have been given in chapter 10.

As man has uprooted the greatest forests, so can he also annihilate the richest oyster-beds. In England it is now understood to be absolutely necessary that the natural oyster-banks should be regularly and systematically protected if they are to remain uniformly and permanently productive. A commission for the investigation of the English oyster-fisheries, which met in London early in the year 1876, recommended to Parliament that fishing for oysters be forbidden by law from the 1st of May until the 1st of September each year, and that definite limits of time be designated, during which certain definite oyster-territories must be allowed entire rest. During the close-time all handling of oysters for the purposes of food should be prohibited under penalty of fines; yet it should be permitted, even during close-time, for the purposes of transplanting, with the design of preservation and improvement, oysters taken in a lawful manner upon public beds. Upon the banks in the open sea the close-time was to last only from the 15th of June until the end of August, since these banks can very seldom be fished during the stormy seasons of the year. The size of the sea-oysters brought to market was to be at least 2½ to 3 inches in diameter.*

A close-time has been enforced upon the Schleswig-Holstein beds for a long period. This time extends from the 9th of May to the 1st of September, and, furthermore, no oysterman is permitted to take away any oysters which are less than 2½ inches in diameter. All oysters which are not of this size must be thrown back into the water. Both of these laws have been carried out; yet, nevertheless, in the course of the last twenty years the fertility of the beds, in comparison with earlier rental periods, has very significantly fallen off. These laws in regard to close-time and a minimum size for marketable oysters, which were designed to preserve to the banks an undiminished power of renewal, did not, therefore, attain their object at the very time of the high price of oysters, and when oysters should have been plentiful. It is, therefore, not enough to regulate the time of catching and the size of oysters, if, at the same time, care is not used to prevent too large a number of oysters from being taken from the beds during any one fishing season. *But what number is too great?* A foundation for an estimate of the number of oysters which may be taken away from the beds without injury to their productiveness can be obtained, for the Schleswig-Holstein beds, by means of the inquiry in regard to their productiveness. This productiveness is, upon an average, 421 per thousand; so for every 1,000 full-grown

* Report on oyster-fisheries, 1876, p. iii.

oysters which are now upon the beds not more than 421 ought to be taken away annually. Upon a number of banks where the productiveness is less than this the number taken should be less. Upon the Huntje Bed, where the production is more than 421 per thousand, as many as 484 for every thousand can be taken yearly without endangering or lessening the productiveness, since that number of medium oysters grow into marketable oysters every year. But although the productiveness is thus expressed by a proportional number, yet the absolute number of full-grown oysters which may be taken from a bed during any one season cannot be arrived at without further consideration. One must know how thick the full-grown oysters lie upon the beds; whether, in fact, there is a sufficient number to secure an average fecundity to the bank. Upon banks such as those in the Bay of Arcachon and near Cancale, which are left dry during spring-tides, it is not difficult to observe the number of oysters necessary per square meter, in order to maintain the fecundity of the bank at its highest point, for at such times they are so exposed that they can all be counted. But those beds along the German and English coasts and in the open North Sea, which, on the contrary, remain continually under water, are much less favorably situated for the purposes of these inquiries. I have often been told that "such beds could be best investigated by means of divers." The general impression is that the divers can see, through the glass in the front part of their helmets, everything which lies upon the sea-bottom. But this is erroneous, for in those shallow coast-seas which have ebb and flood tides the water is so clouded by the floating particles of mud that very little light can penetrate to the bottom. But even in clear water a diver would not be in a condition to ascertain by sight the number of oysters, for whenever he steps he renders the water cloudy, by stirring up the lighter particles lying upon the bottom; and so he would have to depend principally upon his hands, and ascertain, by feeling, those oysters which could just as well be taken up by means of the dredge, for the dredge brings from the bottom not only some of the soil, but also a portion of its inhabitants. And if the contents of the dredge be placed in large vessels or aquaria, with sea-water, the animals will very soon assume their customary positions and motions, so that we can see, in quiet and clear water, just how they live at the bottom of the sea. An aquarium with the living inhabitants of an oyster-bank is thus a segment of the bank itself.

When, in imagination, I have united many such segments together, I can picture to myself the sea-bottom, with its inhabitants, as a diver would never be able to see it. I can see the ground covered with oyster-shells, and here and there among them a living oyster with open shell, out of which protrude the fringed borders of its mantle. Upon the upper valve polyps are growing with expanded heads, looking like delicate, many-rayed stars. Hermit-crabs, bearing their snail-shell houses, are crawling hither and thither over the rough surface, and groping about

with their claws for something to eat. Worms stick their heads out of holes and crevices; sea-urchins stretch out their sucking feet beyond the points of their spines and pull themselves slowly up on to a stone; a star-fish, with greatly arched back, has fastened itself about a mussel in order to suck it out of its shell; and a small fish has stationed itself under an open oyster and snaps up the embryos as they come from the shell.* Of this life of the oyster-bank the diver would see little or nothing, even if he happened to be a zoologist, for as soon as he had descended to the bottom the oysters would shut themselves up, the crabs and worms creep out of sight, and the fish swim away. I thus sketch this picture of a small portion of the really abundant life of an oyster-bank in order to show that one may become really very well acquainted with an oyster-bed by means of a dredge. It can also be used to estimate the thickness of oysters upon a bed, if the distance passed over by the dredge while it is taking oysters be measured. In the inspections of the Schleswick-Holstein banks, during the last few years, this has been accomplished in the following manner: At those points, where the dredge is dropped upon the bed, an empty cask, attached by means of a rope to a heavy weight, is cast overboard. The weight sinks to the bottom and holds the cask securely anchored, floating upon the surface of the water. Connected with the rope of the cask is a measuring-line, which is wound upon a roller, and which runs off as long as the vessel is going forward and the dredge drags over the bottom. The mouth of our larger dredges is one meter in width. Thus, if we let the dredge drag over the bottom until 100 meters of line have run off, and find that we then have 50 oysters in the bag, we can conclude that one oyster came from every two square meters of bed-surface; and if an oyster-bank, the length and breadth of which are known, is dredged over in this manner in different directions, a foundation is obtained from which to estimate the number of oysters upon the bed with certainly as much accuracy and with far greater speed and ease than a diver; and when the proportional productiveness of a bed thus examined is ascertained, we can estimate the number of oysters which can be taken from the bed without injury to its productiveness.

Practical persons will object to these methods as being too detailed, and yet not leading us to a sufficiently high estimate of the number of oysters; but they will be obliged to admit that there is no better means of finding out, with any degree of certainty, the number of oysters upon these banks. A skillful oysterman, one who has been acquainted with the beds for a number of years, will notice, without the use of a measuring-line, whether the oysters lie upon the banks in sufficient

* An oyster-breeder, Captain Johnston, saw, at some oyster-station for artificial culture, small fish of the genera *Gobius* and *Mullus* swallowing young oyster-swarmlings. He caught the fish, opened their stomachs, and found therein partially digested embryos. (Report on the oyster-fisheries, p. 87, Nr. 1711.)

numbers for the prosperity of the banks, or whether the beds have become impoverished. He will reach this conclusion from the number of oysters which he can catch with a certain speed of his vessel, and during a certain definite time which his dredge drags over the bottom.

Those authorities who have control of the inspections of the oyster-fisheries might, therefore, be able to avail themselves of the services of skillful dredgers to find out the condition of the banks before they decide, each season, the particular places which can be fished and the number of oysters which can be taken from each. The inspectors at Arcachon, after observations extending over many years, have arrived at a definite conclusion in regard to the number of breeding oysters which it is absolutely necessary to retain upon the banks, in order to maintain them at that stage of fruitfulness necessary for a permanent and profitable oyster-culture.

The report of January, 1877, upon oyster-culture in France says: "Although the natural oyster-beds in the Bay of Arcachon are regarded as breeding-beds, yet, nevertheless, the government allows them to be fished for some hours ever year, in order to remove the surplus of oysters." This is a fundamental proposition which a judicious oyster-breeder must carefully consider if the greatest amount of profit would be gained. In accordance with this proposition, oysters should never be allowed to remain upon a bank after they have passed the period of their greatest growth and fecundity, or until they die of old age; but we should anticipate nature, which demands the death of the old and weak as an indispensable condition for the production and bringing to maturity of the greatest number of young upon any bed. I do not consider it, then, as for the best interests of the beds to prevent dredging upon one or all of them for any long periods of time. The French Government has not, therefore, in my estimation, acted in the best interests of the beds, in entirely forbidding dredging upon a strip of territory which lies along the edge of the oyster-banks of Cancale and Granville. The object of this protection is to retain there an undisturbed stock of breeding oysters, from which to rejuvenate the impoverished beds of both these places. Upon such unfished beds the natural biocönotic balance, from which a certain definite average germ-fecundity results, will very soon become established. But this will become less if, with the same proportion of nourishment, more superannuated than mature oysters are to be found upon the beds. The productiveness of any territory will thus be much less, if it is left entirely undisturbed than if it is judiciously fished, and, moreover, the profits which result from the food-oyster taken from such territory are lost. Upon the Schleswig-Holstein banks the oysters are best when from about seven to eight years old. In warmer regions they become fully matured in a shorter time.

The amount of increase in the length of oyster shells during a given time is very different upon different portions of the Schleswick-Holstein sea-flats, but their average growth in thickness is much more uniform;

hence it would be more correct to estimate the minimum size for marketable oysters according to the average thickness of the shell than according to its breadth. Estimated thus, a thickness of shell of 18 millimeters would be a judicious minimum size for the Schleswig-Holstein oysters. In conclusion, I hereby give, as a foundation for all oyster-culture, the most important rules for the preservation and improvement of natural oyster-banks.

An oyster-bank will give permanently the greatest profit if it possesses such a stock of full-grown oysters as will be sufficient to maintain the productiveness of the bank in accordance with its biocönotic conditions.

Whenever the natural conditions will admit of it, the yielding capacity of an oyster-bed may be increased by improving and enlarging the ground for the reception of the young oysters.

The natural banks should be improved by removing the mud and sea-weeds with dredges and properly constructed harrows, and by scattering the shells of oysters and other mussels over the bottom. When circumstances will permit, all animals which are taken in the dredge, and which kill the oysters or consume their food, should be destroyed.

It would be much more judicious, and much better for those who eat oysters, if the close-time could be extended until the 15th of September or the 1st of October, so as to allow the oysters sufficient time, after the expulsion of the contents of the generative organs, to become fat before being brought to the table.

If it is desired that the oyster banks should remain of general advantage to the public, and a permanent source of profit to the inhabitants of the coast, the number of oysters taken from the beds yearly must not depend upon the demands of the consumers, or be governed by a high price, but must be regulated solely and entirely by the amount of increase upon the beds.

The preservation of oyster-beds is as much a question of statesmanship as the preservation of forests.

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