

76.—REPORT ON THE ARTIFICIAL FECUNDATION AND GENERATION OF OYSTERS.***By G. BOUCHON-BRANDELY,***Secretary of the College of France.*

Our experiments in the artificial fecundation of Portuguese oysters were made during the course of 1883 at different points on the coast. Before giving an account of the results obtained, and of some new observations which we were fortunate enough to make during the year, it is necessary to point out a fact which, in our opinion, is of the greatest importance as regards the subject in question, and which shows that we were right in stating in our last year's report to the minister of marine that the artificial fecundation of oysters opened out new prospects to the industry of oyster culture.

The following is the fact referred to, which was first reported by an English journal. In the beginning of September, 1883, the Pall Mall Gazette contained the following:

“Mr. J. A. Ryder, professor of embryology, attached to the U. S. Fish Commission, is said to have solved at last the problem of the reproduction of oysters from artificially fecundated eggs. The correspondent of the Pall Mall Gazette reports that on September 4 he saw, at the Government fish-cultural station, at Stockton, Md., several thousands of young oysters, a quarter of an inch in diameter, which had been produced from artificially fecundated eggs, and had been hatched at the station forty-six days previous.”

To the honor of the administration of marine, under whose auspices we have made these experiments, let it be stated that the first application of the methods of artificial fecundation was made in France, and through our efforts, as appears from a notice presented by us last year to the Academy of Sciences, which was entered in the acts of the Academy under date of July 31, and from a report on our operations to the minister of marine published in the *Journal Officiel* and in the *Revue Maritime*.

After having made this statement we are happy to acknowledge the success of the Americans. Their success is full of encouragement, from which we hope our French oyster cultivators will profit. We also learn therefrom that, thanks to the new methods, it is possible to acclimatize in France some of the fine varieties of oysters found on the coasts of

*“*Rapport sur la fécondation artificielle et la génération des huîtres*,” Paris, 1884. Translated from the French by HERMAN JACOBSON.

the New World, which, owing to their sexuality, are, like the Portuguese oyster, suitable for artificial reproduction, and are in many respects, especially as regards their flavor and size, superior to the Portuguese oyster.

The following has been the endeavor of our researches during this year:

1. To find out whether artificial fecundation could yield practical results in entirely closed waters; and
2. To ascertain whether the raising of the Portuguese oyster is possible and profitable in the ponds on the Mediterranean.

To begin with, it should be stated that it appears from observations made both on the coasts of the Mediterranean and of the Atlantic Ocean that aeration, a constant renewal of the water, and also its agitation, are necessary for succeeding in certain cases, especially when the temperature is high. Up to a certain point, heat favors the hatching of the eggs and the development of the embryos produced from them; but if it passes this point, it causes the rapid decomposition of the generative elements and the death of the young embryos. To operate under such a condition will almost certainly result in failure.

The majority of the experiments made during the last season have proved this beyond dispute. At Verdon these experiments were made in the salt marshes where we had previously been stationed. We had purposely isolated one of the experimenting reservoirs, so that the fresh water of the tide could not get into it. In this closed reservoir, there were placed, at different intervals, the fecundated products of at least a hundred male and female oysters; while in a larger reservoir, which received fresh water at every tide, there was placed the fry of only a dozen breeders. The result was that the collectors placed in the closed marsh remained free from spat, while each of the tiles placed in the reservoir, where the water entered and flowed off freely, contained from thirty to forty young oysters. This may to some extent be explained by the want of aeration and agitation, but it must be attributed principally to the high temperature of the water. In fact, when the embryos were placed in the reservoir, which was at the time when the most intense heat of summer sets in, it was found that there was a considerable difference between the temperature of the water in the open reservoir and that of the closed one. Similar observations were made at Cette and at Berre, in the reservoirs which the Southern Salt-Works Company had kindly placed at our disposal.

We must here give an important observation, made on the shores of the Mediterranean, relative to the forwardness of the oysters raised in the waters of the south as regards reproduction. We found that the oysters transferred last year from Verdon to the pond of Thau and the pond of Lattes were capable of propagating at the end of May. Artificial fecundation attempted at this period produced ninety lively em-

bryos from about one hundred eggs treated. Less than a month later all these oysters had spawned.

Another observation was made at Toulon. It was our good fortune to have as our co-worker M. Sénès, the principal administrative agent of marine, whose ability in matters relating to oyster culture is universally acknowledged. In the course of the month of July, when the scorching heat on the shores of the Mediterranean was most intense, M. Sénès received from Verdon breeders which, when shipped, were ascertained to be fully capable of exercising the generative functions, and which, immediately upon their arrival, were placed at the most favorable points in the roadstead of Toulon. All the efforts made by M. Sénès and myself to have the eggs hatched were in vain. Fission set in, and the eggs reached an advanced stage of development, but the process was not completed. This state of infecundity lasted during the months of July and August, and in some cases continued till the middle of September, and in a few even till the beginning of October. Not till then did M. Sénès obtain lively embryos.

Other oysters which had for some time been accustomed to the waters of the roadstead exhibited nearly the same phenomena. Although we ascertained as early as July that the generative elements were on the point of arriving at maturity, the tendency toward reproduction did not manifest itself in these specimens in a manner which promised results till the month of October, that is to say, almost three months later.*

We should add that most of the time fecundation did not succeed as well at Cette as at Verdon during the hot season, because in the latter place the precaution was taken to use only cooler water, and because the elements were brought together in receivers large enough to prevent the effect of the surrounding atmosphere from being felt too quickly. It was also necessary to change the water several times during the course of incubation. Subsequent researches have shown that the incubation of the eggs and the development of the embryos in water whose temperature exceeds 32° C. [89.6° Fabr.] can hardly be accomplished. Is this also the case with the American oysters and the unisexual oysters of the Indian Ocean? We hope soon to hear this question answered.

After stating that the experiments made at the island of Aix, in the moats of the fortifications, whose water is not sufficiently renewed and not at all aerated, were seriously interfered with by the stormy weather and the excessive heat, and yielded fewer results than we had anticipated, considering the successful manner in which fecundation had been accomplished, we give below a brief report on experiments made at the mouth of the Loire, at Pouliguen, in the oyster-cultural establishments

* We must here state that the opinion expressed in our last year's report as regards the infecundity of Portuguese oysters penned in Mediterranean waters is contradicted by this observation.

of M. Laurent, director of the Transatlantic Company. These researches were made under the direction of Pierre Laurent, the son of the learned director, a summary account of whose labors is here given.

REPORT OF PIERRE LAURENT.—Our parks at Pouliguen are located in the old abandoned salt marshes which have been appropriated for the cultivation of oysters and fish. The water is brought into them by a canal 500 meters [1,640 feet] long, which opens in the harbor of Pouliguen. There are gates which allow the different reservoirs to be emptied and filled.

The experiments were made in two separate basins, whose supply of water is kept absolutely separate, and whose levels differ 1 meter [$3\frac{1}{2}$ feet]. The first is a *claire* having an area of 50 square meters [about 538 square feet] and a depth of 90 centimeters [about 3 feet]. The second is an old salt-pit, having an area of 11,000 square meters [nearly $2\frac{3}{4}$ acres]. The water of the *claire* was partially renewed at every tide; while the water of the salt-pit was renewed only by strong tides, and on account of its large surface was continually agitated by a strong splashing. The same kinds of collectors were placed in these basins. They consisted of the shells of mussels and oysters, pieces of calcareous stones, and potsherds.

While these experiments were going on the saltness of the water varied between 2.5° and 3.2° ; it being naturally greater in the salt-pit, where the water was rarely renewed, than in the *claire* where it was renewed nearly every day.

Under conditions differing so much, both as regards the saltness of the water and its renewal and agitation, the results obtained were identical. The spat attached itself in great quantities to the collectors, especially to those which presented a rough surface, such as the oyster-shells, calcareous stones, and potsherds. Some fagots used as collectors remained bare, which may perhaps be ascribed to the slow decomposition of the wood in the closed water. Nevertheless the results were on the whole very remarkable. On certain shells as many as 300 young oysters could be counted; and if we take an average of 60 to 80 per shell, we are certainly below the actual facts.

The following was the method pursued for obtaining embryos: We took simultaneously or successively as reproducers: (1) Oysters from the Government bed at Verdon, which the commissioner of marine at Pauillac had sent us; (2) oysters originating at Arcachon, which had been penned in our establishments for a year, and which never before had shown any trace of reproduction. (These oysters are in a basin entirely separated from the former.) The experiments succeeded equally well in both cases, and the results were essentially the same, only the Verdon oysters appeared, as regards the maturity of their seminal liquids, to be eight or ten days ahead of those from Arcachon.

We threw the eggs and spermatozoa detached from the seminal glands into a large glass vessel containing 30 liters [about 8 gallons] of

water; we put in the liquid at intervals of from five to ten minutes. During that time the eggs reached the bottom of the vessel, carrying with them the spermatozoa which surrounded them. There remained floating only infecund eggs, the overplus of spermatozoa, and organic matter. Then, by means of a siphon and another reservoir we caused a current of water to pass into the glass vessel, regulating the flow in such a manner as to let in during one hour a quantity of water almost equal to that contained in it. To prevent the current from raising the eggs from the bottom of the vessel, the longer branch of the siphon opened out into a little glass saucer floating in the water. In this way the water was continually kept pure by the current during the entire process of incubation. Useless organic matter, which rapidly decomposes in the water, was thus carried off, and the aeration of the water was constant and perfect. (See Plate II.)

Several comparative experiments have demonstrated the superiority of this system. I think that the eggs should not be deposited on the bottom in too thick layers, and that a depth of water of 15 to 20 centimeters [6 to 8 inches] is sufficient.

We made twelve such experiments from July 19 to August 27. The proportion of embryos obtained to the number of eggs used increased from 5 or 6 per cent to 80 or 90 per cent. These latter results, however, were not obtained till August.

The duration of the incubation was from five to twelve hours, according to the temperature. A thermometer plunged into the water showed a variation of 12° to 29°. It was noticed that the higher the temperature the more rapid was the incubation and the greater the result. I think it is preferable, however, that the temperature in the vessel should not greatly exceed that of the water in which the embryos are to be planted, so as not to expose them to too great and sudden a change. As soon as there were enough lively embryos in the glass vessel they were poured on the collectors as uniformly as possible.

Only the fecundations which took place in August produced spat; and they were also the only ones which yielded any considerable result. Ten to fifteen days after the last sexual liquid had been poured into the glass vessel perfectly formed little oysters could be distinguished on the collectors with the naked eye. For some days a decided growth was observed in them. Unfortunately the precautions taken against an accumulation of mud were not sufficient, and gradually the mud began to cover the collectors and caused the spat to disappear.

To sum up: The experiments at fecundation made at Pouliguen were perfectly successful, in that (1) we obtained embryos which became fixed to collectors, and began to develop on them; and (2) we have shown the possibility of using as reproducers oysters raised in our country. These experiments will again be taken up next year, and promise a still more complete success, that is to say, the entire development of the young oysters.

This question is of the greatest importance to oyster cultivators. Besides showing the possibility of producing oysters by a truly practical and industrial process, artificial fecundation, according to the method of Bouchon-Brandely, makes it possible to improve the breeds by selection and crossing. It will perhaps also make it possible to acclimatize in France foreign unisexual oysters, such as the American oyster and the pearl oyster.

It will, moreover, furnish the means to devote to a remunerative industry immense tracts of land on the shores of the ocean which were formerly devoted to the production of salt, an industry which, at present, is on the decline. In the salt region of Croisic alone there are 2,700 hectares [nearly 7,000 acres], a great portion of which is at present not under cultivation, while the rest is almost barren. A larger and richer center of oyster culture than that of La Tremblade might here be established.

Although recognizing the validity of the reason given by Mr. Laurent for the mortality of the young spawn, we think that there are still other reasons why the experiments made this year were not altogether successful, at least not so successful as the fine results obtained last year at Verdon led us to expect.

Not only was the weather very disagreeable during the entire spawning season, but the winter which preceded it was one of the most severe known in many years. The losses experienced by the oyster cultivators of Marennes, La Tremblade, Arcachon, &c., were very considerable. There was incessant rain for several months, and the oysters became very soft; and although the Portuguese oyster, which seems to have greater vitality, was not specially affected by the brackish water, its fecundity seems nevertheless to have considerably decreased from this cause. We observed that the oysters from the Gironde, when the spawn was emitted, were much smaller than those of last year, whose shells were filled to repletion on account of the sexual gland being so full.

The late season when the eggs were laid also indicates some trouble in the generative evolution. Last year, at Verdon, there were successful fecundations from the last half of June; this year there were none till the end of August.

We have to give a brief account of our attempts to raise Portuguese oysters in the waters of the Mediterranean, especially in the ponds of Languedoc and Roussillon. It is well known that for some years Mr. Malespine has obtained good results in this respect in the waters of the roadstead of Toulon. The experiments which we made in the ponds of Thau, Mauguio, and others were just as satisfactory. Oysters which had come from Verdon in spring, and were placed in the pond of Lattes grew 4 centimeters [about $1\frac{1}{2}$ inches] in two and a half months. The growth was particularly noticeable during the months of April, May,

and June. These oysters, inclosed in wooden boxes, the upper and lower portion of which was composed of laths about a centimeter apart, were placed in the deepest parts of the lagoon, on bottoms almost 1½ meters [5 feet] deep.

It should be stated that there was considerable mortality among the oysters, but as we ascertained later this was caused by a little fish very common in the lagoons of the south, of a harmless appearance, but exceedingly voracious, called the goby. Wherever there was any considerable loss, both in the oyster-boxes and in the fish-pots, we noticed these little fish. What was particularly surprising was to see by the side of oysters whose death might be attributed to different causes others which were in good condition and evidently developing in a healthy manner. A sick oyster which will finally succumb does not grow. One day, when raising one of the boxes deposited in the pond of Lattes, we found in it such fine, fat, and large gobies that they could no longer escape from the box, owing to their size. Having evidently found in this box something that was very much to their taste, they had established themselves in it. But they had reached their fine condition at the expense of our oysters, most of which were dead and half of them had been devoured. Further observations have shown that the goby is really a dangerous enemy to the oyster. The oysters may be protected against them by having the boxes covered with a close net-work of metal.

We were fortunate enough to have another proof during last season of the remarkable vitality of the Portuguese oyster. In the pond of La Nouvelle oysters of this variety lived several months in water containing so little salt that the densimeter scarcely indicated the presence of salt at all.

In short, large portions of the ponds of Berre, Mauguio, Thau, La Nouvelle, and Leucate appear perfectly adapted to the cultivation of the Portuguese oyster.

EXPERIMENTS WITH COMMON OYSTERS.

At the same time when we commenced our experiments with the artificial fecundation of Portuguese oysters we undertook a series of experiments relative to the incubation, hatching of the eggs, development, and fixation of the embryos of the common oyster.

We shall pass as rapidly as possible the mere technical parts of certain questions; but to make this report clear it is necessary to give a succinct account, from an embryological point of view, of the natural history of the mollusk in question.

The ordinary oyster, known as the *Ostrea edulis*, is a hermaphrodite. Among Frenchmen, Quatrefages, Lacaze-Duthiers, Milne-Edwards, Coste, Gerbe, Davaine, and others; and among foreigners, Eyton, Mö-

bius, Hart, and others have written excellent works on the oyster, and all of them reach the same conclusion.*

We have already stated in a former report that there was a time when this question of the hermaphroditism of the oyster possessed some real interest; the time when public opinion went into ecstasies over the discovery of the artificial fecundation of fish eggs by Messrs. Géhin and Remy, two fishermen of the Vosges Mountains. People lived in hopes that the method of artificial fecundation which succeeded so well with salmonoids might also be applied to mollusks. One began to look even further—as we see from various communications made to the Academy of Sciences—and hoped that our race of oysters might be improved by cross-breeding. It was, therefore, important to know whether the sexes of this mollusk were separate. It was found that hermaphroditism was the rule with the *Ostrea edulis*, consequently the projected plan of operation became impossible.

Hermaphroditism is not the only cause which prevents the success of artificial fecundation as regards the common oyster. Would it be possible to practice this method with hope of success without being previously assured that the eggs are mature? and how can this be ascertained, and how can the eggs be brought into direct contact with the fecundating element, considering the fact that impregnation takes place inside the shells, and probably in the oviducts? And even supposing that the eggs and the fecundating element could be brought together, artificial fecundation would not yet yield any practical result, in view of the fact that the eggs and the embryos of the *Ostrea edulis*, which should necessarily be treated separately, cannot develop or even live outside of the liquid secreted by the mother oyster and contained in the incubatory cavity of its shell.

The inquiry whether the oyster is a complete hermaphrodite, that is to say, whether it is capable of generating without the aid of another oyster, has given rise to very interesting researches; but as this special question of embryology can hardly be of interest in this report, we shall confine ourselves to giving a brief recapitulation of the different opinions

* By the generic term *Ostrea edulis* we understand most of the varieties of oysters caught on the coast of Europe, namely, the violet-colored oyster with white stripes, called the bi-colored oyster of Brittany; the oyster with violet streaks from the basin of Arcachon; the reddish oyster from the river Quimper; the oyster with mother-of-pearl shell from the bank of Dives; the wandering oyster from the island of Ré; the cinnamon-colored oyster from the river Bélon and the Arcachon basin; the green oyster of Marennes and La Tremblade; the brown oyster from the roadstead of Toulon; the oyster with a thick white shell which was formerly caught near Cette, Port-de-Bouc, and other places on the Mediterranean; the rough-shell oyster of Corsica; the Isle of Wight oyster; the small English oyster, and two varieties, the *Ostrea tinota*, and the *Ostrea deformis*; the rose-colored oyster from the cold waters of Norway; the large Baltic oyster; the thick-shell oyster from the Ionian Sea; the Adriatic oyster; the Balearic oyster; the Santander oyster; the horse-foot oyster; the small Toulon oyster, which is also found in the Bay of Genoa and in the Bay of Naples, and whose scientific name is *Ostrea plicatula* or *Ostrea stentina*.

which have been advanced. Some authors have asserted that fecundation takes place in the ovary by a contact effected between the two generating elements, when these elements, which are formed in one and the same gland, both arrive at the condition of maturity, so that all the eggs would be fecundated when they pass into the oviducts. It has also been stated that the embryo is completely formed (that is, provided with shells) when it passes from the ovary into the mantle of the mother oyster. This latter opinion is entirely erroneous, for by examining the white spawn of oysters it will be seen that the eggs which compose it are mostly in the very first stage of their development.

One of our most distinguished naturalists, Lacaze-Duthiers, has found the truth by showing that the oyster is a hermaphrodite, performing by turns, but never simultaneously, the functions of each sex; and that the fecundation of the eggs which probably takes place in the generative orifices, is accomplished by the participation of another oyster. The observations which we made in the laboratory of M. Balbiani, at the College of France, corroborate this opinion of the great French zoologist, which is also shared by Möbius. We have never yet found, in one and the same gland, eggs and spermatozoa, the two generative elements, in the same stage of development; and we have never seen these two elements reach maturity at the same time. From this we have drawn the logical conclusion that they do not come in contact with each other.*

The spawning season of the *Ostrea edulis* occurs at different periods and varies very much in length. Sometimes it commences in April and does not end till some time in September. Even in December oysters containing embryos have been found. Sometimes the spawning season does not begin till May or June and ends in August. It is regulated by the temperature of the season and by the mildness or severity of the preceding winter. In June and July, however, the emission of spawn is generally most abundant.

The activity of the reproductive organ is, so to speak, constant. After the embryos have been emitted the oyster, which has become very lean, begins to pick up again, and soon arrives at a state of repletion similar to that which it possessed before spawning, but which is due to the presence of fat around the gland. This is the time when it is most sought after for the market. But while the accumulation of fat is going on epithelial cells develop, which later are transformed and bring forth the generative elements. When the weather is mild, even in winter, the transformation takes place very rapidly. We have fre-

* It will be seen further on that the eggs of the *Ostrea edulis* perish in pure sea-water. This is not the case with zoosperms. These, while they are inside the gland, are not vigorous, no matter what stage of development they have reached. But as soon as they are brought in contact with sea-water they become animated and begin to yibrate. It would seem that they do not acquire their fecundating quality until they have been in the water for a while. This would be another argument against auto-fecundation.

quently in January found in the glands producing eggs and sperm small but well-formed eggs and spermatid animalcules, which had only to be brought in contact with the sea-water to produce animation and vibration.

From April and May the first milky oysters are found. The term "milky" is employed because the spawning products, when emitted, present the appearance of thick milk. But when this so-called "milk" is examined under the microscope it will be found to consist partly of freshly fecundated eggs, partly of eggs which have already split, and of embryos recently hatched. As these develop, the whitish color of the spawn changes and it turns gray; and when they approach their complete transformation and full maturity, their color gradually turns from a dark gray to black.

The number of embryos produced by a single oyster during the year is estimated at from 1,200,000 to 1,500,000.* The embryos are sheltered in the folds of the mantle of the mother oyster for a period whose length has not yet been ascertained, and find in the mucilaginous liquid in which they live the nutritive elements which they need in order to reach the period when their roving or pelagic life commences.

Some naturalists have asserted that the oyster can spawn twice in one year. What has given rise to this supposition is the circumstance that frequently during the spawning season there are two well-defined emissions, the first about the beginning of June, the second towards the end of August.

The following experiment shows that there is no good reason for this opinion, and that it is not founded on facts. Proposing to follow up the incubation of the eggs and the transformation of the embryos in the interior of the shell, we perforated the upper valve of several mother oysters. This opening, which was made directly opposite the incubatory cavity, was corked up, so that no water could enter the oyster, and we could at any time take the observations which the experiment required. As regards the principal object of the inquiry, the data gathered by us were not very precise, as most of the oysters which had been perforated had emitted their spawn, either at the time when the operation of perforating the shell took place, or one, two, or four days afterwards; but, as regards the final development of the genital gland, we could see this gland re-form, grow, and become covered with fat; and although the specimens examined by us had produced embryos from the beginning of the spawning season, we never noticed that they were in condition to emit others at the end of the season.

* M. Gerbe, the distinguished co-worker of M. Coste, who has taken so large and active a share in the work of the last-named naturalist, has found that oysters may be considered adult when they have reached the age of one year. Oysters of this age, by reason of their size, are not as fecund as those of which we are about to speak. These measure 8 to 10 centimeters [about $3\frac{1}{2}$ inches], a size which is usually not reached until they are three to four years old.

Fearing that the trepanning operation might have disturbed the generative functions of the oysters we made another experiment which entirely confirmed the former. In the very beginning of the season, towards the end of April, we selected some oysters in which we had observed spawn, and placed them separately in a very fine bed where they would find all the conditions for reproduction in the greatest perfection. When opened in September, at the time when the last breeders emitted their embryos, cuts made in their full glands proved conclusively that they could not have spawned again before the following spring.

There remains the supposition that there is an annual spawning season in several successive emissions. It is possible and probable that ovulation is not accomplished at one time and in a single day, but it cannot be supposed that there is an interval of several months between the emissions, like that between the period of June and the period of September. We have, moreover, noticed that when, in an oyster engaged in the process of gestation, the eggs remained in the oviducts they were invariably damaged or sickly. It appears to us, therefore, that one spawning per season is the rule in the common oyster, as well as in the Portuguese oyster, and that any variations from this rule are anomalies, like oysters spawning in December or January.*

The idea of keeping and raising in close waters the embryos of the oyster, and to find them later on the collectors, has tempted many per-

*As we deemed the trepanning process referred to above eminently suitable for facilitating the study of certain questions of natural history, some of which concern directly the science and industry of oyster culture, we consider it proper to add some details to the information already furnished.

The fact of making an opening, even comparatively large—the trepan which we used measured not less than $1\frac{1}{2}$ centimeters [over one-half inch] in diameter—in the valves of an oyster does in no wise endanger its life. It is advisable, however, to work the trepan with caution when the perforating process approaches its end, so as not to injure the animal. A slight wound, however, will heal very quickly. After the hole has been made, and the little pieces of shell which have fallen into it have been removed, it becomes necessary to stop up the opening as firmly as possible, either with a piece of cork, wax, or some other substance.

The closing up of the hole is to prevent lice, small crustaceans, &c., from penetrating into the shell, or attacking the animal at a defenseless point, and also to prevent the water from entering the shell. If the oyster which has been thus operated upon is placed in a good park, and if it is in a period of vigorous growth, the cicatrization, or the restoration of the shell, is accomplished within a week. It is not absolutely complete, but the animal has covered the cork with a thin shell of mother-of-pearl, which protects it against outside enemies. In some oysters which we observed we could only counteract the too rapid formation of this mother-of-pearl by turning the cork several times every two or three days.

In this manner we have made as many as five holes in the shells of French and Portuguese oysters, and they had been so little hurt by the operation that they were exhibited last year at the Bordeaux Exposition, and still bore on their shells the marks caused by our experiments.

sons, and we must confess that we have not escaped the seductions of this idea.*

In June, 1880, we arranged in the laboratory of M. Balbiani, at the College of France, a contrivance destined for the artificial incubation of oyster eggs and the fixation of embryos, composed of a series of tubs through which a constant current of filtered and aerated sea-water circulated. (See Plates III and IV.) Eggs in every stage of development and embryos of every age were placed, each separately, in the different apparatuses. A layer of fine sand, placed towards the outflow of each tub, permitted the water to flow out easily, while the young oysters and eggs remained safely inside, it being impossible for them to escape.

The oysters from which the subjects for our experiments had been drawn came partly from Arcachon and partly from Brittany, and arrived in a perfect state of preservation and freshness. The following took place: Some hours after they had been extracted from the mantle of the mother oyster, and had been placed in one of the incubating boxes, the eggs which were at the point of splitting ceased to develop and commenced to decay. Embryos in the condition of white spawn, although very lively when placed in the water, became motionless, and died after three or four days, according to their degree of development; while

* As regards collectors, we have heard a man who is exceedingly competent and thoroughly conversant with all matters pertaining to oyster culture advance a theory, which we deem proper to report without, however, passing any opinion as to its value: Is it indispensable for the young oyster to attach itself to some object in order to live and grow? When it is in its natural state there is not the slightest doubt in this respect. The currents to which the embryo is exposed compel it to attach itself to some object, if it is not to be buried in the mud or tossed about, injured, or suffocated by the waves. But under certain conditions, on a suitable bottom, on sand free from sediment, where very pure water circulates slowly, would it not be possible for the young oyster to develop without an object to which it is fixed, which object under all circumstances is only of temporary use, because it may, with impunity, be removed from it a few days after it has become fixed? At the time when the spawn is black the embryo is nearly perfect. Some may be seen whose ciliary apparatus is so much reduced that they can hardly move. Their two valves, however, work well; in short, they differ from an adult oyster only by their small size and the convexity of their shells.

At the agricultural exposition of Edinburgh an oyster cultivator exhibited small oysters which appeared independent; but he did not tell how he obtained them, nor could he prove that they would be able to raise themselves. Possibly they were only embryos in an advanced stage of development.

In this connection we will relate a circumstance which occurred at a reservoir of M. Léon Lesca, counselor-general of the Gironde, and owner of fish ponds on the banks of the Arcachon basin. Four years ago Mr. Lesca observed in one of his reservoirs small oysters which appeared to have been deposited on, rather than attached to, the gravel and broken pieces of algæ at the bottom of the pond. This discovery was not without interest, as spawn of oysters had never been seen in that pond. The oysters were allowed to grow freely, without giving them the least care, in order to see what would become of them. Mr. Lesca has recently sent us some specimens of these oysters, which had reached an average size of 9 to 12 centimeters [about 4 inches], and in several of them we noticed that there was no place for attachment; or, at any rate, it was not visible.

embryos in the condition of black spawn held out eight or ten days. But as they approached that time they could be seen to grow more feeble every day, and finally to succumb, none of them having become fixed to the collectors placed in the boxes.

Thinking that the location (light and air being lacking) was not favorable for such delicate experiments, we went to Arcachon to repeat them there. Messrs. de Montangé extended to us the hospitality of their establishment of St. Joseph; they placed at our disposal the laboratory which they had organized, and the reservoirs surrounding this laboratory, reservoirs in which the water could be renewed at every tide.

An apparatus on the same model as that which we had used at the College of France was constructed, and eggs and embryos were placed in it as at the first experiment. The result did not answer our expectations any better, and it became necessary to change our method of experimenting. We now determined to establish ourselves at the large reservoirs referred to. The difficulty was to keep the spawn in compartments spacious enough to make them feel just as much at their ease as in open water and at the same time to have a constant renewal of water in all the compartments. Two board frames, perforated, the one measuring $3\frac{1}{2}$ meters long and broad by 70 centimeters high [$11\frac{1}{2} \times 11\frac{1}{2} \times 2\frac{3}{8}$ feet, about], the other measuring $2\frac{1}{2}$ meters long and broad and 70 centimeters high [$8\frac{1}{2} \times 8\frac{1}{2} \times 2\frac{1}{4}$ feet, about], were placed one within the other and deposited on the stone edge of the sheet of water. We piled fine sand, which had been washed, into the space of 50 centimeters [nearly 20 inches] between the outer wall of the smaller frame and the inner wall of the larger one. The apparatus worked to our complete satisfaction, and the level of the water rose and fell according to the condition of the sea. We scattered inside black spawn of several oysters, and fearing that the elements of nutrition contained in the water and coming from outside should be retained by the sand, thus depriving the captive embryos of their food, we took care to pour into their compartments several times a day several buckets of water taken from the sea when the tide came in. When the collectors were examined two weeks later there was nothing on them, and at the end of a month they were still empty. We were obliged to consider the experiment a failure; but attributed our lack of success to rain, which set in during our operations, and also to the want of heat.

Last year we resumed our experiments. We found ourselves under conditions almost identical with those of the bay of Arcachon. Thanks to the kindness of Mr. Johnston, we commenced new experiments in the vast lagoons of La Teste. In these lagoons the water is not stagnant and oysters are naturally produced there. In the very center of one of the largest sheets of water we constructed two vast basins, measuring 6 to 8 meters [about 20 to 25 feet] square, and working in the same manner as those described above. (See Plate V.) Surrounded by water on every side, infiltration, which constituted the only way of feeding the

basins, was strong enough to make the tide felt in the inside of the basins. During an entire month embryos were thrown in from time to time; even oysters were put inside which were found to have black spawn. And still our collectors showed no sign of spawn.

What is the reason that the eggs and embryos of the *Ostrea edulis*, at least during the entire period of gestation and up to the time when the embryo leaves the maternal shelter, cannot live outside the liquid contained in the shell; and why do they die in pure sea-water? Has it not been observed that the flavor of the water contained within the shells of a common oyster differs from that of the natural sea-water? The former has a peculiar and very agreeable flavor which the latter does not possess. In this difference we thought we could find an explanation, or at least an explanation of part of the phenomenon in question. It appears from an analysis made in the laboratory of M. Berthelot, the result of which we have given in another place, that the water of the oyster (that which had been subjected to an analysis had been taken from spawning oysters) contains, among other substances, a considerable quantity of albumen. It is well known that the sea-water does not contain a particle of that substance. Is the albumen the only substance causing this difference of flavor? We do not know as yet, and new experiments will be necessary to demonstrate it.

We have dwelt at such length on experiments which have only yielded negative results for several reasons: First, because we think that the problem, whose solution we have sought in vain, will one day be practically solved; secondly, because we deem it the duty of every searcher for truth to report what he has seen and observed, in what way he proceeded, and at what final point he arrived in his researches, with the view to facilitate the researches of those who may go in the same direction, thus saving them the useless and disappointing first attempts; thirdly, because, under date of July 15, 1881, we received from Bergen, Norway, a letter addressed to us by Mr. Kjørbo Schmidh, secretary of the Society for the Promotion of the Norwegian Fisheries, in which he advised us that he had succeeded in fixing the embryos of oysters on potsherds deposited on the bottom of the vessel containing these embryos. Although fortune has not favored us like our intelligent and sympathetic competitors in oyster culture beyond the North Sea, we can nevertheless say that we have done all we could. We deem it interesting to give here some extracts from the letter in question.

In the beginning the writer states that the spawn of two mother oysters was placed in a vessel whose water was renewed every day by pouring in a bottle of sea-water. He then goes on to say: "In this vessel even we could notice the influence of the rain and a lower temperature on these small animals. When there was bright sunshine they sported about near the surface; but we had only to lower the curtains at the windows to make them perfectly quiet. If from the sun they

were carried into a cold room without sunshine, they went 2 to 4 centimeters [about 1 inch] below the surface of the water. By letting a fine shower of fresh water fall into the vessel from a sprinkler, the little oysters immediately stopped their movements and went a little below the surface of the water. By continuing the sprinkling, a layer of fresh water formed at the surface, and the little oysters could be seen going down until this layer had reached a thickness of 5 to 6 centimeters [about 2 inches]. At the end of the thirteenth and fourteenth day the shells and potsherds which had been placed at the bottom of the vessel were so thickly covered with young oysters that it would have been difficult to insert a pin anywhere."

We have several times attempted this experiment, following in every particular the directions given in the communication of Mr. Schmidt, but without obtaining any result.*

* In a report made to the minister of public instruction, in 1878, we gave an account of experiments similar to those made by General Wergeland in a bay near Christiania, in latitude about 59° north, and stated the following:

It was necessary to counteract the influence of an early and severe winter, of weak tides (which at the most reach the height of only a foot or a foot and a half) and the violent storms which sometimes move masses of water more than 7 feet high. When the winter comes on in Norway, about the beginning of September, the spawn is still too young to resist the great and sudden changes of temperature. It was, therefore, of the utmost importance to keep it from contact with the outer air.

In the upper part of the establishment a reservoir of supply was constructed, filled by a pump worked by a windmill. Immediately below, and inside a shed, which insured protection against the severity of the cold, the spawning basin was constructed, 8 meters long and 6 meters broad [26½ by 19½ feet]. A metal pipe, furnished on the upper side with a fine grating to keep out hurtful animals, and on its lower side with stop-cocks to regulate the flow of the water, connected the two reservoirs. This pipe turned several times on itself, and passed through a chamber filled with water, which could be heated, if necessary, so as to keep at an almost even temperature the water feeding the spawning basin. The level of this basin was regulated by a tube, to the mouth of which was attached a filter destined to prevent the spawn from escaping. In this covered basin the mother oysters, to the number of 2,200, were placed in the beginning of the season; and although they had undergone the fatigue of a long journey, they emitted enough spawn for some of it to be found on the collectors by which they were surrounded.

In addition to this we have to state the following:

M. Bonnasset, an oyster cultivator of Marennes, succeeded two years ago in obtaining some spawn, which had come from some very fine oysters, in a *claire* which he had devoted to this purpose, by placing some mother oysters in a brook which fed this *claire*. The spawn carried along by the current attached itself to shells found at the bottom of the reservoir. This is not a rare occurrence. It has been observed in the pond of Brénéguy, near Auray, where, during the first year the oysters were placed there, a very fine reproduction was obtained, although the water of this pond was renewed only when there was a spring-tide.

A similar occurrence was observed in the ponds constructed by Mrs. Sarah Félix, at Régnéville, when these ponds were first worked. Unfortunately, the harvest reaped under similar conditions is exceedingly uncertain, for it has been observed that oysters living in close waters hardly ever propagate. This is not the case in the *claires* of Marennes, where the oysters regularly fulfil their generative functions, but is so in the two other establishments mentioned above.

There is evidently a time when the embryo is capable of living an independent life, and is liable to attach itself to any body which may resist its course. But when does this time come? Is it when the embryo is expelled from the valves of the mother oyster, or leaves them voluntarily? Or is it necessary that it should first be in the water some time in order to undergo a change and reach a greater degree of completeness? How long does its roving or pelagic life last? All answers to these questions are thus far mere conjectures and suppositions, and the few successful experiments which have been made prove nothing conclusively or even precisely.

In this direction, however, our efforts should principally tend, for it would not matter if the fecundation of the common oyster proved impossible, as long as we could succeed in keeping the legions of embryos which it produces, and cause them to attach themselves to collectors in close waters.*

PARIS, FRANCE, *November*, 1883.

EXPLANATION OF PLATES.

Plate II.—Showing method of working.

III.—1. Supply of water to move the hydraulic wheel.

2. Water-wheel for operating pump.

3. Pump for renewing the sea-water.

4. Distributing pipe receiving the sea-water raised by the pump.

5. Boxes for incubation, hatching, and fixation.

6. Basins containing the mother oysters.

IV.—A. Slate fixed to the bottom and sides of the box.

B. Slate fixed to the sides, and raised about one inch from the bottom of the box.

C. Sand preventing the escape of the embryos.

D. Outflow.

V.—1. Dike of Armaillé.

2. Bay of Arcachon.

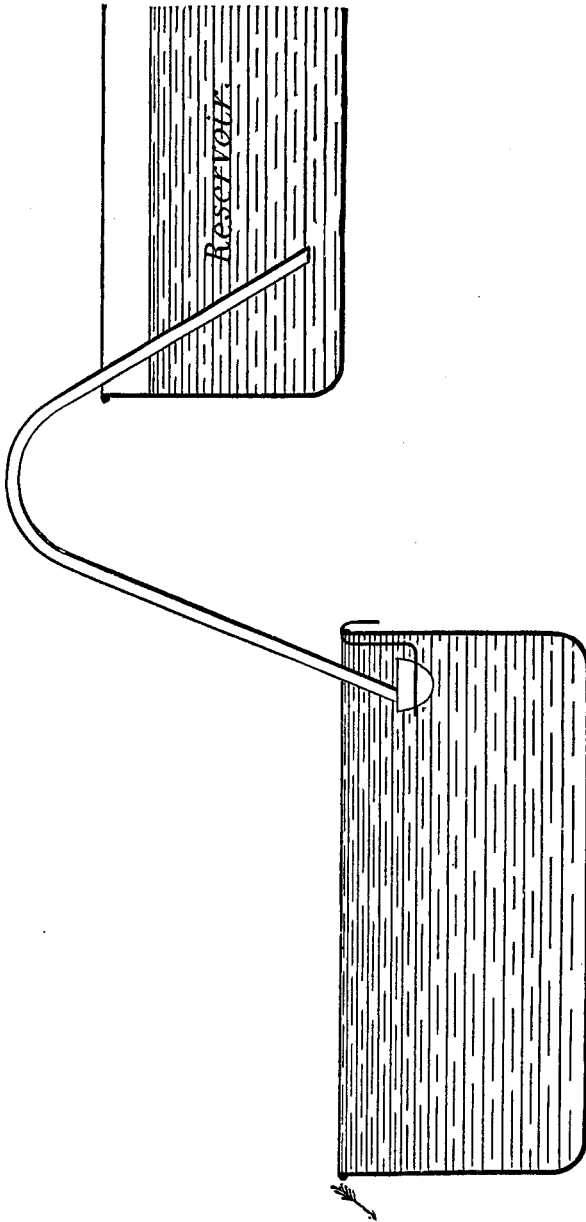
3. Aiguillon Point.

4. Board palisades, with holes.

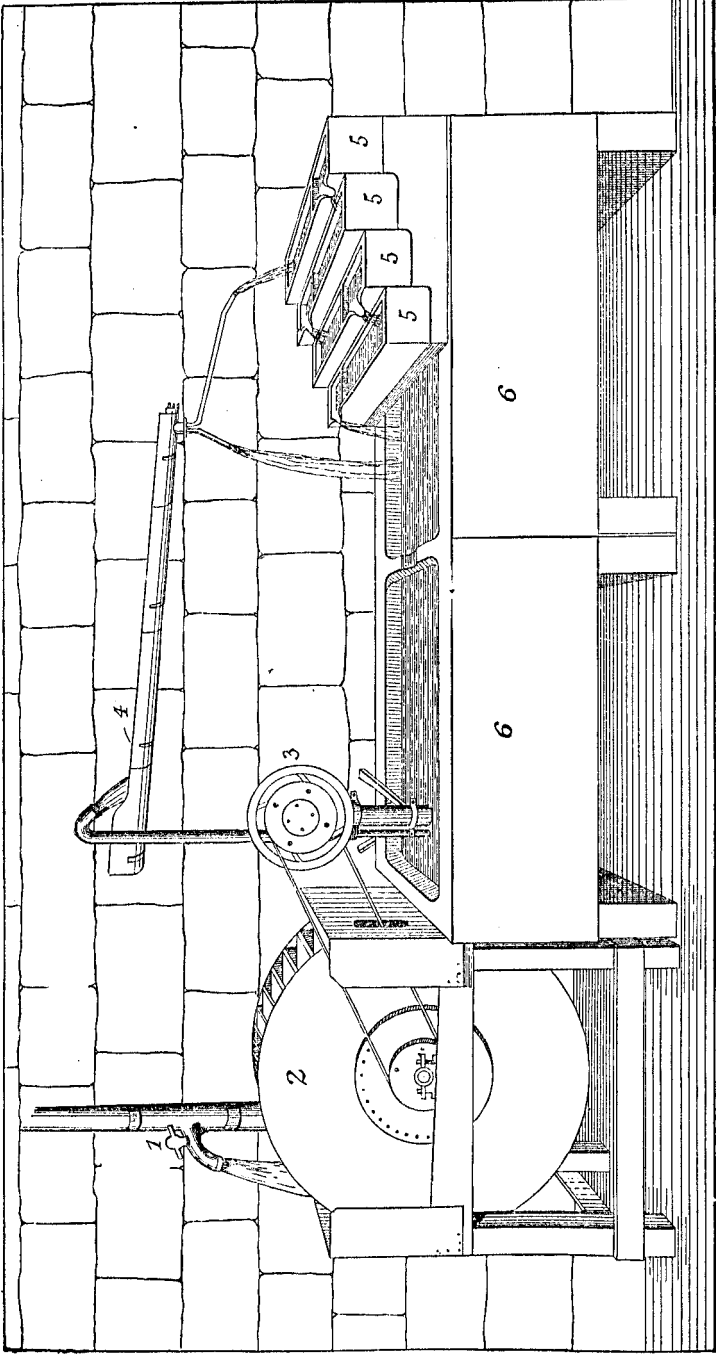
5. Sand for filtering the water.

6. Reservoir containing the embryos.

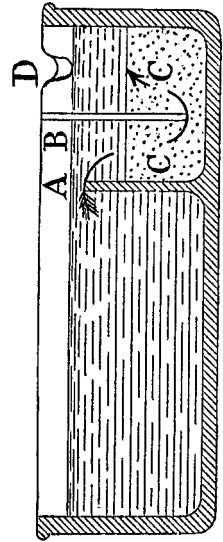
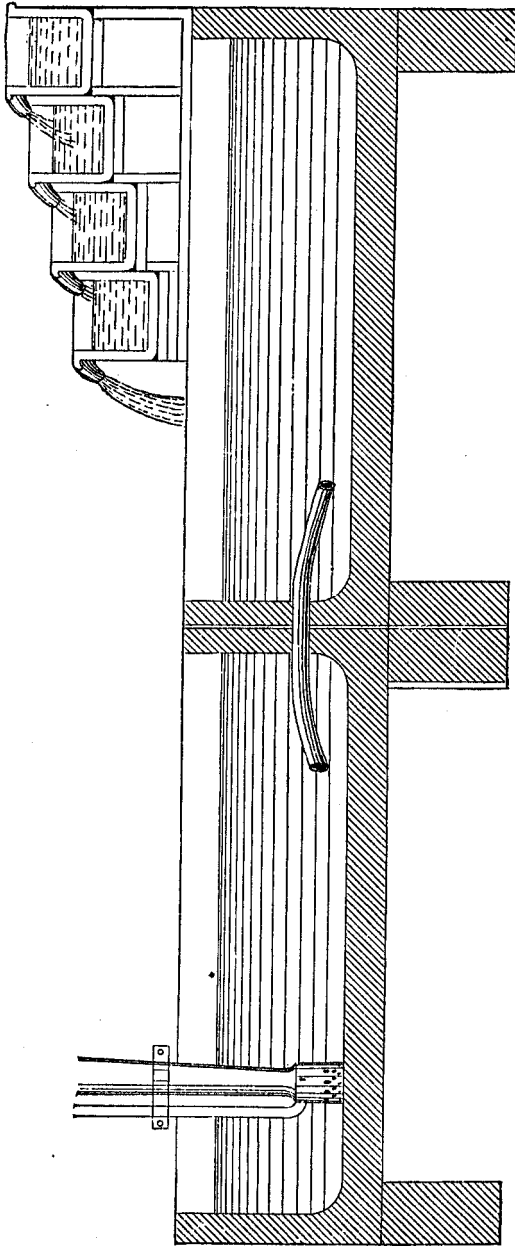
*The quantity of spawn which is lost is truly enormous. Let us take, for instance, the basin of Arcachon, a portion of the coast where the greatest quantity of spawn is gathered regularly, owing to the character of this immense reservoir, to which the sea has access only through a narrow entrance. It is estimated that there are in this basin upwards of a thousand millions of adult oysters, each emitting from 800,000 to 1,500,000 embryos. The annual harvest of spawn is estimated at 1,200,000, that is, nearly one embryo to an oyster; the loss, therefore, is not less than a million to each oyster.



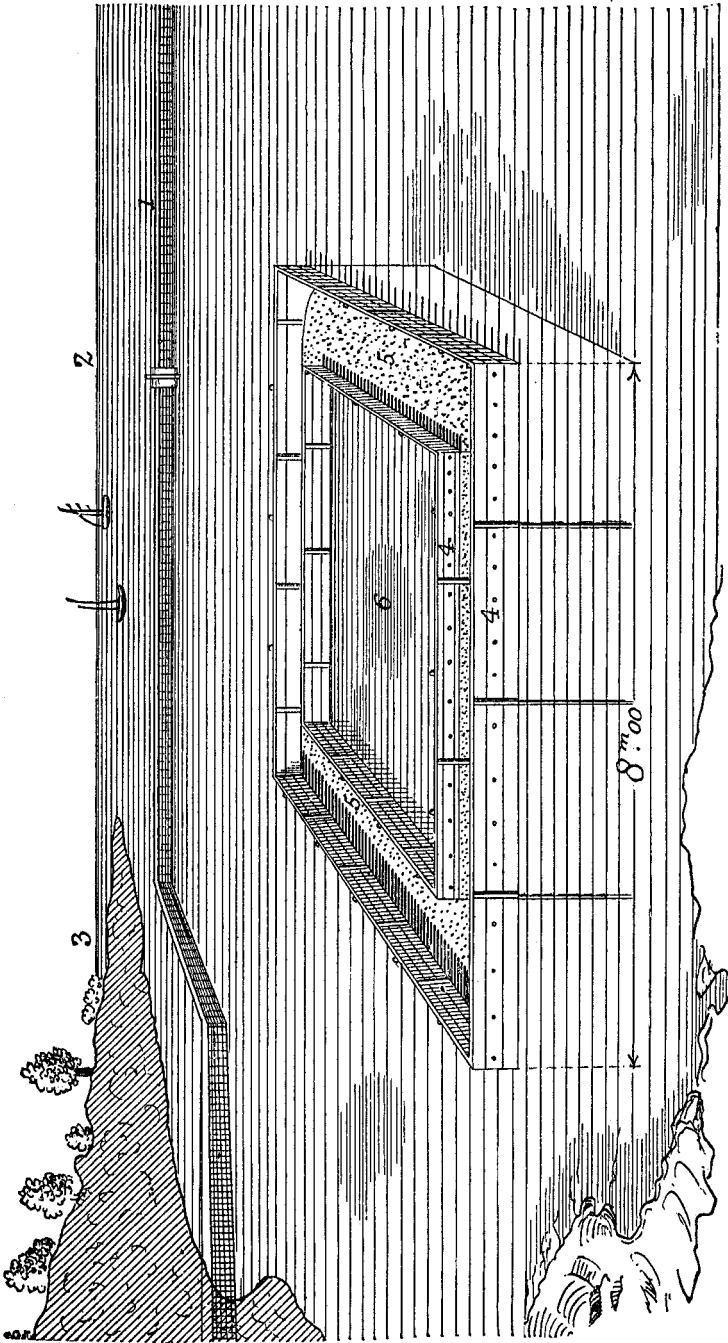
Apparatus for aerating and purifying water containing oyster embryos



Apparatus for incubating and hatching oysters and for the fixation of the embryos.



Sectional views of the basins and hatching boxes.



Experimental *claire* for obtaining oyster embryos in close water.